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Environmental Opportunities in Low Lying Coastal Areas Under a Scenario of Climate Change

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National Rivers Authority

ENVIRONMENTAL OPPORTUNITIES IN LOW LYING COASTAL AREAS UNDER A SCENARIO OF CLIMATE CHANGE

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Conservancy Council
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PREFACE

Many of the low lying areas of England and Wales are currently protected from salt water inundation by artificially maintained sea or tidal defence structures. A significant proportion of Britain's richest coastal ecological sites are also situated in these low-lying areas, either to the seaward side of the defences, or immediately behind them.

Current concerns over the extent and significance of past coastal habitat losses due to development, and the possible future losses under a scenario of climate change and sea level rise, combine to demonstrate the need to promote the restoration or creation of sites of nature conservation interest in Britain's coastal zone.

This report demonstrates that significant opportunities for environmental enhancement of this nature might arise if a retreat from the existing line of flood defence is accepted as an option.

Various retreat strategies can be identified, ranging from the do nothing option, through a minimum intervention approach, to the implementation of engineering works to create a desirable habitat. Under a true do-nothing strategy, the sea defence is abandoned and no further action of any kind is taken. The way in which the site evolves over time is left entirely to natural forces. "Managed" retreat, on the other hand, covers a variety of different potential options which are specifically directed towards restoring or creating desirable habitat, landscape or amenity features.

The coastal environment is dynamic and the mechanisms at work are powerful. Particularly on exposed coasts, the coastal process regime will need to be understood if habitat restoration/creation opportunities are to succeed and are not to cause problems elsewhere. The physical characteristics which are likely to be of greatest importance in the development and control of sustainable coastal habitats are waves; tidal currents; sediment regime; surges; elevation; grade; drainage; and site size.

In addition to these physical parameters, a number of biological and chemical parameters must also be assessed and possibly controlled, if a more environmentally desirable habitat is to be restored or created. The major biological considerations associated with the retreat option include the proximity of similar sites and the related availability of soil fauna, and also the preferred method of establishing vegetation cover. Primary chemical parameters relate to soil chemistry and structure, and the quality of the water entering and leaving the site.

The conclusions of this study indicate that carefully planned, managed and monitored habitat restoration and creation projects could provide a means of significantly reducing the impact of both recorded and anticipated coastal habitat loss. Such artificially created habitats could, however, take upwards of ten or twenty years to realise their maximum environmental value.

Recommendations are therefore made in respect of short-term experimental needs and long-term monitoring requirements. Funding opportunities are examined and a framework is developed to ensure that the managed retreat option is properly considered in terms of its technical, economic and legal viability as well as its site specific environmental and ecological desirability.

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EXECUTIVE SUMMARY

BACKGROUND TO THE REPORT

Many of the low lying areas of England and Wales are currently protected from salt water inundation by artificially maintained sea or tidal defence structures. A significant proportion of Britain's richest coastal ecological sites are also situated in these low-lying areas, either to the seaward side of the defences, or immediately behind them.

Current concerns over the extent and significance of past coastal habitat losses due to development, and the possible future losses under a scenario of climate change and sea level rise, combine to demonstrate the need to promote the restoration or creation of sites of nature conservation interest in Britain's coastal zone.

This report demonstrates that significant opportunities for environmental enhancement of this nature might arise if a retreat from the existing line of flood defence is accepted as an option. In particular, the report investigates the issues surrounding the concept of a "managed" retreat specifically designed to maximise nature conservation benefits.

The term "managed retreat" is used throughout the report. Managed retreat should not, however, automatically be interpreted as meaning that extensive and/or expensive engineering works will be required on a particular site. The term is used to imply a level of awareness and, if appropriate, control. Experience both in the United States and in Europe has demonstrated that understanding and careful planning are likely to be two of the most important criteria determining the success of habitat creation/restoration initiatives. Good management does not necessarily involve intervening in the natural processes of site evolution.

The Scope of the Study

Preliminary results from the National Rivers Authority's Sea Defence Survey (England and Wales) indicate that a total of around 40km of sea defences, protecting in excess of 10,000 ha of agricultural land, currently have a residual life of less than five years. Where these defences protect lives and property it is likely that a decision will be made in favour of reinstatement. Where the defences protect agricultural land, however, managed retreat should be considered as an option.

A series of meetings with Regional National Rivers Authority and Nature Conservancy Council (now English Nature and the Countryside Council for Wales) personnel led to the identification of more than forty sites at which the opportunities and constraints associated with the retreat option might be further investigated. While the NRA Sea Defence Survey identifies only those sites protected by sea defences, these Regional meetings identified a number of candidate sites in estuaries which are currently protected by tidal defences, as well as sites protected by sea defences.

Agricultural Land

The scenario of creating saline or brackish water habitats in areas which were formerly protected against inundation forms the principle basis of the report. Once an area has been subjected to brackish or saltwater inundation for any length of time, options for reclamation are significantly reduced. Retreat for nature conservation benefits in the coastal zone has significant implications for agricultural land-use over the short to medium term and the needs of both interests must therefore be very carefully assessed at local, regional and national levels.

Climate Change Scenarios

For the purposes of this study, the climate change and sea level rise predictions described by the Intergovernmental Panel on Climate Change (IPCC, 1990) as being most likely under their "business as usual" scenario have been adopted. It has also been assumed that both increased storminess and increased saline intrusion might be anticipated in the coastal zone as a result of global warming.

The United States Experience

Throughout the report, the situation in England and Wales is compared to that in other countries, notably the United States. The emphasis on the US stems largely from the requirements of their 1972 Clean Water Act which introduced a requirement for mitigation on development projects damaging wetland resources. As a result of this Act, the Americans have built up an extensive literature on habitat creation and restoration and, although it is recognised that care needs to be taken in applying the results of this research in Great Britain, the US nevertheless provides an invaluable source of information of direct relevance to this study.

THE IMPACTS OF SEA LEVEL RISE ON COASTAL HABITATS

Mean sea level, tidal rise and fall, meteorological surges, tidal streams and other currents, and wave action are all important in shaping Britain's coastline. All of these factors may be modified to some extent by climate change, most particularly through the predicted rise in mean sea level and by the possible increase in the occurrence and severity of storms.

Around 70% of the world's shores are currently eroding, to a large extent irrespective of any change in climate. Erosion is influenced locally by a number of factors. Two key factors are the "hardness" of the coast and human intervention. The increase in global warming is likely to lead to increased erosion and hence to more littoral material being freed for transport into sheltered areas. Assuming such erosion is not prevented by man (e.g. by coast protection works), sediment necessary for the accretion of mudflats, sandflats, saltings and shingle beaches may be generated in at least as great, if not greater, quantities than at present. The littoral zone is, however complex. **The need for monitoring, both of coastal processes and of ecological changes, cannot be overstated if climate change and sea level rise is to be both accommodated and managed in order to maximise opportunities and minimise threats.**

Sand Dunes and Sandbanks

Under a scenario of climate change and sea level rise, some sand dune systems may retreat landwards or even disappear depending on sand supply, wind characteristics, and man's willingness to allow the particular dune system to retreat. To some extent, however, instability within certain dune systems may not be detrimental. Coastal ecosystems are dynamic and change is important.

The process behaviour of many of the sandflats and sandbanks around the coast of the UK is not fully understood. The effect of global sea level rise may be significant, but whether it would lead to a net loss or gain of such features - and hence seal haul out areas and bird breeding and feeding sites - cannot be ascertained.

Saltmarshes and Mudflats

With an adequate supply of sediment, saltmarshes can accrete upwards by 2-10mm/year. Some saltmarshes might therefore be expected to "keep up with" sea level rise. Without an adequate supply of sediment, however, saltmarsh plants would be detrimentally affected because they can only tolerate limited submergence. The edges of saltmarshes are also likely to become cliffed, and creeks might become steeper and wider. Most importantly, sea walls and other hard defence structures will prevent the inland migration of saltmarshes in many areas. Sea level rise might therefore be expected to lead to a reduction in the overall area of such habitats where they are backed by sea defence structures.

Mudflats generally occur in sheltered areas. The processes that shape mudflats are very site specific and it is not possible to generalise on how they will respond to global warming. A rise in sea level might lead to a decrease in the extent and exposure of mudflats but deposition would tend to counteract this tendency if there is an adequate supply of sediment.

Other Coastal Habitats

Sea level rise is likely to have a variety of impacts on shingle features. Transgressional adjustment at a few of the large shingle structures could compensate for sea level rise to some extent. Many other single features, however, would be vulnerable to both erosion and breaching, and shingle vegetation communities might be lost due to increased inundation, storminess and the general increased mobility of shingle under a scenario of sea level rise.

The general rise in water level under a scenario of sea level rise will tend to increase saline intrusion into coastal lagoons. This is likely to disturb existing lagoons whilst possibly encouraging the formation of new ones. Flora and macrofauna lagoon communities are also very sensitive to salinity levels and increased salinity could therefore lead to significant changes in lagoonal species composition.

Sea level rise could affect reedbeds as a result of changes in salinity, currents and water depth. There is likely to be some loss of existing reedbeds with sea level rise, with colonisation in other areas.

The effects of sea level rise on coastal grazing marshes will depend on changes in the frequency and duration of tidal inundation and the salinity range.

Cliffs composed of hard rock would be largely unaffected by global warming, their durability protecting them from marginal increases in wave attack. Softer rocks might be expected to erode more rapidly than at present. Sites which are dependent on cliff falls to maintain their geological interest might benefit from sea level rise, but sites of conservation value because of their vegetation and invertebrate interest might be lost if the frequency of cliff falls increases to the point where cliff communities are unable to become re-established.

Sub-tidal habitats are unlikely to be severely affected by a rise in sea. There may, however, be significant opportunities for the creation of new sub-tidal habitats under a scenario of sea level rise.

TECHNICAL VIABILITY

On a site-specific basis, the decision-making process in respect of the retreat option should start with an assessment of the technical viability and the management implications of a range of alternatives. These alternatives should include both maintaining the flood defence and creating coastal habitats. It is then necessary to determine their relative benefits in terms of ecological desirability and to assess the economic implications of each option.

In many situations an option involving a retreat from the existing line of flood defence will offer significant environmental benefits. If this is the case, the degree of management or intervention which might be required to achieve different environmental objectives must be carefully considered. This is important because of the possible cost implications of a long-term management policy based on intervention; the general desirability of creating or restoring a sustainable habitat; and the need to avoid undesirable consequences (e.g. increased erosion or deposition) elsewhere in the estuary or along the coast. In particular, **sustainability criteria are of vital importance if habitat creation or restoration initiatives are to succeed. It is not an objective of this study to promote the creation of habitats which subsequently require as much maintenance as the flood defence structures which preceded them.**

The study demonstrates that there are dozens of sites throughout England and Wales where flood defences have failed and the land formerly protected against flooding has reverted to various types of coastal habitat. Very few such sites have been properly documented, yet the information which could be collated from photographic records and discussions with local conservationists could be invaluable for future decision-making in respect of the retreat option. **It is therefore recommended that research be undertaken to identify a series of sites where the necessary information is likely to be available, albeit in a somewhat subjective form, and to establish and compare rates of habitat development or habitat change. The physical, biological and chemical controls on the nature and extent of ecosystem development could then be evaluated, and a database would ultimately be established against which future retreat options might be assessed.**

Experience, in the United States in particular, has demonstrated that a key factor in successful habitat creation/restoration initiatives is a careful prior appraisal of the situation and, if appropriate, well researched design undertaken by suitably qualified personnel. The physiology of a created site, its biodiversity and its long-term sustainability will then determine its eventual success. The development of the soil physiology will, in many cases, affect the rate and extent of vegetation colonisation. If the soil invertebrates, algae and other organisms, nutrients and structure are not properly established, vegetation growth will be inhibited. Similar problems will be experienced if physical processes are not fully effective. **A key to successful habitat creation, from a biological as well as a physical viewpoint, is understanding and re-establishing natural processes, and then allowing enough time for the habitat to develop.**

Physical Considerations

The coastal environment is dynamic and the mechanisms at work are powerful. Particularly on exposed coasts, the coastal process regime will need to be understood if habitat restoration/creation opportunities are to succeed and are not to cause problems up or down-stream. The physical characteristics which are likely to be of greatest importance in the development and control of sustainable coastal habitats are waves; tidal currents; sediment regime; surges; elevation; grade; drainage; and site size.

Biological and Chemical Considerations

In addition to these physical parameters, a number of biological and chemical parameters must also be assessed, and possibly controlled, if a more environmentally desirable habitat is to be restored or created. The major biological considerations associated with the retreat option include the proximity of similar sites and the related availability of soil fauna, and also the preferred method of establishing vegetation cover. Primary chemical parameters relate to soil chemistry and structure, and the quality of the water entering and leaving the site.

A great deal of practical research has been carried out, notably in the United States, into the potential beneficial uses of dredged material in habitat creation and restoration. In general terms, these materials simply provide a substrate on which to work. A number of further factors must, however, be considered in terms of the testing and use of materials and the monitoring of sites if contaminated or potentially contaminated dredged materials are to be used.

Technical Manuals

It is not the purpose of this report to provide site specific technical guidelines for habitat creation or restoration. The report's objective is to highlight the factors which must be considered if such projects are to have a reasonable chance of success. Nevertheless, a great deal of technical information was examined during the preparation of the report and a list of the manuals, reports and other papers dealing specifically with methods and techniques for restoration and creation is therefore appended to the report. It should be noted, however, that much of this guidance is American: there is very little in the way of documented technical support for coastal habitat creation or restoration in the British context.

Experience with Restoration and Creation of Coastal Habitats

All the examples of British sand dune restoration/creation investigated related to sites which already support, or are in the immediate vicinity of, an existing dune system. Dune creation on sites without any previous evidence of dune systems is apparently unprecedented.

In Great Britain there are very few examples of saltmarsh creation. There are, however, a number of examples of restoration, and most schemes are either designed to stabilise an area of sediment or to re-establish a damaged marsh.

In the British context, mudflats are a particularly valuable coastal habitat because of their importance for migratory birds. Notwithstanding this, British experience in the deliberate creation or restoration of mud or sandflats is minimal.

Experience in the creation or restoration of shingle features, both in the US and in Great Britain, is largely limited to beach recharge schemes. Creating or restoring shingle habitats is likely to be very difficult because of the mobility of the material and because of the sensitivity of shingle vegetation to disturbance.

Several examples of the creation and/or restoration of coastal lagoons, reedbeds, sea grass beds, bird islands and other habitats were investigated during the study process. The physical and biological requirements for the first two habitat types in the British context are reasonably clearly defined. Experience in the others, however, is largely restricted to work in the United States.

For most of the coastal habitats mentioned above, tables have been prepared setting out the primary physical and biological requirements for the successful restoration or creation of that habitat. Where records exist, however, it is clear that some coastal habitats will take up to 20 years to become properly established and hence "successful".

In Great Britain, although we can learn a great deal from overseas experience, some experimentation will be required simply to establish which management techniques are likely to be most successful. **If the country is to sustain its coastal ecological resource in the face of rising sea levels, it would therefore be prudent to explore opportunities for creation and restoration sooner rather than later.**

ASSESSMENT AND EVALUATION OF RETREAT

The decision rule generally adopted in the evaluation of flood defence options is based on economic viability. If the damage-costs-avoided (the "benefits") are greater than the engineering costs, then the maintenance or improvement works are justified. When comparing a number of different options for a particular scheme, the option which provides the highest level of net benefit or is the most cost-effective in meeting a given set of criteria should be chosen. If the engineering costs are greater than the damage-costs-avoided, however, the engineering works are not justified and a decision may therefore be taken to do-nothing.

Various retreat strategies can be identified, ranging from the do nothing option through a minimum intervention approach to the implementation of engineering works to create a desirable habitat. In a true do-nothing strategy, the sea defence is abandoned and no further action of any kind is taken. The way in which the site evolves over time is left entirely to natural forces. Managed retreat, on the other hand, covers a variety of different potential options with the common aim of restoring or creating "desirable" habitat, landscape or amenity features.

The identification of potential retreat options should take into account not only technical viability but also the environmental desirability of the restored or created habitat. A mixture of ecological and landscape criteria should therefore form the basis not only for identifying restoration and creation priorities, but also for assessing and evaluating potential options.

The appraisal process for managed retreat will therefore frequently involve more than one stage. The ecological and landscape criteria will generally be used first, to screen and assess potential options. A more formal evaluation within an overall cost-benefit analysis (CBA) framework should then be carried out using non-monetary and/or monetary techniques. The type of technique chosen will depend on the nature of the impact and the most suitable assessment approach.

Qualitative and Quantitative Techniques

Qualitative techniques aim to provide information which allows comparisons to be made between sites or proposals, rather than providing some absolute figure representing conservation or habitat "value". The techniques are generally based on the use of subjective judgement to determine performance in respect of different evaluation criteria. Some criteria may be measured in objective terms in that they are based on scientific assessments, but qualitative descriptions or values are generally used for assessment purposes.

Quantitative techniques were developed in response to the need for more scientific and objective assessments of environmental goods such as habitat, landscape and amenity. They also help to provide greater differentiation between sites or proposals, in that they indicate not only that one is better than another, but also by how much.

Valuation Options

Where the mechanism for funding an option requires evidence of economic viability, a simple cost-effectiveness approach (i.e. demonstrating best value for money) towards assessment and evaluation may not be acceptable and cost-benefit analysis (CBA) may be preferable. The CBA framework dictates that as many of the costs and benefits as possible - including non-market effects such as those generally associated with environmental goods and services - should be quantified in money terms. Because costs and benefits occur at different times over the project lifetime, a discounting exercise is then undertaken to convert them into a comparable money value. A project is then deemed economically viable if its net present value (NPV) is positive: that is if the discounted stream of benefits is greater than the discounted stream of costs. When a number of alternatives are being considered, the option with the highest NPV should be the preferred choice.

In many cases when dealing with habitat creation or restoration, it may not be possible to place money values on impacts on environmental goods and services due to the absence of markets in which they can be traded. These impacts must still be described or quantified within the CBA framework, however, and presented together with the monetary values. The option providing the greatest overall level of net benefits will remain the preferred choice.

Coastal habitats provide benefits which correspond to three different categories of value held by individuals towards environmental goods: use values (associated with the benefits gained from use of the environmental resource, along with option values which relate to the desire of an individual to maintain the ability to use the resource in the future); bequest values (the preservation of the environment so that future generations may also have the option of use); and existence values (the values which result from an individual's altruistic desire to assure the availability of a good or service for other individuals and for future generations).

It is important that both use and non-use values are taken into account in the assessment of any particular project. If an analysis only assesses the values related to direct use, a gross underestimation of the total economic benefits to be gained from any restoration or creation activities could result.

The application of cost-benefit analysis techniques to the evaluation of activities, including those affecting the environment, requires that all future costs and benefits are discounted. This ensures that money values are converted into comparable units and can, therefore, be added together to give an overall estimate of net benefit.

Valuation Techniques

The aim of CBA is to quantify in money terms as many costs and benefits as possible. This report identifies six potential methods for the monetary valuation of benefits associated with coastal habitat restoration and creation activities. These are methods which could be used to develop either "reference values" or "specific values". Reference values are values which are based on benefit estimates calculated for existing sites, but which are considered to be comparable to the habitat resulting from restoration or creation. Specific values are developed for the proposed restored or created resource itself, and are generally based on predictions of the functions and services that will be provided.

Change in productivity approaches can be used to value benefits related to services or functions for which either direct or indirect markets exist. This method may, therefore, seem to be of limited applicability to the valuation of habitat creation initiatives, but where such benefits have been identified specific values for the created resource could be developed.

Preventive expenditure and replacement cost methods rely on using measures of expenditure incurred (such as costs of engineering works) to place a value on an environmental good or service. These methods would have to be used in the development of reference values and, due to their site-specific nature, the reliability placed on the resulting benefit estimates would be low. They are, however, easily applied techniques.

Damage-costs avoided, as defined here, involves determining the value of an environmental good or service using the damage that would otherwise be incurred should that good or service be removed. Specific values could be produced through this type of approach as long as the nature and type of functions that would result from the restoration or creation activities could be predicted.

Travel cost techniques infer the value placed on an environmental good by determining the amount of money spent to travel to that good. Although a frequently used method for the valuation of recreational benefits, its application to the valuation of restoration or creation initiatives is likely to be limited to sites which have an existing or adjacent use value.

Contingent valuation methods use various survey techniques to develop direct valuations of individuals' willingness to pay for a particular environmental good or service. These methods are the most flexible of those reviewed, and can be used to estimate both use and non-use related values. CVM therefore offers the most potential for the valuation of environmental benefits associated with habitat creation or restoration initiatives. Care must be taken, however, to minimise potential bias in the survey, and to validate the results as far as possible through the use of statistical techniques.

Energy analysis approaches rely on estimating the total energy produced by an environmental system and converting this to a monetary value using prices placed on fossil fuels. Although this method is attractive in that it produces a total value for the habitat, there is considerable debate over the use of energy prices as the measure of monetary value. The use of this technique is not therefore recommended for valuation of the environment benefits associated with habitat creation or restoration initiatives.

In summary, the techniques which are likely to prove most applicable to the assessment of benefits associated with habitat creation or restoration are preventative expenditure and replacement cost methods (reference values), and contingent valuation methods (reference and specific values). Only contingent valuation could be used to provide estimates of non-use related benefits including option, bequest and existence values.

Acceptability of Different Valuation Techniques to Interested Agencies

The monetary valuation of environmental costs and benefits is generally accepted by the National Rivers Authority as being of use in the benefits assessment process, notably as a means of demonstrating economic viability to MAFF when applying for grant-aid funding. The Nature Conservancy Council prefers the use of qualitative evaluation methods but accepts that there may be a need in some circumstances to place monetary values on a particular site of nature conservation interest. The RSPB supports the quantification of environmental costs and benefits, but has some reservations about the implications of applying monetary valuation techniques and would urge caution in their use. The Countryside Commission does not support, in general, the principle of monetary valuation, particularly when applied to landscape assets.

Future Evaluation of the Retreat Option

There are considerable difficulties in applying monetary assessment techniques to the valuation of environmental assets such as habitat or landscape. This may limit the feasibility of valuing habitat creation/restoration initiatives and hence the reliability of any estimates generated through these techniques for input into CBA.

It is nevertheless recommended that managed retreat options should be evaluated as far as possible within a cost-benefit framework. This approach provides an indication of whether or not benefits exceed costs and has the advantage over a cost-effectiveness approach in that it takes into account the full range of environmental (habitat, conservation and amenity) implications associated with each option. Assuming that quantitative and qualitative impacts are fully considered alongside monetised benefits and cost within the benefit-cost framework, this approach will help to ensure that the most beneficial or worthwhile options are selected.

IMPLEMENTATION

A large number of organisations have an interest in the management of Britain's coastal zone. The National Rivers Authority (NRA) is arguably one of the most important of these agencies, having powers and duties in respect of both Flood Defence and Conservation, the latter under Section 8 of the Water Act 1989. The Nature Conservancy Council (now English Nature and the Countryside Council for Wales), Ministry of Agriculture, Fisheries and Food, Countryside Commission, and the local planning authorities are among the other statutory authorities with powers and duties to conserve or enhance environmental resources through designation and enforcement policies. Voluntary organisations such as the National Trust and the Royal Society for the Protection of Birds could also play a key role in the implementation of the managed retreat option.

Support for the principle and objectives of the retreat option from groups such as the Country Landowners Association and National Farmers Union would, however, also be desirable. Such support is unlikely to be forthcoming in the absence of an adequate compensation provision. In the long-term, if the creation of environmentally desirable coastal habitats is to become widely accepted, the issue of compensation for the landowner must therefore be both addressed and resolved.

There are two primary mechanisms for compensation. The first involves the purchase of the land in question; the second, the negotiation of some form of on-going payment to the landowner. Several of the agencies listed above have compulsory purchase abilities in respect of nature conservation. Compulsory purchase is, however, generally regarded by these agencies as a last resort and this study does not advocate any change in that presumption.

Some managed retreat options may offer opportunities for landowners to continue to utilise their land productively. In particular there may be potential spin-offs in the form of financial gains from managing a site for nature conservation as a form of diversification. Wildfowlers may be prepared to pay the farmer to pursue their interests; if there is an adequate supply of freshwater reeds might be grown commercially; reedbeds may be set up to treat sewage or waste water; or a nature reserve might be developed. In these cases, it may be possible for one of the interested agencies to negotiate a management agreement with the landowner to ensure that environmental objectives are also achieved. Alternatively, an agency may assume the control of a site in return for the payment of an agreed "rent" or lease.

NRA's Legal Responsibilities in Respect of Conservation

Counsel's Opinion in defining the Water Act 1989 S.8(1)(a) duty for NRA appears to offer positive support for the retreat option, where that retreat is planned and/or controlled to ensure nature conservation benefits. Counsel's Opinion states that "Attention needs to be given to its positive expression: the duty is concerned not merely with the assessment of harm but also the achievement of a better environmental result by the use of one alternative [e.g. retreat] even if the other, or others, [e.g. flood defence] are not in themselves particularly harmful to ecology or amenity" [authors' parentheses].

Under S.17 of the 1976 Land Drainage Act, the drainage authorities (including the NRA) have a permissive power to maintain and improve existing works and construct new works. In certain circumstances, therefore, the NRA can make a decision to abandon a defence when it reaches the end of its residual life without becoming liable to pay compensation. However, if the NRA intervenes and does something (e.g. undertaking habitat creation work in line with their S.8 duties) which actively reduces that residual life and hence the value of private land, there may be a requirement for compensation.

In this situation the NRA might, for example, consider negotiating a management agreement and/or setting up a nature reserve. There is no precedent for the NRA setting up nature reserves, but they would be able to do so under the Water Act 1989. The NRA may also charge any visitors to such a reserve under the same Act.

The Role of Other Statutory Bodies

The Nature Conservancy Council is generally supportive of the retreat option. Under the terms of the Environmental Protection Act 1990, NCC may be able to use their management agreement budget to provide funding for managed retreat in areas adjacent to sites of existing conservation interest. The NCC's ability to contribute towards individual projects may also be important, particularly in early applications of the managed retreat approach where experimentation is required. The NCC has, in the past, acquired some sites for research or experimental purposes but land acquisition by the NCC is regarded as a last resort to protect threatened sites for which no other safeguard mechanisms are felt to be appropriate.

The Ministry of Agriculture, Fisheries and Food has a wide range of powers and duties of direct relevance to this report, notably flood defence and coast protection (the latter under the Coast Protection Act 1949); environmental responsibilities under the terms of the Agriculture Act 1986; and the issuing of dumping licences under the terms of the Food and Environment Protection Act 1985. MAFF also provide funds for sea defence, tidal defence and coast protection schemes (among others) in the form of grant-aid. The managed retreat option might, in some cases, attract funding from MAFF, if it can be demonstrated either that the particular habitat restoration/creation initiative serves a coastal engineering function, or that it is essential to meet planning permission or Environmental Assessment requirements.

A major new countryside initiative has been announced recently by the Countryside Commission to help to enhance and re-create valued English landscapes and habitats, whilst making them more accessible to the public. This pilot scheme, known as Countryside Stewardship, will initially target chalk and limestone grasslands, heathlands, waterside landscapes, coastal land, freshwater and estuarine grazed marsh, and grazed dune systems. It also offers enormous potential for the implementation of the managed retreat option. **The recreation and restoration of natural coastal landscapes and habitats could represent an appropriate application of the Countryside Stewardship objectives, but it may be necessary to amend the list of targeted habitats to specifically include coastal lowlands.**

Local planning authorities (LPA) have a number of flood defence, coast protection and nature conservation powers and duties relevant to the retreat option. Many LPAs regularly or occasionally carry out projects specifically to create habitats of conservation value, preferring to support site specific projects. This approach is very encouraging in respect of possible future implementation of the managed retreat option - either in areas where the LPA are responsible for the flood defences, or in support of NRA or NCC initiatives.

Local planning authorities also have what is arguably a crucial role to play in enabling the option of retreat for nature conservation benefit to be implemented, because managed retreat, in some cases, might require planning permission from the LPA. On the other hand, if proposed new developments in low-lying coastal areas are granted planning permission future potential sites for retreat will be lost. Similarly, if new cliff top developments go ahead, a source of sediment to support existing and new coastal habitats might be lost if coast protection works are subsequently undertaken.

The role of the Crown Estates Commissioners under a retreat scenario will be important, primarily because the Crown owns all land between Mean High Water (MHW) and Mean Low Water (MLW) subject to admitted claims only. In cases where, as a result of erosion, additional areas gradually and almost imperceptibly become "intertidal", these areas are automatically taken over by the Crown. If, however, the "movement" in MHW and MLW is achieved deliberately through the actions of the NRA, District Council or other body, the situation in respect of ownership is, as yet, untested in law.

The voluntary agencies contacted during the preparation of this report - including the National Trust, RSPB, Wildfowl and Wetlands Trust, Worldwide Fund for Nature, Royal Society for Nature Conservation and others - have all expressed support for the principle of managed retreat for nature conservation benefits. Most of these agencies would be able to contribute towards the funding of certain retreat options using existing monies and all would be keen to become actively involved should new monies become available.

The Mitigation Option

Section 404 of the United States Clean Water Act 1972 makes provision for a thorough review of proposals which are likely to have a significant detrimental impact on wetlands. Steps are first taken to see if the proposed development project can be relocated, or if damage can be minimised to an acceptable level. If this is not possible, but a habitat creation initiative would represent an acceptable alternative, compensation in the form of mitigation (e.g. the creation of a site of at least equivalent interest elsewhere) may be required.

At the present time there is no parallel requirement for mitigation in Great Britain. Much British environmental "protection" relies on a largely voluntary approach to conservation, through the type of initiatives discussed above. **A mandatory requirement to minimise the environmental damage caused by waterside developments and, if this cannot be achieved, the introduction of a requirement for mitigation measures might provide an opportunity for developers in the private sector to meet some of the capital costs of the type of habitat creation initiatives discussed in this report.**

A fundamental problem associated with the concept of habitat creation as mitigation, however, is the risk factor. Habitat creation and restoration is not a precise science. The risks of a perceived failure, at least in the short term, can be quite high and some scientists are now arguing that it may not be possible to recreate all the characteristics of a natural wetland habitat. **It is therefore essential that a "no loss" policy is still pursued to try to protect Britain's most valuable habitats from development, and that habitat creation/restoration "experiments" are carried out, in the first instance, on sites with little or no existing nature conservation interest.**

New Funding for Coastal Habitat Creation Initiatives

One alternative to redirecting existing monies (as discussed above) to meet the capital and/or management costs of habitat creation or restoration projects would be to set up a new budget from which the promoting agencies could draw. This concept is already being put into practice in both the United States and Canada, where the respective Federal Governments are providing funding for habitat creation initiatives. An example of an equivalent existing budget provision in Great Britain is that associated with the Environmentally Sensitive Areas scheme, administered by MAFF. **The viability of setting up a similar budget specially aimed at funding coastal habitat creation/restoration initiatives needs to be further investigated.**

KEY RECOMMENDATIONS

The conclusions of this study indicate that carefully planned, managed and monitored habitat restoration and creation projects could provide a means of significantly reducing the impact of recorded and anticipated coastal habitat loss. Such artificially created habitats could, however, take upwards of ten or twenty years to realise their maximum environmental value. With both the need for a period of experimentation and the possibility of future coastal habitat losses due to increased rates of sea level rise in mind, it is therefore recommended that NRA, NCC (now English Nature and CCW), Countryside Commission, DoE and other appropriate bodies :-

- **promote an active consideration of the potential benefits of the managed retreat option at an early stage in the decision-making process for all non-urban sea and tidal defence schemes;**

- **ensure that habitat creation and restoration opportunities are considered, not in isolation but as part of an integrated approach to coastal management;**

- **initiate, wherever possible, programmes for monitoring coastal processes and ecological changes to help to ensure that data is available for future decision-making;**

- carry out research to establish the lessons which can be learned from sites where defences have failed in the past and use this information in the future assessment of the retreat option;

- undertake a series of experimental pilot projects to test the practical application of the framework identified in this report;

- implement a study aimed at producing a set of technical guidelines for the managed retreat option;

- examine the possibility of extending the Countryside Commission's "Countryside Stewardship" scheme to incorporate explicitly coastal habitat creation and restoration initiatives in low-lying areas;

- investigate the need for the modification of existing funding mechanisms to enable agencies to fund managed retreat initiatives;

- investigate the need for additional funding for managed retreat through the establishment of a new "coastal habitats" budget.

SECTION 1 INTRODUCTION

1.1 Preamble

1.1.1 Many of the low lying areas of England and Wales are currently protected from salt water inundation by artificially maintained sea or tidal defence structures. A significant proportion of Britain's richest coastal ecological sites are also situated in these low-lying areas, either to the seaward side of the defences, or immediately behind them. Environmental resources in the coastal zone have been seriously depleted over recent centuries, largely as a result of human activities. If rates of sea level rise increase as predicted in the recent Intergovernmental Panel on Climate Change Reports on global climate change (IPCC, 1990), further losses might be anticipated because coastal habitats will be "squeezed" in the narrowing areas of land between mean low water mark and the defence structures. A significant opportunity to reduce the overall impact of both past and anticipated habitat losses might, however, exist if some coastal land areas are made available for habitat creation or restoration. These benefits could be realised if Britain accepts the principle of retreating from the existing line of flood defence in carefully targetted areas.

1.1.2 In general terms, where an existing flood defence has a low residual life, current practice comprises an appraisal of various structural solutions. Such solutions generally involve the carrying out of engineering works - in other words, intervening to improve the defences. Various options, or one preferred option, will then be compared to the implications of doing nothing (i.e. allowing the defence to deteriorate and fail).

This report explores the possibility that there is a third alternative. This alternative may also involve intervening, in so far as planning, design and engineering works might be required. But rather than those works being undertaken to maintain or improve a flood defence, their objective would be to create, restore or enhance environmentally important habitats. The report examines, in principle, the opportunities which might arise if a retreat from the existing line of flood defence is accepted as an option. In particular, the issues surrounding the concept of a "managed" retreat designed to maximise nature conservation and landscape benefits are investigated. The degree of management which might be required is discussed, areas of uncertainty are highlighted, and conclusions are drawn in respect of the technical, legal and economic viability of this type of environmental enhancement initiative.

1.1.3 The report, in accordance with the Terms of Reference set out in the Project Investment Appraisal (see Appendix A1.1), aims to draw together information from a wide range of disciplines, reviewing the available data in the context of the retreat option. Relevant information is therefore presented in a form which clearly identifies whether or not, and under what circumstances, it may be realistic to pursue a managed retreat from the existing line of flood defence. In this respect, the report provides a framework for the consistent and informed future evaluation of the managed retreat option.

1.2 <u>Report Structure</u>

1.2.1 The remainder of Section 1 of this report determines the geographical scope of the study and defines areas where retreat might be considered as an option in the future. The terminology used in the report is discussed and other important assumptions are highlighted.

Section 2 of the report sets out the background to the report in respect of climate change scenarios and nature conservation interests. Section 3 evaluates the technical viability of the retreat option, discusses possible constraints and determines likely biological, physical and chemical requirements for habitat creation and restoration.

Section 4 examines the various issues surrounding the evaluation of retreat options. Ecological desirability criteria are reviewed, qualitative and quantitative evaluation procedures are briefly explored, and the principles of economic valuation are appraised. Six environmental economics techniques are also assessed.

Section 5 investigates a series of options for the implementation of the managed retreat option. The legal situation is examined, the respective roles of NRA and other interested parties (statutory and voluntary) are discussed, and their existing and possible future policies on retreat are assessed. Finally, Section 6 of the report presents the study's conclusions and recommendations.

1.3 <u>The Scope of the Study</u>

1.3.1 **Geographical Study Limits**

This report deals largely with issues which are broadly consistent on a national basis throughout England and Wales. Where it has been necessary to focus on smaller geographical units, however, the National Rivers Authority's (NRA) Regions have provided a common basis for such assessments. It was not within the brief of this study to consider issues on an intra-regional basis.

1.3.2 **Defining Areas Where Retreat may be an Option**

The low-lying coastal areas towards which this study is directed can be broadly defined in the following terms:-

- land areas at or below the 5m AOD contour (e.g. those identified by the Institute of Terrestrial Ecology, see Figure 1.3.1).

- land areas protected against saltwater or brackish inundation by sea defences (typically on open coasts) or tidal defences (typically within estuaries).

Figure 1.3.1 Areas of Great Britain Vulnerable to a Rising Sea Level

Source: Institute of Terrestrial Ecology. Climatic Change, Rising Sea Level and the British Coast (1989).

In theory, any (part) of the areas identified on Figure 1.3.1 could be considered as a potential candidate for a retreat from the existing line of flood defence. In practice, in the short term at least, various constraints are likely to operate. The current standard of protection and the quality of the defences themselves are, for example, likely to be important considerations. The recent National Rivers Authority Sea Defence Survey provides an opportunity to assess the current situation, but only in respect of areas protected by sea defences. At this stage, no equivalent information is available on a national basis in respect of tidal (estuarine) sites.

1.3.3 Preliminary results from the NRA's Sea Defence Survey (I. Whittle, NRA, personal communication, 1991) indicate that a total of approximately 40km protecting more than 10,000ha of land around England and Wales meet the following criteria:-

- The overall condition of at least one element of the existing defence is poor or bad.
- At least one element of the defence has a residual life of less than five years.
- The defences protect land which is primarily in agricultural or other non-domestic/non-commercial use. Urban areas are excluded.

In all these cases, a decision will therefore need to be made in respect of possible investment within the next five years.

On a Regional basis, the above figures break down as shown on Table 1.3.1. It should be noted, however, that both the above definitions of "poor" and "bad" quality and the estimates of residual life are somewhat subjective and may vary from region to region. The table should therefore be regarded as being indicative only.

Table 1.3.1 Regional Breakdown of Sea Defences with a Residual Life of Less than Five Years

REGION	LENGTH[1] KM	AREA[3] HA
Anglia	16.43	2850
North West	0.00	0
Northumbria	3.04	200
Severn Trent	1.10	25
South West	2.00	75
Southern	12.05	7300
Welsh	0.66	25
Wessex	3.97	200
Yorkshire	0.87	50
TOTAL	**40.12**	**10725**

Notes (1) The inclusion of a defence in the above analysis means that an element of that defence meets the above criteria. It is probable that if appropriate work on that element is undertaken, the defence may once again be returned to a state of full effectiveness.

(2) Length of defence containing elements meeting above criteria.

(3) Area of land protected by defences containing elements meeting the above criteria.

1.3.4 In addition to extracting information from the Sea Defence Survey, a series of meetings was held with Regional NRA and Nature Conservancy Council (NCC, now English Nature and Countryside Council for Wales) personnel. The purpose of these meetings was to collect data specific to each Region and to identify possible case study sites at which more detailed investigations might be undertaken to test the results of this report. These case studies were carefully selected to include both "typical" sites and those which might require special consideration because of peculiar or unique characteristics. The individuals involved in these Regional Meetings are among those listed in Appendix A1.2 and the results of this element of the consultation exercise are presented detail in Table B1.1, Appendix B. It should be noted, however, that the list of potential candidate sites for retreat is not intended to be definitive.

Table 1.3.2 lists, in summary, the number of sites identified as candidates for possible detailed investigation of the retreat option within each of the NRA Regions. This does not mean that retreat will necessarily be selected as the best option at these sites, simply that it might be evaluated with a view to possible implementation if circumstances are appropriate. Where these sites are currently protected by sea defences, there will be some overlap with sites highlighted on Table 1.3.1 but the consultation process also pinpointed many estuarine sites which are currently protected by tidal defences of varying standards. Most of the sites identified are outside of built up areas because retreat involving the extensive loss of property is unlikely to be a politically realistic option. One of the sites identified has, however, been zoned for industrial use but no development has yet taken place. Habitat creation here would represent a major benefit in an area which has, to date, suffered a significant loss of nature conservation assets.

Table 1.3.2 Potential Case Study Sites for the Retreat Option

Region	Number of Sites	Comments
Anglian	9+	Generally agricultural sites; some existing nature reserves.
North West	2+	Areas originally claimed from sea; some private defences.
Severn Trent	6	Estuarine sites; navigation and retention of flood storage function both important.
Southern	7	Estuarine and coastal sites; some private defences.
South West	5+	Mostly estuarine sites; some with existing nature conservation interest. Also sites on the Isles of Scilly.
Thames	N/A	
Welsh	3	Coastal and estuarine sites on agricultural land.
Wessex	4+	Variety of sheltered and exposed sites.
Yorkshire and Northumbria	7+	Some (former) industrial sites; some potential enhancement of sites with existing environmental interest.

It should be noted that the case study sites vary in size quite significantly - from less than 20ha to more than 500ha. This reflects the likelihood that the size of sites considered for future retreat will vary widely. The upper size limit is likely to be determined by what is politically acceptable. For certain types of habitat a lower size limit will also apply - a limit determined by environmental worthwhileness. Site size is discussed in more detail in Section 3.3.8. Finally, the case study sites also include both intensive and extensively farmed agricultural land. This is important because many intensively farmed sites are of less existing nature conservation value than low-input agricultural land and the former may therefore offer the most scope for significantly improving environmental interest.

1.3.5 In the short term it is felt that the results of this study might be applied in some of the areas indicated in Tables 1.3.1 and/or 1.3.2 above. If, however, the deterioration of the defences protecting other areas is accompanied by an increase in the rate of sea level rise (see Section 2.2), it is anticipated that a number of additional areas might become candidates for a consideration of the retreat option in the medium term. This latter scenario will ultimately be determined not only by climatic conditions, but also by political and economic factors. The Dutch, for example, have recently decided that coastal recession must be stopped and have adopted a coastal defence policy based essentially on preserving the existing line of flood defence (i.e. holding the coastline at its present location) (Ministry of Transport and Public Works, 1990). Quite obviously the situation in the Netherlands is very different to that in Great Britain in terms of the total proportion of land at or below sea level. As Section 2.3 will demonstrate, however, the consequences for coastal nature conservation interests if a "defend at any cost" policy were to be introduced in Great Britain could, potentially, be severely detrimental.

1.4 Terminology

1.4.1 ■ Sea and Tidal Defences

In order to ensure that the terminology used in this study is consistent with that of the National Rivers Authority where this is appropriate, it should be noted that "sea defence" is defined in accordance with the Schedule 4 boundary of the 1949 Coast Protection Act. "Tidal defence" relates to the length from the Schedule 4 boundary to the Ministry of Agriculture, Fisheries and Food (MAFF) agreed limit of tidal dominance on main rivers (i.e. the limit above which fluvial flooding predominates). Sea defences are located on the coast, with tidal defences in estuaries and along tidal river systems. NRA and MAFF responsibilities in respect of sea and tidal defences are further discussed in Section 5.2 and 5.3.3.

1.4.2 ■ Defence Structures

As far as possible throughout the report, the term "defence structure" has been used to identify defences which have been constructed or are artificially maintained by man. Where "defences" is used, this includes a range of flood protection features including natural sand dunes and shingle ridges.

1.4.3 ■ **Restoration and Creation**

For the purpose of this study, restoration is defined as the process of re-creating a habitat which was found on the site in question until relatively recently. The definition of "relatively recently" will vary from place to place. It assumes, however, that some important physical and biological characteristics (e.g. soil salinity, fauna, etc.) remain receptive to the restoration process.

Creation is defined as imposing something new on a site. The "new" habitat might, in fact, have been present on the site at some stage in the past, but the term creation is used to imply that characteristics such as salinity, soil nutrient status and seedbank will have changed significantly. This is particularly important where land claim, for agricultural use for example, took place several hundred years ago.

1.4.4 ■ **Managed Retreat**

The term "managed retreat" should not automatically be interpreted as meaning that extensive and/or expensive engineering works will be required on a particular site. Managed retreat is used to imply a level of awareness and, if appropriate, control. The concept of pro-active or forward planning is fundamentally important if nature conservation benefits are to be maximised and a high quality habitat achieved. Managed retreat might, in some cases, mean heavy engineering works and high capital costs, but it is equally likely to be applied to sites which require little more than pre-retreat survey, post-retreat monitoring, and possibly the management of public access.

1.4.5 ■ **Do Nothing**

Do nothing refers to the option of abandoning the defences without intervening in any way at the time of, or following, failure.

1.4.6 It is appreciated that the line dividing do-nothing from a minimum intervention managed retreat is a very fine one. In some cases, the do nothing approach may lead to the natural development of valuable habitats but without monitoring, little will be learnt from such areas. Section 3.2 demonstrates that there are many examples of historic breaches and defence failures around Great Britain. Some of these sites are now deemed to be of ecological significance, some are not. What is conspicuous, however, is that many of the sites which are now considered to be of greatest value from a nature conservation point of view, are currently managed -as RSPB reserves, National Nature Reserves and Local Wildlife Trust reserves. In a similar context, research undertaken in the United States (see Section 3.1.5) has demonstrated that understanding and careful planning are likely to be two of the most important criteria determining the success of habitat creation/restoration initiatives. **Good management does not necessarily involve intervening in the natural processes of site evolution.**

1.5 Climate Change Scenarios

1.5.1 For the purposes of this study, the climate change and sea level rise predictions described by the Intergovernmental Panel on Climate Change (IPCC, 1990) as being most likely under their "business as usual" scenario have been adopted. These are discussed further in Section 2.2. It has also been assumed that both increased storminess and increased saline intrusion might be anticipated in the coastal zone as a result of global warming.

1.5.2 Because of the difficulties in predicting the impact of a relatively small rise in sea levels, many of the discussions about the regional implications of climate change focussed on the likely consequences of a rise in sea levels of up to 0.5m. It is acknowledged that, according to the IPCC predictions mentioned above, such a rise is unlikely to occur within the next few decades. It is also important to recognise, however, that coastal habitats might take upwards of 20 years to become properly established. The results of early habitat creation initiatives in the United States, for example, demonstrate that it is relatively difficult to replicate all the characteristics of a natural wetland ecosystem, at least in the short to medium term (P. Williams, J. Zedler, personal communication, 1990). **In Great Britain, although a great deal can be learnt from overseas experience, some experimentation will be required simply to establish which management techniques are likely to be most successful. If the country is to sustain its coastal ecological resource in the face of rising sea levels, it would therefore be prudent to explore opportunities for creation and restoration sooner rather than later.**

1.6 Soft Engineering Options

1.6.1 Many habitat creation or restoration initiatives - artificial reefs, saltmarsh creation and sand dune restoration for example - could equally be interpreted as soft engineering options for flood defence or coastal protection purposes. This study is concerned, however, with habitat creation and restoration initiatives **landward of the existing defences**. The potential role of other soft engineering options in enhancing the water's edge environment, possibly improving the wildlife interest and reducing visual intrusion is therefore acknowledged, but no further account is taken of these options in this report.

1.7 Reversibility Criteria

1.7.1 Many of the sea or tidal defences around the English and Welsh coasts, whether natural or artificial, currently protect areas which are dependent to some extent on freshwater. If a defence fails these areas will be subjected not only to increased levels of salinity but also to tidal action and other physical disturbance. The scenario of creating saline or brackish water habitats in areas which were formerly protected against inundation therefore forms the principle basis of the report. Increased freshwater flooding, due to phenomena such as increased tidelocking under a scenario of sea level rise, is not considered in detail. Freshwater flooding may or may not be considered beneficial from the point of view of nature conservation. What is more important in terms of this report, however, is that it is potentially reversible.

Agricultural land which is subjected to an increased frequency of freshwater flooding can, if necessary, be returned to agricultural use relatively easily and cheaply. Once an area has been subjected to brackish or saltwater inundation for any length of time, options for such reclamation are significantly reduced. Enclosure is possible, but it is expensive and time consuming. Retreat for nature conservation benefits in the coastal zone has significant implications for agricultural land-use over the medium term and the needs of both interests must therefore be very carefully assessed at local, regional and national levels.

1.8 The United States Experience

1.8.1 Throughout this report, the situation in England and Wales is compared to that in other countries, notably the United States. The emphasis on the US stems largely from the requirements of their 1972 Clean Water Act which introduced a requirement for mitigation on development projects damaging wetland resources. As a result of this Act, the Americans have built up an extensive literature on habitat creation and restoration and, although it is recognised that care needs to be taken in applying the results of this research in Great Britain, the US nevertheless provides an invaluable source of information of direct relevance to this study.

1.9 Study Limitations

1.9.1 This study, as specified in the Project Investment Appraisal (Appendix A1.1), covers a very broad range of issues. An extensive consultation exercise was undertaken during the preparation of the report (see list of organisations and individuals contacted, Appendix A1.2), and this process raised a number of additional questions. Most such questions have now been investigated and the results are presented herein. There are, however, some cases in which the amount of detail provided is limited. This is because the study team have concentrated on the interests of the sponsoring agencies.

In particular, the issue of privately-maintained flood defences was raised on several occasions. Although the study concentrates on those defences currently maintained by the NRA, the technical considerations in respect of the retreat option will apply irrespective of who maintains the defence. The legal requirements might vary, however, and the interactions between the NRA and the individual or agency responsible for maintenance have therefore been explored (Section 5.2). Similarly, a significant increase in the rate of sea level rise might lead to more requests for the NRA to take over responsibility for some of these defences. If this is the case, it is assumed that the decision making process promoted in the report in respect of the retreat option would be applied to newly acquired sea and tidal defence structures.

1.9.2 Finally, the study identified a wide range of coastal information relating to climate change and sea level rise, which is currently held on various databases and Geographic Information Systems around the UK. Although it was not within the scope of the study to review all of the information available, an inventory of such databases is provided in Appendix A1.3.

1.10 Nature Conservancy Council

1.10.1 The Environmental Protection Act (1990), which came into force on 1st April 1991, disbanded the NCC and created instead three independent agencies for England, Wales, and Scotland with British coordination being provided by a new Joint Committee. In Wales, the NCC and Countryside Commission have been merged to create the Countryside Council for Wales. The functions of the Joint Nature Conservation Committee, English Nature and the Countryside Council for Wales are, however, predominantly the same as those provisioned under the 1981 Wildlife and Countryside Act and previous Acts (see below).

The majority of the research carried out for this report, including the production of the draft report, took place prior to February 1991. Given that most of the functions of the new organisations set up under the 1990 Act will be the same as existed previously, and that many of the results of this report will apply to Wales as well as England, references to NCC throughout the text remain generally unchanged.

SECTION 2 BACKGROUND TO THE REPORT

2.1 The Need for the Study

2.1.1 As indicated in Section 1.1.1, the coincidence of two issues of current national concern has made the further investigation of the retreat option and the production of this report particularly appropriate at this time. The first of these issues is the international debate about the changes in climate anticipated as a result of global warming. This possibility has prompted bodies such as the Nature Conservancy Council (Doody and Burd, 1990), Worldwide Fund for Nature (Hollis et al, 1990) and the Natural Environment Research Council (Boorman et al, 1989) to investigate the likely effects, particularly those associated with sea level rise, on the British nature conservation resource.

The second concern is reflected in recent reports assessing the extent of past coastal habitat loss in Britain. The RSPB's publication "Turning the Tide" (RSPB, 1990a) and the Nature Conservancy Council's Coastwatch Programme, Estuaries Review, and Coastal Habitat Inventories (NCC, 1989; 1991) have all demonstrated that the natural resources of the British coast have been severely depleted, largely as a result of human activities, over recent decades.

Section 2.2 of the report therefore reviews the climatic change debate. Section 2.3 assesses the current status of different coastal habitats and investigates the likely impacts upon these habitats of climate change and sea level rise. Appendix A2.1 provides additional details in respect of the objectives and status of ongoing research dealing with various relevant climatic change and/or habitat related projects.

2.2 The Climatic Change Debate

2.2.1 Past Sea Level Rise

The Intergovernmental Panel on Climate Change (IPCC) "Business-as-Usual" scenario for emission of greenhouse gases predicts a rate of increase for global mean temperature during the next century of about 0.3°C per decade (with an uncertainty range of 0.2°C to 0.5°C per decade; IPCC, 1990). This is a greater rate of increase than the world has seen over the past 10,000 years and will result in a likely increase in global mean temperature of about 1°C above the present value by 2025 and 3°C above today's temperature before the end of the next century.

Mean sea level has risen by 10-20cm during the last 100 years (Warrick, 1986). To date, however, there is no evidence of an acceleration in the rate of sea level rise. Observations show that the planet has warmed by 0.5 ± 0.2°C since the late nineteenth century (Warrick 1986), and six of the seven global-average warmest years on record have occurred since 1980. The extent of the warming is broadly consistent with the predictions of global climate models produced in recent years, but it is also of the same magnitude as natural climatic variability. The observed increase in temperature could therefore be due largely to this natural variability. The lack of reliability of these models at the regional level also means that the expected signal from greenhouse warming is not yet well defined and the ideal modelling experiments required to define the signal have not yet been carried out. The shortage of available instrumental records means that little is known about the low frequency characteristics of natural variability for many climate events. The detection of the enhanced greenhouse effect from observations cannot be guaranteed for more than a decade (Wigley and Barnett, 1990).

There is a long-term trend demonstrating rising ocean levels occurring for 6,000 years since the end of the ice age. The shrinking of alpine glaciers may account for one-third to one-half of the observed rise (Warrick and Jones 1988). The contribution by thermal expansion of the oceans and by Greenland ice-sheet melt is less certain. Peltier and Tushingham (1989) refer to work that suggests 25% of recent sea level rise is explicable by this steric effect. Although it does seem likely that recent sea level changes are related to climatic change, as with the changes in global mean temperatures it is not possible to confidently ascribe this past sea level rise to the greenhouse effect.

2.2.2 Predicted Sea Level Rise associated with Global Warming

As a result of the predicted rates of increase for global mean temperature under the IPCC Business-as-Usual scenario, sea level is expected to rise by between 8cm and 29cm by the year 2030, with a 'best-estimate' of 18cm. The projected range for the year 2070 is 21-71cm, with a best-estimate of 44cm (IPCC, 1990). The point is made, however, that projections this far into the future should be treated with caution as they are subject to many uncertainties (Warrick and Oerlemans, 1990).

The Report of Working Group 1 of the IPCC provides the most authoritative current estimates of climate change and sea level rise. Its findings have therefore been adopted for use in this report.

2.2.3 Contributions Towards Projected Sea Level Rise

The effect of increasing global temperatures on land ice will vary depending on the temperature range where the ice is situated. Ice mass balance increases (i.e. accumulation exceeds ablation) with temperature until annual temperatures higher than -15 to -10°C when ablation occurs. The Greenland ice sheet and most glaciers are in the warmer regions of the planet where any increased temperature will result in increased ablation. Hulton (personal communication, 1990), in work completed during his thesis but as yet unpublished, has studied Greenland ice sheet dynamics and expects accumulation in the centre of Greenland while ablation may occur at the edges. This will steepen the profile of the ice sheet but the ice mass balance will still decrease slightly under a scenario of global warming.

The Antarctic ice sheet with its much colder climate may experience an increase in accumulation, possibly reducing the rate of sea level rise (Hekstra, 1989). Warmer air over Antarctica can hold more moisture and therefore produce greater snowfall (Meier, 1990). There is great uncertainty about the response of the crucial Antarctic ice sheet, but with its geometry and the regional climatic characteristics, it is unlikely to contribute to global sea level rise in the short term (Warrick and Oerlemans, 1990). Drewry (1990), however, points out that it is crucial to understand ice sheet dynamics to estimate the effects of global warming. Ablation of ice is not simply dependent on temperature. Direct ablation is a very slow process. The effects of ice shelves and floating ice at the margin's and the occurrence of calving on the rest of the ice sheet are more influential.

The melting of Arctic sea ice will not contribute to sea level rise since the ice is floating, displacing an amount of water roughly equal to that in the submerged ice (Titus, 1989).

Finally, Warrick and Oerlemans (1990) are among the scientists who expect more than half of the rise in sea level to be attributed simply to thermal expansion (rising sea surface temperatures decreasing the density of sea water and hence raising sea level).

2.2.4 **Regional Variations in Global Sea Level Rise**

Predictions of sea level rise on the global scale do not take into account vertical land movements due to natural isostatic movements, sedimentation, tectonic processes and even anthropogenic activities (eg. groundwater and oil extraction) (Alcock, 1990). Research has been carried out to determine what proportion of secular (long-term, observed) sea level rise in the UK is attributable to vertical land movements. However, there are inherent problems in estimating **actual** land movements rather than **relative** movements. The variable quality of the data available, the errors associated with tide gauge monitoring, and the temporary short nature of the record, all serve to complicate the research (Rossiter, 1972; Pugh and Faull, 1982). There is also a paucity of tide gauge data for mean sea level records in the UK. Although 34 tide gauges now make up the UK 'A Class' network of gauges, only four of them have sufficient data to provide time series of mean sea level for most of the twentieth century (Woodworth, 1987). Another way of determining regional variations in sea level changes due to vertical land movements is from stratigraphic data. Shennan (1987), for example, has estimated land movements on the east coast of England from analyses of sedimentary data and saltmarsh reclamations of different ages.

Despite the complications, it is widely accepted that the south of Britain particularly the south-east is subsiding, while the north of Britain is rising by the same amount (Valentin, 1953; Rossiter, 1967, 1972; Woodworth, 1987; Pugh 1990; Alcock, 1990; Boyle and Ardill, 1989). Estimates of the rates of subsidence and uplift in Britain are summarised in Table 2.2.1.

Table 2.2.1 Regional Vertical Land Movements

Subsidence	Rate of Subsidence	Reference
Southern England	1mm/year	Rossiter, 1972
Thames Estuary	2mm/year	Rossiter, 1972
Sea levels at Newlyn	Rising 1.3mm/year relative to Aberdeen	Woodworth, 1987
Sea levels at Sheerness	Rising 0.6 ± 0.2mm/year relative to Newlyn	Woodworth, 1987
South East England, East Anglia	1-2mm/year	Shennan, 1989
Humber Estuary	1-2mm/year	Posford Duvivier, 1991
Uplift	**Rate of Uplift**	**Reference**
East Scotland	0.5mm/year	Rossiter, 1972

Pugh (1990) has tabulated linear mean sea level trends relative to land for selected UK ports, based on Woodworth's work. Table 2.2.2 shows the land movement estimates based on the assumption of a eustatic (global) sea level rise of 1.5mm/year. As previously mentioned, however, a common data span only exists for four of the eight stations. Isostatic movements are modified in some areas by local tectonic effects, for example the Portsmouth area appears to be sinking fastest, probably due to subsidence associated with a geological feature known as the Hampshire-Dieppe Basin (Alcock, 1990). The apparent anomalous figure for North Shields is viewed by Rossiter (1967) as evidence of land subsidence from mining activity. Carter (1988) splits the British Isles into two provinces, one in the south east, the other in the north and north west, corresponding to the late Quaternary loading pattern.

Table 2.2.2 Vertical Land Movement in the British Isles

	Data Span	**Estimated Vertical Land Movement (per annum)**
Newlyn	1916-82	- 0.3mm
Portsmouth	1962-82	- 3.5mm
Sheerness/Southend	1916-82	- 0.4mm
Lowestoft	1956-82	+ 1.2mm
North Shields	1916-82	- 1.1mm
Douglas (I.O.M.)	1938-77	+ 1.2mm
Aberdeen	1916-82	+ 0.6mm
Lerwick	1958-82	+ 3.5mm

Source: Based on Pugh (1990)

2.2.5 The Role of Vertical Land Movement

It is difficult to make predictions of how regional vertical land movements in the UK will contribute to or counteract expected eustatic sea level rises from global warming. Longer term changes, over 100 years or so, cannot be reliably hind-cast from data over one or two decades, and the stratigraphic record indicates that some short-term variations in sea level will not have a significant effect on the development of the coastline (Shennan 1987). Further research is in progress to enable more accurate estimates of future sea levels in different UK regions. Consistent monitoring is essential and satellite altimeter data should enhance observations by tide gauge in the future.

At present, the process of drawing the most reliably researched predictions of global sea level rise together with estimations of regional land movements provides the best guide to the expected rates of sea level rise in the UK. In general, the north of Britain is uplifting by a rate of 0.75-1mm/year while the south of Britain is subsiding by 0.5-1mm/year. As Woodworth and Rossiter concluded, the rate of sinking in the south east (Sheerness) and the Thames area appears faster than in the south west (Newlyn). The south east corner of Britain and the East Anglian region are therefore subsiding at a rate of around 1mm/year to 2mm/year (Shennan, 1989). There are other anomalies in localised areas, however, such as the Portsmouth example where subsidence of the rate 3-4mm/year may be occurring.

2.2.6 Storminess under a Scenario of Global Warming

While the implications of climatic change on global sea levels have been modelled and discussed extensively, the effects on storms, winds and disturbances is less certain. There have been many statements suggesting that storms will increase in intensity and frequency at mid latitudes generally and more specifically around Britain. Kelly (cited in Gribben, 1990) suspects that intense storms will be more likely to occur at temperate latitudes as the world begins to warm. Kelly points out that the pattern of warming is expected to be uneven, generating strong temperature gradients. Sinclair (1990) expects increasingly intense storms as warmer temperatures stimulate weather systems into greater activity. A report produced by the Ark Foundation in 1989 also predicts the occurrence of more frequent and violent storms in the UK. Finally, Carter and Draper (1988) reveal that several authors have concluded that wave conditions over the North Sea and North Atlantic have become more severe in recent years. There is, however, no evidence to suggest that this is more than just natural variability.

IPCC (1990) point out that current climate models have limited success in simulating storm tracks of low frequency variability. Results from the current models at least, only give an indication of the likely changes in winds and disturbances. The Report explains that mid-latitude storms, such as those which track across the North Atlantic, are driven by the equator-to-pole temperature gradient. In a warmer world, this gradient would probably be weakened, and it might therefore be argued that mid-latitude storms will weaken or change their tracks. There is some indication of a general reduction in day-to-day and interannual variability in the winter storm tracks, though the patterns of change vary from model to model.

Further research with higher resolution models is needed to assess changes in storminess with any assurance. As storm tracks also depend on global conditions there is a need to run 'General Circulation Models' (based on a global scale) and regional high resolution models together. Hekstra (1989) accepts that a decreasing temperature gradient between the equator and poles should result in fewer and weaker depressions, but he also warns that the effect on specific regions and locations is less easily foreseen.

Alcock (1990) suggests that an increase in mean sea level, and hence water depth, would tend to decrease the effect of wind stress, resulting in smaller surges. He warns, however, that locally generated wind-waves will encounter less resistance from the bottom and grow higher.

2.2.7 Impact of Sea Level Rise on River Discharge Characteristics

Sea level rise will also have a subtle effect on estuaries and the tidal rivers that feed them. Law (1989) notes that recent dredging of the River Thames has moved its saline sector much further upstream. In Louisiana, researchers have been able to see the characteristics of saline intrusion as the Mississippi River deltaic plain subsides and eustatic sea level rises. Vegetation maps indicate a northward movement of saline marsh types in some areas and anthropogenic activities have also accelerated the rates of saline intrustion (Salinas, DeLaune and Patrick, 1986; McKee and Mendelssohn, 1989; Day and Templet, 1989; Schroeder, 1989).

Where the freshwater discharge down a river is large it takes time for the effect of salinity to move upstream, but if the flow of freshwater drops away in times of drought, the sea will move in to make up the shortfall (Law, 1989). A rise in sea level will increase the intrusion of saline water because of the increase in water depths and the increase in tidal flood volumes (Volker, 1987). Titus (1986) refers to De Sylva's comments (1984) that a rise in sea level increases the salinity of an estuary by altering the balance between freshwater and saltwater forces. During droughts the salt water penetrates upstream, while during the rainy season low salinity levels prevail. A rise in sea level has an impact similar to decreasing the freshwater flow. The implications of drought conditions for saline intrusion up tidal rivers and drainage ditches are made more serious by the predictions of the effect of global warming on precipitation. Climatic models cited by IPCC Working Group 1 agree that Britain could expect a change in the seasonality of its rainfall, with wetter winters accompanied by drier summers. The unreliability of models in making regional predictions at high resolution, however, lends suspicion to further quantitative predictions beyond this general pattern.

2.2.8 **Saline Intrusion**

Though less dramatic than inundation by salt water as a result of sea level rise, the likely intrusion of saline water further inland is an important factor in the sea level rise debate. The most publicised threat from saline intrusion is the effect on aquifers and groundwater supplies near to the coastal zone. If the shoreline moves landward under a scenario of rising sea levels, the boundary between fresh and saltwater in a coastal aquifer will move inland and rise nearer to the surface (Barth and Titus, 1984). The displacement of freshwater by denser saltwater provides the greatest danger to coastal aquifers where existing water levels are within a few metres of mean sea level and the implications are particularly serious if salt water migrates up an estuary that recharges an aquifer (Kana et al., 1984; Sorensen et al., 1984). Titus (1987) references Hull and Tortonello's (1979) work showing that since the last ice age, as sea level rose approximately one hundred metres, freshwater rivers such as the Susquehanna have evolved into estuaries like the Chesapeake Bay. A decrease in the flow of a river or an increase in the volume of water allows salt to migrate upstream. An increase in sea level of only 13cm could result in salt concentrations in the Delaware River migrating 2-4km upstream. A rise of one meter could cause salt concentrations to migrate over 20km, possibly enough to threaten part of Philadephia's water supply during a drought (Barth and Titus, 1984) and the Delaware River Basin Commission, for example, has responded to salt water intrusion by constructing reservoirs that release water during droughts, maintaining a minimum flow (Barth and Titus, 1984).

Law (1989) suggests that rises in mean sea level will also increase seepage into the ditches behind tidal embankments and Volker (1987) agrees that such seepage of sea water will increase with changes in the difference between the level of the land to that of the sea. Finally, one further potential problem anticipated by Law, is the impact of saline water becoming trapped upstream of a fixed weir. Either of these scenarios could have potentially serious implications not only for human use of the affected land and water (e.g. agriculture, fisheries), but also for the natural ecosystems in those areas.

2.2.9 **Impact of Sea Level Rise on Sediment Supply**

Any reduction in river discharge in summer has potential implications not only for saline intrusion but also for sediment supply. The expected change in seasonal rainfall patterns (discussed in Section 2.2.7) could lead to a demand for new reservoirs to provide greater potential for water storage. Reservoirs interrupt the natural sediment supply to the river mouth. Dams and other barriers to salt water intrusion can protect water supplies and fresh water habitats, but such structures can retain sediments which in turn can increase erosion of coastal headlands and impair the ability of deltaic wetlands to keep pace with sea level rise (Coastal Zone Management Subgroup, IPCC, 1990).

Law (1989) expects higher sea levels to instigate suspended sediment movements to areas that currently receive negligible material. He refers to the Wash tidal sluice records in dry years, where sediment has been deposited on the seaward face of the sluice gates to such an extent that they would be hard to open on the first autumn flood to illustrate this potential impact.

2.3 Nature Conservation in the Coastal Zone

2.3.1 Coastal Habitats

Britain's coastline, with its outstanding diversity of landscapes and habitats, has been shaped by the islands' complex geological history, by changes in sea level, and by continuous erosion and deposition. Habitats in low lying coastal areas include sand dunes, saltmarshes, mud and sand flats, shingle features, coastal lagoons, reedbeds and grazing marshes. All of these landscapes and habitats have now been affected to a greater or lesser extent by human activities. Land claim for agricultural or industrial use has caused major losses of coastal habitat. Development immediately behind sand dunes and shingle ridges has inhibited their natural migration inland, particularly under storm conditions, and the building of seawalls and other structures has similarly prevented the natural retreat landwards of saltmarshes and coastal wetland features.

Table 2.3.1 demonstrates the current extent of each of the major types of coastal habitat in England and Wales. Figure 2.3.1 shows the distribution of three of these habitats - saltmarsh, shingle and sand dunes. The most valuable examples of all these habitats around the English and Welsh coast are designated as National Nature Reserves (NNR). The primary habitats in the coastal NNRs are shown in Table 2.3.2, and all the NNRs listed are highlighted on Figure 2.3.2.

The recent publication of documents such as Turning the Tide (RSPB, 1990a), together with the NCC Estuaries Review (1991), demonstrate quite clearly the extent and significance of coastal habitat loss. The recent introduction of legislation requiring an Environmental Assessment to be carried out on certain development projects, combined with the nature conservation objectives set out in the recent White Paper "This Common Inheritance" (HMSO, 1990a), indicate that the nation is beginning to take a more positive approach to environmental protection. But, in the short-term at least, more of our coastal habitats will be lost. Some will be lost as the result of development or planning pressures as discussed above. Some will be damaged or degraded because of pollution. Over the longer term, however, increased rates of sea level rise, increased storminess, and saline intrusion, even of the relatively small magnitudes discussed in Section 2.2, could have a major adverse effect on our remaining coastal wildlife resource. The possible environmental impacts of such changes in climate on low-lying coastal areas are discussed in Sections 2.3.5 onwards.

Table 2.3.1 Areas and Lengths of Coastal Habitats in England and Wales

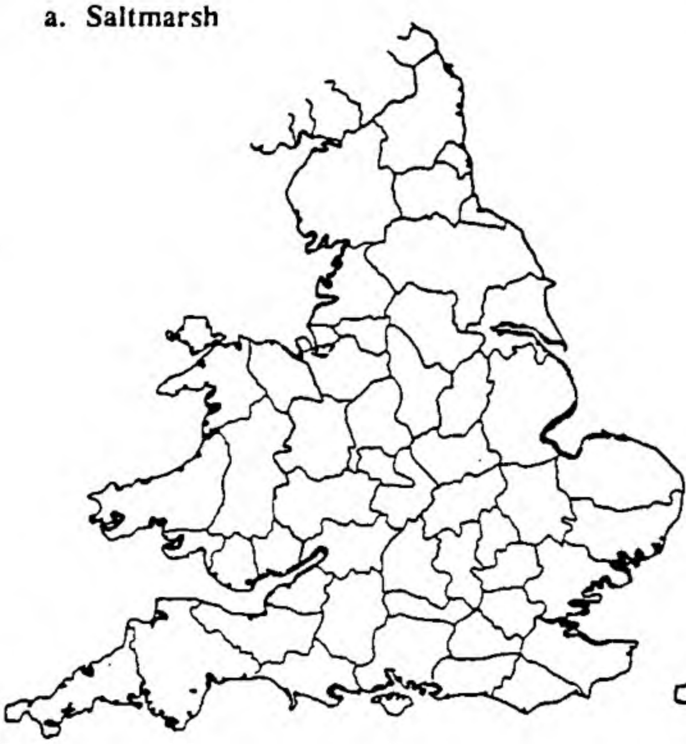
Coastal Habitats	Area (ha)
Intertidal Flats*	181,705
Saltmarsh	33,794
Sand Dune	16,334
Vegetated Shingle	3,527
Total Area	**235,360**
Foreshore Habitats	**Length (km) (Measured at Mean High Water)**
Mud	1,513
Sand	1,305
Rocky Shore	1,038
Shingle	640
Mixed Sediment	1,107
Saltmarsh	1,607
No intertidal area	325
Total Length (MHW)	**7,535**
Terrestrial Habitats	**Length (km)**
Sand Dune	474
Cliffs	1,605
Shingle Vegetation	358
Artificial Embankment	1,945
Other habitat	2,679
Total Length (Terrestrial)	**7,061**

Source: Coastal resources Survey, Chief Scientist Directorate; Nature Conservancy Council, Peterborough, UK. December, 1990.

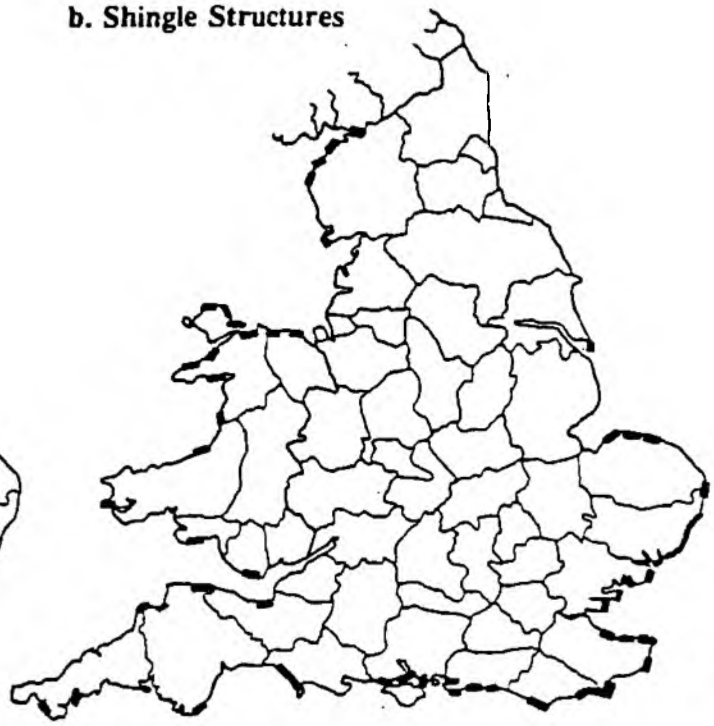
* There is no strict definition of intertidal flats but it is taken to mean areas of intertidal muds and sands.

Figure 2.3.1 General Distribution of Major Coastal Habitat Types around the Coastline of England and Wales

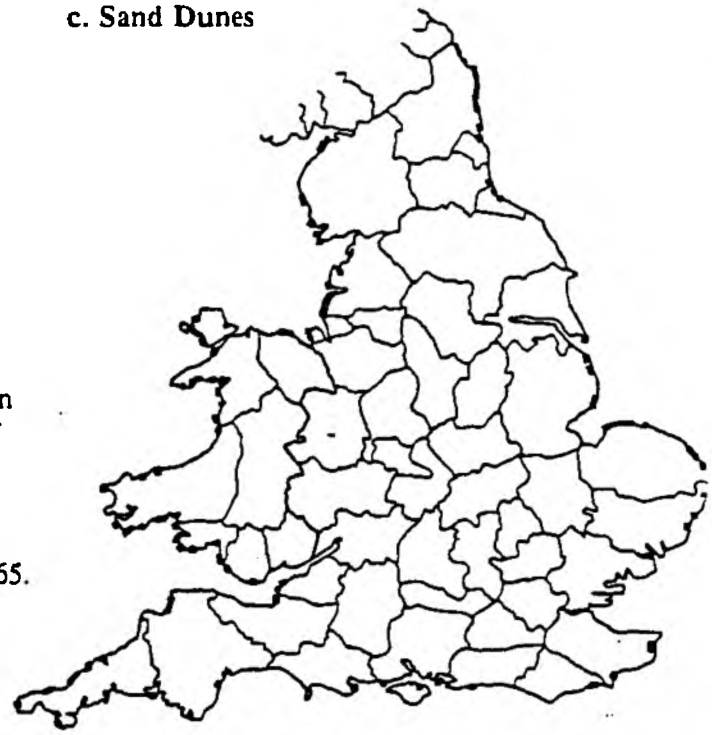
a. Saltmarsh



b. Shingle Structures



c. Sand Dunes



a. Source: based on a figure in Burd F. (1989) The Saltmarsh Survey of Great Britain : An Inventory of British Saltmarshes. Research and Survey in Nature Conservation Series No. 17, NCC, Peterborough.

b. Source: Based on figure provided by P. Sneddon (personal communication, 1990), Department of Geography, University of Cambridge.

c. Source: Based on figure in Doody, J.P. (1989) Management for Nature Conservation pp 247-265. In: Proceedings of the Royal Society of Edinburgh, 96b.

Table 2.3.2 Coastal National Nature Reserves and their Primary Habitat Interests

HABITAT	NATIONAL NATURE RESERVE (NNR)	OTHER ASSOCIATED HABITATS
Sand Dune	Winterton Dunes	Acid dune system
	Studland Heath	Lagoon and heathland
	Braunton Burrows	
	Morfa Harlech	
	Dyfi (Ynyslas Dunes)	Estuary and raised bog
	Ainsdale Sand Dunes	Slack and woodland
Sand Dune and Saltmarsh	Gibraltar Point	
	Oxwich	Freshwater marsh between wooded limestone headlands
	Whiteford	Foreshore
	Ynys Llanddwyn/Newborough Warren	Pools and rocky headlands
	Morfa Dyffryn	
Sand Dune, Saltmarsh and mudflats	Lindisfarne	
	Saltfleetby/Theddlethorpe Dunes	Freshwater marsh and sandflats
	Holkham	Sandflat and farmland
Sand dune, Shingle and Saltmarsh	Scolt Head Island	
Saltmarsh	North Solent	Grazing marsh
	Hartland Moor	Heathland inland

HABITAT	NATIONAL NATURE RESERVE (NNR)	OTHER ASSOCIATED HABITATS
Saltmarsh and Mudflats	Blackwater Estuary	Grazing marsh
	Colne Estuary	
	Dengie	Shingle
	Leigh	
	The Swale	Grazing marsh lagoons
	Arne	Heathland inland
	Ribble Marshes	
Shingle and Saltmarsh	Orfordness and Havergate Island	Havergate - lagooned island
Mudflats	Walberswick	Reedbeds, saltmarsh, woodland and heath island
	Hamford Water	Fringing saltmarsh
Sandflat and Shingle	Bridgwater Bay	Lagoons
Cliff	Axmouth and Lyme Regis Undercliffs	
	The Lizard	Complex of coastal cliff and heathland
	Gower Coast	Cliffs and foreshore
	Stackpole	Dunes, calcareous grassland and freshwater lakes
	Skomer	Rocky island
Island	Bardsey Island (Ynys Enlli)	

N.B. There are a total of 34 coastal NNRs (Gubbay, 1988). Saltmarsh is represented in at least 25 NNRs, sand dune systems in 15 NNRs and mudflats in 12. Shingle habitats are found in 3 NNRs while sandflats occur in only one. Many of these habitats also occur as fringing areas at other sites, adding to the general diversity of NNRs.

Figure 2.3.2 Coastal National Nature Reserves in England and Wales

Source: Based on a figure in Gubbay, S. (1988)
A Coastal Directory of Marine Nature Conservation
Marine Conservation Society, Ross-on-Wye

2.3.2 Coastal Habitat Functions and Services

Low-lying coastal habitats in Great Britain are of critical importance for nature conservation, both nationally and internationally. They provide feeding, breeding and roosting areas for many British bird species and act as wintering or stop over habitats for migratory species. In this latter role they are a vital link in the Eastern Atlantic Flyway - the ecological link between the breeding grounds of the northern tundras and the warmer wintering habitats of temperate Europe and tropical Africa. Coastal habitats are also a source of food and refuge for many British invertebrates, mammals, amphibians and reptiles and they are a favoured breeding ground for many marine invertebrates. The flora and fauna of coastal habitats therefore constitute a vital and highly productive part of Great Britain's natural wildlife resource

Primary productivity, a measure of the conversion of solar energy to a form of energy that may be used to power the biological processes that sustain life, gives rise to many other valuable functions (Larson, 1980). Coastal habitats are, for example, very important to fisheries resources which are currently suffering from both pollution and over-exploitation. The wetlands' rich nutrient supply and the sheltered conditions of estuaries are used seasonally, both by migratory fish and as spawning and nursery areas. Creek channels in particular are inhabited by several fish and shrimp species. Worldwide, over 50% of fishing is estuarine dependent (Asthana, 1989). Eighteen British fish species are dependent on estuaries for part or all of their life cycle. These include commercial species such as bass, flounder, and eel (NCC, 1991).

Coastal habitats provide many additional functions and services on which people depend to a greater or lesser extent. Some perform valuable flood defence and storm protection functions. Salt marsh, for example, acts as a buffer absorbing wave energy and hence preventing erosion. Reedbeds have a role in treating waste water; filtering water, retaining and removing nutrients and some heavy metals, and thus improving water quality. Other wetlands contribute to the groundwater recharge or discharge process; some provide a source of fuel. Most coastal habitats also provide an important recreational resource for walking, birdwatching, hunting and fishing. Many have protected or highly prized landscapes, and some are of considerable heritage value.

A number of authors have dealt in detail with the concept of wetland functions and services (e.g. Adamus and Stockwell, 1983; Larson, 1980; Gosselink et al., 1974) and it is not the purpose of this report to replicate their work. These functions and services are, however, of particular importance to this study in two respects. Firstly, the "success" of many habitat creation or restoration projects will ultimately be judged by the extent to which the natural characteristics of a particular habitat can be recreated. Secondly, a number of authors have attempted to place economic values on the services and functions provided by natural coastal wetlands, (e.g. King, 1990; Shabman and Batie, 1978). Some of these values may be of use in attempting to justify expenditure on habitat creation or restoration initiatives - if, of course, we can in fact duplicate the natural processes being evaluated. The economic valuation issue is discussed in detail in Section 4.

2.3.3 The Impacts of Climate Change and Sea Level Rise on the Coastal Resource

Mean sea level, tidal rise and fall, meteorological surges, tidal streams and other currents, and wave action are all important in shaping Britain's coastline. All of these factors may be modified to some extent by climate change, most particularly through the predicted rise in mean sea level and by the possible increase in the occurrence and severity of storms discussed in Section 2.2.

In the absence of other influences, a rise in mean sea level on a sloping shore will lead to a change in the position of the mean water line and thus an effective erosion. Before attempting to predict future changes, however, the possible impact of sea level rise on the other factors listed above must be assessed.

- **Tidal rise and fall**

Tides are driven by astronomical forces and are unaffected by weather conditions. They may, however, be influenced by a rise in sea level. The tidal range along many parts of the UK coast is large, the spring tide range being some thirteen metres in Bristol and more than three metres along most of the coast. The variations from place to place are a function of the shape of the coast, as well as the fact that the main tide in the North Atlantic reaches the south of England by passing around the north of Scotland and down the North Sea. The shape of the coast, particularly in Liverpool Bay and the Severn Estuary, can greatly amplify tidal range.

The effect on tides of an increase in sea level of the order of less than half a metre is not yet known. In particular, the impact on the high tidal ranges in estuaries such as the Severn is likely to be somewhat complicated. The overall increase in water level will reduce the significance of frictional losses as tides flow over the sea bed. The resonant characteristics of tidal estuaries may change and the tidal volume will increase if there is increased flooding of marshes. Pending further investigation into the subject, however, it is believed that changes in vertical tidal movement are not likely to be great. Tidal levels will of course be displaced upwards as a direct result of a rise in sea level. Recent analysis of long term tidal records at Immingham (Posford Duvivier, 1991), during which time sea level rose by some 0.25m, indicated that mean high water, mean water level and mean low water level had all risen by the same amount and at the same rate.

In terms of the impacts on the coastal resource, the effect of a rise in tidal levels is likely to be most significant where it leads to the greatest change of the intertidal zone. For example, an area with a large tidal range such as the Severn Estuary could potentially be much less seriously affected than Poole Harbour, which has a spring tidal range of just 1.5m. In this latter case a rise in sea levels of 0.5m could destroy much of the salting and mudflat habitats in the absence of compensating accretion.

- **Meteorological Surges**

The most extreme high water levels around the coast of the UK are the result of a combination of high tides and surges. The latter are caused by meteorological effects - low pressure and strong winds. Any change in the occurrence and/or strength of storms is therefore likely to modify surges and consequently extreme high water levels. Until more is known about the degree of any increase in storminess, it is not possible to predict what the precise effect of sea level rise on surges may be.

A rise in sea level will also influence the generation and propagation of surges due to changes in hydrodynamics resulting from the increased water level. Information from Proudman Oceanographic Laboratory, however, suggests that any such changes are likely to be of minor significance.

- **Tidal Streams**

As discussed above, it is believed that changes in tidal levels other than those due simply to the direct impact of a higher mean sea level, will be minor. It follows that tidal streams will remain similar except where the tidal prism at a site is increased greatly by increased flooding. Such a situation is most likely to develop in enclosed tidal waters such as estuaries and creeks. The impact would be greatest when the increase in tidal volume is proportionally large, for example, where the rise in sea level is of a similar magnitude to the tidal range, or possibly when land presently protected is allowed to flood. Increased tidal volume will lead to a more energetic flow overall, and thus to some changes in the sea bed configuration particularly at the entrance to enclosed tidal waters.

- **Wave action**

In considering waves at the shore, two aspects need to be considered:-

- the offshore wave climate.
- the shallow water processes which transform offshore waves as they travel shorewards.

Offshore wave climate in the open sea will be largely unaffected by sea level rise but an increase in storminess has considerable potential for causing an increase in the severity of wave climate. Section 2.2.6 indicates that there is already evidence of such an increase, but because accurate wave records have only been kept for the last 25 years or so, the identification of statistically valid long term trends is not yet possible. A visual assessment by Carter and Draper (1988) does suggest a progressive rise in mean wave height offshore from south-west England of some 1-2% per year. Weather patterns show considerable year-on-year and decade-on-decade variability, however, so the existence of a trend over some 20 years is no evidence of anything longer term, let alone an indication of an impact of global warming. Nonetheless the potential effects could be serious, and IPCC (1990) therefore identified the importance of studying this topic in considerable detail.

Possible shallow water effects of sea level rise include such factors as wave breaking, wave height loss due to sea bed friction, wave refraction due to depth, shoaling, and wave refraction due to currents. Water depth is a major influence in the first four. An increase in sea level will therefore lead to a change in inshore wave climate by increasing water depths. This will for the most part take the form of an increase in wave height. Waves in shallow water travelling over a flat bed, for example, are limited in height by breaking to approximately 70% of the depth.

The largest waves to reach the UK's shores are generated over fetches several hundred miles long. Within estuaries, however, the shore may be protected to the extent that it is only exposed to waves generated over a fetch as little as a few hundred metres. In this case, a rise in sea level which leads to a greater flooded area at high water could significantly increase the fetch and thus the severity of wave climate at the shore.

2.3.4 The Dynamic Environment of the Coast

Before commencing discussion on the impact of global warming on defined habitats, it is prudent to set sea level rise in the context of the coastline as a dynamic environment. The natural tendency is for the coast to erode to the point where, by virtue of its profile, it becomes stable. Around 70% of the world's shores are currently eroding, to a large extent irrespective of any change in climate.

There is an underlying tendency for erosion to be influenced locally by a number of factors. Two key factors are the "hardness" of the coast - granite will erode much more slowly than sand and fine particles will stabilize at a far flatter slope than sand - and human intervention. Human interference might have the following impacts:-

- preventing erosion on one part of the coast may enhance erosion elsewhere.
- constructing dams may reduce the supply of riverborne material to the coast.
- dredging and extraction of materials from rivers and the coast may lead to erosion.
- building breakwaters and other major works might interrupt natural sediment transport patterns.

Furthermore the weather itself is variable, irrespective of long term changes. A single severe event (such as the 1953 floods) can be of major significance with respect to the evolution of a coast.

Finally, sea level is already rising and the rate at which it rises varies along the coast due to land movement. Land is sinking in the south east (see Section 2.2.4), to the extent that sea level rise in that region over the last century has already been greater than it is likely to be in the north west over the next century. In this respect there is clearly much to be learned from monitoring the impacts of past changes.

Both sea level rise and the potential increase in storminess are significant. The other factors discussed above do not alter this significance. They do, however, remind the reader that global warming should be viewed within the context of past and present changes.

2.3.5 Impacts on the Coastline

The physical processes that shape the coast combine to form a complex interrelated regime. Erosion in one place provides material for a beach or mudflat on another part of the coast. Similarly, prevention of erosion can (and has) led to the starvation of beaches elsewhere. The understanding of the coastal regime, and the development of strategies for coastal works which take this into account, are increasingly becoming part of shoreline management planning. Shoreline management, in turn, will need to become an integral part of the management of the entire coastal zone in respect not only of nature conservation, landscape and coastal defence, but also tourism and recreation, fisheries, commercial interests etc.

Global warming, in so far as it affects these coastal processes, will also need to be brought into shoreline and coastal management. The following discussion considers various coastal habitats and the impacts of global warming on these coastal habitats independently, and thus in isolation. In reality, of course, this will not be the case. The increase in global warming is likely to lead to increased erosion and hence to more littoral material being freed for transport into sheltered areas. Assuming such erosion is not prevented by man (e.g. by coast protection works), sediment necessary for the accretion of mudflats, sandflats, saltings and shingle beaches may be generated in at least as great if not greater quantities than at present. The littoral zone is, however, complex. In such a complex regime, the value of monitoring is high and represents a good return on investment. Relatively cheap yet effective forms of monitoring include:-

- tide records
- beach profiles
- coastline surveys
- soundings surveys
- wave records.

The need for monitoring, both of coastal processes and of ecological changes, cannot be overstated if climate change and sea level rise is to be both accommodated and managed in order to maximise opportunities and minimise threats.

2.3.6 Sand Beaches and Dunes

Sand dunes as a terrestrial habitat currently extend along 474 km of the English and Welsh coastlines, and dunes cover a total area of 16334 ha (see Figure 2.3.1(c)). Around 120 dune systems in Great Britain are within Sites of Special Scientific Interest (SSSI) (Doody, 1989a) and, out of 34 coastal National Nature Reserves in England and Wales, 15 include sand dune habitats as a primary feature (see Table 2.3.2).

Degradation and losses of sand dune systems have occurred in the past due to a variety of activities including afforestation, military operations, housing, golf courses, extraction and agriculture. Many sand dune systems are also under intense pressure from recreational activity, leading to extensive erosion within and at the edges of the dune system. Damage may also result from indirect pressures: development directly behind the dunes, for example, has caused serious problems by inhibiting the natural tendency of the dune system to migrate inland.

The sand dune system between Liverpool and Southport has been particularly seriously affected by a wide range of encroachments. As a result, only 10% of the original area of 15,000 ha now remains. Similarly, in Swansea Bay South Wales, only 776 ha of the 1260 ha present 100 years ago are still intact (Doody, 1989a).

Although most dune losses are due to human activities, it should be noted that natural phenomena can also cause damage and destruction, at least temporarily. At Brancaster in Norfolk, for example, 20m of dunes were lost during storms in 1990.

2.3.7 Sand beaches and dunes are widespread on exposed areas where there is an adequate supply of material from cliff erosion, rivers, offshore sources or from alongshore. Sand beaches respond rapidly to storms or changes in coastal conditions and can be expected to be modified by sea level rise as well as by change in storminess. Work by Bruun (US Army Corps of Engineers, 1962) postulates a method of determining the amount of beach retreat due to a given amount of sea level rise (The Bruun rule). Its validity has been questioned and tested in many situations and it is by far the most widely used method of assessing coastal erosion due to global warming.

In essence The Bruun Rule assumes that, in the event of sea level rise, the beach profile will readjust to the point where the wave induced shear stress acting on the sea bed is restored to present values. The new profile thus predicted, inevitably (in the case of sea level rise) shows a retreat of the coast. The actual magnitude of retreat is a function of the existing profile. As an example, however, Wind (1987) suggests that a sea level rise of 30cm could lead to beach retreat of 20-60m. This amount of retreat could, however, be further affected by other factors which are not included in The Bruun Rule, such as changes in longshore transport. As erosion proceeds, finer cohesive materials may be exposed as is currently happening on the Lincolnshire coast. Once eroded this material will pass into suspension, will be transported (probably) offshore, and will not be reworked into the new profile as assumed in The Bruun rule. Finally, increasing storminess will tend to increase the net offshore loss of sand from beaches and so increase erosion.

The sand beaches of the UK have already suffered widespread erosion and global warming could exacerbate this problem. Sand dunes are an integral part of the natural coastal defence system. In the event of beach retreat accelerating, dunes will be called upon to perform their vital coastal defence function which is to provide sand to the beaches in front of them when they are drawn down. If this becomes a chronic tendency one can expect dunes to decrease in size since, for the most part, rates of material eroded by the sea are substantially greater than the rates of aeolian supply.

The effect on sand beaches and dunes of relatively modest rises in sea level, even without any increase in storminess, could therefore be substantial. In the absence of human assistance (e.g. beach nourishment or structural works) this is likely to lead to significant erosion of both the beach and seawardmost dunes. The sand released would either:-

- become available via aeolian transport for new dune building further inland
- be removed from the dune system to feed the beach
- be removed and lost by the sea.

A number of factors will determine whether the dunes retreat landward or disappear. The susceptibility of individual dune systems will vary depending on:-

- their location and physical and biological characteristics including sand supply
- the balance between prevailing and dominant winds
- the strength and direction of the prevailing wind (Boorman et al., 1989) and also:-
- man's willingness to allow the dunes to retreat (see Section 2.3.6).

To some extent, instability within certain dune systems generated by climate change may not be detrimental. Coastal ecosystems are dynamic and change is important. Many sand dune systems might be expected to retreat inland under such a scenario, but where there is development immediately behind the dune, such retreat is likely to be prevented by man. Where the dune system does retreat significantly, the habitat behind the dunes may become susceptible to inundation by sand. Increased blowouts will cause instability and the saltwater flooding of fresh water slacks might have a detrimental effect on some important ecosystems including, ultimately, the overall ecology of the dunes. On the other hand, however, the area of slack communities might increase if a rise in sea level causes a subsequent rise in the fresh water table.

2.3.8 Sandflats and Sandbanks

The process behaviour of many of the offshore sandbanks around the coast of the UK is not fully understood. They often exist as part of the delicate balance (or imbalance) between divergent or opposing sediment transport mechanisms. They can also exist on exposed coasts such as those off Great Yarmouth and Lowestoft. In spite of lengthy studies, however, their future behaviour cannot be predicted, even in the absence of global warming. The effect of global sea level rise may well be significant, but whether it would lead to a net loss or gain of sandbanks cannot be ascertained. Among the biological implications of any disappearance of sandbanks, however, would be the loss of seal haul-out areas, notably around the East Anglian Coast, and the loss of low intertidal sand and shingle islands used by breeding terns.

Coastal sandflats are different from sand banks in geomorphological terms, as they lie in more sheltered areas. It is difficult to postulate the likely effects of global warming, but one would expect that any edges exposed to wave action may well suffer from a net erosion in a manner similar to that addressed by the Bruun rule. There may also be changes in the overall extent of sandflats, and in their location. If exposure times are changed or sandflats "drowned" as a result of sea level rise, the opportunities available for feeding birds will be lost or detrimentally affected. Sandflat invertebrates remain in contact with the water table and are subsequently very susceptible to changes in water level. The nature of the flats might also be altered by changes in sediment characteristics but, as with much of sediment transport, the coastal process regime is very site specific and it is therefore unwise to generalise.

2.3.9 Saltmarsh

Saltmarshes currently extend over 1,607 km of the English and Welsh coastlines (covering an area of 33,794 ha; see Table 2.3.1) and occur in at least twenty coastal National Nature Reserves. 87% of England's saltmarsh areas are designated SSSIs (Hollis et al., 1990). Saltings exist in sheltered areas, usually at the crest of muddy foreshores.

Despite their undeniable importance as roosting and feeding areas for birds and as fish nursery areas, saltmarshes are arguably Britain's most threatened coastal ecosystem. Over the last 500 years the area of saltmarsh in Britain has been reduced by 55000 ha (Gubbay, 1988), the majority of loss occurring in the 1800s. The remaining saltmarshes are still threatened in a variety of ways. Marsh losses are attributable to land drainage schemes and land claim for both agricultural and industrial purposes. Increased pollution from industrial and domestic sources also has a detrimental effect on saltmarsh vegetation.

In many parts of southern and eastern England, saltings appear to be eroding, a process which is not fully understood and which is being studied further. However, a prime factor in their demise when they do erode appears to be an increase in wave action which attacks the seaward edge of the saltings. This increase could result from the loss of adjacent mudflats due to change in sedimentation regime or an increase in water level allowing larger waves to reach the saltings edge.

On Dengie in Essex, approximately 10% of the total area of saltmarsh was lost between 1960 and 1981 (Harmsworth and Long, 1986). Although possibly related to changes in land-sea levels, this type of loss may also be indirectly caused to some extent by coastal protection work reducing the sediment available for accretion.

With an adequate supply of sediment Wind (1987) suggests that saltmarshes can accrete upwards by 2-6mm/year while Beeftink (1977) suggests 3-10mm/year. Providing rates of accretion do not exceed the ability of saltmarsh plants to colonise, some saltmarshes might therefore be expected to "keep up with" sea level rise. Without an adequate supply of sediment, however, saltmarsh plants would be detrimentally affected because they can only tolerate limited submergence. Further, as waterlogging increases, anaerobic conditions prevail. Organic substances are not oxidised and accumulate in the soil to the detriment of plants, particularly higher level marsh (Beardall et al., 1988).

Under a scenario of sea level rise the edges of saltmarshes are likely to become cliffed, and creeks might become steeper and wider (Boorman et al., 1989). Any change in sediment size (due, for example, to the predicted higher energy environment) will also affect saltmarshes detrimentally because certain species will not survive if sediment becomes coarser.

Existing higher level saltmarsh is important as a roosting and nesting site for waders, while low level marsh provides a significant feeding area for birds. Sea walls and other hard defence structures prevent the inland migration of saltmarshes in many areas. Sea level rise might therefore be expected to lead to a reduction in the overall area of saltings where they are backed by sea defence structures. Within a marsh a reversion to vegetation type characteristics of an earlier development phase might be expected (e.g. upper to lower marsh species; lower marsh to pioneer species; drowning of lower zones and/or reversion to mudflats). Any major reduction in the area of saltmarsh could therefore be expected to have a major adverse impact on coastal birds and other wildlife.

2.3.10 Mudflats

Mudflats, which are important intertidal habitats because their high organic matter content attracts dense populations of invertebrates and hence feeding brids, currently extend along 1513 km of the English and Welsh coastlines. Intertidal flats (including both muds and sands) cover an area of 181,705 ha (see Table 2.3.1) and are represented in more than thirteen National Nature Reserves. Hollis et al (1990) report that up to 90% of mudflats are protected by SSSI status, and fifty five estuaries containing intertidal mudflats meet the criteria for designation as Ramsar Convention Sites and as Special Protection Areas under the EC Birds Directive. Only sixteen of these, however, have been formally designated (RSPB, 1990).

Many intertidal flats exist within estuaries which have historically been subjected to human interference. Pressures from marinas, land reclamation, barrages and industry are often irreversible and reduce the area of intertidal habitats. The intertidal mudflats of Teesmouth, for example, have been reduced from 2,400 ha to 175 ha over the last hundred years (Greenpeace, 1987), the loss being largely attributable to industrial land-claim. In the Tyne, all intertidal flats have been lost (RSPB, 1990a), while in Suffolk the construction of the Felixstowe dock extension has destroyed prime mudflats at Faybury Creek in part of the River Orwell SSSI (RSNC, 1989). As well as these permanent losses, significant temporary disturbances to the ecology can be caused by uncontrolled bait-digging, cockle fishing and recreation activities.

Mudflats generally occur in sheltered areas. As estuarine features, whilst they can be part of long term deposition (as a drowned river valley fills with silt), they can also vary substantially over time as with the mud and sandflats in the Humber. The processes that shape mudflats are very site specific and it is not possible to generalise on how they will respond to global warming. One would expect that, simply due to rise in sea level, the extent and exposure of mudflats would decrease. Deposition would tend to counteract this tendency (Hollis et al., 1990), but only if there is an adequate supply of sediment.

As with sandflats, any reduction in the exposure time due to a rise in sea levels will reduce the value of mudflats to feeding birds because, although invertebrates remain in the upper layers of mud during low tide, the time during which the mud is exposed is critical to wading bird feeding cycles. Similarly, any change in the nature of the sediment could detrimentally affect invertebrate communities and hence birds. Sediments consisting only of coarse particles have very poor faunas because of the grinding action of the particles when they are moved by waves or currents. Eroding sediments, whether fine or coarse, have poor fauna when compared to those in areas of deposition, presumably because larvae have difficulty in settling (Boorman et al., 1989).

Within estuaries, mudflats are to a large extent shaped by tidal currents, and the position of mudflats along a tidal river is strongly influenced by the interaction between fresh and saline water. A rise in sea level could well cause changes in the position and shape of mudflats, and work in France suggests that the stability of mudflats may also be very sensitive to quite subtle changes in velocities. Overall, therefore, sea level rise could potentially have a significant impact on Britain's mudflats.

2.3.11 Shingle Features

Shingle currently extends over 640 km of the English and Welsh coastline and vegetated coastal shingle covers 3,527 ha (see Table 2.3.1). Three National Nature Reserves and thirty five SSSIs contain major shingle structures (P. Sneddon, personal communication, 1990).

Shingle structures such as Orfordness in Suffolk have suffered from human activities, primarily shingle extraction for construction work. Recreation pressures also inhibit colonisation of shingle by plants (Beardall et al, 1988). Shingle is a very mobile habitat and, although its species are adapted to these conditions, damage to shingle ecology may result from further disturbances. One further, albeit indirect, cause of damage to shingle features is man-induced or natural interference in sediment supply. Shingle transport along the coast may, for example, be interupted by harbour or sea defence structures (e.g. groynes, breakwaters).

Sea level rise is likely to have a variety of impacts on different shingle features. Trangressional adjustment at a few of the large shingle structures could compensate for sea level rise to some extent. At Dungeness for example, a rise in level would increase erosion along the south shore, but this would be compensated for by increased deposition along the east shore (Boorman et al., 1989). Many other shingle features, however, are effectively "fossil structures" with little contemporary shingle supply (Doody and Burd, 1990). These are, therefore, vulnerable to both erosion and breaching.

Many of the UK's shingle beaches extend only down to mean sea level, with a much flatter mud/sand foreshore below, although in places the steep shingle beach is founded much deeper. Shingle beaches do not generally suffer from offshore losses in the same way as sand beaches. Frequently, they rely on a continuing longshore supply of shingle, perhaps from cliff erosion or from ancient geological deposits. In time (perhaps over very long periods) the shingle decreases in size as a result of attrition.

In the event of global warming, an increase in sea level is likely to produce a net change in the beach profile. This will result in an effective erosion (as with sand beaches) and greater storminess would further increase this effect. Erosion by this mechanism would be less than in the case of sand beaches, because shingle beach profiles tend to be steeper (at say 1:7-8) than sand beaches say (1:20). Where the beach forms the front face of a shingle ridge, however, the retreat would not simply be a reworking of the profile.

Shingle ridges occur in various parts of Great Britain - for example at Porlock (Somerset), Westward Ho (Devon) and Cley (Norfolk). Naturally they tend to migrate landwards because shingle transported over the crest in storms is not returned. In the event of sea level rise and larger waves reaching the shore, overtopping of a ridge would become more frequent and the rate of retreat would increase accordingly. The action of retreat could, however, restore the ridge to its present effective level if the land onto which the ridge retreats slopes upwards to the extent that the level of the ridge is raised. The effect of retreat can reduce the cross section of the ridge when, as is often the case in an enclosed bay, one end of the ridge is held by some natural or artificial structure. In this case, as the ridge retreats, it stretches over a longer distance. The volume of shingle per length of ridge therefore decreases, the frequency of overtopping increases further and the rate of retreat accelerates. The logical conclusion of this process is a breach or a series of breaches in the shingle ridge.

Finally, it might be anticipated that many shingle vegetation communities will be lost due to a combination of increased inundation, storminess and particularly the general increased mobility of shingle under a scenario of sea level rise.

2.3.12 Coastal Lagoons

Two types of coastal lagoons are considered in this report: those which normally lie immediately landward of shingle ridges, and those which comprise sheltered tidal inlets protected by shingle or sand spits. In both cases the input of freshwater is significant in determining the mix of habitats. Britain has only 41 coastal lagoons of the first type making this a relatively rare habitat. All such lagoons are isolated behind barriers of shingle and most receive sea water influx only by percolation through, or occasional overtopping of, this shingle (Barnes, 1989). When considering possible losses in the event of global warming in respect of this lagoon type, perhaps the most significant impact is likely to be any increase in rate of retreat of the ridge (see Section 2.3.11) and a possible associated increase in overtopping. In addition, the general rise in water level will tend to increase saline intrusion into the lagoons. This is likely to disturb existing lagoons whilst possibly encouraging the formation of new ones. Breaching of ridges would of course threaten the existence of lagoons leading to their draining and possibly to their replacement by saltmarsh.

In the case of tidal inlets, the first potentially significant impact under a scenario of sea level rise is any increase in littoral transport due to higher waves reaching the spit. In extreme cases this could threaten the existence of the tidal opening to the lagoon. The second major aspect is the increase in tidal levels. This would increase tidal currents through the entrance and may counteract any tendency for closure. On balance therefore it would be expected that tidal lagoons would generally remain intact.

In both cases, the flora and macrofauna lagoon communities are very sensitive to salinity levels. Most lagoons are brackish and some are largely freshwater in nature. Increased salinity could therefore lead to significant changes in lagoonal species composition (Gubbay, 1988).

Lagoons are threatened by people as a result of utilisation for dock and harbour developments, quarrying, saltworks and waste disposal, as well as reclamation for agriculture (Gubbay, 1988). Eutrophication can seriously affect the value of the lagoon and the habitat can be easily damaged by pollution because of the characteristically low flushing rate. Indirect effects can also be caused by changes in land drainage patterns, affecting sedimentation and the water regime of the lagoons.

Lagoons can, however, develop and disappear naturally over relatively short time scales due to changes in the shingle spit or bar often found fronting the lagoon. It is therefore difficult to predict whether or not increased rates of sea level rise would lead to significant changes in the overall number and/or characteristics of Britain's coastal lagoons.

2.3.13 Reedbeds

Reedbeds are of nature conservation importance partly because they offer a sheltered sanctuary to many important bird species. Coastal reedbeds greater than two hectares cover 933 ha at a total of just 28 sites (Bibby and Lunn, 1982). Within the area of interest to this study, reedbeds are predominantly estuarine as they require a freshwater input. The pressures of land claim, industrial activity and recreation associated with estuaries all pose a potentially serious threat to reedbeds. Natural succession can also lead to reedbed loss: accumulation of silt and dead organic matter will raise the land level, enabling colonisation by more terrestrial species. This is particularly the case during drier years when lower water tables allow species such as willow (Salix spp.) to invade.

In the coastal zone, reedbeds occur where fresh water flows into tidal saline rivers. Sea level rise could influence these sites as a result of changes in salinity, currents and water depth. As with saltmarshes, however, if reedbeds have room to retreat upstream or landward they may well do so. There is likely to be some loss of existing reedbeds with sea level rise due to their preference for a water depth of between 0.5-1.0 m and salinity of less than 5 parts per thousand, but they are likely to colonise other areas. Reeds are, for example, often present in ditches, and the managed flooding of agricultural land could allow for the creation of new reedbeds. Coastal reedbeds could also be created behind sea defences if saline water entry was controlled by sluices.

2.3.14 Grazing Marsh

Grazing marsh is important from the point of view of nature conservation for several reasons. During the spring and early summer, such areas are used as breeding sites for many ground-nesting bird species. During the winter they are used by migratory birds as feeding areas. The low intensity agricultural regimes on many grazing marshes require a minimum input of fertilisers, pesticides and herbicides, and wetland plant communities frequently thrive in the unpolluted high water table environment. In some cases these marshes depend on freshwater, in others there is a marked brackish water influence. Halvergate Marshes on the Norfolk Broads offers an example of both types of interest. Saltwater intrusion through North Breydon flood wall creates a valuable brackish water habitat at the rear of the bank, while freshwater flowing off the upland produces a rich and diverse marshland habitat further inland. This type of salinity gradient may be extremely important to the diversity of invertebrate life on grazing marshes, as well as supporting a variety of botanical interest.

Grazing marsh, however, has been and remains susceptible to drainage, to the intensification of grazing regimes, and conversion to arable cultivation. In the Thames Estuary, for instance, 48% of the grazing marsh has been drained since 1935 (Greenpeace, 1987). 13% is due to urban development and the remaining 35% has been converted to arable cultivation (NCC, 1984). In Essex, only 20% of the grazing marshes present in 1930-39 remain (NCC, 1990), while between 1955-58 20% of the Suffolk grazing marshes were converted to arable (Beardall et al, 1988). Finally, the Yare Basin in Norfolk has shown a decrease of 31% in the area of grazing marsh between 1967 (19,000 ha) and 1982 (13,060 ha) (NCC, 1984).

A high proportion of existing coastal grazing marshes are on land previously claimed from the sea, and the breaching of sea walls may in fact lead to the reversion of these areas to inter-tidal or sub-tidal habitats depending on present elevation. The 1953 storm surge caused many bank failures along the East Anglian coast and in some places grazing marshes did revert to tidal regimes.

As with saltmarshes and coastal lagoons, grazing marshes are likely to suffer increasingly severe and frequent flooding under a scenario of sea level rise. The extent of saline influence, through both overtopping and intrusion would increase. If the topography is suitable, such areas may in time convert to saltmarsh or, with an adequate freshwater influence, to reedbeds. Whether adjacent land would then be available to convert into grazing marsh, however, would be dependent both on topography and the extension of human development including new flood defence structures.

Overall, the effects of sea level rise on coastal grazing marshes will depend on the frequency and duration of tidal inundation and the salinity range. In some coastal areas a small increase in tidal inundation may in fact increase the diversity of species/communities. On the south east coast of England certain grazing marshes with a brackish water influence already support upper saltmarsh communities in addition to brackish or freshwater species. A significant increase in the frequency or duration of saline inundation in brackish grazing marshes, or the seawater inundation of primarily freshwater marshes may, however, cause detrimental effects to the existing flora and fauna. On the other hand, however, those which revert to saltmarsh or mudflat may retain some, albeit changed, environmental interest.

2.3.15 Other Habitats

- **Cliffs**

Cliffs comprised of hard rock would be largely unaffected by global warming, their durability protecting them from marginal increases in wave attack. Softer rocks, on the other hand, might be expected to erode more rapidly than at present, providing more material for beaches and mudflats elsewhere unless, of course, man extends his coast protection activities.

The likely impacts of such increased rates of cliff erosion on nature conservation interests will be varied. Sites which are dependent on cliff falls to maintain their geological interest might benefit from the sea level rise. The impact on sites where the nature conservation interest is associated with exposures on the beach, however, is more difficult to predict (e.g. Chapel Point Geological Conservation Review Site on the Lincolnshire coast, or the submerged forest in Porlock Bay, Somerset). Such areas may become generally less accessible if they are inundated for a longer period of time. More important, however, they will be affected by any change in beach level. A fall in beach levels might lead to increased exposure to wave action and hence erosion, culminating in the loss of some sites. Alternatively, if sediment supply to the beach increases because of cliff erosion, the sites may no longer be exposed at all. They will therefore be better protected, but of rather less scientific interest.

Elsewhere on the coast, other Sites of Special Scientific Interest may be lost as a direct rather than indirect result of increased rates of cliff erosion. In the south west, for example, the ancient woodland on rising cliffs at Boscastle Dizzard would suffer from increased rates of erosion. Sites of conservation value because of their vegetation and invertebrate interest might also be lost if the frequency of cliff falls increases to the point where cliff communities are unable to become re-established.

- **Sub-tidal Habitats**

Sampling and surveying techniques for sub-tidal habitats are less well developed than those for terrestrial habitats. NCC are currently compiling a descriptive account of British marine flora and fauna.

Zostera seagrass beds, which are important in protecting certain coastal habitats by reducing wave strength and hence erosion, are found at a number of sites in Great Britain. The most important sites are the Isles of Scilly, The Fleet and Maplin Sands with the latter covering 325 ha (Gubbay, 1988). Physical damage can occur due to both trampling and anchoring in the sheltered shallow areas, but the most significant damage to Zostera beds in the last 50 years has been from an epidemic wasting disease which devastated these plant communities (Owen et al., 1986). Extensive areas of mudflat were lost as a consequence.

Other sub-tidal habitats, including oyster beds, clam flats, reefs, etc., are important in terms not only of their nature conservation interest, but also their contribution to the marine fisheries resource. Such habitats are unlikely to be severely affected by a rise in sea levels of the order discussed in Section 2.2. There may, however, be significant opportunities for the creation of new sub-tidal habitats under a scenario of sea level rise.

- **Rocky Shores**

Rocky shores occur along 1038 km of the English and Welsh coastline (see Table 2.3.1). Threats to these habitats from human disturbance are minor in comparison to those imposed on soft sediment communities, but damage through seaweed cropping, boulder disturbance and collection, pollution, and recreational activities can all affect the species composition. Increased rates of sea level rise might lead to the loss of flora and fauna through inundation and erosion, but the significance of this will generally be determined by site specific characteristics.

2.3.16 Effects on Coastal Landscapes and Amenity

Coastal landscapes are important for their amenity, recreation, and aesthetic value, natural beauty and diversity. Dramatic features such as chalky cliffs and shingle ridges add to the often unique landscape interest of certain stretches of coasts, for example, the spectacular "Seven Sisters" at Seaford in Sussex and impressive shingle spit at Blakeney in Norfolk.

In addition, parts of the coastline are designated for their unspoilt character, in particular Areas of Outstanding Natural Beauty (AONB) and Heritage Coasts. Forty three stretches of Heritage Coast have been defined covering one third of the coastline of England and Wales, some 1,460km. Most of these lengths also incorporate AONB's. The largest continuous stretch of Heritage Coast is along the north Northumberland coast, and the coastline of south west Britain is also particularly well represented. In other areas National Parks abut the coast (e.g. Exmoor and Pembrokeshire).

Increasingly, the coastal landscape is under pressure from recreation developments including marinas, and sea defence and coast protection projects, as well as other issues such as pollution and water quality. Such pressures have lead to visual intrusion and loss of valuable features.

The previous sections (2.3 to 2.3.15) discussed the likely impacts of sea level rise on coastal habitats. Concurrently, such impacts will have similar landscape implications primarily in terms of visual impact and loss or degradation of features of landscape interest. Such losses are likely to include "soft" cliffs; shingle banks; dune systems and areas of saltmarsh and mudflats. In other instances, however, sea level rise may have beneficial landscape impacts. Increased erosion, for example, may lead to establishment or enhancement of existing dune, shingle or beach features downstream (see Section 2.3.7).

The effects of sea level rise will be particularly detrimental if the coastal habitat is unable to retreat due to prohibitive development behind. In these cases it may be necessary to improve or construct coastal protection works which will further degrade the coastal landscape.

Loss or reduction of beaches and cliff tops have attendant recreation and amenity effects. Much of the coastline of England and Wales provides public accessibility via long distance paths (e.g. the South West Peninsula Path) and numerous footpaths. It is not desirable to lose any part of this network. Once a right of way is lost, in this instance to the sea, it ceases to exist and cannot legally simply take the route of the new coastline. Statutory mechanisms are, however, available to create footpaths through management agreements and/or the "dedication and acceptance" method which involves dedication by the owner and an acceptance of the right of way.

2.3.17 Regional Effects of Sea Level Rise

Sections 2.3.6 to 2.3.15 inclusive discuss the likely implications of increased rates of sea level rise for specific types of coastal habitat. Around the English and Welsh coasts, however, there are a number of potential consequences which are likely to be peculiar to a particular region. Table 2.3.3 summarises some such impacts which were raised as a result of the Regional meetings discussed in Section 1.3.4

Table 2.3.3 **Regional Implications of Sea Level Rise**

Region: Anglian

Site and Habitat	Implications
Kessingham Level, Thorpeness (grazing marsh); Benacre Broad (brackish lagoon)	Sites fronted by a natural shingle ridge. Liable to loss or redistribution of shingle and/or saline intrusion.
Minsmere (fresh and brackish water lagoons)	Protection is offered by a natural dune system of sand and shingle which is liable to loss or redistribution.
General	Eastern region is already prone to land loss, especially as most of the region is low lying with large areas of claimed land.

Region: North West

Site and Habitat	Implications
General	The high density of developed areas means that coastal habitats will be lost because of a lack of land onto which to retreat

Region: Northumbria and Yorkshire

Site and Habitat	Implications
Northumbria (sand dunes)	Significant scope for allowing natural migration inland as sea levels rise
Yorkshire (sand dunes)	No scope for migration inland due to both local topography and development behind dunes
Humber Estuary (general)	Erosion from the Holderness coast may produce increased sediment which feeds into the mouth of the Humber
Durham (general)	The rocky coastline means habitat creation opportunities are likely to be limited

Region: Southern

Site and Habitat	Implications
Solent Estuary	The tidal pattern in the western part of the Solent has a double tide giving an extended period of high water. Time for wave erosion at high tide will therefore become longer and ebb tide scour will be much more intense leading to increased erosion at the saltmarsh cliff.
Chichester Harbour and Southern harbours generally	Many harbours in Southern Region are carved out of raised beaches with low cliff edges which are susceptible to wave attack. Sea level rise and increased storminess could extend the harbour area especially in undefended harbours such as Chichester.
Hurst Spit	If the spit was breached or washed away it would increase the vulnerability of sea walls to the east by altering the water circulation and tidal regime in the intertidal area that is presently sheltered.
Lymington (river valley)	Increased risk of fluvial freshwater flooding as tidelocking would be greater due to sluices at the eastern side of the harbour.
Stanswood Bay (cliffs)	Presently subject to acute erosion which would increase and cause erosion of the Pleistocene terraced gravel/brick earth cliff.
Southampton Water (river estuary)	At the head of the estuary a natural salinity gradient exists. Historically sea level rise has led to the loss of a former grazing marsh and the development of Phragmites. This zone will steadily migrate up the valley.
Titchfield Haven (estuary)	The estuary was dammed off and sluiced. An increase in sea level rise would cause the marsh to migrate up the valley as increased freshwater inundation occurs alongside an increase in the rate of sea level rise.

Region: South West

Site and Habitat	Implications
Rivers Yealm and Dart (river estuaries)	Typical steep-sided wooded valleys where sea level rise would lead to the loss of fringing habitats.
Rivers Axe, Exe and Tamar (river estuaries)	Large areas of these estuaries are privately defended, but some would suffer habitat losses under sea level rise.
Loe Pool (shingle); Shapton Ley	Mobile shingle bar protecting the lagoon system. The SSSI may be threatened by increased salinity and/or the retreat of the bar inland.
Marazion Marsh (reedbed); South Milton Ley	Large reedbeds in Devon and Cornwall which are likely to be threatened by an increase in the frequency of saline inundation.
Fal Estuary	Maerl beds which occur in only a few British localities may be threatened because they require calm, shallow, turbidity-free conditions in the sub-tidal zone.
Isles of Scilly	Low-lying dune and boulder beach habitats could be breached with a dramtic impact on breeding storm petrels in "fossil" boulder beaches and rare plants e.g. Dwarf Pansy (Viola Kitaibeliana) on dune grassland. Also loss of freshwater and brackish lagoon habitats.

Region: Welsh

Brandy Brook and St. Brides Bay (wetland)	Shingle features protecting wetland SSSI (rushes, carrs, etc.) may be threatened.
General	Only 10% of the Welsh coastline is protected by NRA defences. British Rail is responsible for many embankments.

Region: Wessex

Severn Estuary (estuary and associated habitats)	A relatively small absolute increase in water level on a high tidal range will generally mean only limited habitat loss or inundation. Areas of low tidal range, however, will be more seriously affected.
Berrow Dunes (sand dune)	Dunes are liable to sand loss or roll back threatening both dunes and marsh behind, a Sedgemoor District Council reserve and SSSI.

SECTION 3 TECHNICAL VIABILITY

3.1 The Decision-Making Process in Respect of the Retreat Option

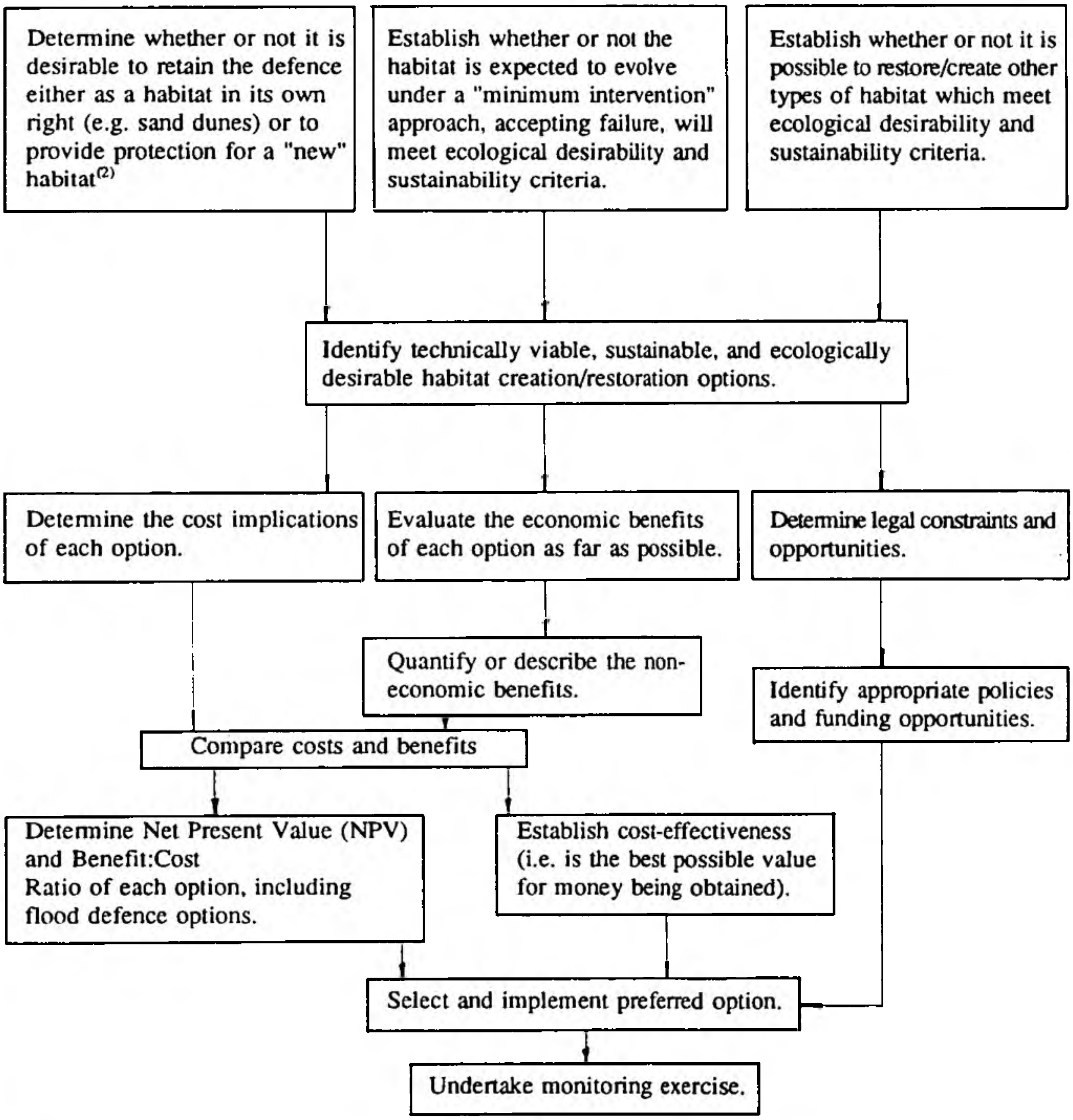
3.1.1 Section 2 sets out the combination of issues, concerns, and threats to coastal habitats which have combined to place the concept of retreat to benefit nature conservation and landscape quality onto the decision making agenda.

The creation or restoration of coastal habitats in association with a retreat from the existing line of flood defence is fine in principle. If the idea is to become reality, however, the technical, economic and legal viability of such initiatives must be demonstrated, and the question of ecological desirability must be resolved.

On a site-specific basis, the decision-making process is likely to start with an assessment of the technical viability and the management implications of a range of alternatives. These alternatives will include both maintaining the flood defence and restoring or creating coastal habitats under a retreat scenario. In some cases it may be necessary to maintain the flood defence in order to protect a site of existing nature conservation interest which is considered to be "too valuable" to lose even if the creation of an alternative habitat appears to be technically viable. This possibility is examined in Section 4.1.6. Elsewhere however, having determined the type of habitat(s) which it might be possible to create or restore and sustain at the site, it is necessary to determine their relative benefits in terms of ecological desirability and to assess the economic implications of each option. The mechanisms by which a preferred option might be implemented in practice, will then also depend on legal constraints and opportunities; the policies of the various interested parties involved; and the availability of funding. This decision making process is summarised in Figure 3.1.1 and it **should be stressed that <u>all</u> routes through this figure will need to be investigated for any specific project.**

3.1.2 Figure 3.1.1 demonstrates that the identification of sustainable, technically viable options and the determination of their ecological desirability will be very closely linked for a particular site. There is little point in devoting time and money to the economic evaluation of a resource which is not considered to be desirable and/or valuable in terms of potential nature conservation interest. The purpose of this report, however, is to investigate the general issues associated with the retreat option and to put forward a framework for future use in assessing issues on a site specific basis. Section 3 therefore deals with the technical viability and sustainability of habitat creation and restoration under a scenario of managed retreat, independently of ecological desirability which is considered alongside other evaluation requirements in Section 4. In both sections, the issues which need to be addressed as part of the overall decision making process are identified and reviewed. In neither case, however, is the report intended to provide detailed technical guidance on "how-to-do" managed retreat. Although the United States in particular has a great deal of practical experience in both habitat creation/restoration and the economic evaluation of environmental goods and services, many of the various techniques discussed in the following sections will require careful examination and experimentation before they can be applied with confidence in Great Britain.

Figure 3.1.1 The Decision-Making Process in Respect of the Retreat Option[1]



(1) Figure 3.1.1 assumes that retreat will not be considered as an option if the environmental assessment process demonstrates that an existing nature conservation resource protected by the defences is considered to be too valuable to lose (see Section 4.1.6).

(2) Such protection could involve e.g. a breakwater protecting a new saltmarsh against erosion or a defence for a new grazing marsh against unacceptably frequent flooding.

3.1.3 The Nature Conservation Value of the Defence

One of the first issues which should be investigated when evaluating the technical viability of the retreat option is whether or not the defence itself is of nature conservation or landscape value. If the defence consists of a natural feature such as a shingle ridge, saltings or sand dunes, a careful assessment will be required to investigate both the desirability and technical viability of restoring that feature. Restoration options might include shingle or sand replenishment, the placing of dredged material, or vegetation planting. The various techniques associated with these options are discussed in Sections 3.3 to 3.5 inclusive. Additional considerations, however, relate to the land behind the defence and to the upstream and/or downstream implications of abandonment. In many cases if a defence is being maintained simply for its habitat value, a general reduction in the standard of flood defence provided might be anticipated. Flooding might be expected more frequently, saline intrusion through or under any bank might increase or a lagoon habitat might develop. Depending on the existing nature of the hinterland area, any such implications could potentially be of significant environmental importance, particularly if the land in question is currently intensively farmed. An increasing risk of inundation might dictate a less intensive agricultural regime and the overall total benefits of this type of option (i.e. maintaining a defence as a habitat in its own right and accepting a reducing standard of protection) could therefore be quite high. Another possible benefit of this strategy would be that the maintenance of the defence in some form should ensure that possible significant (adverse) effects elsewhere on the coastline are minimised.

In many situations, however, it is envisaged that an option involving a retreat from the existing line of flood defence will offer significant environmental benefits, enabling or encouraging the migration inland of coastal habitats. If this is the case, the degree of management or intervention which might be required to achieve different environmental objectives must be very carefully considered because of:-

- the possible cost implications of a long-term management policy based on intervention
- the general desirability of creating or restoring a habitat which will become self-sustaining
- the need to avoid undesirable consequences (e.g. increased erosion or deposition) elsewhere in the estuary or along the coast.

3.1.4 Sustainability Criterion

Some of the criteria discussed in Sections 3.3 and 3.4 will define the short term viability of an option according to present conditions (ie. proximity of adjacent habitats, wave climate, etc.). Due consideration must, however, also be given to the longer term situation, particularly in respect of the implications of an increase in the rate of sea level rise discussed in Section 2.2. Habitat creation using dredged material, for example, has a better chance of long term sustainability if there is a natural source of sediment available for subsequent accretion. Similarly, consideration might be given to the removal of a groyne structure to help restore the littoral movement of material, rather than creating or restoring a habitat which will subsequently require continual artificial replenishment over the longer term. **It is not an objective of this study to promote the creation of habitats which subsequently require as much maintenance as the flood defence structures which preceded them.**

3.1.5 Project Planning Requirements

Finally, whichever option is selected, one important additional factor must be considered throughout the decision making process. **Experience in the United States has demonstrated that a key factor in successful habitat creation/restoration initiatives is a careful prior appraisal of the situation and, if appropriate, well researched design undertaken by suitably qualified personnel.** The San Francisco Bay Conservation and Development Commission (BCDC, 1988) highlight this issue in a review of fourteen marsh creation and/or restoration projects undertaken in the San Francisco Bay area. Their report cites general poor planning, or the unauthorised modification or inadequate execution of the plan submitted and approved under Section 404 procedures (see Section 5.5.3), as being among the primary reasons for the failure or partial failure of eight of these fourteen projects. In Great Britain Hollis et al (1990), reporting on work carried out by Sills and Becker (1988), similarly conclude that **sea level rise is likely to lead to the creation of new habitats which, with sufficient skill and funding, can be turned into nationally or even internationally important sites.**

3.2 <u>Ecological Development Following Bank Failure</u>

3.2.1 Review of Available Information

Areas where sea defences or tidal embankments have failed in the past provide case studies of the ecological processes which might be anticipated if sea level rise leads to increased saline flooding and a retreat from the existing line of sea defence. These areas present an opportunity to study the natural biological and physical implications of the retreat option. In order to understand fully the ecological changes likely to occur under a planned retreat scenario, however, a complete knowledge of the processes and characteristics affecting the site are required. This enables the most appropriate habitat restoration and creation initiatives to be identified and implemented at any particular site.

As demonstrated in Table 3.2.1 which presents the results of one element of the "regional round-up" exercise discussed in Section 1.3.4, the Essex and Suffolk coastlines offer many examples of where bank failure has led to the inundation of low coastal lands - often lands which were previously "reclaimed" from the sea. Mudflats, low level Aster, and high level Halimione saltmarsh are the main habitats which have developed in these areas, the differences being a result of the particular land levels at the time of flooding and the physical and biological processes subsequently operating at the site. Following bank failure, sites such as Bridgemarsh Island and Brandy Hole reverted to saltmarsh, but these are presently rapidly eroding to mudflat, possibly because the level of protection afforded by the deteriorating defence has declined (see Section 3.1.3). At other sites (e.g. in the Blyth Estuary), areas of mudflats have developed, fringed by accreting saltmarsh and at North Fambridge, high level saltmarsh has formed in the area which breached in 1902, while low level saltmarsh has developed in the area breached before 1902.

These differences in habitat development may be due to erosion or a lack of accretion affecting the habitat since bank failure, or they may be a result of different land levels prior to bank failure. A general lack of monitoring at most of the sites described on Table 3.2.1, however, means that no precise data are available to enable the habitat development process at specific sites to be assessed.

The present ecological importance of these sites depends on the location, the type of habitat lost and the value of the "new" habitat. In addition to assessing the past and present botanical importance of a site, however, ornithological and entomological characteristics should also be reviewed. In the Suffolk estuaries of the Blyth and the Alde large areas of mudflat have developed, but on observation the "new" mudflats have been found to support a lower density of feeding birds than other Suffolk estuaries. The Suffolk Wildlife Trust is currently surveying invertebrate densities to try to account for the low numbers of feeding birds. In areas of Hamford Water in Essex meanwhile, the breached sea banks have led to the formation of isolated islands which form excellent undisturbed habitats for nesting gulls and shelduck.

Finally, any gain to conservation following retreat will also depend on the wildlife value of the habitat present before bank failure. Shotley Marshes in the Orwell Estuary, for example, is already an ecologically important area of grazing marsh. Bank failure and a reversion to mudflat at this site may therefore lead to a net loss in conservation terms.

Table 3.2.1 Examples of Ecological Development Following Bank Failure (By Region)

Region: Anglian

Area and Habitat at Time of Failure	Failure Date (If Known)	Resulting Habitat	Desirability	Reference
Holbrook, Stour Estuary *Grazing Marsh*		Muddy lagoon due to low land levels prior to failure.	Limited habitat or ecological benefit, but within the Stour Estuary SSSI.	Personal Communication (1)(2)
Bridgemarsh Island, Crouch Estuary *Grazing Marsh*	1930/40's	High and low level saltmarsh depending on land levels prior to breaching; some areas rapidly eroding to mudflats.	In area of estuary designated as a SSSI.	Personal Communication (1)(2)
North Fambridge, Crouch Estuary *Grazing Marsh*	Southern side 1902 Northern side pre-1902	Southern part: high level saltmarsh - Halimione. Northern part: low level saltmarsh - Aster.	In area of estuary designated as SSSI.	Personal Communication (1)(2)
Brandy Hole, Crouch Estuary *Grazing Marsh*	1902	Low level Aster saltmarsh.	In area of estuary designated as a SSSI.	Personal Communication (1)(2)
Northey Island, Blackwater Estuary *Grazing Marsh*		Saltmarsh	National Trust; SSSI	Personal Communication (1)(2)
Wivenhoe area, Colne Estuary *Grazing Marsh*	1953 and subsequent failures	High level saltmarsh		Personal Communication (1)(2)

Area and Habitat at Time of Failure	Failure Date (If Known)	Resulting Habitat	Desirability	Reference
Horsey and Hedge-End Island, Hamford Water *Grazing Marsh*		Saltmarsh	Estuary designated as a SSSI.	Personal Communication (1)(2)
Pewit and New Island, Hamford Water *Grazing Marsh*		Saltmarsh	Estuary designated as a SSSI.	Personal Communication (1)(2)
Garnham's Island, Hamford Water *Grazing Marsh*		Low level saltmarsh	High level saltmarsh/old seawall support a gull colony. SSSI.	Personal Communication (1)(2)
Skipper's Island, Hamford Water *Grazing Marsh*	1953	Saltmarsh developed and the island has been subsequently separated into three. Diverse habitat, supporting breeding birds and unusual plants.	Site now an Essex Naturalists Trust Reserve; SSSI.	Personal Communication (1)(2)
Northern edge of Hamford Water *Grazing Marsh*		High level saltmarsh protected by relatively new low dune system.	Estuary designated as a SSSI.	Personal Communication (1)(2)

Area and Habitat at Time of Failure	**Failure Date (If Known)**	**Resulting Habitat**	**Desirability**	**Reference**
Titchwell Marsh *Root crops and grazing marsh used by cattle and horses*	1949-1953	Gradual reversion to low diversity saltmarsh behind dunes and shingle; formation of a large tidal reedbed in the area influenced by freshwater.	In 1970's the RSPB created a reserve by using sluices to create brackish and freshwater marsh and freshwater reedbed. The reserve is designated as a SSSI, Ramsar site and SPA.	Hollis et al (1990) Sills (1988) Personal Communication (3)
Blyth Estuary *Grazing Marsh*	1903-1950	Intertidal mudflats fringed by saltmarsh in zones of accretion and reedbeds in areas of freshwater influence.	Designated a SSSI and proposed Ramsar Site because of habitat diversity.	Beardall et al (1988) Personal Communication (2)(4) Anglian Regional Meeting
Deben Estuary *Grazing Marsh*	1940 and subsequent failures.	The Deben Estuary's area above MHW increased from 182 to 251 hectares (since the 1840s) following breaches at a number of sites. North and South Waldringfield - formation of saltmarsh with some mudflats. Martlesham Creek - mudflats Sutton Hoo - mudflats and saltmarsh.		Beardall et al (1988) Anglian Regional Meeting

Area and Habitat at Time of Failure	Failure Date (If Known)	Resulting Habitat	Desirability	Reference
Alde Estuary *Grazing Marsh*		Snape Warren - mudflats and saltings formed Iken Marsh - mudflat and reedbed formation due to freshwater input.		Beardall et al (1988) Anglian Regional Meeting
Read's Island *Mudbank*	1970 and subsequent failures	Following the seawall failure, erosion and flooding caused a loss of half the island to mudflat.		Yorkshire Regional Meeting

Region: Severn Trent

Area and Habitat at Time of Failure	Failure Date (If Known)	Resulting Habitat	Desirability	Reference
Arlingham	1980s		Retreat from defence line to ease flood flow. Produced conservation benefits.	Severn Trent Regional Meeting

Region: Southern

Area and Habitat at Time of Failure	Failure Date (If Known)	Resulting Habitat	Desirability	Reference
Bunnymeads, River Hamble *Low-lying pasture, below river level*	1930s and subsequent failures.	Three breaches have occurred with the subsequent formation of tidal mudflats, fringing saltmarsh and reedbeds. In 1980-81 the bank was repaired to reinstate the public footpath but the tidal character was maintained by culverts. This has caused some channelling and scour.	Significant amenity and conservation gains.	Personal Communication (6) Southern Regional Meeting
Pagham Harbour *Reclaimed agricultural land*	1890	Reverted to a tidal inlet following failure. Over the past 20-30 years the narrow entrance formed by a shingle spit has moved.	The site is very important having been designated a Ramsar site and SPA. Managed as a Local Nature Reserve by West Sussex County Council.	Personal Communication (5) Southern Regional Meeting
Newtown Harbour, Isle of Wight	1953	Mudflat grading into saltmarsh.	Very good site ecologically, managed by the Isle of Wight County Council as a Local Nature Reserve.	Southern Regional Meeting

Area and Habitat at Time of Failure	Failure Date (If Known)	Resulting Habitat	Desirability	Reference
Exbury		Estate land flooded following failure. Spartina marsh has developed.		Southern Regional Meeting
Brading Harbour, Bembridge, Isle of Wight *Former Reservoirs*		Tidal mill failed and the area reverted to intertidal mudflat.		Southern Regional Meeting
Pennington *Coastal Grazing Marsh*	1953	Seawall failed and was reconstructed further inland. Mudflat formed in abandoned area.	The area still existing as grazing marsh is a nature reserve managed by Hampshire County Council.	Southern Regional Meeting
Sowley, East Lymington *Medieval saltings*	1950's	Medieval saltings were protected by a small shingle bank which failed in 1910. The area has reverted to an intertidal area since further failures in the 1950s.		Southern Regional Meeting
Elmley Marshes *Grazing Marsh*	1953	Various breaches killed reedbeds, etc. No documentation is available.	RSPB Reserve, SSSI, Ramsar Site and SPA.	Personal Communication (7)

Area and Habitat at Time of Failure	Failure Date (If Known)	Resulting Habitats	Desirability	Reference
Barksore, Medway Estuary *Grazing Marsh/ Agricultural land*		History of breaches and subsequent repair of the privately owned defence. The peninsula is presently impounded and maintained, though the tidal creek system is still evident.		Personal Communication (7)
Nor Marsh, Medway Estuary *Grazing Marsh*		Protected in the past, now reverting to intertidal habitat - both accretion and erosion are occurring.	RSPB Reserve and SSSI.	Personal Communication (7)

N.B. There are a number of further examples in the Southern Region where bank failures have led to the development of natural/semi-natural habitats.

Region: South West

Area and Habitat at Time of Failure	Failure Date (If Known)	Resulting Habitat	Desirability	Reference
River Dart *Low grade agricultural land*	1980's	Slowly reverting to mudflat.		South West Regional Meeting
North of Millbrook	1940's	Area formerly impounded for fish ponds has now reverted to marsh.		South West Regional Meeting
Erme and Yealm Estuaries		Some failures; little documentation.		South West Regional Meeting

Region: Yorkshire and Northumbria

Area and Habitat at Time of Failure	Failure Date (If Known)	Resulting Habitat	Desirability	Reference
Holy Island *Agricultural*	19th Century	Failure of some defences led to general changes in vegetation type over parts of the island.		

Personal Communication
(1) Dr. R. Hamilton; Dr. C. Gibson (Colchester, NCC)
(2) Dr. M. George
(3) Mr. N. Sills
(4) Dr. C. Beardall
(5) Nature Conservancy Council, Lewes Office
(6) Mr. C. Cuthbert (County Recreation Department)
(7) Dr. M. Clarke (South East Region, RSPB)

3.2.2 Titchwell Marsh

Titchwell Marsh was originally claimed from the sea in 1786. It was converted to grazing land and arable land for root crops, while the reedbed was grazed by horses (N. Sills, personal communication, 1991). At the end of the 1940's the sea walls were weakened and in the tidal surge of 1953 the wall breached. Following bank failure, the agricultural marsh gradually reverted to a low diversity Aster saltmarsh and a large tidal reedbed developed (Hollis et at, 1990). The marsh was protected from the sea by sand dunes and shingle, but tides regularly flooded the saltmarsh and most of the reedbed during the summer (Sills, 1988), limiting the viability of the site for breeding birds. In the 1970's the RSPB purchased the marsh and, using seawalls, dams and sluices, regulated salinity and water levels to create 10 ha of freshwater reedbed, 11 ha of freshwater marsh and 17 ha of brackish marsh. 58 ha of the original saltmarsh and 14 ha of tidal reedbed (Sills, 1988) were retained. The higher level saltmarsh which is now only flooded by 10 per cent of tides supports a diversity of flora and provides a suitable area for ground nesting birds; the lower Aster marsh is flooded by approximately half the tides and, while not suitable for nesting, provides a valuable winter food source for birds. As a SSSI, Ramsar and SPA, and as part of the North Norfolk Heritage Coast and Area of Outstanding Natural Beauty, Titchwell Marsh therefore provides a superb example of the type of resource which can be created with careful management following the failure of sea defences.

3.2.3 Blyth Estuary

In the Blyth estuary, over 1100 hectares of intertidal habitat had been subject to land claim and converted to arable by 1842. In 1991, approximately 1,278 hectares of agricultural land in the locality are estimated to have been "claimed" from former saltmarsh and mudflat. Since the turn of the century, however, 250 hectares have reverted back to intertidal areas following bank failures with the 1953 tidal surge causing the most damage. The Blyth presently has 10km of tidal channel containing 55 ha of saltmarsh and 276 ha of mudflats (Beardall et al, 1988). Where breaches have occurred, the majority of the area has reverted to intertidal mudflats due to the low level of land behind the embankments, but accretion has allowed saltmarsh to develop round the periphery of the new estuary. In areas where a freshwater flow is predominant, reedbeds are also present. Areas of tidal mudflats and associated habitats of the Blyth are part of the Walberswick National Nature Reserve adding to its diversity of habitat. The area is also classified as a proposed Ramsar site, an internationally important wetland site under the terms of the Ramsar Convention.

3.2.4 Monitoring Requirements

In France, the monitoring of an area at L'aber de Crozon where a flood defence barrier was deliberately breached by the Conservatoire du Littoral ensured that biological changes were documented and habitat development processes were recorded. Unfortunately, none of the British sites recorded in Table 3.2.1 have been monitored in any detail following bank failure and flooding. Such monitoring would have provided valuable information on the rate of habitat development and ecological desirability in terms of colonising species and sustainability. Some information about when the failure occurred and what subsequently developed is, however, available from maps and aerial photographs of differing dates, and this would enable a more detailed investigation to be made of ecological development in certain cases. This type of research would then enable more accurate predictions to be made in terms of the type of habitat likely to develop at a specific site.

Any information which can be gained about habitat development through studies of past failure sites would be of immense value to future decision-making. It is therefore recommended that a study be undertaken, firstly to identify sites at which photographic evidence, unpublished data etc. is likely to be available, and subsequently to document changes over time and compare development at different sites. In this way it is hoped that a picture could be built up, explaining the physical, biological and temporal processes of significance in the past development of different coastal habitats, improving our understanding and providing important lessons for the future.

3.3 Physical Considerations

3.3.1 General discussion

The coastal environment is dynamic and the mechanisms at work are powerful. Particularly on exposed coasts, the coastal process regime will need to be understood if habitat restoration/creation opportunities are to succeed and are not to cause problems elsewhere. The various physical considerations in respect of the retreat option are summarised on Table 3.3.1 and discussed in more detail in the following sections. The specific relevance of these considerations to different coastal habitats is then considered in Section 3.5. The relatively brief discussion in Section 3.3 is not meant to reflect the level of analysis that will be necessary when considering retreat at a particular site: coastal processes are complex and frequently require detailed analysis, numerical modelling, measurements and monitoring. The discussion in the report does, however, serve to highlight those areas where such detailed information will be required.

Table 3.3.1 Physical Characteristics Controlling the Development of Sustainable Habitats

Waves	Coastal habitats in exposed, high wave energy environments may require protection (e.g. a breakwater, peninsula or similar).
Tidal Currents	Knowledge of tidal currents is essential in determining sediment transport regime. Tidal prism at a site is important because it enables the exchange of waters and hence sediments, fauna, seeds, etc.
Sediment	Sediment type and availability, and the site specific transport regime will be key factors in determining both the technical viability of types of habitat, and their likely long-term sustainability.
Surges	Important in determining extreme high water levels.
Elevation	Elevation controls the type of coastal habitat which can be sustainably developed at a site, as different habitats depend on different periods of inundation.
Grade	Grade controls drainage which is essential in maintaining a healthy habitat.
Size	Site stability and ecological diversity will both benefit from the largest possible size, particularly if the site is isolated from other similar habitats.

3.3.2 Waves

At any individual location, exposure to wave action is a function of wind climate, fetch (the distance over which the wind can blow before reaching the site), water depth and, in the case of protected waters, exposure to the open sea. The importance of these characteristics cannot be overstated: the US Army Corps of Engineers (USACE), for example, suggest the wetland habitat creation in an unprotected area where the fetch is greater than 10 miles will have less than a 20% chance of success (USACE, personal communication, 1990). Similarly, the chance of success reduces as offshore depth increases.

To assess the wave climate at a given location there are published techniques (USACE, 1984) for calculating wave heights if water depth, wind speed and fetch are known. On an exposed coast, waves are often generated elsewhere (swell waves) and there is no substitute for records. Full account should also be taken of shallow water wave processes (wave breaking, friction loss, wave refraction) which, depending on the site, can require numerical modelling.

Exposure to wave action plays a large part in determining whether a particular coastal site should be considered a low energy or high energy environment. To a large extent this in turn governs the type of habitat that will survive. That is not to say that a saltmarsh, for example, cannot survive on an open coast. What it does mean is that for saltmarsh to survive it may require protection. In the US, at Shooter's Island New York for example, protection has been achieved using breakwaters (USACE, personal communication, 1990). A suitably shaped site will, however, afford its own protection.

In areas less exposed to wind and waves, boat-generated waves have been found to be significant. In estuaries and on tidal rivers, due note should therefore be taken of the type of navigational uses.

3.3.3 Tidal Currents

Assuming tidal levels are known, a knowledge of land levels will indicate the extent of land which would be regularly inundated under a retreat scenario. For an enclosed tidal water body (such as a harbour or an area of low lying land into which the tide will flow if a wall is breached) a knowledge of tidal levels will also enable ebb and flood flow discharges to be calculated. However, tidal currents around the site may require specific measurement campaigns using current meters, floats or other techniques. A good knowledge of tidal currents will be essential in determining the sediment transport regime at a defined location but the required extent of measurements, and possible subsequent modelling (which can greatly enhance measured data at modest cost) can only be judged on a site specific basis.

The tidal prism at a site is equally important not only because of its role in stabilising the channel inlet to a site, but also in ensuring water circulation exchange and flushing, and hence the supply of sediment, fauna, seeds, etc. Finally, the impact of abandoning the flood defences at a site should be viewed not only in the light of any consequent increase in the tidal prism (the volume of water entering and leaving the site) and thus in tidal streams at the retreat site, but also the possible implications in terms of erosion or sedimentation elsewhere in the estuary or along the coast.

3.3.4 Sediment

The subject of sediments and sedimentation is broad, covering wave and current induced sediment transport, the type and quantity of sediment, local conditions within the site under consideration, and the overall coastal regime within the area. An awareness of sediment size, type, availability and transport will be of critical importance to the decision-making process for the managed retreat option becuase these factors will determine:-

- whether or not, in the short-term, material will need to be imported (e.g. to raise the elevation of the land)
- whether or not the created or restored habitat is likely to be sustainable over the longer term (e.g. will the habitat be able to accrete sufficiently quickly to keep up with sea level rise?)
- which species of fauna and flora will thrive in the created/restored habitat (vegetation developed on an area of uniform sediment size/type will be less diverse than that on an area of mixed sediments).

- **Sediment type**

The physical nature (organic content, pH, salinity, particle characteristics, and chemical composition) of sediment will need to be determined both at the site and in the general vicinity. This is particularly important in areas, such as in the channel inlet to a proposed intertidal area, where sediment may be eroded. Away from the site, the foreshore/seabed/riverbed/beach sediment properties should also be investigated in terms of their potential for being transported. The biological and chemical considerations in respect of sediment requirements for habitat creation or restoration are considered in detail in Section 3.4.

- **Sediment in suspension**

The ability of coastal and estuarine habitats to adapt to sea level rise is often dependent on the amount of sediment available for deposition. An assessment of the likely ability of a particular area to provide sufficient sediment must be based on measurements of the amount of sediment in suspension. At minimum, measurements should be taken at all depths in the water column, throughout a full 12.5 hour spring tide. The need to take additional measurements during, for example, times of high rainfall when suspended solids may be temporarily increased, should also be carefully assessed.

- **Transport regime**

A knowledge of wave climate, tidal currents and sediment availability provides the basic data for an analytical treatment of sediment transport. However, sediment transport (particularly by waves) is not well understood, and as much factual data as possible will be required on the physical evidence of transport in the vicinity of the site. Such data might include old maps, soundings, surveys, and any details on the effect of port works such as dredging or construction. Taking these data together, and supplementing them with modelling as necessary, an attempt should be made to define some or all of the following as appropriate:-

i. the amount of material that will be brought into or onto a new tidal area on each tide, and will thus be available for deposition

ii. the annual and storm-related rates of longshore drift along a stretch of coastline: this is particularly important if habitat creation involves the artificial breaching of a defence because, unless the habitat area has a large enough tidal volume, there is a substantial likelihood of rapid closure of that breach by longshore transport. Although such a closure could possibly be re-opened in times of high fresh water flow, there may be a significant decrease in the salinity and/or quality of the retained water in the meantime.

iii. the variation in beach profiles, including on/offshore transport, through the year

iv. past trends of erosion or deposition

v. the likely impact of the proposed scheme on other areas. This assessment should include the possibility of a blockage or interruption in longshore transport and also the likelihood of an increase in the tidal volume of an estuary leading to increased scour and deposition, problems with navigation, or a general disturbance to the tidal regime.

3.3.5 Surges

Data on surges will be required where it is necessary to know extreme high tide levels, the maximum area likely to be flooded, or where prolonged surges occur (i.e. over low water). This can cause long periods without an effective low water, such as frequently occurs in the Norfolk Broads. The Proudman Oceanographical Laboratory are the main British centre in this field and might, therefore, be contacted as part of a site specific assessment. The likely increase or change in surge patterns as a result of increased rates of sea level rise has already been discussed in Section 2.3.3.

3.3.6 Elevation

Elevation relative to typical tide levels and the tidal range is of prime importance in determining the viability of different coastal habitat types. The design of habitat creation/restoration projects should also make allowance for sea level rise and the predicted changes in tide levels. Values such as mean high water of spring and neap tides (MHWS and MHWN), mean sea level, and mean low water of spring and neap tides (MLWS and MLWN), which are obtainable for many locations from the Admiralty Tide Tables (published annually) are of particular significance. The elevation of the site relative to a standard datum should thus be established, and tidal levels can be used to assess the site's suitability for the development of a particular habitat type. Where the site elevation is too low for the desired habitats, experience elsewhere has demonstrated that it is possible to raise the elevation either by encouraging natural deposition or by artificially filling the site.

The first case (natural deposition) requires that adequate sediment be brought in to raise the site over an acceptable period of time. Data required to determine this will include suspended solids measurements (see Section 3.3.4), tidal range and the tidal volume of the site. The shape of the site should be such that good tidal flushing is achieved (ie. as much exchange of water on each tide as possible). Warping (deliberatly retaining water to enable sediments to settle out) may also be a practical option at some sites.

In the second case (artificial raising with imported materials) the proposed fill will need to be acceptable in terms of its chemical composition and drainage characteristics. In fine materials, clays and silts, settlement or consolidation should be expected. The use of dredged material as an option for raising land levels is discussed in detail in Section 3.4.7.

3.3.7 Grade and Drainage

The grade or slope of the land behind the defence will represent a significant control on habitat creation opportunities. If the profile is concave, there may only be a narrow area available for the creation of a new inter-tidal habitat before the land rises steeply. A gentler slope, on the other hand, might provide significant opportunities for developing a range of habitat types, for example mudflats through to upper saltmarsh and on to terrestrial habitats.

On a site specific basis, the micro-grade is also important in the establishment of many coastal habitats. With saltmarsh, for example, its major importance is in respect of surface drainage which should be adequate but not too rapid. Naturally accreting material will tend to evolve into suitable gradients, and will in time develop a creek system. Artificial fill may require manipulation. Pumped spoil can produce flat grades which are poor for drainage. Drainage may thus require management if the evolution of the site is to be speeded up. In some sites creeks have been mechanically excavated, often using aerial photographs to identify the orginal creek pattern at a site. A novel alternative solution suggested for use in the US has been to lay bales of hay along desired creek routes. In time the hay degrades, forming the required channel and providing valuable organic material to the soil. In general, however, the US Army Corps of Engineers' preferred strategy is to set up a site for nature to work with, and in these cases neither creek formation nor micro-scale grading is carried out.

3.3.8 Site Size

In general terms, the larger the site available for habitat creation or restoration initiatives, the greater the chance of success. Site size becomes increasingly important, however, as the isolation factor increases, as suggested by island biogeography theory (Begon et al., 1986). Work by the US Army Corps of Engineers suggests that it may be possible to create a shallow marsh or wetland habitat as small as 4 ha, as long as it is open to tidal ingress and hence to waterborne flora and fauna from nearby sites. The minimum viable size will, however, ultimately depend on the requirements of the species using the site. US experience suggests that isolated but accessible areas of marsh will be used by fish, and that isolated mudflats, in cases as small as 0.4 ha, will be used as resting areas by birds. Work at the University of California at Berkeley (J. Blanchfield, personal communication, 1990) on the other hand, suggests that a minimum size of nearer 80 ha may be required in order to ensure that the tidal prism (the amount of water entering or leaving a site) is large enough to maintain a natural cycle of sedimentation and erosion.

In Great Britain, the expansion of sites of existing nature conservation interest is a stated priority of several agencies (see Section 4.1). Section 3.4.2 demonstrates the importance of adjacent habitats as a source of flora, soil fauna and invertebrates. Given these dual requirements, size may become a secondary consideration in some retreat cases. If a site is created in isolation from existing habitats, however, it appears that site stability, sustainability and ecological diversity will all benefit from the development of the largest area possible.

3.4 Biological and Chemical Considerations

3.4.1 In addition to the physical parameters discussed in Section 3.3, successful habitat creation or restoration initiatives will require that a number of biological and chemical parameters must also be:

i. assessed, in order to determine the type of habitat which might be expected to develop as a result of natural processes following bank failure, and

ii. controlled, if a more environmentally desirable habitat is to be restored or created (see Section 4.1.4).

These factors will both require full consideration and evaluation at the pre-feasibility or planning stage of a project. Site surveys are likely to be required at the proposed project site, and also at other natural or semi-natural habitats in the vicinity to establish biological and soil/water characteristics. Further, close liaison with those undertaking the physical surveys will also be required as the inter-relationships between the physical, biological and chemical parameters will, in many cases, be complex.

The major biological considerations associated with the retreat option include the proximity of similar sites and the related availability of soil fauna, and also the preferred method of establishing vegetation cover. Primary chemical parameters relate to soil chemistry and the quality of the water entering and leaving the site.

3.4.2 The Importance of Adjacent Habitats

Irrespective of the type of resource being restored or created, many studies have shown that the proximity of a site with similar interest to that being proposed can be of critical importance to the success of the project. In five of six successful marsh restoration projects, examined in the San Francisco Bay area (BCDC, 1988), the fact that there was an adjacent marsh "source" of flora and fauna was cited as being among the reasons for success.

Nearby sites of a similar nature to a proposed creation or restoration project can provide a supply of seeds and vegetation which may subsequently take root, and also benthic organisms and soil invertebrates. This assumes, however, that the hydraulic connection between the new wetland and such sites is adequate to permit their passage.

Vegetation can be planted if the seed supply is inadequate or undesirable - the Nature Conservancy Council, for example, might prefer to see saltmarsh species such as Salicornia or Puccinellia planted, rather than allowing Spartina to colonise. The artificial introduction of soil organisms, on the other hand, is not generally as successful because of the complexity of their life cycles and habitat requirements, and natural migration is therefore essential.

3.4.3 The Planting of Vegetation

There are essentially three options in respect of vegetating a restored or created site, assuming that controlling conditions such as drainage, elevation and salinity are acknowledged and have been met:-

- predicting what will grow and providing the correct physical conditions to encourage natural colonisation of desired species
- seeding or planting of desired species
- waiting to see what, if anything, might colonise the site.

Planting can be expensive but may be recommended if there is a known risk of alien or undesirable species invading the site. The most common (desirable) species used for planting/transplanting/seeding operations in British coastal habitat creation and restoration initiatives are listed on Table 3.4.1.

Table 3.4.1 British Coastal Vegetation Species suitable for Planting/Transplanting

Habitat	Species
Saltmarsh	Pioneer saltmarsh species include Salicornia and Puccinellia.
Sand Dunes	Main species for planting include Ammophila arenaria (Marram grass): Leymus arenaria and Elymus farcutus.
Shingle	No records of artificial planting: natural colonisation is slow because of shingle mobility, and limited nutrient/organic matter/sediment supply.
Reedbeds	Phragmites australis and Carex sp. are most commonly planted.
Grazing Marsh	Appropriate herb or flower-rich seed mix according to soil type, salinity, nutrient status, etc.

In general, transplanting vegetation has been found to be more successful than seeding because transplants are better able to adapt to a wider range of conditions. Seeding, however, is a rapid and economic route to achieving vegetation cover - if the seeds can survive the exposure to wave energy and, frequently, the instability of the substrate. Woodhouse et al (1972) also found that seed storage is difficult because viability is lost if seed is stored in damp, cool, saline conditions.

In all cases, it should be noted that perennial species of vegetation will not bind sediments on a long term basis. Any planting should therefore be undertaken using pioneer species which will allow a natural progression to, for example, higher marsh species (e.g. sea lavender and sea purslane). Similarly, the timing of planting is very important in relation to climatic conditions. Frost might cause serious damage, but summer heat and drought can also cause stress to young plants. Spring planting is desirable, as autumn planting may expose the relatively young plants to winter storms and hence erosion.

Work undertaken by the US Army Corps of Engineers has demonstrated that the health of plants is very important and this may, in some cases, dictate whether planting is preferred to natural colonisation (e.g. if the existing or adjacent stock is of poor quality artificial planting may be preferred). The Corps have also demonstrated that seeded areas, seedlings, or young plants may require protection in the form of a breakwater to prevent washing out, particularly in a high energy environment. Experiments undertaken for this purpose include:-

- floating tyre breakwaters (research into the use of old tyres in the UK has shown that toxins may be released from the tyres, causing local pollution).
- sand bags which ultimately degrade and release the sand
- fibrous or organic erosion control mats
- artificial plant rolls (artificially cultivated carpets of vegetation planted in consolidated clays).

The cost of these techniques varies significantly, from the cost of little more than installation only for old car tyres, to around $340 (£170) per linear metre for the plant rolls (1990 costs).

In Norfolk, England, where reed rhizomes were planted under geotextile matting, problems were encountered in establishing vegetation growth in the inter-tidal zone (see Table A3.5.3, Appendix A). In this case, however, the grazing of young shoots by waterfowl contributed to the problem and a string of floats had to be installed to keep the birds away from the site (Brooke and Ash, 1988).

A further problem encountered in establishing sand dune or saltmarsh vegetation relates to people pressure. BCDC (1988) found that pressure from recreational users caused severe damage to the developing salt marsh communities, for example. Once vegetation is established, the physical conditions required to ensure that the vegetation cover is self sustaining (including access) must be closely monitored and, if necessary, controlled.

3.4.4 Soil Conditions

Soil conditions provide a further control on successful habitat creation. There are generally two sediment supply options unless a restoration option simply involves re-vegetating an existing site (e.g. with selected salt marsh or sand dune species). The first option is the use of the existing soil (e.g. former agricultural land or land used for some other development purpose). The second involves the use of dredged material or similar as fill to raise the elevation of a site. A range of issues in respect of the latter option are dealt with in detail in Sections 3.4.7 and 3.4.8; the soil issues are dealt with below.

The particular soil characteristics of relevance to habitat creation or restoration are as follows:-

- nutrient status
- degree of contamination (if any)
- structure (including compaction)
- sediment size
- bulk density
- plasticity
- permeability

Present land-use will affect the type of habitat which develops or can be created. Plants, in general, are unlikely to grow on heavily contaminated soil. Several mitigation schemes in the United States and elsewhere have failed because previous land-uses have rendered the soil toxic. Depending on the type of habitat required, potential toxins include excessive salinity, excessive nutrients, heavy metals and/or pesticides. Salinity might be a problem if material is dredged in seawater for use in the creation or restoration of reedbeds or brackish seasonal wetlands. Over time, however, an adequate freshwater input might be expected to leach excess salts out of the soil. In other circumstances, however, a high residual saline content in agricultural soils may prove to be beneficial if the desired habitat is salt marsh. Where sites have been in agricultural use for a relatively short time, there may still be enough salt in the soil to develop salt marsh species following winter rains. Much British low-lying land has been in agricultural use for several hundred years, and around the Wash land claim for agricultural purposes started in the 14th Century (Doody, 1991). At Porlock Bay in North Somerset and in part of the Norfolk Broads area, however, regular salt water flooding already leads to the frequent occurrence of salt tolerant species in low intensity grazed agricultural areas.

If retreat is to be considered for some areas which are currently in intensive agricultural use, excessive nutrients or herbicides/pesticides might cause problems for habitat creation initiatives. Conversely, a limited amount of nitrogen, phosphorous and potassium might be beneficial to plant development and careful soil testing would therefore be required. Finally, a thorough chemical analysis of any dredged materials to be used in habitat creation/restoration initiatives, or of the soils of former industrial land on which such projects are proposed, would also be required in order to ensure that contaminants are not likely to be made bio-available as a result of a project. Even if the habitat creation element of a project on contaminated material appears successful, contaminants (e.g. pesticides or heavy metals) could nevertheless enter the food chain with potentially serious consequences. In the United States, the Environmental Protection Agency sets limits above which sediments are defined as being polluted. The Dutch also set quality standards for the environmentally acceptable disposal of dredged materials (Davis et al., 1990) but similar guidelines for Great Britain have not yet been developed.

3.4.5 Soil Structure

Another consideration in respect of soil or sediment use is the degree to which the soil has changed through oxidization, subsidence or compaction. Land which has been in agricultural use for some time may have changed to the point where it will no longer support the desired natural habitats. In the Norfolk Broads area, for example, the installation of deep land drains to improve drainage for intensive agricultural production led to a process known as saline deflocculation in the Wallasea soil series. Saline deflocculation destroys the soil structure, and there are now limited areas in which nothing will grow because the clay soils become waterlogged during the winter months, but dry out completely leading to extreme cracking in summer. It is not yet clear whether simply raising the water table back to its former position will encourage vegetation to return.

Compaction during the placing and grading of fill might also cause problems with soil structure and subsequent habitat development.

Finally, it should be noted that the development of interesting wetland ecosystems have been recorded on both contaminated and inert sediments. In the United States, a site for the disposal of contaminated dredgings monitored by the University of Wisconsin has recently been designated as being of environmental importance, and on the river Fal in Cornwall, salt marshes have developed on inert china clay waste. In the latter case, the clay material provided a substrate on which nutrient-rich sediment subsequently settled and this was followed by colonisation by various salt marsh species (NCC, personal communication, 1991).

3.4.6 Water Quality

The quality of water supplying or surrounding a proposed habitat creation or restoration project will be of particular significance in determining viable habitat types. Heavily polluted waters (e.g. oil slicks, chemical leaks) can cause problems for most types of coastal habitat, although British coastal waters are rarely chronically polluted to the point of damaging habitats on a day-to-day basis. Three water quality issues are, however, likely to be of importance in identifying appropriate coastal habitat creation initiatives:-

- Many vegetation types are sensitive to salinity levels. Reeds, for example, will not survive if salinity levels regularly exceed five parts per thousand. Certain sand dune grasses will tolerate salinities up to 35 parts per thousand and British salt marsh species prefer salinity in the range 5 to 38 parts per thousand.

- Large areas of stagnant water are not desirable in coastal regions and, although Britain does not yet have the same type of problems with mosquitoes and other insects as many of our European neighbours, care should nevertheless be taken to ensure that water circulation objectives are achieved.

- Eutrophic conditions (i.e. nutrient-enriched) such as those occurring around some sewage outfalls may lead to the excessive growth of algae which will, in turn, deter the development of vegetation, notably salt marsh species.

3.4.7 The Beneficial Use of Dredged Material

As discussed throughout the report, a great deal of practical research has been carried out, notably in the United States, into the potential beneficial uses of dredged material in habitat creation and restoration. The US Army Corps of Engineers, for example, has experimented using both clean and contaminated sediments for such initiatives in both the sub-tidal and intertidal environments. The 1988 publication "The Beneficial Uses of Dredged Material" (USACE, 1988a) sets out a wide range of options extending well beyond the coastal zone, and gives details in respect of the physical and biological needs of a particular habitat. On the whole, this publication and others simply use dredged material as a substrate. If sediment is uncontaminated, the criteria set out in Section 3.4.5 in respect of soil conditions (e.g. structure, nutrient status, etc.) apply equally to the use of dredged material. There are, however, a number of extra considerations in terms of the testing, use and monitoring of sites where contaminated or potentially contaminated dredged materials are used. Some of these issues are therefore discussed below.

3.4.8 Chemical Considerations Associated with the Use of Dredged Material

In recent years, considerable attention has focused on the possible release of sediment-bound toxic metals as a consequence of both dredging and dredged material disposal (Smith, 1976a; Lee, 1976). The pH and redox potential (degree of oxidation or reduction) of soils, sediments and surface waters alike are among the factors regulating the chemical forms of toxic metals and affecting their bioavailability. The pH and oxidation-reduction status of bottom sediments containing potentially toxic substances may be altered by the dredging process and by the subsequent disposal of the dredged material. A change in these parameters may result in chemical transformations, influencing the bioavailability of metals in dredged sediments by directly affecting the chemical speciation of a metal (i.e. altering valence charge) or by affecting the presence of ligands which regulate the mobilisation or immobilisation of toxic heavy metals.

The sediment characteristics that most affect mobility and biological availability in dredged materials are particle size, organic matter content, amount and type of ions, amount of iron and manganese, oxidation/reduction potential, pH and salinity. When the physical and/or chemical environment of a contaminated sediment is altered by removal and placement, the chemical and biological processes important to mobilisation or immobilisation of potentially toxic materials may be affected.

Considerable information is available from the agricultural literature on toxic heavy metals uptake by crop plants from contaminated or sludge amended soils (Dowdy and Larson, 1975; Cunningham et al., 1975; Jones et al., 1975). However, much less is known about factors influencing metal uptake by marsh plants from wetland soils or dredged sediments. A strong pH influence on trace metal availability to plants is supported by the agricultural literature, and an increase in acidity may also favour the plant uptake of these materials. Laboratory studies have further demonstrated that the availability and subsequent accumulation of irons, manganese, and zinc in rice and marsh plants is strongly influenced by both pH and oxidation intensity (Jones and Etherington, 1970).

The DoE Intergovernmental Committee on the Redevelopment of Contaminated Land (ICRCL) issues threshold values and action trigger values for heavy metals in contaminated soils. They emphasise, however, the need to assess the soil's phytotoxicity properties in terms of increasing soil acidity (ICRCL, 1987). Of the potentially toxic metals, more cadmium is mobilised to readily bioavailable forms by moderate changes in pH and redox-potential than other metals, and the gradual oxidation of dredged material applied to land for habitat development could significantly increase the mobility and subsequent plant availability of sediment-bound cadmium.

In conclusion, therefore, it has been demonstrated in laboratory studies that both pH and redox potential affect the geochemical distribution and bioavailability of potentially toxic metals in sediment water systems. These parameters have also been found to affect the accumulation of some of these metals in above ground marsh plant tissue. Minimal increases in the plant availability of some metals may occur as the pH/redox potential environment of a sediment water system is altered following wetland deposition, but substantial increases in bioavailability and subsequent plant uptake may occur for other metals. It may, however, be possible to manage disposal methods, predominant plant species, and possibly the physicochemical parameters of dredged material applied to land in order to minimise plant uptake of toxic metals from contaminated sediment.

3.5 Restoration and Creation

3.5.1 Review of Projects Already Undertaken

Sections 3.3 and 3.4 set out the various parameters which are likely to influence natural or managed coastal habitat development. If a resource is to be established which is both desirable in nature conservation terms (Section 4.1.4) and sustainable (Section 3.1.4), it will therefore be necessary to meet the relevant habitat's often very specific requirements in respect of each of these parameters. The remainder of Section 3.5 is devoted to a review of habitat creation and restoration initiatives undertaken both in Great Britain and internationally, and to the development of a series of tables setting out the limits within which each particular type of coastal habitat might be expected to survive.

As discussed earlier, it is not the purpose of this report to provide site specific technical guidelines for habitat creation or restoration. The report's objective is to highlight the factors which must be considered if such projects are to have a reasonable chance of success. Nevertheless, a great deal of technical information was examined during the preparation of the report and the manuals, reports and other papers dealing specifically with methods and techniques for restoration and creation have therefore been singled out. A list of these documents is presented in Table A3.5.1 in Appendix A. Discussion papers and other publications relating to specific creation and restoration projects were also reviewed and a detailed summary of these initiatives, which fall broadly into the categories listed in Table 3.5.1 below, is presented in Table A3.5.2, Appendix A. In both cases, the large number of projects undertaken in the United States (the US Army Corps of Engineers cited over one thousand examples of habitat creation schemes involving the use of dredged materials alone (USACE, 1988)) arises primarily from the mitigation requirements of Section 404 of the 1972 Clean Water Act. This is discussed in Section 5.5.3.

Table 3.5.1 Summary of Habitat Creation/Restoration Initiatives Reviewed (by Habitat Type)

Habitat	Number of Examples	Countries	Comments
Sand dunes	11	UK, USA, Australia, Netherlands	All restoration projects. Mostly successful.
Saltmarsh	24	UK, USA, France	Creation and restoration. Varying degrees of success.
Island Habitats	6	UK, USA	Most used dredged material or similar to create habitats for birds.
Mudflats	2	USA, France	Limited experience. Some success.
Reedbeds	3	UK	Generally successful.
Lagoons	3	UK	Produced valuable habitats for birds.
Sub-tidal habitats	9	UK, USA, USSR, Netherlands	Some notable successes especially for benthic communities/shellfish

Finally, as part of the Regional round-up of information undertaken during the preparation of this report, a review of British habitat creation and restoration initiatives was carried out, mainly because of concern that many such initiatives had not been formally documented. The results of this process are presented in Table A3.5.3, Appendix A, and the number and type of projects undertaken in each region is listed in Table 3.5.2 below. Two points should be noted. Firstly, that these lists are not intended to be exhaustive, and secondly that the overlap with schemes highlighted on Table A3.5.2 is, in fact, minimal.

Table 3.5.2 British Habitat Restoration/Creation Projects (by NRA Region)

Region	Number Restoration	Number Creation	Habitat Types Involved
Anglian	4	2	Saltmarsh; lagoons (for reedbeds and sand dunes see Table A3.5.2).
North West	5	2	Saltmarsh; sand dunes; lagoons.
Severn Trent	-	1	Marsh/brackish wetland (proposed).
Southern	4	7	Sand dunes; wetlands/scrapes; shingle island; shell beach.
South West	2	-	Sand dunes; boulder beaches.
Thames	-	-	
Welsh	2	2	Sand dunes; saltmarsh; scrapes; (proposed) mudflats.
Wessex	1	3	Lagoons; scrapes; reedbeds; saltmarsh.
Yorkshire and Northumbria	2	4	Lagoons; reedbeds; sand dunes; brackish wetlands.

3.5.2 Success Criteria

The physiology of a created site, its biodiversity and its long-term sustainability will determine its eventual success and it is this factor which has led authors such as Zedler (San Diego State University, personal communication, 1991) to question how often it will be possible to fully recreate a "natural", stable and functioning ecosystem. In particular, she points out that it may be very difficult to create habitats for endangered species because their range is limited, physical requirements are very specific and tolerance thresholds may be low (see, for example, Table 4.1.1).

The development of the soil physiology will, in many cases, affect the rate and extent of vegetation colonisation. If the soil invertebrates, algae and other organisms, nutrients and structure are not properly established, vegetation growth will be inhibited. Similar problems will be experienced if physical processes are not fully effective. A researcher at Stanford University, California (Philip Williams Associates, personal communication, 1990), reviewed the performance of restoration projects in the San Francisco Bay area and concluded that they were all "failures". Her criteria, however, related to vegetation establishment and plant cover, rather than to the hydrodynamic status of the site. Experience in the United States is now demonstrating that created marsh habitats take upwards of ten to twenty years to become properly established. The projects reviewed had generally been in place for much less than ten years and the soil (biological) and physical parameters on which the vegetation depends, may not have been fully functioning. In particular, soil invertebrates may not have become properly established following the change from freshwater to saline conditions, and the hydrological status of sites may not always have been properly considered at the planning stage of such early projects. It therefore seems that a key to successful habitat creation, from a biological as well as a physical viewpoint, is understanding and re-establishing natural processes, and then allowing enough time for the habitat to develop.

Determining viable habitats for a particular site will therefore depend to a large extent on the characteristics of the existing environment and the scope for manipulation. As discussed in Section 3.1.1, the selection of technically viable habitats at a given site should, however, be made with a number of ecological desirability criteria also in mind (Section 4.1.3/Table 4.1.1).

The importance of developing a sustainable habitat was discussed in Section 3.1.4. Site size was discussed in Section 3.3.8 and the extension of sites of existing interest is highlighted in Table 4.1.1. Of equal significance, however, is the "diversity" criterion listed on the same table. In this part of the report, sub-sections 3.5.3 to 3.5.8 deal with different coastal habitats in isolation. In reality, the creation of a single habitat type will rarely represent the optimum opportunity. A transition through different habitat types (e.g. sub-tidal to mudflats to saltmarsh, etc; see Tables 3.5.4 and 3.5.10) would usually be far more desirable and hence of greater value. Similarly, the existing habitat at the site in question should be reviewed and appropriate elements retained in any habitat creation/restoration proposals. These points are particularly important in selecting technically viable habitats to go forward to the evaluation process (Section 4).

3.5.3 Sand Dunes

All the examples of British sand dune restoration/creation initiatives investigated (see Table A3.5.3) relate to sites which already support, or are in the immediate vicinity of, an existing dune system. Dune creation on sites without any previous evidence of dune systems is apparently unprecedented and any proposal would therefore need to be fully assessed to determine whether or not the site's criteria meet the requirements of a self sustaining system.

Geographically, natural dune systems are most common on dissipative coasts with strong onshore winds and a plentiful sediment supply. Dune systems are classified into two main categories (Ranwell, 1972):-

- frontshore (offshore island, spit and ness dunes).
- hindshore (bay and hindshore dunes).

Assuming that restoration or creation initiatives are to be undertaken in the proximity of an existing dune system, it is important to identify and understand the topographical and climatic conditions which led to the formation of that particular dune system. Overall it should be noted that the parameters of dune formation are very site specific.

At Camber Sands, Sussex for example, an adequate littoral supply of sand sized material available for aeolian transport facilitated successful dune creation. Dune creation has also been successful at East Lothian in Scotland where an unstable system with low sand supply had to be considered, and creation was achieved by leaving the central hindshore unvegetated as a source of sediment supply. Sediment has to be effectively trapped in order to create and restore foredunes, but this may lead to the deterioration of the unvegetated inner dunes, as in the case of Braunton Burrows, Devon. In Portrush, County Antrim restoration resulted in undermining and scour because fences were too widely spaced given the low sand supplies. The planting of marram was also initially unsuccessful because the gradient of slope was too steep. Brooks (1979) recommends that slopes steeper than 27° should be contoured before planting: contouring was later tried at Portrush and proved successful. The porosity of fencing also influences sand-trapping success and at Camber Sands, mentioned earlier, successful sand accumulation was achieved when fence porosity was reduced from 69% to 42% (Metcalfe, 1977 cited in Ranwell and Boar, 1986).

The size of sediment required for forming sand dunes is loosely defined in most literature as "sand-sized". The International Classification describes sand as between 0.02 and 2.0mm and the United States Department of Agriculture (USDA), also in Fitzpatrick (1986), defines sand-sized as particles between 0.05mm and 2.0mm. Sediment characteristics are among the overall physical and biological requirements for sand dune creation/restoration set out in Table 3.5.3 below.

Table 3.5.3 Physical and Biological Requirements of Sand Dunes

Elevation	Above MHW. For vegetation establishment a minimum of 1m vertical distance above MHW (Adrinani and Terwindt, 1974, cited in Ranwell and Boar, 1986) is required or 2m to escape storm damage (Brooks, 1979).
Grade	For successful vegetation establishment, a slope of less than 27 degrees is required (Brooks, 1979).
Salinity	Marram tolerates 1% salinity. Lyme-grass and couch grass tolerate salinities up to 3.5% (seawater strength) provided inundation is only for a few hours (Ranwell and Boar, 1986).
Sediment Regime	Sufficient sediment supply of sand-sized material 0.02-2.0mm (Fitzpatrick, 1986) from coastal (beaches, cliffs), river and/or sea bed sources is essential to sustain dune building. Porosity and positioning of fencing needs to be carefully selected according to sand availability.
Waves	Dune face should not be exposed to wave action.
Currents	N/A
Importance of adjacent habitats	Provision of a seed bank is important, either in the water <u>Cakile maritima</u> (sea rocket) and <u>Salsola kali</u> (saltwort), or as seed and rhizome fragments in the strandline (e.g. dune-building grasses) (Ranwell and Boar, 1986).
Wind	Sufficient wind required to enable effective aeolian sand transport. A wind speed of 5m per second can lift sand grains (Brooks, 1979) and initiate movement and saltation.
Foreshore/Backshore	Adequate backshore above MHW will provide 80% of sand for dune building while the foreshore between MLW and MHW will provide 10-20% (Ranwell and Boar, 1986).

3.5.4 Saltmarshes

In Great Britain there are very few examples of saltmarsh creation. There are, however, a number of examples of restoration, and most schemes are either designed to stabilise an area of sediment or to re-establish a damaged marsh. Many involve turf transplants, in sheltered areas and on a small scale. At Farlington Marshes, Hampshire, thick Reno-mattresses were covered in dredged material and saltmarsh communities have developed in the sheltered sections. In Lancashire, on the Ribble Estuary, Puccinellia clods were thrown onto high level sand flats and saltmarsh subsequently developed. The planting of Spartina has also been used to repair denuded areas in Southampton Water although the use of this species may not be considered appropriate at many sites in the UK. In more exposed, coastal rather than estuarine, locations such as at Dengie in Essex, saltmarsh restoration projects have been undertaken using groynes and poldering systems to reduce wave energy (see Table A3.5.3). Some of these projects have been more successful than others, but the reasons for success or failure are not entirely clear.

In the United States an extensive programme of saltmarsh creation and restoration has been undertaken because of the requirement for mitigation in the form of habitat creation if a proposed development will damage an existing wetland habitat (Section 5.5.3). In 1988, the San Francisco Bay Conservation and Development Commission (BCDC) reviewed the successes and failures of fourteen mitigation projects involving habitat creation, mostly saltmarsh, and concluded that four factors were of particular importance in cases where marsh restoration was judged successful:-

- The site elevations achieved were suitable for the desired habitat.
- The site was adjacent to an existing "source" of flora, fauna, etc.
- Water circulation objectives were achieved and water quality was satisfactory.
- The sites had been the subject of careful planning and detailed design by suitably qualified personnel.

Suitable soil conditions, successful planting, and a requirement for ongoing monitoring and maintenance were also cited as contributing to successful projects.

Among the reasons given for the total or partial failure of projects were the following:-

- The project had simply not been completed.
- Problems with soil chemical composition or with soil structure (e.g. soil had been compacted during construction).
- Poor planning or unauthorised modification of the approved plan.
- The site elevation achieved was not suitable for the desired habitat.
- Adverse impacts of man (i.e. disturbance by all-terrain-vehicles, recreationalists, pets, etc.).

The lessons from the BCDC report are equally important in the British context, particularly given our relative lack of experience in creating "new" saltmarsh. The physical and biological requirements of saltmarsh, whether created or restored, are set out in Table 3.5.4.

Table 3.5.4 Physical and Biological Requirements of Saltmarshes

Elevation	Initial development between MHWN and MHW (Beeftink, 1977) may be critical to ±30cm. Contouring of topography will provide suitable elevations for most saltmarsh species (Zedler, 1984). Sedimentation should lead to development of upper saltmarsh and a transition through to terrestrial habitats.
Grade	1-3 degrees, relatively flat, reflecting the conditions under which marsh sediments are laid down. Steep and/or concave slopes will reduce the scope for (e.g. the width of) saltmarsh development. Adequate drainage is also important as the impoundment of water may prevent vegetation growth.
Salinity	5-38 parts per thousand (Beeftink, 1977). Salinities in excess of 50 parts per thousand may lead to high mortality of some Spartina species (Zedler, 1984). Lower salinities will lead to invasion by brackish and freshwater species.
Sediment Regime	Sufficient sediment in suspension to allow accretion to occur at a rate of between 3-10mm per annum (Beeftink, 1977). Accretion in excess of 25mm per annum could lead to smothering of some plants, particularly pioneer species. Sediment size is also important in determining viable plant species.
Waves	More exposed sites will require protection from wave attack particularly while young seedlings become established. UK literature suggests that fetch should be less than 2000m for initial colonisation of saltmarsh (Boorman, 1987). A mudflat or similar breakwater fronting the saltmarsh is important in reducing direct wave attack.
Currents	Must be sheltered site. Good tidal circulation is, however, essential.
Importance of adjacent habitats	Very important for provision of a seed bank for colonisation. Also a good indication of where a saltmarsh can grow. If saltmarsh is nearby it shows that conditions are or were generally acceptable.
Planting	Width of planting should be greater than 6m if marsh is to become self-sustaining.

3.5.5 Mud and Sand Flats

In the British context, mudflats are a particularly valuable coastal habitat because of their importance for migratory birds. Notwithstanding this, British experience in the deliberate creation or restoration of mud or sandflats is minimal (see Tables 3.5.1 and 3.5.2). Several proposals to create such sites to mitigate against anticipated losses are, however, currently under consideration.

Experience in the US is also limited, largely because mudflats do not qualify as wetlands under S.404 requirements and there is therefore no requirement for mitigation if existing sites are damaged or destroyed The only exception to this is if endangered species will be threatened by a particular development. The US Army Corps of Engineers have, however, carried out mudflat creation schemes using dredged material to create habitats for birds. In these instances, underwater placing has been used to raise the level of the sea bed. The main problems encountered have been littoral drift causing sediment loss and, in sites which were exposed to high wave energy, erosion. In the latter case, rip rap breakwaters have been placed to reduce wave energy and promote stability.

Some uncertainty exists over the potential for the colonising of created mud and sandflats by benthic organisms and, as these are transported on the tide, proximity to existing sites would appear to be important. Studies in France, where mudflat creation using dredged material is proposed for Le Harvre estuary, further suggest that mudflat stability is very sensitive to velocity. Velocities in the range 0.5 to 0.7 m/s are therefore being promoted as suitable to avoid excessive erosion while minimising the chance of excessive accretion leading to colonisation by pioneer saltmarsh species.

The physical and biological requirements for mud/sand flat creation or restoration, as far as these are known, are specified on Table 3.5.5.

Table 3.5.5 Physical and Biological Requirements of Mud or Sand Flats

Elevation	Below MHWN
Grade	Site specific. Little information available.
Salinity	N/A.
Sediment Regime	Site specific. Clearly important but little information documented.
Waves/Currents	Site must be protected to allow deposition of sediment and ensure minimal erosion. Related to sediment regime. Site specific understanding required.
Importance of adjacent habitat	Must be close enough for faunal colonisation.
Velocity	Velocities of 0.5m/s to 0.7m/s are suggested in Cellule de Suivi du Littoral Haut Normand, 1989.

3.5.6 *Shingle Features*

Experience in the creation or restoration of shingle features, both in the US and in Great Britain, is largely limited to beach recharge schemes. Creating or restoring shingle habitats is likely to be very difficult because of the mobility of the material and because of the sensitivity of shingle vegetation to disturbance.

3.5.7 Coastal Lagoon Features

British experience in creating or restoring lagoon-type habitats is limited, but several successful examples do exist. The extraction of gravel on Walney Island, Cumbria has led to lagoon creation for birds in former gravel pits (see Table A3.5.3). Careful control of water levels at Havergate Island, Suffolk has produced exceptional brackish lagoon habitat for breeding waders, wildfowl and terns on a former grazing marsh. Sluices and ditches help increase water circulation and control salinity levels in the lagoons. Trimley Marshes, also in Suffolk, contains created brackish and freshwater lagoons, with salinity being controlled by a combination of freshwater piped from an inland source and saline water brought in from the sea. Here, however, only the highest tides provide a supply of saline water because the lagoon elevation is higher than would be ideal.

Many islands in the USA created from dredged material incorporate lagoon systems created as to improve habitats for birds: Gaillard Island, Alabama (Table A3.5.2) is one such example.

Table 3.5.6 sets out the biological and physical requirements for the creation of coastal lagoons including both those linked to the open sea (3.5.6a) and those enclosed behind and bar or similar feature (3.5.6b).

Table 3.5.6 Physical and Biological Requirements of Coastal Lagoons

a. Linked to the open sea	
Elevation	Below low water at centre of lagoon.
Grade	N/A.
Salinity	Varies, freshwater to saline.
Sediment Regime	Entrance must be stable in terms of tidal inflow/outflow and longshore drift (i.e. longshore drift should not cause closure). Low suspended sediment loads in both tidal water and freshwater inflow are essential to avoid excessive siltation and hence encourage habitat stability.
Waves	Protected site is desirable.
Currents	Protected site is desirable. Adequate tidal circulation is essential.
Importance of adjacent habitats	Requires faunal and floral colonisation from adjacent freshwater and saline habitats.
b. Not linked to sea	
Elevation	Low enough to ensure flooding (e.g. site should not dry out at low water). Water should not be too deep, or freshwater and saltwater may not mix.
Grade	N/A.
Salinity	Varies, freshwater to saline.
Sediment Regime	Needs stable ridge between lagoon and the sea. Sediment load of freshwater inflow should be low.
Waves	N/A.
Currents	N/A.
Importance of adjacent habitats	Requires faunal and floral colonisation from adjacent freshwater and saline habitats.

3.5.8 Reedbeds

There are some British examples of the planting of reeds within tidal river systems (Lewis and Williams, 1984). At Swinefleet, an estuarine site in the River Ouse, Yorkshire, reed rhizomes were planted at mean high water levels and have successfully colonised downslope. A major controlling factor on reed growth is, however, the salinity of the water.

Reeds are often planted along banks of rivers to prevent scour and trap silt. Rapid accumulation of silt may produce elevated land levels leading to a reduced frequency of flooding and the succession of plants such as Scirpus maritimus (sea clubrush), Atriplex spp. (Orache) and Agropyron pungens (sea couch) (Bibby and Lunn, 1982). As the site becomes drier, Salix spp. and other scrub species may invade. This tendency towards succession means that upper estuarine reedbed sites are particularly difficult to maintain unless there is a sufficient fresh water supply.

Reedbed creation and/or restoration requirements are set out in Table 3.5.7.

Table 3.5.7 Physical and Biological Requirements for Reedbeds

Elevation	Not documented but considered to be above MHW for planting.
Grade	N/A.
Salinity	<5 parts per thousand. Requires a regular freshwater input.
Sediment Regime	Excessive sediment supply and frequent inundation will lead to sediment accumulation, rapid heightening of land level and eventual habitat change (Bibby and Lunn, 1982). Low sediment content is therefore desirable.
Waves/Currents	Sheltered (relatively intolerant of water movement).
Importance of adjacent habitats	Not essential; can be planted.
Water Depth	Will grow in water up to 1m depth. Planting must be done out of water (Lewis and Williams, 1984) (Beeftink, 1977).

3.5.9 Sub-tidal Habitats and Bird Islands

As indicated in Section 2.3.15, opportunities for the development of new sub-tidal habitats are likely to become increasingly frequent if rates of sea level rise increase as predicted by IPCC (1990). Even in the short-term, a number of sites (notably in East Anglia) will offer the potential for creating sub-tidal habitats. This is because peat shrinkage, subsidence, or other vertical land movements (see Section 2.2.5) have combined with historic sea level rise to produce land, now protected by flood defences, which is already up to 2m below mean water level.

Much of the experience in the creation of sub-tidal and island habitats is once again found in the United States. The physical and biological requirements for two such habitats, seagrass beds and bird islands, are set out in Tables 3.5.8 and 3.5.9 respectively:

Table 3.5.8 Physical and Biological Requirements for Seagrass Beds

Elevation	MLW to -10m
Grade	N/A
Salinity	Most species require salinity greater than 20 parts per thousand; some species will tolerate 10-15 parts per thousand.
Sediment Regime	Seagrasses tolerate wide range of sediment size (sands to muds). Consolidation and retention may initially be a problem if dredged materials are used.
Waves/Currents	Low energy environment required but sufficient circulation/flushing to prevent development of lethal temperature extremes.
Light	Sufficient light penetration through water to support growth.
Time of Planting	Spring.

Table 3.5.9 Physical and Biological Requirements for Bird Islands

Elevation	Ideally 1m to 3m above MHW to prevent flooding of areas used for nesting while also reducing the risk of wind erosion.
Grade	Steep sides should be avoided.
Size	2 ha to 20 ha have been recorded.
Salinity	N/A.
Sediment Regime	Coarse materials (sand and shell) provide bird nesting substrates.
Location	Isolated from predators and human disturbance. Adequate food resources.
Timing	Build in autumn/winter in preparation for breeding season.

Finally, various other types of habitat which have been created, together with their environmental objectives and important parameters determining their success of failure, are summarised on Table 3.5.10 below:-

Table 3.5.10 Sub-Tidal Habitat Creation Initiatives

Habitat	Environmental Value	Critical Parameters
Topographic bottom features	Fish/shellfish "refuge"	Not enough known to target species for conservation
Eel grass beds (Zostera)	Precursor to saltmarsh development; encourages siltation	Sediment supply; waves/currents
Nearshore Berms	Benthic habitat; breakwater function	Grain size; consolidation and settlement; littoral drift characteristics
Feeder Berms	Beach recharge	Onshore migration; drift characteristics
Oyster beds	Commercial value	

SECTION 4 ASSESSMENT AND EVALUATION OF RETREAT

4.1 The Overall Context

4.1.1 Introduction

Section 3 outlines some of the technical requirements for the creation or restoration of coastal habitats under a scenario of managed retreat. Such information forms an important input into the decision-making process by determining the technical viability and hence the likely success of a particular proposed initiative. Having established the critical physical and biological parameters it will then often be necessary to evaluate the various options at a site, in qualitative, quantitative or monetary terms, for example to compare the benefits of retreat against the benefits of maintaining a flood defence. Placing values on alternatives in this way can help both to establish their relative environmental desirability and to ensure that the best possible value for money will be obtained.

Section 4.1 reviews the need for, and context of, such evaluations. It summarises the process within which decisions concerning flood defence have traditionally been made and discusses some of the general issues related to the identification and valuation of retreat options. Sections 4.2 to 4.4 review non-monetary and monetary assessment procedures and discuss their respective roles in the evaluation process. Section 4.5 examines the attitude of the main interested parties to environmental evaluation, and Section 4.6 develops a framework for the future economic valuation of habitat creation or restoration initiatives, comparable to that which already exists for flood defence evaluation.

4.1.2 The Evaluation Context

The decision making process at sites where the existing flood defences have a low residual life has traditionally revolved around determining whether the defences should be improved, maintained or abandoned. There may be a number of different engineering options under the headings of maintenance or improvement, while abandonment is usually equivalent to a "do-nothing" option. Once such a set of options has been identified, they are assessed and evaluated taking into account technical (engineering), economic, environmental, and political considerations.

Environmental and economic considerations will usually be addressed through some form of Cost Benefit Assessment and/or Environmental Assessment. Factors appraised through the former will typically include the costs of capital engineering works and subsequent maintenance, and scheme benefits in terms of the damage-costs-avoided. Potential damages may include flood damage to properties, vehicles, infrastructure and services; loss of agricultural output; and other economic and environmental impacts. Ecological, landscape, amenity and recreation impacts might be expressed qualitatively, quantitatively or in money terms. The form in which impacts are expressed or evaluated will depend to some degree on the purpose of the exercise. For example, if the proposed flood defence works are to receive grant-aid funding from MAFF, a full monetary assessment of costs and benefits will usually be required (see Section 5.3.3).

The decision rule generally adopted in the evaluation of maintain/improve options is based on economic viability. If the damage-costs-avoided - in other words, the benefits - are greater than the engineering costs, the maintenance or improvement works would be justified. If the engineering costs are greater than the damage-costs-avoided, however, the engineering works would not be justified and a decision may therefore be taken to do-nothing.

4.1.3 The Managed Retreat Option

Various retreat strategies can be identified, ranging from the true do-nothing approach, through a minimum intervention approach to heavy engineering works undertaken to create a desirable habitat. In a true do-nothing strategy, the sea defence is abandoned and no further action of any kind is taken. The way in which the site evolves over time is left entirely to natural forces, usually without monitoring or intervention of any kind. Managed retreat, on the other hand, covers a variety of potential options, with the common aim of restoring or creating desirable habitat, landscape or amenity features. Possible "management" activities range from carrying out feasibility studies, monitoring site changes or controlling access, to the introduction of flora and fauna or the undertaking of engineering works to change site elevation. Given this wide variety of scenarios, it should be stressed that the term "managed" indicates that the future development of the site is being planned in some way. As discussed in Section 1.4.6, good management does not necessarily mean intervening in the natural processes of site evolution.

The first step in assessing and evaluating alternative retreat strategies is to identify both the consequences of a minimum intervention approach and possible alternative management options. The following questions are likely to be particularly important in this process:

- what type of habitat would develop if nothing was done to influence the natural development of the site?
- are the habitat, landscape or amenity improvements proposed under managed retreat of the greatest possible nature conservation value given both national desirability criteria and the local context of the particular site?
- what is the nature and extent of management that would be required to realise the preferred habitat option and are any proposals technically viable?
- what are the sustainability criteria and long-term maintenance requirements for the restored or created habitat?

4.1.4 Environmental Desirability

As indicated by the above questions, the identification of potential retreat options should take into account not only technical and economic viability but also the nature conservation and landscape desirability of the restored or created habitat.

In identifying sites of existing conservation or landscape value for designation and hence protection, certain criteria defined by the various conservation agencies must be met. To be designated as a biological SSSI for example, a site must meet some or all of the pre-determined criteria set by the NCC (NCC, 1989). The NCC are also responsible for identifying British sites of outstanding international importance for migratory wildfowl and waders under both the Ramsar Convention and the EC Birds Directive. Again, very specific criteria are used to determine which sites should be protected (NCC, 1990). Countryside Commission also designate sites with high quality and often nationally important landscape and amenity features - as Heritage Coasts, National Parks and Areas of Outstanding Natural Beauty.

Sites where managed retreat is being considered in order to improve nature conservation and landscape values will usually have, by implication, little or no existing interest. They may, however, have significant potential, for example as sites which could be developed as NNRs and Local Nature Reserves. In any area subject to a planned retreat, it is important that landscape, recreation and habitat creation objectives are assessed as a whole and not in isolation. In many instances, the coastal environment depends on a variety of habitats and landscapes and a mixture of ecological and landscape criteria such as those identified in Tables 4.1.1 and 4.1.2 should therefore form the basis not only for identifying restoration and creation priorities, but also for assessing and evaluating potential options.

At any particular site some of the criteria discussed in these tables will be more important than others. Nature conservation criteria and landscape criteria will often be compatible, and recreation interests might be accommodated if they are not detrimental to the former. Even so, priorities might be quite different depending on whether the proposed site for retreat is adjacent to a site of existing environmental importance or whether it is effectively isolated from such interest. Within the framework provided by this report, however, it is not possible to generalise and it is recommended that detailed discussions should be held with representatives of the appropriate nature conservation and landscape bodies to establish priorities on a site specific basis.

As a guide in setting priorities for creation or restoration it may nevertheless be useful to refer to the general priorities of the main conservation bodies and to the key ecological and landscape criteria used by these bodies in their own assessments. These are reviewed in Table 4.1.3.

Table 4.1.1 Key Ecological andManagement Factors in the Evaluation of Habitat Creation or Restoration Options for a Particular Site

CRITERION	EXPLANATION	APPLICATION TO MANAGED RETREAT
Existing nature conservation interest	Sites of existing importance (e.g. assessed in relation to NCR criteria).	Established habitats of importance should not be lost to managed retreat unless it can clearly be demonstrated beyond reasonable doubt that what is likely to replace it will be of significantly higher conservation value (see Section 4.1.6).
Necessity for intervention	The likely results of a non-intervention approach should be fully assessed.	The level of management should be determined and the objectives of any management clearly stated (see Section 3.1.4).
Resource Implications of Intervention	The cost in staff time, capital and maintenance works, and management.	Resource implications of managing the site from construction to maintenance must be fully considered and an appropriate long-term management framework identified and put in place (see Sections 4 and 5).
Technical Viability	The creation/restoration options which are technically feasible at a given site.	The range of options needs to be reviewed alongside the corresponding likelihood of success (see Sections 3.3 to 3.5 inclusive).
Sustainability of created/restored habitats.	Capacity for survival and regeneration. Coastal habitats are dynamic not static. Change is an important element of survival.	To minimise management costs in the long-term, sites and habitats involved should be persistent and self-sustaining (see Section 3.1.4). Selection of habitats for creation/restoration should also consider natural succession and the sensitivity of the habitat to storms, etc.
Degree of control over influencing factors.	Ability to control physical and human influences.	Factors which might affect the site's ecology, including drainage and pollution, need to be under the control of site managers.

CRITERION	EXPLANATION	APPLICATION TO MANAGED RETREAT
Location adjacent to designated sites of existing nature conservation interest.	The need for buffer zones; the need to extend established sites of conservation value.	By selecting sites adjacent to current interest, the existing SSSI legislation might be utilised for management agreements (see Section 5.3). In some cases, existing site management staff and facilities may already be in place.
Site size.	Larger habitats are likely to be more valuable for nature conservation.	Site size should be maximised to help ensure greatest sustainability and to accommodate species with larger range requirements. Management resources should, however, be sufficient to adequately cover the site.
Rarity	Rare habitats or habitats supporting rare species	The reason for initial rarity must be understood. Re-establishing viable populations of rare species can be a lengthy, costly and ecologically difficult process. Notable successes, however, include work undertaken by RSPB to create habitats to encourage the Avocet to recolonise UK estuaries. (Marchant et al., 1990)
Degree of threat	Priority for habitat restoration/creation should be given to habitats or species which are threatened by (undesirable) natural change or human influence.	Firstly, the severity of any threat should be assessed in local, national and international terms (see Note 1). One approach is then to remove the threat (e.g. allowing the seawall to fail may remove the obstacle preventing the habitat's inland migration). Where the threat cannot be removed, it may be possible to restore/create that habitat elsewhere.

CRITERION	EXPLANATION	APPLICATION TO MANAGED RETREAT
Diversity	Diversity of habitat types increases the range of species present at a site.	Site management can be used to improve habitat diversity and hence opportunities for wildlife observation and research into intra-species interaction. However, care must be taken to ensure that each habitat unit remains an ecologically viable size.
Vulnerability to disturbance	Some habitats/species are more tolerant of disturbance than others.	Those habitats and species vulnerable to disturbance must be identified and protected by effective management of access. Where human disturbance cannot be excluded, careful selection of habitats for creation/restoration is essential. Screening using vegetation (e.g. reeds) or embankments could be considered; visitor management should ensure that habitats are not damaged by trampling, etc.
Naturalness	Natural appearance of coastline contributes to overall value.	The large open vistas of the coastal zone invoke a feeling of wilderness. Managed retreat may provide an opportunity to remove artificial features which can impede this feeling. Natural plants and habitat should also be encouraged, notably those native to the UK or to the particular region. Landscape requirements are further discussed on Table 4.1.2.
Position on migration route	Particularly relevant to habitats for birds.	Identifying and restoring/creating habitats suitable for migratory species.
Long term trends	Recorded changes in habitat composition, species numbers, etc.	Habitat creation/restoration should accommodate desirable trends in species population growth, etc. and may also be used to counter undesirable changes (see Note 2).

CRITERION	EXPLANATION	APPLICATION TO MANAGED RETREAT
Source of colonising flora and fauna	Vital for initial colonisation and long term sustainability.	Habitats which colonise naturally may have a greater chance of survival in the long term than those planted artificially. Natural colonisation may therefore be desirable for some habitat types (see Section 3.4.2).
Wildlife corridor	Linking areas of similar habitat.	Reduces isolation, improves species mobility and hence chance of survival. Opportunities to create/restore such corridors may therefore be important particularly if existing or created sites are small.
Education and research potential	Important at certain sites (e.g. Local Nature Reserves, near centres of population, research establishments, etc).	Careful habitat selection required to maximise educational value and usefulness for research.
Amenity and recreation value	Leisure use may encourage the public to develop an interest in conservation.	Access and safety issues may be important. With careful management, it may be possible to combine nature conservation objectives with activities such as fishing, cycling or wildfowling.

NOTES:

1. Human threats to British habitats are increasingly well documented (e.g. RSPB, 1990a; NCC, 1991) and, as a result, rates of coastal habitat loss are now beginning to be quantified. The degree of threat to coastal habitats in northern Europe as a whole is not yet clear, but attempts are being made to bring such information together, through such projects as the EC's Environmental Directorate CORINE geographical information system (Pritchard, 1989).

2. A number of long term monitoring programmes operate for coastal species, enabling trends in species to be identified. Relevant examples include the Birds of Estuary Enquiry (BTO), National Wildfowl Count (WWT), Seabird Colony Register (NCC), and the Reedbed Survey (RSPB).

Table 4.1.2(a) Primary Landscape Requirements for British Habitat Creation or Restoration Initiatives

Criterion	Explanation	Application to Managed Retreat
Holistic approach	Assess landscape requirements alongside those of nature conservation, amenity, etc.	Ensures a variety of habitats, a diversity of landscapes and compatibility with surrounding area. Should include a consideration of access and informal recreation opportunities.
Conservation versus preservation	Conservation accepts change. Preservation maintains the status quo.	In areas designated for their unspoilt character, a conservationist rather than preservationist approach should be taken to potential loss of land to the sea.
Coastal management	Establishes a moveable and transient coastline.	A flexible, long-term approach, enabling natural systems to migrate as required.
Control of development	Development needs to be in harmony with, and contribute to, landscape character.	The Countryside Commission do not promote, for example, the development of formal recreational facilities in areas notified as being of landscape importance.

Table 4.1.2(b) Countryside Commission Objectives for British Habitat Creation or Restoration Initiatives

Countryside Commission Objective	Explanation	Application to Managed Retreat
Attractive and diverse countryside	Natural beauty and landscape diversity should be conserved and new countryside should be created wherever possible.	New landscapes and land cover should be harmonious and sympathetic to existing characteristics. Important facets in the creation of new countryside include the creation or natural regeneration of habitats for a range of wildlife, and the creation of places accessible to the public.
Countryside of quality	Quality of structural design of houses, barns and bridges, for example, is essential.	Would apply to any structures required.
Accessible countryside	The quiet enjoyment of the countryside is vital to the quality of life for millions of people.	There should be public access wherever this can be integrated with other conservation objectives.
Thriving countryside	Much of the beauty an diversity of the countryside depends on the presence of a prosperous rural economy.	In terms of the retreat option, the growing of reeds, the promotion of wildfowling, and the opening of new nature reserves all represent environmentally sympathetic and sustainable rural development options.

Countryside Commission Objective	Explanation	Application to Managed Retreat
Environmentally healthy countryside	New landscapes must be managed and protected.	Economic development, landscape and wildlife conservation and public access must be integrated to achieve a sustainable and multi-purpose countryside.

Table 4.1.3 Habitat Creation/Restoration Priorities of Nature Conservation Agencies

AGENCY	PROCESS	AVAILABLE DATA	COURSE OF ACTION
Nature Conservancy Council (now English Nature and Countryside Council for Wales)	■ Habitat prioritisation 1. Establish current extent of habitat 2. Monitor rate of change 3. Identify habitats under threat	Estuaries Review; Coastwatch; Coastal Habitat Inventories (Saltmarsh Survey, Shingle Survey, Sand Dune Survey) (NCC, 1989a; 1991)	Site protection where possible then restore/create most threatened habitats.
	■ Prioritisation of conservation needs in agricultural lowlands 1. Protect surviving semi-natural areas 2. Control pollution 3. Retain and enhance important habitats 4. Create new habitats on intensively farmed sites of low existing conservation value	Nature Conservation and Agricultural Change (NCC, 1990)	Habitat creation/restoration works should not be considered if important sites of existing interest will be lost. Preference shown for such initiatives on intensively farmed land.

AGENCY	PROCESS	AVAILABLE DATA	COURSE OF ACTION
Royal Society for the Protection of Birds (RSPB)	1. Review all major vegetation/habitat types. 2. Identify community classes of greatest ornithological importance (10/25 habitat groupings identified as such). 3. Establish degree of threat.	National Vegetation Classification	Protect/restore/create "high value" habitats for birds (e.g. native wet grassland; swamp, fen and carr; sand, shingle and machair; intertidal flats; saltmarsh; coastal lagoons).
World Wide Fund for Nature (WWF)	■ In consultation with other conservation bodies, review major threats to habitats.	Advice from voluntary and statutory conservation agencies.	Allocation of grant-aid for land purchase and management costs for priority habitats.
National Trust	■ Land acquisition depends on donations, bequeaths, etc. ■ Some targeting of funds through Operation Neptune. ■ Main emphasis on hard coastlines rather than low-lying areas.	Site assessment by regional staff.	Preference for land acquisition in areas of national quality for existing natural beauty. NT have only limited interest in low-lying agricultural areas.
Wildfowl and Wetlands Trust (WWT)	■ Establish value of different habitats for wildfowl.	National wildfowl counts	Enhance/create habitats for wildfowl (e.g. wader scrapes; pastures managed for geese; open water areas; fringing habitats such as reedbeds).
Royal Society for Nature Conservation (RSNC)	■ Establish rate/cause/ extent of habitat loss.	Internal review on habitats under threat from sea level rise (with County Trusts)	No clear priorities yet identified.

AGENCY	PROCESS	AVAILABLE DATA	COURSE OF ACTION
British Association for Shooting and Conservation (BASC)	■ Establish existing value of site for shooting.	Feedback from wildfowling clubs, etc.	Protect valuable sites from saline flooding. BASC would not generally support saltwater creation/restoration if freshwater grazing marsh were to be lost; otherwise favour habitats supporting quarry species.

4.1.5 Assessment and Evaluation of the Retreat Option

Once a set of potential retreat options have been identified using technical viability and environmental desirability criteria, the next step is to assess the "benefits" (and "costs") associated with each. Different options can then be compared and/or cost-effectiveness can be demonstrated. It will be important to determine whether or not the benefits gained through the management activities are greater than any costs incurred. In other words, would the environmental or habitat gains associated with the managed retreat option justify any capital, management and/or maintenance costs?

A clear definition of criteria for comparing options, such as the "desirability" criteria defined in Tables 4.1.1 to 4.1.3, is therefore important for several reasons.

i. Any expenditure on habitat creation or restoration should be focused on those sites and habitats where maximum nature conservation and/or landscape benefit will accrue. To enable the identification of such sites and habitats, clear criteria must be established by which the comparative worthiness of one scheme or habitat against another can be established.

ii. By setting such criteria, the goals for restoration and creation are made explicit. This provides a means by which success or failure can be measured and is likely to be important for conservation bodies when approaching government for funding for a managed retreat scheme. The Treasury is likely to want a clear indication of how value for money is being obtained in achieving conservation benefit.

iii. Ecological criteria will have a role to play where the benefits of managed retreat have to be compared with the value of any conservation assets that would be lost in the retreat process.

iv. By identifying the most beneficial options for retreat in a particular area, conservationists can be more pro-active in planning and campaigning for the longer term selection of optimum sites for managed retreat. Conservation organisations increasingly have the capacity to carry out economic and technical appraisal of schemes outside their traditional areas of conservation expertise, and are therefore able to research the socio-economic, and engineering components of managed retreat options as well as the environmental aspects. The identification of economically and technically feasible retreat options can therefore be more thoroughly investigated, by a wider range of bodies, at an earlier stage in the decision making process.

v. Landowners may seek clarification of the options assessed for managed retreat, including the potential benefits for conservation. Ecological selection criteria will help provide these answers.

The assessment process itself will therefore frequently involve more than one stage. The ecological and landscape criteria will generally be used first, to screen and assess potential options. A more formal evaluation should then be carried out using either non-monetary or monetary techniques. The type of technique chosen will depend on the type of decision criteria to be used for evaluating the various options. In general, however, a cost-benefit approach should be adopted as this approach requires that the full implications of an option are taken into account (rather than those pertaining to only one or a few criteria). In some cases within this framework, an indication of cost-effectiveness or value for money may then be sufficient for decision-making purposes. In others, either the size of the proposed expenditure or the nature of the funding mechanism may require that economic benefits should be shown to exceed the costs.

Non-monetary techniques can also be used, particularly to determine how different retreat options perform relative to each other. They can be used to demonstrate maximum cost-effectiveness or can form part of a wider cost-benefit assessment which may also include the use of monetary valuation techniques. The techniques in both categories which are most relevant to the assessment and evaluation of retreat options are therefore reviewed in the Sections 4.2 and 4.3.

4.1.6 Continued Protection Against Inundation for Sites of Existing Interest

As discussed in Section 3.1.1, there may be some circumstances in which an (economic) evaluation is required to evaluate protection for an existing site of high environmental value. The Ministry of Agriculture, Fisheries and Food (MAFF) has recently commissioned the University of East Anglia and Southampton University to evaluate the economic implications of rising sea levels for the East Anglian and South coasts respectively. The main objective of this research is to define a methodology for assessing the economic implications of sea level rise for each area's assets. The studies are looking at three different scenarios in respect of coastal defence: do-nothing, maintain current defences and improve current defences. Wherever practicable, economic values are being assigned to different assets to reflect the social loss associated with their damage or destruction. Assets considered in the studies include infrastructure; domestic, industrial and commercial properties; and agricultural resources. Areas of specific environmental value, amenity value and recreational value are also being considered.

The findings of the UEA and Southampton studies will provide a valuable contribution to the overall problem of wetland and coastal habitat valuation. Conclusions drawn on the applicability of the different techniques, together with any values developed through their application, will be useful to this study in terms of providing reference values for existing habitats of different types and quality (see Section 4.3.3). It is not the purpose of this study, however, to further investigate mechanisms by which the continued protection of sites of existing nature conservation interest might be achieved.

4.2 Non-Monetary Assessment Techniques

4.2.1 Introduction

Non-monetary techniques have been widely used to aid the assessment of environmental costs and benefits, particularly those related to habitats, landscapes and amenity and recreation. For evaluation purposes, these techniques generally rely on the definition of a set of criteria (such as those listed in Tables 4.1.1 and 4.1.2), against which the characteristics of different sites or, in the case of alternative retreat strategies, of different proposals for a given site are judged.

Non-monetary evaluation methods can be divided into three different categories: qualitative methods, quantitative methods and methods which allow a mixture of qualitative and quantitative criteria to be considered. The types of techniques in each of these categories are discussed below.

4.2.2 Qualitative Techniques

Qualitative techniques aim to provide information which allows comparisons to be made between sites or proposals, rather than providing some absolute figure representing conservation or habitat "value". The techniques are generally based on the use of subjective judgement to determine performance in respect of different evaluation criteria. Some criteria may be measured in objective terms in that they are based on scientific assessments, but qualitative descriptions or values are then used for assessment purposes.

Qualitative methods generally involve some form of distribution mapping or site "type" classification, and frequently result in the development of a system which ranks different proposals or alternative sites. Although methods will differ, application will usually involve the following steps:-

- description of the characteristics or attributes of the existing area and the created resource. This will include details of location, species, numbers, density, etc;
- classification or organisation of this information through mapping, tabulation or the use of checklists;
- definition of criteria to be used in developing overall rankings for various sites or proposals, reflecting the relative importance of different attributes;
- undertaking a ranking exercise to indicate the relative overall performance of the different sites or proposals.

The selection of criteria to be used in the evaluation has been the area of most debate and, as can be seen from those listed in Table 4.1.1, criteria rarely relate to biological or physical factors alone, frequently including political and other criteria. Similarly, the mix between objective and subjective criteria will inevitably depend to some extent on what is being examined. Landscape, for example, may be assessed wholly in subjective terms, while habitat and other ecological concerns may be measured objectively and then evaluated in qualitative terms.

4.2.3 Quantitative Techniques

Quantitative techniques were developed in response to the need for more scientific and objective assessments of environmental goods such as habitat, landscape and amenity. They also help to provide greater differentiation between sites or proposals in that they indicate not only that one is better than another, but also by how much.

The sophistication of quantitative techniques varies considerably, with some relying on simple scoring approaches and others involving more complex scoring and weighting systems. Most of the techniques result in the development of a rank order using a numerically derived index. This may involve the aggregation of information into a single measure (i.e. an overall measure of conservation value).

Quantification supposedly allows for greater repeatability of the results than is achievable using descriptive techniques. As is the case with qualitative techniques, however, the selection of criteria (or evaluation variables) may not be straightforward, and those used can vary considerably between different assessments.

It should be noted that the application of weighting techniques to derive overall indices of value relies on the use of subjective judgement. Choices must be made concerning the relative importance to be placed on the different characteristics or attributes included in the assessment. Individuals with varying environmental interests may, for example, assign very different weights to the same attributes.

Problems can also arise in the choice and application of aggregation procedures. Such procedures must be mathematically valid: "5" (parts per thousand of salinity) cannot be added to "7" (invertebrate species recorded at a particular site). If aggregation has to take place, the calculation of standard scores may offer one means of adding like with like.

The mixed nature of data, and the inter-relationships between the different variables used in the assessment, may also make it difficult to define the attributes to be assessed in a comprehensive manner but avoiding double-counting. If this cannot be resolved, it may not be appropriate to aggregate the information. Finally, although the aggregation of information into a single value may make decision making easier, it also results in the loss of valuable information, notably on the differences between sites. It may not be possible, for example, to differentiate between a site which is "about average" over all variables and one which is "exceptional" but only for one or two variables.

4.2.4 Mixed Techniques

The various types of scoring and weighting techniques described above can also be applied to the assessment and evaluation of a mixture of qualitative and quantitative criteria. Multi-attribute scoring and weighting techniques or more complex multi-criteria analysis can, for example, be used to transform information on different types of characteristics (measured in qualitative terms, in quantitative terms based on natural physical units, and in monetary terms) into a common form which can then be aggregated to provide a single measure of value.

However, because these methods involve the specification of attributes and related criteria, the aggregation of large amounts of information and the use of subjective judgement in the setting of weights, they suffer from the same sort of problems as noted in Section 4.2.3.

4.3 <u>Monetary Assessment : Background</u>

4.3.1 Introduction

The adoption of a CBA framework requires that as many of the costs and benefits as possible - including non-market effects such as those generally associated with environmental goods and services - are quantified in money terms. Costs and benefits which cannot be valued in money terms should nevertheless also be assessed.

Because costs and benefits occur at different times over the project lifetime, a discounting exercise is then undertaken to convert them into a comparable money value (a fuller discussion of discounting procedures is provided in Section 4.3.7). A project is deemed economically viable if its "Net Present Value" (NPV) is positive: that is if the discounted stream of benefits is greater than the discounted stream of costs.

The placing of money values on environmental "costs" and "benefits" is difficult in practice, however, because of their public good nature. They fall into a category of assets for which either no markets or only limited markets exist in which they can be bought or sold. The absence of efficient markets means that there are no common prices which can be relied on to indicate the value attached to the good or service in question, and no measure of economic value is therefore readily available.

4.3.2 The Valuation of Habitat Restoration and Creation Options

The decision on whether or not to pursue any particular managed retreat option involves determining if the benefits stemming from management, monitoring and/or engineering works outweigh the costs of those activities. Such benefits might accrue from the increased value of the resulting coastal habitat or from landscape and amenity features. In some cases, where it is felt that intervening and carrying out engineering works will produce a habitat of greater value than that which would result from adopting a non-intervention approach, the "benefit" of the former will be equal to the difference between the value attached to the habitat which would develop naturally following failure and that attached to the more heavily managed habitat. If, for example, the "value" placed on an area of sub-tidal habitat is £1 million and that on a (created) saltmarsh on the same site is £3 million, the benefits gained from the creation works would be £2 million. If the works necessary to create the saltmarsh would cost less than £2 million, the saltmarsh creation would be economically justified. Conversely, if the costs were greater than £2 million, saltmarsh creation would not be justified in economic terms.

Assuming that any management or engineering costs associated with the creation or restoration of a preferred habitat are known (see Section 3), the development of the cost side of the benefit cost equation should be fairly straightforward. In other cases, of course, the habitat which will develop naturally (i.e. with minimal intervention) could prove to be the most desirable at that particular site. Estimation of the benefits associated with either managed habitat creation/restoration initiatives or with natural habitat development will, however, be more complex than the estimation of costs because of the difficulties (discussed above) associated with the valuation of most environmental assets including coastal habitats.

4.3.3 Valuation Approaches

Two basic approaches towards the valuation of retreat options have been identified:-

- the first relies on using the values assigned to existing wetland and coastal habitat areas of a similar nature to provide, by **reference**, an estimate of the value that would derive from the restored or created resource;

- the second requires the derivation of values **specific** to the area of habitat to be created or restored.

There are advantages and disadvantages associated with both approaches. The first approach, which is referred to here as the "reference value" approach, has a number of limitations. These stem mainly from uncertainty surrounding the comparability of an existing area with a restored or created habitat. Comparability will depend on the location of the site and the type of functions and services actually provided (rather than just predicted) by the created or restored habitat. Variations between the existing area and a created or restored site may have significant impacts on its value as expressed, for example, through an individual's willingness to pay. In contrast, a number of techniques are available for determining the value of existing habitats and it may, therefore, be possible to use estimates of value which had previously been developed.

The second approach, which is referred to here as the "specific value" approach, has an advantage in that any values developed will relate directly to predictions made in respect of the characteristics of the habitat to be developed at a particular location. The main disadvantage of this second approach, however, is the limited number of valuation techniques which can be used. As discussed further in Section 4.4, the method which seems most suitable for developing specific values is contingent valuation, with other techniques being either not applicable or not recommended for other reasons.

4.3.4 Issues in the Valuation of Retreat

There are several issues associated with both of the valuation approaches outlined above. The three most important relate to identifying the types of economic values which are being estimated (use versus non-use values), the impact of variations in stock, and to the problems associated with the discounting of environmental costs and benefits.

- **Use versus Non-Use Values**

Wetlands and coastal habitats provide benefits which correspond to three different categories of value held by individuals towards environmental goods.

The first category is that of **use values**, those values associated with the benefits gained from use of the environmental resource. There are two types of use values: direct and option values. Direct values arise from the actual use of the good, and include recreation-related experiences, agricultural and commercial outputs, and aesthetic value. Option values relate to the desire of an individual to maintain the ability to use the resource in the future. They reflect an individual's willingness to pay to secure the future use of a good, and express the potential benefits of an environmental good as opposed to the benefits gained from actual use. Option values therefore indicate the preservation or conservation value attached to a good.

Related to option values are **bequest values**. These are the benefits attached to the preservation of the environment so that future generations may also have the option of use.

Existence values form the third category. These can be defined as the values which result from an individual's altruistic desire to assure the availability of a good or service. These values are not associated with actual or potential use, but solely with the fact that the good exists and should continue to do so. Similar to existence values are intrinsic values: these are said to reside in non-human biota and are not related to any sources of human satisfaction.

All three categories of value will be important in determining the potential benefits associated with the adoption of a retreat strategy. Table 4.3.1 presents a summary of the types of functions and services generally associated with British coastal habitats. Most of these functions and services will have associated use, option or bequest values (whether zero or positive for any given resource area).

Non-use values of wetland and coastal habitat areas are related to the flora and fauna and to landscape features which are recognised as important heritage assets. Non-use values related to migratory waders and waterfowl are, for example, likely to be of most significance in the UK.

Table 4.3.1 British Coastal Habitats : Functions and Services

Services	Functions
Recreation and amenity services	Habitat for wildlife
Agricultural (e.g. grazing, reeds, sedge and willow production).	Shoreline protection, flood protection and flood storage
Commercial outputs (e.g. medicines, dyes, etc.)	Aquifer recharge
	Water quality restoration (e.g. the use of reed beds for natural sewage treatment capabilities)

4.3.5 Any valuation of coastal habitat restoration and creation benefits will require some prediction of the type and level of functions and services that will arise under the various options. These predictions must be at a level of detail and resolution which will allow the assessment of differences, particularly in the economically important functions or services provided by alternative options. It is important that this "with and without" principle is followed if the assessment is being undertaken to compare the benefits which would occur without intervention following failure with those stemming from restoration or creation activities.

It is also important that both use and non-use values are taken into account in the assessment of any particular project, regardless of whether "reference" or "specific" values are used. If an analysis only assesses the values related to direct use, a gross underestimation of the total economic benefits to be gained from any restoration or creation activities could result. This point is well illustrated by studies carried out in the US which have found that option and existence values may be almost as great as (or even greater than) those related to direct use (Loomis and Walsh, 1986).

In some cases, proposed restoration or creation works might be justified on the value attached to one function alone. If analysts feel that this would be the case, then that function should be valued first. In others cases there may be a need to value a number of different functions or services. Care must be taken, however, to ensure that the double counting of benefits does not take place. This is particularly true when more than one method is used to estimate the values of use related benefits and where the functions providing the different benefits are interrelated. Care must also be taken to ensure that the benefits really do exist. The habitat must, now or at some time in the future, be likely to provide the service being valued. Water purification, for example, can only be a benefit of any value if the area in fact receives and processes waste water.

The analyst must also ensure, when including more than one service or function in the benefit estimates, that the services are not competitive. Taking water purification once again as an example, the benefits from this service and those from shellfish production functions are mutually exclusive. They are not additive as both cannot be provided at the same time.

Finally, when estimating use-related benefits stemming from a given function or service, not only must the measure of value associated directly with that function or service be considered, but also whether or not a substitute for the function or service exists. If a substitute exists, then the cost of using that substitute provides an alternative measure of value. The value of any given function or service will be the lesser of (a) the least-cost combination of substitutes or (b) the direct measure of value. Theoretically, individuals are not willing to pay any more for a use-related service than the lesser of the value of benefits it provides or the cost of replacing it through substitutes. Some recent studies have indicated that in the case of "environmentally friendly" goods, individuals may be willing to pay more, but this behaviour may stem from non-use related objectives.

4.3.6 ■ Stock Effects

As noted in Section 2.3, there has been a widespread loss of coastal habitats and, in the short-term at least, more losses are expected. A key question related to the valuation of retreat options, therefore, is how changes in the stock of coastal habitat will affect their importance and thus the values attached to different habitat types and particular sites.

If significant on-going losses of habitat occur, the value of remaining areas may increase over time. There may also be consequent changes in the priorities attached to the protection or creation of different types of habitat. If the increase in value attached to habitat type is great, then the benefits stemming from restoration or creation activities will also increase.

At the time when costs and benefits of different options are being evaluated, however, it will not be possible to predict whether and, if so, how values will change over time. In some cases this may lead to an underestimation of the benefits that would be gained through adopting a managed retreat option.

4.3.7 ■ Discounting

The application of a cost-benefit approach to the evaluation of retreat strategies requires that all the costs and benefits which have been valued in monetary terms, including environmental costs and benefits, are discounted. The object of discounting is to enable the adding together of costs and benefits which occur at different times throughout the project. The sum of the costs and benefits then provides the net present value of the option under consideration. If all of the costs and benefits can be valued, then the option with the highest net present value would generally be preferred (HMSO, 1991).

The discounting procedure is based on the principle that costs and benefits which occur now are more important that those occurring in the future. This is because people prefer money today rather than money tomorrow. For most government projects (including flood defence works), the Treasury require a time preference rate of 6% a year.

A number of issues arise over discounting and these are adequately discussed elsewhere. One issue of key concern to the evaluation of retreat strategies, however, is that any significant benefits to be gained from restoration or creation activities are likely to occur far into the future (see Section 3.5.2)

With the application of discounting, less weight is placed on these future benefits that the "costs" which would be incurred in the short term. The higher the discount rate used, the less the importance is placed on future benefits and costs. At a rate of 6%, for example, benefits occurring in 25 years time will have only 23% of their value today. At any positive discount rate, costs or benefits which accrue more than 50 years into the future will have a very small present value. Hence activities such as managed retreat with benefits occurring well into the future are less likely to be favoured than those with benefits in the shorter term (which may be the case with flood defence maintenance options). In other words, policies with high future costs but which yield short term benefits may be preferred to those with lower short term benefits and also lower future costs.

In the evaluation of retreat strategies, the problem is therefore one of costs incurred in the short term giving rise to benefits far into the future. The majority of costs associated with restoration or creation activities (e.g. the capital costs of engineering works) will occur in the first few years. Although some benefits may be realised in the early years, it is likely to take a long period of time for invertebrates, soil fauna and flora to become established and thus for the area to become valuable as a habitat for birds and other wildlife. The period before full (or even significant) benefits are achieved may be as long as 20 years.

Discounting this highly divided stream of costs and benefits puts far greater weight on the costs. Further, if more than one restoration or creation option is under consideration, the one which provides benefits in the shortest period of time may become favoured even though another option would eventually provide a habitat of greater overall signficance. It becomes important therefore that full consideration is given to the value of environmental costs and benefits over time, particularly if the value of coastal habitat is expected to increase (due to losses of habitat or changes in factors underlying society's willingness to pay).

The above discussion also raises the question of how to deal with residual benefits. These are the benefits that would be realised in years outside of the time frame used in the appraisal. For flood and coastal defence works the time frame adopted generally varies from 25 to 50 years. In some cases, the full benefits from habitat restoration or creation activities may not be achieved until more than 20 years after any works have been completed, yet they will continue in perpetuity. This on-going stream of benefits should be brought into the analysis either through the assumption of a residual value or by discounting to a period where the discounted value of additional benefits becomes insignificant.

4.4 Monetary Valuation Techniques

4.4.1 The considerable differences in the type of benefits associated with coastal habitat functions and services, means that a range of methods should be considered for the valuation process.

The techniques which have been identified as being the most applicable to the valuation of retreat options, and in particular to coastal habitat restoration and creation benefits, are summarised briefly below and discussed in more detail in Appendix A4.4. The Appendix covers the theory underlying each method, its relevance to managed retreat, past applications, and advantages and disadvantages of the technique.

The techniques discussed in Sections 4.4.2 to 4.4.7 below include some which could be employed to value both use and non-use related benefits. They could also be used under either or both of the "reference" or "specific" values approaches. Table 4.3.2 summarises some of the key aspects of each technique, indicating the basis for deriving values, the functions and services to which a given method is applicable, and some of the key assumptions and issues involved in application.

Tables 4.3.2 Summary of Valuation Methods

Method	Valuation Basis	Approach	Functions or Services	Comments (see also Appendix A4.3)
Change in productivity	Change in output and market prices.	Reference or specific values.	Agricultural production, fish and shellfish production, timber, other commercial goods, water supply.	Easily applied when markets exist. Values may be more acceptable than those derived through surrogate or hypothetical market techniques. System relationships and cause and effect must be properly under-stood. Measures use-related benefits only.

Method	Valuation Basis	Approach	Functions or Services	Comments (see also Appendix A4.3)
Preventative expenditure and replacement costs	Actual and potential expenditure on mitigating environmental effects or replacing damaged or lost goods and services.	Reference values only.	Flood protection, water supply, water quality enhancement, and habitat/ environmental quality.	Easily applied but provides a lower bound estimate. Cannot be used when secondary benefits exist. Assumes current system is optimal.
Damage-costs-avoided	Value of damage avoided as measured in market prices.	Reference or specific values.	Flood protection, water supply, sediment control, erosion, and shoreline protection.	Easily applied but measures use-related benefits only. Does not address question of optimality.
Travel Costs	Valuation based on determining costs incurred in visiting a site/ undertaking an activity.	Reference values only, unless parts of the site are currently being used for recreation when specific values might be estimated.	Recreation related activities, natural habitat areas.	Extensive application to valuation of recreation, but values use-related benefits only. Method is site-specific. Method does not reflect quality of experience. Several modelling concerns and large data requirements.

Method	Valuation Basis	Approach	Functions or Services	Comments (see also Appendix A4.3)
Contingent Valuation	Individuals are surveyed to determine their willingness to pay for a good or service.	Reference or specific values.	All functions and services.	Requires surveying of individuals to elicit values. Potential biases in results due to several factors including design of survey and hypothetical nature of questions.
Energy Analysis	Primary productivity converted into money terms using fossil fuel prices.	Reference or specific values.	Comprehensive value covering all functions and services.	Requires prediction of primary productivity. Debate over use of energy prices to reflect value of environmental goods and services.

4.4.2 Change in Productivity

Where there is a market for the good or service involved, estimates based on the value of given changes in productivity can be used to derive values representing the benefits (or costs) of restoring or creating a particular habitat. Impacts on productivity resulting from actions affecting the environment are determined and market prices are then used to value these changes.

This technique could therefore be used to value changes in agricultural productivity (including reed, sedge or willow production), effects on fisheries and shell-fisheries, and water purification/water supply capabilities. In this respect, it could be used to derive "specific values" by predicting the change in productivity that would occur from the various retreat options.

Because of the reliance on market prices, the changes in productivity technique could not easily be applied to the valuation of landscapes, wildlife or aesthetic benefits. Its application is therefore limited to the use-related services and functions provided by coastal habitats.

4.4.3 Preventative Expenditure and Replacement Costs

The preventative expenditure and replacement cost methods are related techniques for placing a value on a change in environmental quality or the loss of an environmental service.

The preventative (or defensive) expenditure approach is based on using actual expenditures incurred (or likely to be incurred) by individuals or a government body to determine the value or importance placed on a particular environmental good or service. In applying this approach, demand for environmental damage mitigation is viewed as a surrogate demand for environmental protection. A British example of where this type of approach has been applied involves using the payments made under the terms of the Environmentally Sensitive Areas policy as estimates of the value to society of the environmental benefits gained by maintaining the low intensity use of agricultural lands (Turner and Brooke, 1989).

The replacement cost approach is based on the principle that the work which would be required to restore or replace the total environmental resource to its original state, possibly in another location, provides an estimate of the value of the environmental good or service threatened with damage or loss. Through this approach, the potential expenditure on replacement serves as a means of placing a value on previously unvalued functions such as those provided by a wetland or other habitat area (see, however, Section 4.5.2).

These methods could be used to provide "reference values", using expenditure undertaken (or threatened) to prevent damage to existing wetlands or other coastal habitats elsewhere, as an estimate of the value of a similar site being restored or created. Values generated in this way would have to be used with care, and should be treated as rough guides or second best only.

4.4.4 Damage-Costs-Avoided

Related to the above methods is the use of damage-costs-avoided as a measure of the value of a given function or service provided by a natural system. The concept underlying this approach is that the value of an environmental good or service is equal to the costs of property or other damage which would occur if that good or service did not exist.

This approach is used extensively to value the costs and benefits associated with the decision on whether to improve, maintain, or abandon flood defence works. In the case of managed retreat, it could be used to develop "reference values" for different functions and services. For example, estimates of the damage costs associated with a loss of reed beds as developed for a previous study may provide an estimate of the value of created reed beds under a retreat strategy. Such valuations may also be possible for other physical functions and services such as flood protection, shoreline protection, sediment control and water quality enhancement.

Any "reference" valuations developed through this method should be used with caution. The original valuations are site-specific and care must be taken to ensure that the functions or services provided by the reference good will also be provided by the created or restored good. Similarly, "specific values" might be developed through this type of approach as long as the nature and types of functions that would result from different retreat options could be predicted with a good degree of reliability. The development of specific values is likely to be limited to those cases where management involves, for example, maintaining sand dunes as a habitat and thereby preventing the loss of assets in the area behind the dunes, which would have resulted if the do-nothing approach had been adopted.

4.4.5 Travel Cost Techniques

Travel cost techniques infer the value placed on an environmental resource by determining the amount of money spent to travel to that resource. In general, most applications are related to recreational use of the resource in question and involve determining how demand for recreation would be affected by changes in site characteristics.

These techniques could be applied to the valuation of changes in habitats, particularly where the latter would produce opportunities for recreation. Travel cost methods could be used to develop "reference values" using existing sites of similar characteristics to those proposed under the different retreat options. The reliability and validity of such "reference values" could, however, be questionable. Where the managed retreat option involves undertaking restoration or creation as an extension to existing nature reserves which currently receive visitors (for example, in an area adjacent to a RSPB reserve), "specific values" could also be derived using these methods.

4.4.6 Contingent Valuation Methods (CVM)

Contingent Valuation uses social survey techniques to develop direct valuations for a given environmental good or service. CVM involves asking individuals what they would be willing to pay (or willing to accept by way of compensation) for a specified change in the quality or quantity of the good or service in question.

Contingent Valuation methods are appealing because they can be applied to a wide range of valuation problems and can be used in almost any context. They are the only methods which can be used to derive estimates of option, bequest and existence values. Their potential for application to the valuation of retreat, therefore, is greater than that of any of the other methods. "Specific values" can be derived for different proposals to cover all of the functions and services to be provided by a particular wetland or coastal habitat.

Care should be taken, however, in the use of these methods to minimise potential biases in the results due to the nature and design of the survey instrument. Statistical analysis should also be used to validate the results of such studies.

4.4.7 Energy Analysis Approaches

The energy analysis approach is based on the principle that there is a fixed relationship between the energy embodied in a product and its market price. The method takes the total amount of energy captured by a system and uses this as an estimate of its potential to do useful work for the economy. For a wetland or other coastal habitat, Gross Primary Productivity (GPP) is used to provide an index of the energy captured by the system. It relates to the amount of solar energy taken in by the system which is used in primary production to form the life support mechanism for all plants and animals in that system. Once the level of embodied energy is determined (through GPP estimates), the energy measurement is translated into money terms using a conversion factor based on prices placed on fossil fuels.

The approach is attractive in that it produces a total value for coastal/wetland habitats (e.g. as systems), but there is considerable debate over the use of energy prices as the measure of economic value. A number of other considerations enter into the pricing of goods and these are neglected by estimating the good's value in terms of its energy content alone. Thus, although there have been several applications of energy analysis in the US (and to a lesser degree in the UK), this method is not recommended for use in the valuation of retreat options.

4.5 Acceptability of Different Valuation Techniques to Interested Agencies

4.5.1 National Rivers Authority/ Ministry of Agriculture, Fisheries and Food

The monetary valuation of environmental costs and benefits is generally accepted by the National Rivers Authority as being of particular use in the benefits assessment process, notably as a means of demonstrating economic viability to MAFF when applying for grant-aid funding. Several cases exist where one or more of the techniques outlined above have been used to assist in the evaluation of alternative engineering or management proposals and where these evaluations have subsequently been accepted by MAFF as providing an adequate assessment of the scheme's environmental or recreation benefits. One of the key projects in this respect was the benefits assessment carried out for the Aldeburgh Sea Defence Scheme (Turner et al., 1990).

4.5.2 Nature Conservancy Council

Qualitative techniques have been used extensively by the NCC, notably in their designation of Sites of Special Scientific Interest (SSSI). Qualitative and statistical data are similarly used in the identification and designation of other sites of nature conservation significance - Ramsar Convention Sites, Special Protection Areas (EC Birds Directive), National Nature Reserves, etc. These designations represent the most important current British use of such methods.

Overall, the NCC prefer the type of system which is based on qualitative methods and which grades sites simply, according to their international, national regional or local importance.

The NCC acknowledge, however, that there may be a need in some circumstances to further quantify the interest at, and in some cases (e.g. economic benefits assessment) place monetary values on, a particular site of nature conservation interest. In these cases, they stress that the limitations of such techniques should be recognised and acknowledged. This is especially important when the techniques are being used to place what is clearly a minimum value on a particular resource. Replacement costs, for example, will only evaluate the physical and biological components of a nature reserve - land purchase, vegetation planting, the provision of walkways and sluices, etc. The technique will not place an economic value on the species themselves, the complex interrelationships between species and the way in which the reserve functions.

4.5.3 Countryside Commission

The Countryside Commission does not support the use of quantitative evaluation techniques, preferring instead the flexibility of qualitative approaches (Turner and Brooke, 1989). The techniques most relevant to the Countryside Commission are those of landscape assessment which can be used to describe, analyse and evaluate landscapes. These methods are relevant to a wide range of planning, design and management issues and are of particular relevance to decision making on the creation and restoration of landscapes.

The document "Landscape Assessment : A Countryside Commission Approach" (1987) adopts a comprehensive and practical approach to landscape assessment based on aesthetic taste, operating within the context of informed opinion, the trained eye and common sense (CCD 18). Landscape assessment concerns not only the appearance of land, but also people's reactions to it and the pleasure which they gain from the landscape. The technique combines both objective and subjective variables, as both are significant in determining the value of an area.

Similarly, the Countryside Commission does not support, in general, the principle of monetary valuation, particularly when applied to landscape assets. They have examined both monetary and other quantitative methods and have concluded that it is very difficult to attach such values to a resource which is perceived so differently by different individuals. They argue, therefore, that assessment of landscape and amenity should be based on qualitative techniques.

4.5.4 Royal Society for the Protection of Birds

The Royal Society for the Protection of Birds uses both qualitative and quantitative techniques to aid in the designation of sites of particular importance for birds. The RSPB have produced a book entitled Red Data Birds in Britain (Batten et al., 1990) which, in conjunction with their Species Action Plans, provide guidance on the measures necessary to conserve rare bird species. These include protected area designation, and in certain cases, habitat creation.

The RSPB support the quantification of environmental costs and benefits, but question how far it might be possible to place money values on non-marketed and non-marketable goods (Turner and Brooke, 1989). In certain cases, however, monetary valuation might be of considerable use, for example in the application of willingness to pay methods.

The RSPB has some reservations about the implications of applying monetary valuation techniques and would urge caution in their use. In general, their preferred assessment and evaluation approach would involve the use of non-monetary techniques for differentiation between options, with monetary techniques only being introduced only when a preferred option has been identified and there is a need to provide a valuation of the resulting costs and benefits in economic terms.

4.6 Future Evaluation of the Retreat Option

4.6.1 The Current Decision-Making Process

In the preceding sections, criteria for identifying potential retreat strategies and techniques for evaluating those strategies were discussed. This discussion has largely been framed in terms of the current decision making process in respect of maintaining/improving or abandoning a flood defence. As noted earlier, this process has (historically) involved two stages of decision making. The first considers whether or not the proposed engineering works can be economically justified. If they cannot and the do-nothing approach is adopted, the possible environmental benefits of managing the retreat to maximise nature conservation benefits have occasionally been considered, albeit as one way of "making the best out of a bad job". More often however, as can be seen from the lack of data/monitoring discussed in Section 3.2, the defences have simply been abandoned and little thought has been given to what might happen in terms of ecological development.

4.6.2 Evaluation Options

There are two potential approaches which can be adopted for the economic evaluation of managed retreat options. The first is to adopt a cost-effectiveness approach, which involves comparing the performance of different options to pre-defined decision criteria. This type of approach provides an indication of value for money, but it does not establish whether or not the benefits of any engineering works, maintenance and/or management activities would be greater than their costs. Under a cost-effectiveness approach this is left to the subjective judgement of decision makers.

An approach using cost-benefit analysis (CBA) on the other hand, indicates whether or not benefits exceed costs and therefore whether or not any given set of management/engineering activities are worthwhile. As discussed in Section 4.3, there are considerable difficulties in applying monetary assessment techniques to the valuation of environmental assets such as habitat or landscape. This may limit the feasibility of valuing habitat creation/restoration initiatives and hence the reliability of any estimates generated through these techniques for input into CBA. This is discussed further in the following sections.

4.6.3 An Alternative Decision-Making Process

It could be argued, particularly in the light of NRAs duties under S.8 of the Water Act 1989 (discussed in Section 5.2), that the current decision-making process should be reduced to a single stage and that the managed retreat option should be considered earlier, at the same time as the maintain/improve options. This would involve undertaking a benefits assessment of maintain/improve, do-nothing and managed retreat at the same time. Such a framework would place managed retreat on equal grounds with the maintenance or improvement of flood defences, and would not treat managed retreat as a subsidiary or second level decision. It would therefore ensure that potential habitat restoration and creation activities are given full consideration in terms of both benefits and costs. In practical terms though, there are a number of issues which need to be addressed if such a framework is to be adopted.

In the evaluation of the costs and benefits associated with proposed flood defence engineering works, the costs side of the equation comprises the total expenditure on both capital works (including associated works such as landscaping) and anticipated maintenance requirements. The benefits side of the equation will include, for example, the value of the properties, infrastructure, and agricultural production to be protected, adjusted if appropriate to give a national value. These benefits, along with the current benefits associated with any existing environmental or recreation interest, would be expressed in the form of damage-costs-avoided.

The equation for the do-nothing strategy is roughly the converse of that for maintain/improve. In this case, however, what were benefits become costs: the "damages" are no longer avoided.

The costs and benefits associated with a managed retreat option will include elements of both of the above. As with the flood defence option, there may be some costs (i.e. a requirement for expenditure) associated with the management activities, engineering works or maintenance requirements needed to create or restore an environmentally desirable habitat. There will also be many of the "losses" associated with the do-nothing option in terms of lost agricultural production, etc. These are interpreted as being among the costs of achieving the desired outcome. The benefits side of the equation for the managed retreat option would comprise the economic value of the ecological, landscape and amenity gains, together with any other non-monetary environmental benefits which would result from the implementation of the managed retreat option.

For managed retreat to be the preferred strategy within this framework, the net benefits must be greater (or more positive) than those expected under both the maintain/improve and the do-nothing strategies. Take, for example, a case where the ecological benefits of undertaking management activities as part of a retreat strategy a) can be evaluated and b) are greater than the costs of those activities. Under the existing decision-making process, where the managed retreat option is not often considered until after the decision to do-nothing has been taken, such creation or restoration measures would be justified because the assets at risk from flooding were already effectively written off when the decision to do-nothing was taken (as discussed earlier, in this case managing the retreat is simply seen as making the best of a bad job). Under the alternative framework, however, the gains stemming from the management activities would also have to outweigh the damages resulting from abandonment of the defence, even in the case where it is known that the option of maintaining an effective flood defence is not economically viable. This would lead to a rejection of managed retreat unless it was found to have the "least negative" net present value of the three options.

4.6.4 The Way Forward

Although it may sometimes be difficult to apply a cost-benefit approach in practice due to valuation problems, it is recommended that this type of approach is nevertheless adopted towards the evaluation of coastal flood defence strategies including managed retreat. It is also recommended that retreat options are considered and evaluated earlier in the decision-making process, concurrently with the maintain/improve and do nothing options (see also Section 5.2.2).

These recommendations arise from the need, in practice, to bring together monetary, quantitative and qualitative information in order to provide an overall indication of the significance of the environmental costs and benefits of each option for consideration in the decision-making process.

SECTION 5: IMPLEMENTATION

5.1 Introduction

5.1.1 Section 3 demonstrates that it is technically viable to restore or create many types of coastal habitats, albeit that there remain a number of uncertainties. Section 4 outlines the options for evaluating such initiatives. If assessment and evaluation are to be followed by implementation, however, the roles and responsibilities of the various agencies with an interest in the coastal zone must be clearly defined in respect of the retreat option. The circumstances under which compensation might be paid to the landowner must also be determined and possible sources of funding to meet the capital, maintenance and/or management costs of habitat creation or restoration must be investigated.

5.1.2 A large number of organisations have an interest in the management of the coastal zone in England and Wales. The National Rivers Authority (NRA) is arguably one of the most important of these agencies, having powers and duties in respect of both Flood Defence and Conservation (see Section 5.2). The Nature Conservancy Council (now English Nature and the Countryside Council for Wales; also the Joint Nature Conservation Committee); Ministry of Agriculture, Fisheries and Food; Countryside Commission; and the local planning authorities are among the other statutory authorities with powers and duties to conserve or enhance environmental resources through designation and enforcement policies. Their various responsibilities of interest to this study are outlined in Section 5.3, along with the agencies' policies relating to the retreat option and any funding mechanisms which are, or may be, appropriate to habitat creation/restoration. Voluntary organisations such as the National Trust and the Royal Society for the Protection of Birds could also play a key role in implementing managed retreat. The scope of their activities, their priorities in respect of habitat creation/restoration, and their funding abilities are therefore discussed in Section 5.4. The situation in the United States is reviewed in Section 5.5 and potentially valuable lessons for Great Britain are highlighted. Finally, some possible sources of new funding for coastal habitat creation or restoration are highlighted in Section 5.6.

5.1.3 **Need for Compensation**

> "Strategic retreat, whether on the beach or in war, has often been the key to ultimate self-preservation and victory. The greatest resistance comes from a misplaced sense of pride and from the very real possibility of short term but large private economic setbacks.... the interests of private property owners are important and politically powerful. The wisdom of strategic retreat will not be accepted, emotionally or legally, unless the needs of property owners are adequately addressed".

Second Skidaway Institute of Oceanography Conference on America's Eroding Shoreline, 1985.

As will be discussed in detail in Section 5.2.2, the NRA have permissive powers which, in many circumstances, enable them to allow a flood defence to fail without becoming liable to pay compensation. In cases where feasibility studies indicate that the habitat which would develop naturally (i.e. without any intervention) following such failure would be of significant nature conservation value, the abandoning of defences may provide an effective means of meeting nature conservation objectives at no cost. The politics of the retreat option, however, cannot be ignored. History has demonstrated that British landowning interests are a politically powerful lobby, being both vociferous and effective in achieving their aims. Support for the principle and objectives of the retreat option from groups such as the Country Landowners Association (CLA) and National Farmers Union (NFU) would obviously be desirable. Such support is unlikely to be forthcoming in the absence of an adequate compensation provision.

In many cases successful habitat creation initiatives will depend heavily on the cooperation of individual landowners. Some projects may even require engineering works in advance of the failure of the flood defence. Works might include, for example, the placing and grading of material to raise the elevation of the land and/or the digging of watercourses to ensure good tidal circulation when the structures do fail. Not withstanding the legal requirements outlined in the following sections, it is therefore likely, and quite reasonable, that the landowner will expect to be compensated if the residual (productive) life of his land is deliberately terminated in order to develop an environmentally desirable resource. **In the long-term if the creation of environmentally desirable coastal habitats is to become widely accepted, the issue of paying compensation to the landowner must be both addressed and resolved.**

5.1.4 Compensation Payment Options

There are two primary mechanisms for the payment of compensation. The first involves the purchase of the land in question; the second the negotiation of some form of on-going payment to the landowner. In some circumstances purchase will be made at full market value, in others the price paid for the land will reflect its residual value (e.g. if a decision has already been taken to abandon the defence when it fails).

The National Rivers Authority have compulsory purchase powers under S.151 of the 1989 Water Act which can be used if land is required by the Authority for the purposes of, or in connection with, the carrying out of its functions. Other agencies also have compulsory purchase abilities in respect of nature conservation: local authorities under the Town and County Planning Act (1990) S.226 and the NCC under S.17 of the National Parks and Access to the Countryside Act (1949). Compulsory purchase is, however, generally regarded by these agencies as a last resort and this study does not advocate any change in that presumption. Irrespective of whether or not land is compulsorily purchased, someone has to pay. The various options for meeting both the short-term capital costs including possible land purchase and the longer term management and maintenance costs of a habitat creation/restoration project are therefore discussed in detail in Sections 5.2 to 5.5 inclusive.

5.1.5 There are many circumstances when land purchase may not be viewed either by the landowner or by the agency promoting a particular scheme as being desirable. As discussed in Section 1.7, the creation of a saline or brackish habitat means that land will quickly become unsuitable for agricultural production. The extent of land claim in areas around the Wash, however, demonstrates that it is possible to return such land to agriculture, albeit in the long term. Some landowners may therefore wish to retain overall control of their land in case there is a future move towards Dutch style enclosure for the purpose of creating or re-creating agricultural land. Farmers might also perceive potential spin-offs in the form of financial gain from managing a site for nature conservation as a form of diversification. Wildfowlers may be prepared to pay the farmer to pursue their interests (see Section 5.4.7); reeds might be grown commercially if there is an adequate supply of freshwater; reedbeds might be set up to treat sewage or waste water; and some landowners may even be interested in opening a nature reserve to the public. Working within the constraints suggested by the Countryside Commission in terms of retaining or improving landscape quality and amenity provision (see Table 4.1.2), and taking account of the ability of different types of ecosystem to tolerate disturbance, there are still a number of ways in which a landowner may be able to utilise his land "productively".

5.1.6 In any of the above cases, it may be possible to negotiate a management agreement with the landowner to ensure that environmental objectives are achieved. Alternatively, an agency may assume the control of a site in return for the payment of an agreed "rent" or lease. Some options for such annual payments are outlined in Sections 5.2 to 5.5 along with a general discussion of how it might be possible to meet any maintenance costs associated with a particular site once the habitat has been established.

5.2 The Role of the NRA

5.2.1 The National Rivers Authority (NRA) was set up following the fundamental restructuring of the British water industry which took place under the Water Act 1989. The principal aims of the NRA, as stated by the Chairman, Lord Crickhowell at the time of its launch on September 1st 1989, are set out below:-

i. To achieve a continuing improvement in the quality of rivers, estuaries and coastal waters, through the control of water pollution.

ii. To assess, manage, plan and conserve water resources and to maintain and improve the quality of water for all those who use it.

iii. To provide effective defence for people and property against flooding from rivers and sea.

iv. To provide adequate arrangements for flood forecasting and warning.

v. To maintain, improve and develop fisheries.

vi. To develop the amenity and recreational potential of waters and lands under NRA control.

vii. To conserve and enhance wildlife, landscape and archaeological features associated with waters under NRA control.

viii. To improve and maintain inland waterways and their facilities for use by the public where the NRA is the navigation authority.

ix. To ensure that dischargers pay the costs of the consequences of their discharges; and as far as possible to recover the costs of water environment improvements from those who benefit.

x. To improve public understanding of the water environment and the NRA's work.

xi. To improve efficiency in the exercise of the NRA's functions, and to provide challenge and opportunity for employees and show concern for their welfare.

Aims iii, vi, and vii are clearly of most relevance to this report. The NRA's Flood Defence responsibilities are among those briefly summarised below. The NRA's specific powers and duties in respect of Conservation are set out in Section 5.2.2, while associated powers and duties of direct relevance to this report are discussed in Sections 5.2.3 to 5.2.7.

"The NRA, through its Regional Flood Defence Committees has a statutory obligation to exercise general supervision over all matters relating to land drainage in England and Wales. In particular it has sole powers to improve and maintain designated "main rivers". It is also empowered to undertake sea defence work and to act in default of Local Authorities and IDBs. Water courses other than main rivers and those in Internal Drainage Districts are the responsibility of the riparian owners, but District Councils have powers to carry out works on them to prevent or alleviate flooding. District Councils are also empowered to undertake sea defence work in their area. County Councils may act in agreement with or in default of District Councils to carry out flood defence work. They also have powers to undertaken drainage work on behalf of riparian owners to benefit small areas of agricultural land. Internal Drainage Boards have powers to carry out works in their districts other than on "main rivers". These works are mostly to alleviate the flooding of agricultural land but they also offer protection to urban land in many cases. Maritime District Councils are empowered to protect land against erosion and encroachment by the sea" (MAFF, 1989).

5.2.2 **NRA's Legal Responsibilities in Respect of Conservation**

Pursuant to Section 8 (1)(a) of the Water Act 1989 (hereafter known as the Act), the National Rivers Authority (NRA) have a duty,

> "so far as may be consistent with the purposes of any enactment relating to the functions of that body and, in the case of the Secretary of State and the Director, with their duties under section 7 above, so to exercise any power conferred on him or it with respect to the proposals as to further the conservation and enhancement of natural beauty and the conservation of flora, fauna and geological or physiographical features of special interest;"

Section 8 (4) is also of importance to this study, stating that:

> "without prejudice to its other duties under this section, it shall be the duty of the Authority, to such extent as it considers desirable, generally to promote -
>
> a. the conservation and enhancement of the natural beauty and amenity of inland and coastal waters and of land associated with such waters;
>
> b. the conservation of flora and fauna which are dependent on an aquatic environment; and
>
> c. the use of such waters and land for recreational purposes".

It therefore appears that the definition of conservation is important to the issue of habitat creation/restoration in respect of NRA's ability to undertake managed retreat: does "conservation" relate only to a resource which already exists at a particular site, or is it more general? There is no statutory definition or legally recognised definition for conservation. The World Conservation Strategy (IUCN; UNEP; WWF; FAO; UNESCO) (1980) define conservation as:-

> "The management of human use of the biosphere so that it may yield the greatest sustainable benefit to present generation while maintaining its potential to meet the needs and aspirations of future generations. Thus conservation is positive, embracing preservation, maintenance, sustainable utilisation, restoration, and enhancement of the natural environment. This living resource conservation has three specific objectives:-
>
> 1. to maintain essential ecological processes and life support systems
> 2. to preserve genetic diversity
> 3. to ensure the sustainable utilisation of species and ecosystems".

For the purposes of this report, conservation has therefore been interpreted as the general furthering of landscape, flora and fauna, and physiographic features on a national basis, as well as the more local site specific protection of what is already present. This interpretation, which is in line with both the S.8 requirements and the third objective of the WCS definition, clearly encompasses habitat creation, restoration and enhancement initiatives.

To date, retreat has generally been considered only if the economic benefit of maintaining a flood defence could not be demonstrated. NRA's Counsel's Opinion in defining the S.8 (1)(a) duty for NRA, however, appears to offer rather more positive support for the retreat option, where that retreat is planned and/or controlled to ensure nature conservation benefits (see Appendix A5.2.1). Counsel's Opinion, states that "Attention needs to be given to its positive expression: the duty is concerned not merely with the assessment of harm but also the achievement of a better environmental result by the use of one alternative [e.g. retreat] even if the other, or others, [e.g. flood defence] are not in themselves particularly harmful to ecology or amenity" [authors' parentheses].

IUCN:	International Union for the Conservation of Nature
UNEP:	United Nations Environment Programme
WWF:	Worldwide Fund for Nature
FAO:	Food and Agriculture Organisation
UNESCO:	United Nations Educational, Scientific and Cultural Organisation

5.2.3 The Abandonment Issue

Under S.17 of the 1976 Land Drainage Act, the drainage authorities (including the NRA) have a permissive power to maintain and improve existing works and construct new works. This power is discretionary and the reasonable exercise of the power confers no additional rights on any third party. If a defence falls below the standard to which it was designed, no compensation is payable unless conditioned otherwise by grant regulations which might, for example, make the grant conditional on maintenance. In the same way, the NRA are also able to abandon one line of defence and retreat either to the upland boundary or to a secondary flood defence line (e.g. a new embankment) without becoming eligible to pay compensation.

There are, however, some exceptions to this general rule, notably where the NRA (or others) have a commuted liability. This exists where defences were taken over from private frontagers and these frontagers made payments to the NRA's predecessors in order that they would take on the liability. Where appropriate, the status of such commuted liabilities should therefore be investigated before it is assumed that the permissive powers apply. The situation in respect of defences protecting Internal Drainage Board areas may also require special consideration and this matter is discussed further in Section 5.2.5 below.

Pursuant to S.136 of the Act, all executive decisions and powers in respect of the Authority's flood defence functions except the raising of revenues, are delegated to the Regional Flood Defence Committee (RFDC). The NRA may, however, give the RFDCs directions of a general or specific nature (Howarth, 1990). In its forward planning role, the NRA/RFDC can therefore make a pro-active decision to do nothing and abandon a flood defence, knowing that the defence will fail at some stage in the future, if it is reasonable to do so. In order to implement any form of managed retreat option to achieve nature conservation benefits, it will usually be necessary to make this decision. NRA would be subject to a judicial review of such a decision only if they were behaving in a way no reasonable NRA could be expected to behave, and in this case the courts would decide whether or not the decision was reasonable.

The timing of the decision to abandon a flood defence is important in relation to the residual life of the defence if a managed retreat option is being considered. If engineering works are required to "create" a habitat, such works (e.g. the placing of fill and possibly the planting of vegetation) may need to take place **before** the defence fails to ensure that the new habitat is "ready" to become subject to inundation.

The courts will interpret the word "abandonment" as a matter of fact. That is to say the time at which the NRA ceased to carry out maintenance works. This equates to the time of the decision to do nothing. If, subsequent to making such a decision, the NRA then wish to undertake other works, for example habitat creation under S.8 of the Water Act, they must seek access to the land (assuming that they do not own the land in question) either by agreement with the landowner or by service of notice under S.147 of the Act. The latter entitles the Authority to enter land in order to exercise a duty. The former course of action would obviously be desirable. The concept of retreat for nature conservation benefit is unlikely to attract widespread support if it is achieved by Order. The entering of land to undertake such works, even by agreement must, however, raise the issue of compensation. The circumstances under which the NRA might be obliged to pay compensation are outlined below.

5.2.4 NRA's Compensation Payment Abilities

As discussed in the previous section, the NRA can, in certain circumstances, make a decision to abandon a defence when it reaches the end of its residual life without becoming liable to pay compensation. However, if the NRA intervenes and does something (e.g. undertaking habitat creation works in line with their S.8 duties) which actively reduces that residual life and hence the value of private land, there may be a requirement for compensation. Consider, for example, a case where a decision is made to do nothing at a site where the defence is believed to have a residual life of two years. In order to ensure that a particular type of habitat will develop when the breach occurs, engineering works taking, say, 18 months are required to raise the elevation of the site, grade the land, create channels, and plant vegetation. The effective residual agricultural life of this land has therefore been reduced, and the landowner may claim for compensation. NRA might apply for a Compulsory Purchase Order under S.151 of the Act, but this would almost certainly be considered undesirable. There are, however, a number of alternative mechanisms by which the landowner might be compensated and/or encouraged to accept nature conservation as a productive use of his land.

NRA might, for example, consider negotiating a management agreement and maybe setting up a nature reserve. There is no precedent for the NRA setting up nature reserves, but they would be able to do so under S8(4) discussed above or under S.145 (1)(A) of the Water Act 1989 which states that the NRA "shall have power to do anything which, in the opinion of the Authority is calculated to facilitate, or is conducive or incidental to the carrying out of the Authority's functions". The NRA may also charge any visitors to such a reserve, for example under S.145 (1)(C) which states that the Authority "shall have power to fix and recover charges for services provided in the course of carrying out its functions".

5.2.5 NRA's Duties in Respect of Internal Drainage Boards

An Internal Drainage Board has similar powers to those of the NRA in respect of carrying out drainage works, but the IDB's statutory powers relate only to non-main river watercourses. The NRA may levy a precept or general drainage charge on an IDB to provide services, including flood defence on adjacent main rivers, under the 1976 Land Drainage Act.

Many of the sites at which retreat for nature conservation benefits might be considered are within IDBs. Where the NRA levies a charge, as for example in Anglian Region, there may be a general duty on the Authority to provide an appropriate service. Forward planning on the part of the NRA so that they cease to levy a charge may represent one option which would subsequently enable retreat, but legal opinion suggests that cases should be examined individually.

5.2.6 Construction of Private Flood Defences

Experience in the United States (see Section 5.5) raises the question of whether or not the NRA have any powers to prevent a landowner from building his own flood defence structures. Sea defences involving engineering works constitute development as defined in S.55(1) of the Town and County Planning Act 1990 and therefore require planning permission. NRA are exempt from needing planning permission on certain developments under GDO 1988 Part 15 Class A (Development by Water Authorities). The GDO does not, however, exempt private parties. An individual wishing to undertake such works requires planning permission from the local planning authority (LPA). The National Rivers Authority will, in most cases, be consulted by the LPA before permission is granted, even on non-main river, and the Authority will therefore have the chance to object on the grounds of their S.8 duties if they so wish. NRA will not, however, make the final decision in such cases.

5.2.7 NRA Decision-Making in Respect of the Retreat Option

Section 5.2.3 indicates that an important part of the decision making process in respect of the feasibility of the retreat option will rest with the Regional Flood Defence Committee. The legal support for the retreat option is, however, provided by S.8 of the 1989 Water Act - the section relating specifically to Conservation, Environmental, and Recreation duties. In making any decision, the RFDC should consider options in the context of all the Authority's duties, balancing interests and assessing possible conservation betterment as discussed in Section 5.2.2. However, it is important that the retreat option and, in particular, any interest which the Authority may wish to retain in a site once a decision to do-nothing in terms of flood defence has been taken, should be the subject of advice from staff from the Conservation Function (see Section 5.2.4). The existing pattern of dialogue between the RFDC and other Committees should provide a mechanism for ensuring that any environmental benefits associated with the retreat option are properly identified and considered, but the overall decision-making approach may require some development in view of the findings of this report.

5.3 Role of Statutory Bodies

5.3.1 In addition to the Flood Defence and Conservation functions of the NRA outlined above, a number of other bodies also have statutory responsibilities in respect of flood defence and/or nature conservation in the coastal zone in England and Wales. These bodies have various powers and duties to conserve or enhance the existing environmental resource, to promote the sympathetic use of the countryside, to designate sites of special value and to enforce protection policies. Section 5.3 therefore sets out the relevant responsibilities of each statutory body. It also explores the options for public sector funding of the managed retreat option, and reviews each agency's land acquisition policies. Table 5.3.1 summarises the attitudes of the main conservation bodies to the idea of managed retreat for the benefit of nature conservation and landscape, and also assesses their willingness to fund or part fund projects using either existing or new monies.

5.3.2 Nature Conservancy Council (English Nature/Countryside Council for Wales)

The Environmental Protection Act (1990), which came into force on 1st April 1991, disbanded the NCC and created instead three independent agencies for England, Wales, and Scotland with British coordination being provided by a new Joint Committee. In Wales, the NCC and Countryside Commission have been merged to create the Countryside Council for Wales. The functions of the Joint Nature Conservation Committee, English Nature and the Countryside Council for Wales are, however, predominantly the same as those provisioned under the 1981 Wildlife and Countryside Act and previous Acts (see below).

The majority of the research carried out for this report, including the production of the draft report, took place prior to February 1991. Given that most of the functions of the new organisations set up under the 1990 Act will be the same as existed previously, and that many of the results of this report will apply to Wales as well as England, references to NCC throughout the text remain generally unchanged.

Table 5.3.1 Summary of Support for the Retreat Option from the Major British Nature Conservation Organisations

Organisation	Supportive of Retreat in Principle	Able to Fund with Existing Monies	Able to Fund with New Monies
Nature Conservancy Council	Yes	Yes, but limited extent because core funding goes to protecting nature reserves with existing conservation value. Contributions would therefore come from research budget.	Yes. The Environmental Protection Act (1990) enables funding of management agreements outside but adjacent to Sites of Special Scientific Interest.

Organisation	Supportive of Retreat in Principle	Able to Fund with Existing Monies	Keen to Fund with New Monies
Countryside Commission	Yes, but each site must be judged on its own merits.		Yes. The new Countryside Stewardship Scheme aims to enhance and recreate valued English landscapes and wildlife habitats.
National Trust	Yes, but only in areas with existing conservation interest in landscapes of national importance and quality.	Yes	Yes
Worldwide Fund for Nature	Yes	Yes, for land acquisition or management costs.	Yes
Royal Society for the Protection of Birds	Yes	Yes	Yes
Wildfowl and Wetlands Trust	Yes	Yes in principle, but unlikely because funds are committed primarily to management of existing reserves.	Possible.
Royal Society for Nature Conservation (County Trusts)	Yes	Yes. RSNC will assist with fund raising for land purchase although priority for land purchase is protection of existing sites of conservation interest under threat.	Yes, primarily in response to threats from development.

The Nature Conservancy Council Act (1973) conferred upon the NCC the following functions and duties:-

- to establish, maintain and manage nature reserves;
- to advise Ministers on policies for or affecting nature conservation in Great Britain;
- to provide advice and disseminate knowledge about nature conservation;
- to commission and support or, if necessary, carry out relevant research;
- to notify Sites of Special Scientific Interest (SSSI) and take such steps as are open to it to protect them - for example by advice and/or by agreements under S.15 of the Countryside Act 1968;
- to issue, or advise Ministers on the issue of, licenses affecting particular species;
- to take account as appropriate in the discharge of its functions of actual or possible ecological changes.

The Wildlife and Countryside Act (1981) substantially extended the NCC's powers and obligations, notably in respect of agricultural and forestry operations affecting SSSI's. This Act also gave the Council new powers to declare Marine Nature Reserves and increased the number of protected species.

- **Funding Abilities**

The NCC is financed by annual grants-in-aid on the Central Environmental Services Vote of the Department of the Environment (DoE), and from income generated by its own activities. It is also empowered to accept gifts and contributions for the purposes of its functions (NCC, 1989/90).

NCC's powers to fund site protection outside statutory conservation sites has, to date, been limited. In pursuit of its objectives under the Nature Conservancy Act (1973) it has concentrated a large proportion of its grant-in-aid resources on establishing, maintaining, and managing statutory conservation sites. In 1988/89 for example, the combined budget for maintenance of National Nature Reserves (NNRs) and management agreements on SSSIs accounted for 26.1 per cent of NCC's government grant (NCC, 1989/90).

By definition, SSSIs, NNRs, Marine Nature Reserves, and Local Nature Reserves must already have existing conservation interest to be candidates for designation. As a result, funding allocated for reserve establishment and management is unlikely to be available for the managed retreat option from existing budgets.

New provisions under the Environmental Protection Act (1990), however, gave the NCC powers outside designated areas from April 1st 1991. Schedule 9 of the Environmental Protection Act, amending Section 15 of the Countryside Act (1968), enables the NCC to enter into management agreements with owners or occupiers on land adjacent to sites of conservation interest. Adjacent land does not have to be of established conservation interest. The purpose of any management on adjacent land must, however, be to support the established conservation interest of the neighbouring SSSI and such management agreements could therefore encompass managed retreat.

As well as site management funding, the NCC has a project-related budget within its overall grant-in-aid. This is spent primarily on sites of existing nature conservation interest. It is not, however, restricted to SSSI's or any other protected areas, and may therefore be a further option enabling NCC to contribute to individual habitat restoration or creation projects, particularly in early applications of the managed retreat approach where experimentation is required.

- **Land Acquisition**

The involvement of the NCC in land acquisitions is governed by three sets of powers. These are:

i. Powers under Section 1(4)(c) of the Nature Conservancy Act (1973) to purchase land for nature conservation benefit;

ii. Powers under Section 38 of the Wildlife and Countryside Act (1981) to give financial assistance, by way of grant or loan, to any person in respect of expenditure incurred or to be incurred by him/her in doing anything which in the NCC's opinion, is conducive to nature conservation or fostering the understanding of nature conservation. These powers have been carried over into Section 134 of the Environmental Protection Act (1990);

iii. Powers of compulsory purchase to acquire land for the establishment of a nature reserve, where it is in the national interest, under Section 17 of the National Parks and Access to the Countryside Act (1949). Section 18 of the same Act gives the NCC compulsory purchase powers to obtain nature reserve land where a management agreement relating to it is being breached. The relevant definition of nature reserve is given under Section 15 of that Act.

A major objective of the original Nature Conservancy was to identify and acquire sites of national importance for nature conservation. Reserves were meant to be for research as well as preservation purposes, as outlined in Section 15 of the National Parks and Access to the Countryside Act (1949). Threats to habitats have increased since 1949, however, and the emphasis of site acquisition has consequently become the protection of the conservation resource, rather than ecological experimentation (Moore, 1987).

The NCC has, in the past, acquired some sites for research or experimental purposes, and on rare occasions other sites have also been bought adjacent to existing land holdings for their habitat creation potential. NCC's current focus for land acquisition under its Section 1(4)(c) powers remains sites of existing high nature conservation interest as identified by the Nature Conservation Review (NCR) (Ratcliffe 1977), or subsequently acknowledged as being of NCR quality.

In the period since 1949, funding for land purchase has not been available at the rate originally envisaged. In addition, the recent political framework in which government bodies have been operating is such that public ownership of land has not been encouraged.

NCC's compulsory purchase powers are generally regarded as a last resort, only employed where other safeguard mechanisms have proved unsuccessful. These powers have only been used twice since they were established in the 1949 Act.

Overall, land acquisition by the NCC is regarded as a last resort to protect threatened sites for which no other safeguard mechanisms are felt to be appropriate. Implicit in this acquisition mechanism is the protection of sites of high existing nature conservation interest. As shown in Table 5.3.1, however, NCC's policy on land acquisition per se does not diminish their interest in or support for the managed retreat option.

5.3.3 Ministry of Agriculture, Fisheries and Food (MAFF)

MAFF has a wide range of powers and duties of direct relevance to this report, notably under the following Acts:-

i. Land Drainage Act 1976
ii. Coast Protection Act 1949
iii. Agriculture Act 1986
iv. Food and Environment Protection Act 1985

The Ministry's various responsibilities under these Acts are reviewed in the following sections:-

- **Flood Defence and Coast Protection**

"Under Sections 90 and 91 of the Land Drainage Act 1976, as amended by the Water Act 1989, provision is made for Ministers to make grants to the National Rivers Authority, Local Authorities and Internal Drainage Boards towards capital expenditure incurred by those bodies in the improvement, or the construction, of flood and sea defences. Similarly, under Section 21 of the Coast Protection Act 1949, Ministers may provide grants towards capital expenditure incurred by Maritime District Councils on coast protection works. Flood defence works (sea defence on the coast) are designed to prevent inundation whereas coast protection works aim to protect against the permanent destruction of the coast by erosion or encroachment by the sea.

Under both Acts it is normally for the appropriate drainage or coast protection authority to determine the need for works and to decide which schemes it wishes to promote. Ministers have no authority to direct that a particular scheme be constructed in preference to another.

All schemes are initially prepared by the relevant drainage or coast protection authority. The Ministry's Regional Engineer will often be consulted in the early stages of scheme preparation and, once a scheme has been submitted, he is responsible for the initial consideration of the scheme. This will include consideration of the technical merit of the proposals, economic viability and relevant environmental factors. To be eligible for approval for grant-aid, all schemes are required to be technically sound, economically effective, environmentally sympathetic (as far as possible) and with no outstanding objections" (MAFF, 1989).

- **Environmental Responsibilities**

Under the terms of the Agriculture Act 1986, MAFF has a duty to balance interests in exercising its agricultural functions. Alongside the promotion of a stable and efficient agricultural industry, economic and social interests and the enjoyment of the countryside by the public, MAFF must have regard to the:-

> "Conservation and enhancement of the natural beauty and amenity of the countryside (including its flora and fauna and geological and physiographical features) and of any features of archaeological interest" (S.17).

This Act also enabled the designation of Environmentally Sensitive Areas (ESAs) through S.18 (ESAs are discussed further in Section 5.6). In many respects the 1986 Act therefore represents the Ministry's primary responsibilities in terms of the protection and enhancement of the British Countryside.

As discussed above, MAFF currently provide funds for sea defence, tidal defence and coast protection schemes (among others) in the form of grant-aid. In common with other projects involving the expenditure of public money, such schemes must be justified in economic terms (i.e. the discounted national economic benefits of a scheme must be at least as great as its discounted costs). The problems associated with quantifying environmental benefits were discussed in Section 4 but, even if a national economic benefit can be demonstrated, MAFF will only grant-aid a project involving the creation or restoration of coastal/tidal habitats if the following conditions are also met:-

i. the scheme must meet the criteria for a flood defence or coast protection scheme as defined in the 1976 Land Drainage Act or the 1949 Coast Protection Act respectively. Schemes not meeting these criteria will not usually qualify for grant-aid under current guidelines.

ii. the habitat restoration/creation element must either serve a coastal engineering function and/or be essential to meet planning permission requirements or those which arise as a result of an Environmental Assessment.

iii. the environmental enhancement component of a scheme should not represent an unreasonable (unspecified) proportion of the overall costs of that scheme.

Given these factors, it is conceivable that some habitat creation/restoration projects associated with a retreat option might attract grant-aid from the Ministry. A scheme involving the establishment of saltmarsh or other species of vegetation could qualify if it can be demonstrated that this vegetation will act as a buffer. Experiments have shown that the passage of waves through saltmarsh vegetation may reduce wave height by 71% and wave energy be 92% (Harmsworth and Long, 1986), and establishing saltmarsh could therefore significantly reduce potential erosion of the "new" post-retreat coastline (the upland edge). Similarly, the creation of an intertidal habitat offshore could attract funding from MAFF if the feature either acts as an offshore breakwater (e.g. preventing cliff erosion) or performs a function as a "feeder" berm (e.g. feeding a beach as part of a coast protection scheme). Further examples are provided by schemes involving the creation of a secondary flood defence line fronted by environmentally desirable habitat, or a managed wetland site which acts as a temporary flood storage reservoir. On the other hand, it is unlikely that a project specifically designated to create a nature reserve for wading birds and therefore requiring strict year-round water level controls, for example, would attract grant-aid in its own right.

- **Dumping Licence Requirements**

MAFF also have duties under the terms of the Food and Environment Protection Act 1985. Operations such as beach replenishment which involve the dumping of materials in tidal areas below the level of mean high water springs, requires a licence from the Ministry. Such a licence may also be required for habitat creation/restoration initiatives **in front of** the existing sea defence (e.g. saltings regeneration building out to seaward).

Sections 3.4.7 and 3.4.8 of this report deal with the possible dumping of dredged material to raise land levels to a suitable elevation relative to the tide for the development of a particular type of habitat. In cases where this operation is carried out **prior to** the failure of the sea defence, a dumping licence will not generally be required. Similarly, any repairs to the sea defence itself will not usually require a licence.

In other cases, however, the raising of land levels to create a preferred habitat may follow the failure of the defence. In circumstances where a decision has already been taken not to reinstate the failed structure as a flood defence and the land behind has become subject to tidal ingress, a dumping licence might be required before any works can be undertaken. MAFF should therefore be contacted if there is any uncertainty in this respect.

- **Land Acquisition**

The Ministry of Agriculture, Fisheries and Food have significantly reduced the extent of their land ownership over recent years and currently retain only limited areas of land for experimental purposes (e.g. experimental farms). There are no proposals to acquire new land for such purposes. The Ministry is essentially a Government department responsible for policy and direction. Similarly, it is not a functional authority in respect of flood defence and coast protection and there is consequently no provision under either the Land Drainage Act 1976 or the Coast Protection Act 1949 for the acquisition of land.

5.3.4 Countryside Commission

The Countryside Commission, originally known as the National Parks Commission, was established by the National Parks and Access to the Countryside Act 1949, and was reconstituted under its present name by the Countryside Act 1968. The principal objectives of this statutory body with responsibility for landscape and recreation, are to seek the preservation and enhancement of the landscape beauty of the countryside, and to encourage the development and improvement of facilities for informal recreation and access to the countryside by the public. The Commission also plays a key role in the designation of Areas of Outstanding Natural Beauty (AONB), Heritage Coasts and National Parks. Among its various roles outside these designated areas, Countryside Commission promote the maintenance of regional distinctiveness and the diversity of landscapes.

The AONB designation, made under the National Parks and Access to the Countryside Act 1949, signals to the local planning authority the importance of applying strict development control policies to the designated area in order to preserve and enhance its natural beauty.

Heritage Coasts have no statutory protection. They are, however, defined in order to protect the UK's most beautiful and undeveloped coastlines, including cliffs and drowned river valleys among others, from the growing pressures of agriculture, recreation and development. Protection is offered by local development control which aims to combine the conservation of unspoiled coast with positive management to enable local people and visitors to enjoy the coast. The recent policy statement on Heritage Coasts, issued by the Countryside Commission (CCP:305), calls for a more "holistic" response in coastal areas. It targets the removal of eyesore caravan sites, a halt to cliff edge cultivation, and the establishment of public footpaths along all lengths of Heritage Coast. It also offers a broader definition for the coastal heritage itself: heritage embraces terrestrial, littoral and marine flora and fauna and architectural, historical and archaeological features. The "environmental health" of inshore waters and beaches is also a relevant consideration, as are the economic and social needs of the communities within Heritage Coast areas.

There are eleven National Parks in England and Wales designated under the National Parks and Access to the Countryside Act 1949. From north to south these are the Northumberland National Park, the Lake District, the North York Moors, the Yorkshire Dales, the Peak District, Snowdonia, the Broads, the Pembrokeshire Coast, the Brecon Beacons, Exmoor and Dartmoor. Five of these parks - the North Yorks Moors, the Lake District, Snowdonia, the Pembrokeshire Coast and Exmoor - have coastal frontages.

The Parks are administered by joint boards in the Lake District and Peak District and by Committees appointed by the County Council in the remaining nine. In all the Parks, the boards or committees have management as well as planning responsibilities. Protection is afforded through development control as well as through other provisions such as Special Development Orders. The latter limits the scope of the General Development Order thereby reducing the categories of development which are exempt from planning permission.

The Countryside Commission's designated areas, like those of the NCC, centre on sites of existing value. The philosophy of "improvement" does, however, play a more significant role in the various policies of the former. If a candidate site for managed retreat is identified within one of the designated areas, the Countryside Commission are likely to be generally supportive of any attempt to improve or restore the "natural" character of the countryside. It is envisaged, however, that the Commission's initiatives in respect of the wider countryside are likely to prove as important, if not more important, in respect of the managed retreat option outside notified areas.

- **Funding Abilities**

The Countryside Commission offers landscape conservation grants towards the creation and management of features in the landscape. Eligible work includes, for example, the planting of trees and small areas of woodland under a quarter of a hectare. The work should be of benefit to the landscape and contribute to the public's enjoyment of the countryside. In terms of providing funding for the managed retreat option, however, a recently announced scheme appears to be far more appropriate.

A major new countryside initiative, which will help to enhance and re-create valued English landscapes and habitats whilst making them more accessible to the public, is currently being promoted among farmers, landowners and anyone with a controlling interest in a suitable area and willing to comply with the management requirements of the scheme.

This pilot scheme, known as Countryside Stewardship, will initially target chalk and limestone grasslands, heathlands, waterside landscapes, coastal land, freshwater and estuarine grazed marsh, and grazed dune systems.

The scheme offers enormous potential for the restoration and re-creation of landscapes in coastal areas under the managed retreat option. In order to be eligible for regular payments under the Stewardship scheme the land must be managed, although it may be possible to apply for a one-off payment for newly created but unmanaged habitat (e.g. to help meet capital costs). **The recreation and restoration of natural landscapes and habitats would, in this respect, represent an appropriate application of the Countryside Stewardship objectives, but it may be necessary to amend the list of targeted habitats to specifically include coastal lowlands.**

- **Land Acquisition**

The Countryside Commission is not itself a land-owning body and it possesses few direct executive powers in respect of land ownership. The Commission does, however, give grants for land acquisition mainly to local authorities and voluntary groups such as wildlife trusts. Their priorities in this respect currently lie with land acquisition at the coast and with land for community forests. It is expected that any land acquired would be of at least regional importance, if not national significance, in terms of its recreation potential and/or landscape.

5.3.5 Local Planning Authorities (LPA)

Local planning authorities have a number of powers and duties relevant to the retreat option:-

- **Flood Defence, Coast Protection and Nature Conservation**

District Councils, subject to the consent of the NRA, have various powers to carry out drainage works on non-main river watercourses for the purpose of preventing or remedying the damage caused by flooding. It is therefore appropriate that the findings of this report should be applied not only by the NRA but also by LPAs. This would ensure that managed retreat to benefit nature conservation is properly investigated and evaluated as an option in areas where the LPA is responsible for flood defences. Such measures are likely to be particularly important in areas such as the NRA's Wessex and South-West Regions where the regional meetings undertaken as part of this study indicated that a significant proportion of sea and tidal defences are maintained by individuals or agencies other than the NRA.

Of less direct relevance to this report, LPAs also have powers in accordance with the 1949 Coast Protection Act to carry out such coast protection works as appear necessary or expedient. This power does, however, become important when new coast protection schemes are being reviewed because of the possible implications for sediment supply to low-lying areas down-drift of proposed erosion prevention works.

From the nature conservation perspective, S.21 of the National Parks and Access to the Countryside Act (1949) gives local authorities the power to acquire, declare, and manage nature reserves where it appears to them expedient to do so. Although in the 1949 Act these reserves are referred to as "Nature Reserves Managed by Local Authorities" they have, by common usage, become generally known as Local Nature Reserves (LNRs). The responsibility for selecting, acquiring, and managing these nature reserves is the local authorities'. However, the NCC must be consulted prior to their designation, and the sites chosen must be of special interest in the context of the local authorities' areas (NCC, 1988).

Financial assistance for carrying out management may be available from the NCC, but LNR designation does not give automatic entitlement to NCC grant-aid. Where a major part of the purpose of a project is for the enjoyment of nature by the public, for example, the Countryside Commission may give grant-aid (NCC, 1988).

- **Funding Abilities**

Local Planning Authorities (LPAs) represent the most disparate source of potential funding for the retreat option, with some 50 County Councils and several hundred District Councils in England and Wales alone. The most significant contribution to nature conservation currently made by LPAs is through the designation of Local Nature Reserves (LNRs) as discussed above.

A survey of the role and performance of LPAs in nature conservation in Britain revealed that nine out of ten county authorities and two out of three district authorities regularly or occasionally carry out projects specifically to create habitats of conservation value (Tyldesley, 1986). Tyldesley also points out that LPAs are less inclined to support research preferring to support site specific projects (e.g. implementation) via grants, advice or donations. This provides a clear indication of what LPAs consider to be their role in nature conservation, and is very encouraging in respect of possible future implementation of the managed retreat option - either in areas where the LPA are responsible for the flood defences, or possibly in support of NRA or NCC initiatives.

Blunden and Curry (1988), however, are critical of the level to which LPAs have exercised their powers to benefit conservation through LNRs, the acquisition of "amenity" land and the establishment of management agreements. National Park Authorities (NPAs), although not LPAs by definition and status, do operate under the auspices of LPAs and cover many of the same functions. NPAs perform better in terms of funding for nature conservation than other LPAs. The most significant difference between the two is the former's annual allocation of financial resources specifically for nature conservation work and the employment of full-time qualified nature conservationists.

- **Planning Powers**

In the short term, local planning authorities have what is arguably a crucial role to play in enabling the option of retreat for nature conservation benefit to be accepted and implemented into the future. Managed retreat, in some cases, might require planning permission. S.55(1) of the Town and County Planning Act 1990 states that "development" means the carrying out of building, engineering, mining or other operations in, on, over or under land, or the making of any material change of use. Further, under S.57(1), planning permission is required for the carrying out of any development on land.

The following are examples of managed retreat options which may involve operations constituting development, and may therefore require planning permission:-

- The deposition of dredged material to vary the elevation of the land (see also Section 3.4.7).
- The excavation of lagoons and wetland areas, which may also involve construction of weirs and sluices.
- The construction of retaining walls.
- The use of bulldozers, etc. to alter the land elevation in the case of saltmarsh regeneration for example.

Under the General Development Order 1988, certain operations undertaken by warer authorities (the NRA) are exempt from planning permission. Part 15 Class A(H) stipulates that any [other] development in, on over or under **their operational land** is permitted development. If, however, the operations involved erection of plant or machinery exceeding 15 metres in height, the development would require planning permission. Finally, if the operation constitutes land drainage works, planning permission would be exempt. Part 15 Class A stipulates that "development in connection with the improvement or maintenance or repair of land drainage works" is permitted development.

The possibility of refusing planning permission for private flood defence works has been considered in Section 5.2.6, but potentially more importance is the issue of granting planning permission for "flood plain" or "cliff top" development. At the present time, the retreat option could, in theory, be implemented relatively easily because many areas of the English and Welsh coast remain comparatively undeveloped. If, however, proposed new developments in low-lying coastal areas are granted planning permission, not only might there be a direct impact on sensitive coastal habitats, but future potential sites for retreat will be lost because flood defences are then more likely to be improved than abandoned. Similarly, if cliff top developments are granted planning permission and increased rates of sea level rise lead to exacerbated erosion of cliffs, a source of sediment for existing and new coastal habitats might be lost if coast protection works are subsequently undertaken to protect that development. Although individually many of these developments might be considered insignificant, the collective impact of incremental decision making is potentially severe.

- **Coastal Zone Management**

The various powers discussed above mean that LPAs are ideally placed to play an important and positive role in developing a long-term strategic approach to coastal planning. In Section 2.3, the interdependence of the various coastal ecosystems was discussed, along with the likely impacts of sea level rise on the coastal resource. The setting up of groups such as SCOPAC (Standing Conference on Problems Associated with the Coastline) and ACAG (Anglian Coastal Authorities Group) demonstrate the high level of awareness of coastal issues among the Maritime District Councils and others. Other initiatives, such as the development of an Estuary Management Plan for the Exe Estuary being undertaken by Devon County Council, support this view, and it appears that LPAs could therefore play a leading role in developing and promoting Coastal Zone Management (CZM) at a strategic or even national level. Given the relevance of the various LPA responsibilities to the retreat issue, an important component of such an initiative would be the designation of sites, identified using the criteria discussed in Section 4.1, as offering significant future opportunities for habitat creation or restoration.

- **Planning Gain**

Opportunities exist for incorporating nature conservation objectives into new development proposals through planning agreements under S.106 of the Town and County Planning Act (TCPA) 1990. Such agreements are often used by local planning authorities when certain objectives cannot be effectively organised through planning conditions - for example the safeguard of valued habitats, amelioration for damage caused, and habitat creation.

Government circular 22/83, Planning Gain, makes it clear that agreements should cover only matters which relate directly to the development. However, "planning gain" often arises where something is demanded by the local authority which is not directly related to the development. A few examples do exist where the old S.52 TCPA (HMSO, 1971) agreements were used for nature conservation purposes, notably at Watermead, Aylesbury, where a waterside village of 800 houses bordered a newly created lake. Facilities here include a small wildlife reserve, interpretation centre and a wildlife hospital.

Whereas it is generally accepted that conventional planning gain should be on site, opportunities do exist for "trade-offs" whereby degradation to one site could be ameliorated by funding habitat creation, and/or other conservation objectives elsewhere in the country. The MCA developers proposing a theme park on Rainham Marshes, Essex, for example, have offered a package to establish a nature reserve within the SSSI, to provide money for its management in perpetuity; and also to purchase grazing marsh to be run as a nature reserve (Dane et al., 1991). This offer is commonly referred to as planning gain. Similarly, the developers of the Cardiff Bay Barrage have proposed the creation of an area of mudflats to compensate for a much larger area which will be destroyed if the development goes ahead.

The question must be asked about whether these examples really offer any gain or whether they merely reduce a loss. Care must be taken when applying the term "planning gain" to conservation issues that there is, in fact, a net gain (i.e. the proposals do not simply represent an attempt at mitigating anticipated damage). There is nevertheless a pressing need to discover ways of combining conservation and development at the local level in an attempt to build in conservation principles from the start, and any formal requirement for environmental planning gain or mitigation in Great Britain must be very carefully controlled. The mitigation issue is discussed further in Sections 5.5 and 5.6.

- **Land Acquisition**

Under S.226 of the Town and County Planning Act 1990, a LPA, on being authorised to do so by the Secretary of State, has the power to acquire compulsorily any land in their area which is suitable for and required in order to secure the carrying out of development, redevelopment or improvement. It is immaterial who undertakes the activity and in particular the LPA need not propose to undertake the activity or achieve the purpose themselves. S.227 of the Act also provides that a LPA may acquire by agreement any land which they require for any purpose under S.226.

5.3.6 Crown Estate Commissioners

The Crown Estate is a landed estate which includes more than 250,000 acres of agricultural land in England, Scotland and Wales together with substantial urban estates. Of particular relevance to this study, however, is the fact that the Crown owns over 50% of the UK foreshore (including Northern Ireland) and nearly all the seabed out to the 12 mile limit (around 20km).

The Crown Estate Commissioners (CEC) are a statutory body charged with the management of the Crown Estate. Their duties are to maintain and enhance the estate's value and the return obtained from it, with due regard to the requirements of good management. A major part of the estate's marine activities are involved with the extraction of marine sand and gravel for which the Commissioners issue licences and collect revenues. In 1989 the "Government View Procedure" for determining applications to extract marine aggregates was revised by the Department of Environment, Welsh Office and Crown Estate. The procedure now incorporates, in principle, the requirements of the EC Directive on Environmental Assessment. The Commissioners collate the available information for presentation to the Department of Environment, who in turn refer to these procedures to determine a positive or negative Government view for the activity in relation to the coastline, sea fisheries and the marine environment.

The Commissioner's commitment to environmental protection is further demonstrated by the leasing of around 340 miles of foreshore (550km, 20% of the total length) to conservation bodies at minimal rent. CEC's foreshore management programme also extends to ensuring the public's rights and, in recent years, to the management of fish farming.

The role of the Crown Estate Commissioners under a retreat scenario will be important primarily because, as indicated above, the Crown owns all land between Mean High Water (MHW) and Mean Low Water (MLW) subject to admitted claims only. In cases where, as a result of erosion, subsidence or sea level rise for example, additional areas gradually and almost imperceptibly become "intertidal", these areas will automatically be taken over by the Crown. If, however, the "movement" in MHW and MLW (e.g. an increased or new area is inundated during part or all of the tidal cycle) is achieved deliberately through the actions of the NRA, District Council or other body, the situation in respect of ownership is, as yet, untested in law.

There is a provision in the Crown Estate Act (1961) for the Commissioners to issue consent for environmentally beneficial uses of the foreshore. Similarly, the Countryside Act 1968 allows an interest in Crown land, other than one held by or on behalf of the Crown, to be acquired compulsorily (S.47(2)) if the Crown Estate Commissioners consent. Their interests cannot be compulsorily acquired.

These factors demonstrate that close consultation will be required with CEC, on a site-specific basis, when managed retreat is being considered in areas outside the statutory control of bodies such as Harbour Authorities (e.g. areas on the open coast).

5.4 Role of Voluntary Agencies

5.4.1 As well as the statutory authorities discussed in Sections 5.2 and 5.3, many other agencies have an active interest in the coastal zone. Most are registered charities which depend on membership subscriptions for income. Groups such as the Royal Society for the Protection of Birds and the National Trust have nearly three quarters of a million and over 1.7 million members respectively (Pearce et al, 1989). Other groups such as the Wildfowl and Wetlands Trust and the British Association for Shooting and Conservation, however, cater for more specialist interests. The main activities of these agencies which are of direct relevance to this study are summarised below, along with information relating to opportunities for funding retreat as an option and, if the information is available, the agency's land acquisition policy. Table 5.3.1 meanwhile summarised the level and type of support for the managed retreat option from the voluntary bodies alongside the same information for the statutory agencies.

5.4.2 Royal Society for the Protection of Birds (RSPB)

The RSPB, Europe's largest voluntary wildlife conservation body, is supported by a subscribing membership of approximately 700,000. It is a charity which takes action to protect wild birds, together with their environment.

Within this broad remit, the RSPB's main aim is to maintain the richness of Britain's heritage of wild birds, including bird numbers, diversity and geographical distribution, and to increase this richness where desirable. The RSPB consider that conserving habitats is the most important means of protecting wild birds. They achieve this by both acquiring and managing land as nature reserves, and by influencing what happens to the rest of the countryside (RSPB, 1990b). The RSPB currently owns or manages 118 reserves.

The RSPB has a substantial income derived from membership fees, reserve admission fees, campaign fund raising, income from farm licences on certain reserves and from government grant-aid.

- **Land Acquisition/Funding Abilities**

The RSPB criteria for choosing potential reserves include (not in any order of priority):-

i. Number of species present.
ii. Species abundance or rarity.
iii. Presence of nationally or internationally important populations of breeding or wintering birds.
iv. Status of bird protection elsewhere in its range.

Within this framework, the RSPB currently aims to establish wildlife refuges on the 50 estuaries with highest bird populations, acquiring land as necessary to achieve this objective.

The RSPB has been at the forefront of highlighting habitat loss and the consequent damage to birdlife in the coastal zone. It is therefore keen to support managed retreat as a means of reinstating lost habitat. The reserve programme of the RSPB does not currently include specific plans for purchasing or managing new sites in low lying coastal areas. Given their commitment to managed retreat, however, combined with their long term aim to establish estuarine wildlife refuges, the RSPB is likely to actively participate in retreat projects in the near future.

5.4.3 The National Trust (NT)

The National Trust is a charitable organisation whose income is derived from the subscriptions of over 1.7 million members, admission fees, donations, legacies, endowments, and also rents from its properties (National Trust, 1988).

Founded in 1895, the National Trust is the largest conservation (as opposed to wildlife conservation) society and private landowner in Britain (Gubbay, 1988). Its aims are to protect landscape and cultural heritage through the acquisition and management of property. It does not generally lease properties (except in a few instances from the Crown Estate Commissioners and Duchy of Cornwall), nor manage the property of other organisations or individuals. Rather the Trust seeks to buy property outright, to enable it to take full advantage of its powers to declare its land and buildings inalienable under the National Trust Act (1907).

The Trust has a substantial agricultural holding, controlling over 1100 farm tenancies. Approximately half of the Trust's land is let in this way. As landlord, the Trust has certain controls on farming practices, and is therefore in a position to promote environmentally sensitive land management. As leases come up for renewal, conservation clauses can be inserted to promote those practices which enhance landscape or wildlife interest. Currently, such leases account for only a small proportion of the National Trust's farm holdings, but the retreat option could be appropriate as a new type of conservation clause providing a means for the Trust to improve the "conservation portfolio" of its low-lying coastal agricultural properties.

- **Land Acquisition/Funding Abilities**

The National Trust obtains land through bequests, covenants, and purchase. As a result, acquisition opportunities are, to a large extent, responded to on an ad hoc basis. This makes prioritisation of acquisition difficult, and therefore each property has to be considered on its own merits.

The Trust has, however, formulated a broad 'statement of principles' to govern property acquisitions (National Trust, 1985):

i. The property must be of national importance because it is outstanding for its natural beauty or historic interest.

ii. There must be adequate benefit to the nation, including public access subject to constraints which may be necessary for the conservation or management of the property.

iii. Property will not normally be acquired for preservation unless the Trust is the most appropriate owner and, without the Trust's protection, it would be in danger of deterioration, demolition, alteration or development in a way which would be harmful to its character or environment.

iv. In certain instances, land of a slightly lower standard may be accepted if it adjoins or is near existing Trust land and its preservation would contribute to the preservation of the existing property.

v. In highly developed areas where there is little unspoilt countryside a property may be accepted which, although it is of a high standard, may be of slightly lower merit than would normally justify preservation by the Trust.

vi. Unspoilt coastal property which falls within the description in (i) above will continue to be acquired under Enterprise Neptune.

vii. Property acquired by the Trust should be and should be expected to remain, financially self-supporting.

viii. The Trust should continue to be highly selective when acquiring further properties. It should include in its financial and staffing forecasts adequate and realistic provision for new properties within the resources expected to be available.

The only attempt by the National Trust to target acquisition more specifically has been through the Enterprise Neptune campaign (guideline (vi)). This appeal was launched in 1965 to raise funds for the purchase of attractive unspoilt coastal areas, after growing concern about the despoliation of the coast by development (Gubbay, 1988). As a result, by September 1990, 839 km of coast had been purchased under Enterprise Neptune, protecting 45,973 ha of coastal land.

The emphasis of Enterprise Neptune and the principles governing the acquisition of other new properties both highlight the National Trust's main objective - the acquisition of land of national importance because of its natural beauty. The extent to which low lying agricultural areas meet this standard is relatively limited according to the Trust and, in consequence, they do not expect to play a major role in land acquisition relating to the managed retreat opportunities. Any exceptions to this general rule are likely to fall under guidelines (iv) and (v).

A review of the conservation management of the National Trust's existing coastal properties suggests a preference for non-interventionist approaches. This would tend to be in conflict with sites where engineering works might be necessary to implement some of the retreat options discussed in this report. It would, however, be entirely in line with requirements at those sites where feasibility studies indicate that the habitat which will develop without engineering works following bank failure would be of significant nature conservation value. In these cases, the only management requirements are likely to be site surveys, monitoring, and possibly the control of access, etc.

5.4.4 Wildfowl and Wetlands Trust (WWT)

The WWT is a charitable organisation with a membership of nearly 34,000 (WWT, 1990). Its income is comprised of subscriptions, legacies, grants (from local authorities, tourist boards, the NCC, etc.), visitor fees, donations, and trading, supplemented by income from its consultancy arm, the Wetlands Advisory Service. The WWT is the only major voluntary conservation body to receive a substantial proportion of its income from visitor fees.

The objectives of the Wildfowl and Wetlands Trust are conservation, research, education and recreation as set out below. The main aims of its reserve management programme are the enhancement of habitats for wildfowl and the provision of education/interpretation facilities.

Conservation : The conservation of the world's wildfowl and wetlands, by providing reserves, managing habitats, studying needs, breeding in captivity, promoting protective measures, and enlightening people.

Research	:	The scientific study of ducks, geese and swans and of the wetlands which form their home, and making use of the results of such studies.
Education	:	The sharing of knowledge, understanding and appreciation of wildfowl, wetlands and nature conservation in general, both with visitors to WWT Centres and with the whole community.
Recreation	:	The provision of uplifting recreational opportunities, by bringing together in their wetland habitat wildfowl and people, young and old, fit and disabled.

In respect of the retreat option, the Trust is in a position to contribute to capital expenditure on land adjacent to its existing reserves, providing enhancement is of conservation benefit and does not upset the balance of on-site/off-site ornithological interest. A project of this kind is currently under consideration adjacent to the Trust's Slimbridge reserve, involving local land-owners, the WWT, and NRA Severn-Trent Region (see Table A3.5.3, Appendix A).

- **Funding Abilities**

Where conservation benefit could be achieved away from WWT's present reserves, the Trust would consider entering into long-term management agreements with land owners, covering the costs of habitat enhancement works. This undertaking would only be made, however, if expenditure could be recouped by the Trust through visitor fees to that site. The Trust has extensive experience in market research for its reserves, assessing potential visitor numbers, incomes, etc, and would be in a strong position to assess whether such returns were feasible.

- **Land Acquisition**

The Wildfowl and Wetlands Trust (WWT) acquires sites either of major importance for wildfowl, or habitats of less importance but with above average access for the public. It currently owns or leases a total of nine reserves in the UK, with advanced plans for a tenth site at Barn Elms in London. Involvement with one further London site at Rainham Marshes, Essex, awaits the outcome of negotiations with the local authority and developers (WWT, 1991). The only other site being actively considered is in the Central Belt of lowland Scotland.

The WWT does not currently propose to establish any further sites, but rather it aims to consolidate it's present reserves network (WWT, 1988). Given this reserve acquisition policy, the scope for management agreements away from existing reserves is restricted. An important contribution which the WWT is nevertheless able to make to the concept of managed retreat is its experience in wetland habitat creation for wildfowl, the establishment of visitor facilities, and visitor supply/demand analysis.

5.4.5 Worldwide Fund for Nature (WWF)

WWF UK is a charity established to raise funds for nature conservation purposes. It is involved with both habitat and issue campaigns, such as rainforest protection and transport policy respectively. It also has a major conservation education programme. The main role of WWF, however, is raising and distributing funds for projects of nature conservation benefit.

WWF's policies and their criteria for grant aiding projects are laid out in the Funding Information Pack for Voluntary Conservation Organisations (WWF, 1990). Twelve broad "themes" for grant-aid have been highlighted by WWF following consultation with other conservation organisations (see Appendix A5.4.1). The allocation of WWF funding is primarily restricted to projects which fall within one or more of these themes. The Site Safeguard theme is clearly relevant to the retreat option because of its reference to habitat creation.

- **Land Acquisition/Funding Abilities**

The WWF has, on many occasions, provided voluntary conservation bodies with grant aid to assist in land purchase. These grants are generally made to conservation organisations, but WWF policy does not prohibit the granting of awards to individuals, local authorities or others.

WWF entertain applications for purchase of both SSSI and non-SSSI land. Each application is assessed against a set of ecological and practical criteria including: habitat type, degree of threat, management requirements, the capabilities of the purchasing organisation to manage the land in the long term, and the site's educational potential.

Recently, WWF funding emphasis has shifted away from contributions for land purchase costs, towards providing resources for management. The retreat option would, in principle however, be eligible for WWF funding either through grant-aid for land acquisition or for management costs.

5.4.6 Royal Society for Nature Conservation (RSNC)

RSNC is an umbrella organisation which oversees a network of 48 County Naturalist Trusts and Urban Wildlife Groups. Together, the Trusts and the RSNC form the largest voluntary organisation concerned with all aspects of wildlife conservation in the UK. RSNC has a total membership of more than 215,000, and owns or manages 1,814 reserves, 116 of which include coastal frontages (Gubbay 1988).

The RSNC has no central policy to guide land acquisition by the County Naturalist Trusts. Instead, local needs are responded to at the County Trust level.

5.4.7 **British Association for Shooting and Conservation (BASC)**

The BASC is the national coordinating body for sporting shooting, including wildfowling. The Association seeks to promote a practical interest in the countryside among the shooting fraternity, and promotes wildlife management and conservation (Environment Council, 1990). It also supports and promotes the interests of local wildfowling groups and, in this respect, has shown an interest in the retreat option. BASC point out that demand for shooting amenities currently exceeds supply.

Shooting is promoted by BASC as a potential source of income for farmers. It clearly provides a possible means of farm diversification which would enable the landowner to retain control over his/her land by leasing it to wildfowling clubs. As well as these leasing options, land is also purchased by wildfowling groups using privately raised funds. Either of these policies could prove to be of direct relevance to the type of retreat option discussed in this report. On a site specific basis, however, care would have to be taken to ensure that BASC objectives were broadly in line with nature conservation aims in respect of habitat creation.

5.4.8 **British Trust for Conservation Volunteers**

The British Trust for Conservation Volunteers (BTCV) is the leading organisation for carrying out practical conservation work in England and Wales. Each year the BTCV leads, trains or equips an estimated 50,000 volunteers to carry out conservation and amenity work on over 15,000 sites in urban and countryside settings.

The great majority of work is done by local groups of conservation volunteers, active in most towns and cities around the country. Over 600 local groups are affiliated to the BTCV, which acts as a central body to promote conservation volunteering at a national level.

The work carried out by the volunteers is necessarily restricted to manual tasks but, as a labour force, the conservation volunteers have substantial experience in habitat creation and restoration, including skills such as sand dune restoration and wetland creation which are of particular relevance to this study.

In return for their labour, the local groups make a charge to the land owner or contractee in the normal way. Rates are, however, significantly lower than for a more typical labour force and the BTCV role may therefore be important in assisting the voluntary agencies (and others) in implementing managed retreat at minimum cost.

5.4.9 **Marine Conservation Society (MCS)**

The MCS, with a membership of over 4000 (Pearce et al, 1989), is involved with promoting the conservation of the coastal and marine environment in the UK. As an organisation it is not directly involved with reserve acquisition or management but it is, however, extremely active in researching means of implementing and enhancing coastal management. MCS would be likely to support the retreat option if conservation benefits could be demonstrated. They would, however, like to see retreat implemented within a coordinated framework of Coastal Zone Management.

5.4.10 **Council for the Protection of Rural England (CPRE)**

CPRE seeks to enhance the beauty and variety of the countryside by influencing decision-makers in the EEC, Parliament, Government and local authorities. Its aims (CPRE, 1989) are to:-

i. promote and encourage the improvement and protection of the English countryside and its towns and villages.

ii. stimulate public awareness and enjoyment of the countryside.

iii. act as a centre of advice and information on matters affecting the planning, improvement, and protection of the countryside.

iv. undertake and commission research to enable a better understanding of the issues affecting the countryside.

In more specific terms, at the water's edge CPRE aims to "promote the wise management and use of water resources and adjacent land so that their beauty, character, wildlife and cleanliness are improved rather than damaged".

This policy in particular supports the type of habitat creation and restoration initiative which might result from the retreat option under a scenario of sea level rise. The CPRE do not, as yet, have defined policies on these aspects of climate change but are currently researching its potential impacts on the wider countryside.

5.4.11 **Council for the Protection of Rural Wales (CPRW)**

In the context of climate change and sea level rise, the views of CPRW generally parallel those of CPRE. CPRW have indicated their full support for the principles of the managed retreat option as discussed in this report.

5.5 The United States Experience

5.5.1 **Coastal Habitat Loss**

In the United States, coastal habitat loss and, in particular, the protection of wetlands are high profile issues. In Louisiana, saline intrusion into brackish estuaries, as land subsides and sea levels rise, is killing marsh grasses and converting more than 9,000 ha (35 square miles) of marsh into open water every year. As the marsh is lost, the natural buffering function which provides protection against storms and hurricanes is also lost. Improved flood protection structures mean that the natural ability of marsh to offset sea level rise by accretion as flood waters deposit layers of silt throughout the delta area has been very much impaired. Louisiana's mainland coastal marshes together with those of the barrier islands comprise 40% of the total US coastal marsh resource. At less than 1m above sea level, the area is potentially very vulnerable to any increase in the rate of sea level rise.

In California over 90% of the State's wetlands have been lost through fill and development. Of the existing area of wetlands, around half have been artificially created. Within the San Francisco Bay area dozens of habitat creation and restoration initiatives have been undertaken, mainly in the past 10-15 years. The San Francisco Bay Conservation and Development Commission (BCDC), who run a Federally approved State programme, have progressively tightened restrictions on permissible wetland loss and the number of permitted restoration (mitigation) projects is beginning to drop. A simple lack of land available for creation provides part of the explanation but, in California as in many other parts of the United States, George Bush's much publicised "no net loss of wetlands" statement is no longer proving adequate. Agencies such as BCDC are pushing for "no loss".

The loss of coastal wetlands is of particular concern in the States partly because of the critical role these sites play in the life cycle of a high proportion of the country's commercial fish species. The other potential functions and services provided by coastal wetlands (see Table 4.3.1) are similarly recognised and are also highly valued.

5.5.2 United States Coastal Conservation Policy

In order to try to redress the balance in terms of coastal habitat loss, many States have introduced policies designed to protect and restore the coast's natural resources. Thirty States have coastlines on the Atlantic or Pacific Oceans, the Gulf of Mexico or the Great Lakes. A National Research Council (NRC) Panel recently noted, however, that only one third of these States has a programme in place which includes what they consider to be a key requirement of sound coastal management: the establishment of erosion setback lines for new construction (NRC, 1990).

A prohibition on new development within a zone likely to be affected by erosion (E) within a defined period (e.g. E10, E30 or E60 years) is just one of a number of policies recently adopted within the US with the objectives of protecting beaches and allowing coastal ecosystems to migrate inland. The US National Parks Service have adopted a "no stabilisation" policy, becoming the first Federal agency to accept land loss. The State of Maine has implemented what is arguably the most far reaching policy on coastal retreat, adopting "presumed mobility" criteria on all post-1987 development in wetland areas. This approach allows development only on the condition that the property will not be protected from rising water levels, and property owners are also made aware that any future construction of sea defence is prohibited.

North Carolina has, among other measures, adopted a comprehensive setback policy, but difficulties are being encountered in establishing rates of erosion and hence the boundary of the E30 and E60 line. One of South Carolina's coastal policies is that no coastal structures should be replaced if they suffer storm damage in excess of a certain percentage of their value. Although no new sea walls were built after Hurricane Hugo, the policy of not replacing damaged structures proved more difficult to implement and more than a hundred badly damaged buildings were rebuilt in the wake of the hurricane. The Carolinas, together with New Jersey, are also among the States which have followed, or are now considering following, Maine's lead in prohibiting the building of new hard defence structures.

Maine's political strength in enforcing the "no new defences" policy is improved by the fact that more than 90% of beach front property owners live out-of-state. Other States, however, are experiencing different difficulties. These difficulties are caused partly by the uncertainty over whether or not prohibiting the construction of defences or otherwise evicting people from their property when resources are theoretically available is, in fact, constitutional (Titus, 1991). The fifth amendment of the US Constitution provides that no-one will be "deprived of life, liberty or property without due process of law nor should private property be taken for public use without just compensation". On the other hand, the intertidal zone in the United States is publicly owned. It could be counter-argued, therefore, that a landowner has no inherent right to construct defences at the expense of the environment. The potential British parallels to this discussion were explored in Sections 5.2.6 (the right-to-build issue) and 5.1.3 (compensation options). In the meantime, one way of diffusing the situation in the States appears to be the use of the presumed mobility policy discussed above. Under this policy the property owner would be given "reasonable" notice, say thirty or fifty years, that defences will be removed and/or no new defences will be built.

5.5.3 Mitigation

In addition to the coastal policies discussed in Section 5.5.2, a number of Federal and State laws have been introduced over the last 20 to 30 years specifically to protect the remaining American stock of wetlands. The "swampbuster" provision of the 1986 Food Security Act effectively halted the reclamation of wetlands for agricultural purposes. The 1972 Clean Water Act which discourages the dredging or filling of wetlands has, however, provided one of the most notable controls on development in these valuable habitats. S.404 of the Clean Water Act makes provision for a thorough review of proposals which are likely to have a significant detrimental impact on wetlands. S.404 requires that steps are first taken to see if the proposed project can be relocated, or if damage can be minimised to an acceptable level. If this fails, but it is thought that a habitat creation initiative would represent an acceptable alternative, compensation in the form of mitigation may be required to take one of the following forms:-

- In-kind (i.e. similar habitat to that being lost), on-site.
- In-kind, off-site (i.e. elsewhere).
- Out-of-kind (i.e. alternative habitat), on-site.
- Out-of-kind, off-site.

A fifth option has also emerged more recently - conservation banking. In California for example, a Trust Fund has been set up to ensure that, when no suitable site for immediate compensatory habitat creation can be found either on or off-site, the developer banks a sum of money to pay for future works at an appropriate site.

Mitigation, at least in California, does not simply involve wetland creation on a hectare for hectare basis. If the environmental damage associated with a proposed development cannot be reduced to an acceptable level, the objective of agencies such as BCDC is to ensure that maximum ecological value is gained from any new habitat creation works. In the San Francisco Bay area, for example, many past mitigation projects have extended over a much larger area, or created a rather more valuable habitat, than that which was under threat. In Sacramento, one mitigation option currently under consideration would involve the restoration/enhancement of more than 26,000 ha (65,000 acres) at just one site.

5.5.4 The Mitigation Option in the British Context

At the present time there is no parallel requirement for mitigation in Great Britain. If a site is designated a Site of Special Scientific Interest (SSSI), it is afforded some degree of protection under the terms of the 1981 Wildlife and Countryside Act. Even so, the last few decades have seen extensive development in and around SSSIs because NCC's powers are in fact relatively limited. Heritage Coasts and Areas of Outstanding Natural Beauty (AONB) are protected to some extent by the planning system. Elsewhere on the coast, however, the development of ports and harbours, marinas and other recreational facilities, residential and commercial complexes, and flood defence and coast protection structures has led to the unmitigated loss of features of significant nature conservation or landscape interest.

Not withstanding this, recent years have also seen an increasing move towards environmental protection. S.8 of the 1989 Water Act, for example, places on the National Rivers Authority various duties in respect of conservation and environmental enhancement (see Section 5.2). Some marinas and other coastal developments have been subjected to Environmental Assessment in line with the requirements of the various Statutory Instruments which implemented EC Directive 85/337. Significant developments within the port and harbour industry have also led to habitat conservation and preservation initiatives which were virtually unprecedented just two years ago.

Much British environmental "protection", however, relies on a largely voluntary approach to conservation and the protection achieved by the initiatives discussed above must be set against the significant losses of natural habitat discussed in Section 2.3. In an ideal world, legislation such as a requirement for Environmental Assessment would lead to the uncompromised protection of all sites of environmental interest. The reality of the situation, in the short-term at least, is that there will continue to be developments, many of which will be deemed to be "in the national interest", which destroy valuable wildlife habitats. **A mandatory requirement to minimise the environmental damage caused by these developments and, if this cannot be achieved, the introduction of a requirement for mitigation measures might provide an opportunity for developers in the private sector to meet the capital costs of the type of habitat creation initiatives discussed in this report.** As stated earlier, however care should be taken to ensure that this is not regarded as planning gain; rather that it is seen as an opportunity to try to compensate for losses which sometimes appear inevitable.

5.5.6 There is also a rather more fundamental problem associated with the concept of habitat creation as mitigation: the risk factor. So far in this report, habitat creation has been discussed as representing a potential opportunity - a chance to create or manage a resource in order to optimise its "value". Once the concept of mitigation is introduced, there is a danger that a net gain might in fact be changed into a net loss because, as discussed throughout the report, habitat creation and restoration is not a precise science. The risks of a perceived failure at least in the short term, can be quite high and some scientists are now arguing that it is not possible to recreate all the characteristics of a natural wetland habitat (see Section 3.5.2). **It is therefore essential that a "no loss" policy is still pursued to try to protect Britain's most valuable habitats, and that habitat creation/restoration "experiments" are carried out, in the first instance, on sites with little or no existing nature conservation interest.**

5.6 <u>New Funding for Coastal Habitat Creation Initiatives</u>

5.6.1 One alternative to redirecting existing monies to meet the capital and/or management costs of habitat creation or restoration projects would be to set up a new budget from which the promoting agencies could draw. This concept is already being put into practice in both the United States and Canada, where the respective Federal Governments are providing funding for habitat creation initiatives. In Canada, one example is provided by the St. Lawrence Seaway Project administered by Environment Canada. Here, $5.1 million (Canadian dollars; 1990 prices) out of a total five year budget of $110 million has been earmarked for wetland creation and restoration schemes (Environment Canada, personal communication, 1990). In the United States, the U.S. Fish and Wildlife Service is spending money to acquire land and create or restore habitats: several such projects are currently underway in the northern parts of San Francisco Bay (San Francisco Bay Conservation and Development Commission, personal communication, 1990). In neither of these cases is there any formal requirement for cost benefit analysis (CBA), either to justify the existence of the budget or expenditure from the budget. The initial allocation of funds has been based on a national recognition (public and political) that wetland habitats are important. Within the budget, expenditure priorities are then determined as a result of environmental appraisals and economic cost-effectiveness analysis (e.g. minimising the cost of achieving a given environmental objective; see Section 4.1).

5.6.2 An example of an equivalent budget provision in Great Britain is that associated with the Environmentally Sensitive Areas scheme administered by the Ministry of Agriculture, Fisheries and Food (MAFF). Under this voluntary scheme, farmers can claim a fixed incentive payment if they agree to follow a strict set of management guidelines. These guidelines, which vary between ESAs, are designed to conserve and enhance the area's wildlife and landscape interest which has developed over many decades as a direct result of traditional farming practices, and which now depend om such practices.

The ESA concept was prompted by public debate about the compatibility of modem farming techniques with the protection of the countryside, and the need to integrate agricultural and environmental policies (HMSO, 1989a). The European Community accepted the initiative promoted by MAFF in March 1985 and the first six English and Welsh ESAs were designated under the terms of the Agriculture Act 1986. In January 1988, a second round of ESAs were designated in England and Wales, and since then further areas have been designated in Scotland and Northern Ireland. The 1990/91 budget for ESAs from Central Government is set at about £12 million per annum, with the EC providing an element of funding.

5.6.3 **This study recommends that the viability of setting up a similar budget to fund coastal habitat creation/restoration initiatives is further investigated.** Such an initiative might require EC approval to ensure that British farmers/landowners will not have an unfair advantage over their European counterparts. An estimate of the total amount of funding likely to be involved will be required, and the logistics of implementing and administering such an initiative must be examined.

The annual cost of a "coastal habitats" policy would depend to a limited extent on whether funding would be available only to meet scheme capital costs or whether ongoing maintenance, site management or management agreement costs would be included. Existing reserve management costs incurred by organisations such as the RSPB could be used to assess possible future management/maintenance costs but, if the objectives of sustainability set out in Section 3.1.4 are achieved, the costs of managing such sites should be relatively small. Similarly, when the number of landowners and land acreages likely to be involved in such an initiative, in the short term at least (see Tables 1.3.1 and 1.3.2 for example), is compared to the 5,200 farmers and 261,000 ha of land currently entered into the ESAs, it is likely that management agreement element will represent a fairly small proportion of any budget. Finally, it is anticipated that the administrative burden of such a scheme would also be minimal.

The bulk of any budget would, therefore, be required to meet the costs of land purchase, engineering works and/or biological inputs. Experience in the United States has demonstrated that the cost of creating a tidal marsh, for example, can range from £3,000 to £45,000 per hectare (1990 prices). British experience is rather limited, and documented costs even scarcer (see Table A3.5.2, Appendix A), but total scheme costs might be expected to range from a few hundred pounds to several hundred thousand pounds. Given the likely limited availability of land for such initiatives in the short term, total budget requirements can therefore be guesstimated to be in the order of £1 million to £2½ million per annum. Further work would, of course, be required to establish a more accurate budget requirement.

5.6.4 Implementation

The question of who might administer such a budget hinges to a large extent on the decision-making process which will be used to ascertain the viability and desirability of any particular proposal or application for funding. It appears at this stage that three criteria will be of particular importance:-

- Is the proposal technically viable and well planned?

- Is the proposed habitat type of the greatest possible nature conservation value given both national desirability criteria and the local context of the particular site?

- Does the proposed method of creating the habitat appear to be the most cost-effective means of achieving the stated objectives?

Five agencies were initially considered as candidates to administer any budget. Although the ESA scheme does represent an example of conservation requirements being built into agricultural policy, MAFF has only a limited statutory nature conservation role. Similarly, both Countryside Commission and the National Rivers Authority have quite general powers and duties in respect of determining nature conservation priorities. The study team therefore felt that it might be most appropriate for the Department of the Environment to promote and administer any coastal habitat creation policy through the Nature Conservancy Council. Other agencies, such as the NRA, RSPB, County Wildlife Trusts, and others might then apply to NCC for partial or total funding for a project, and NCC could make a decision based both on the criteria set out above and those in Section 4.1.

A policy of the type set out above obviously requires further, more detailed investigation before it could be promoted to Treasury. The concept does, however, meet the joint criteria of mitigating against anticipated future coastal habitat losses, particularly under a scenario of climate change (see Section 2); compensating landowners (see Section 5.1); and the more general environmental objectives set out in the recent Government White Paper, Our Common Inheritance (HMSO, 1990a).

5.6.5 EC Funding

Various European initiatives aimed at protecting and enhancing the natural environment are currently underway. Preliminary investigations suggest that some EC funding might be available for the implementation of experimental managed retreat projects under the guidance of DGXI. Site specific proposals would, however, have to be submitted before full or partial funding opportunities could be properly established.

5.6.6 Fish Nursery Areas

As discussed earlier in the text, much of the concern in the United States over the loss of coastal wetlands has centred on the critical role these habitats play in the life cycle of many commercial fish species. In both the US and Great Britain, the seasonal abundance of food in estuaries makes them vital as nursery areas for fish and various invertebrates. Sea grass beds are among the most productive of the shallow sedimentary environments. Their high primary production supports a rich resident fauna and as a result, they are frequently used as nursery areas by nektonic (free-swimming, oceanic) species. Saltmarshes also play an important role in the life cycle of many fish and crustacean species (Boaden and Seed, 1985).

In comparison to the situation in the US, concern over wetlands loss in respect of the fisheries resource has a much lower profile in Great Britain, possibly because many British commercial fish species spawn at sea. Coastal and estuarine areas do, however, play an important role in the life cycle of species such as Bass, Flounder and Eel. Although there may be only limited scope under a retreat scenario for providing habitat for these species, it may be worth further investigating possible opportunities for developing shellfish cultivation and extensive fish farming in flooded low lying coastal areas. Such activities might be beneficial from the point of view of the landowner in that land would continue to be used "productively". In some cases, however, it is envisaged that there might be difficulties reconciling commercial fisheries and nature conservation objectives.

At the present time although MAFF provide grants for the development of fish farming, there are no schemes in existence whereby MAFF would be able to assist a conversion from "agriculture" to "mariculture" (MAFF, personal communication, 1991). It is therefore recommended that the possible appropriateness of introducing such funding be further investigated.

SECTION 6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Background to the Report

6.1.1 Many of the low lying areas of England and Wales are currently protected from salt water inundation by artificially maintained sea or tidal defence structures. A significant proportion of Britain's richest coastal ecological sites are also situated in these low-lying areas, either to the seaward side of the defences, or immediately behind them.

6.1.2 Current concerns over the extent and significance of past coastal habitat losses due to development and the possible future losses under a scenario of climate change and sea level rise, combine to demonstrate the need to promote the restoration or creation of sites of nature conservation interest in Britain's coastal zone.

6.1.3 The report demonstrates that significant opportunities for environmental enhancement of this nature might arise if a retreat from the existing line of flood defence is accepted as an option. In particular, the report investigates the issues surrounding the concept of a "managed" retreat specifically designed to maximise nature conservation and landscape benefits.

6.1.4 The Scope of the Study

Preliminary results from the National Rivers Authority's Sea Defence Survey (England and Wales) indicate that a total of 40km of sea defences, protecting in excess of 10,000ha, currently have a residual life of less than five years. Where these defences protect lives and property it is likely that a decision will be made in favour of reinstatement. Where the defences protect agricultural land, however, managed retreat should be considered as an option.

6.1.5 A series of meetings with Regional National Rivers Authority and Nature Conservancy Council (now English Nature and the Countryside Council for Wales) staff led to the identification of more than forty sites at which the opportunities and constraints associated with the retreat option might be further investigated. While the NRA Sea Defence Survey identifies only those sites protected by sea defences, these Regional meetings identified a number of candidate sites in estuaries which are currently protected by tidal defences, as well as sites protected by sea defences.

6.1.6 Agricultural Land

The scenario of creating saline or brackish water habitats in areas which were formerly protected against inundation forms the principle basis of the report. Once an area has been subjected to brackish or saltwater inundation for any length of time, options for reclamation are significantly reduced. Retreat for nature conservation benefits in the coastal zone has significant implications for agricultural land-use over the short to medium term and the needs of both interests must therefore be very carefully assessed at local, regional and national levels.

6.1.7 **The United States Experience**

Throughout the report, the situation in England and Wales is compared to that in other countries, notably the United States. The emphasis on the US stems largely from the requirements of their 1972 Clean Water Act which introduced a requirement for mitigation on development projects damaging wetland resources. As a result of this Act, the Americans have built up an extensive literature on habitat creation and restoration and, although it is recognised that care needs to be taken in applying the results of this research in Great Britain, the US nevertheless provides an invaluable source of information of direct relevance to this study.

6.2 The Impacts of Sea Level Rise on Coastal Habitats

6.2.1 Mean sea level, tidal rise and fall, meteorological surges, tidal streams and other currents, and wave action are all important in shaping Britain's coastline. All of these factors may be modified to some extent by climate change, most particularly through the predicted rise in mean sea level and by the possible increase in the occurrence and severity of storms.

6.2.2 Around 70% of the world's shores are currently eroding, to a large extent irrespective of any change in climate. Erosion is influenced locally by a number of factors. Two key factors are the "hardness" of the coast and human intervention. The increase in global warming is likely to lead to increased erosion and hence to more littoral material being freed for transport into sheltered areas. Assuming such erosion is not prevented by man (e.g. by coast protection works), sediment necessary for the accretion of mudflats, sandflats, saltings and shingle beaches may be generated in at least as great, if not greater, quantities than at present. The littoral zone is, however complex and **the need for monitoring, both of coastal processes and of ecological changes, cannot be overstated if climate change and sea level rise is to be both accommodated and managed in order to maximise opportunities and minimise threats.**

6.2.3 The study demonstrates that all major coastal habitat types in the low lying areas of England and Wales will be affected by sea level rise and increased storminess. Existing sand dunes, sandflats and sandbanks, saltmarshes, mudflats, shingle features, lagoons, reedbeds and grazing marsh are all likely to experience increased erosion and/or inundation. Many will also suffer from a loss of vegetation or a change in the characteristics of the ecological community, and there will be a general increase in instability. In some cases, particularly where the inland migration of the habitat is not prevented by sea defence structures, such instability may be beneficial: coastal ecosystems are dynamic and change is important. Where inland migration is blocked, however, sea level rise could lead to significant losses of some habitats.

6.3 Technical Viability

6.3.1 On a site-specific basis, the decision-making process in respect of the retreat option should start with an assessment of the technical viability and the management implications of a range of alternatives. These alternatives should include both maintaining the flood defence and creating coastal habitats. It is then necessary to determine their relative benefits in terms of ecological desirability and to assess the economic implications of each option.

6.3.2 In many situations an option involving a retreat from the existing line of flood defence will offer significant environmental benefits. If this is the case, the degree of management or intervention which might be required to achieve different environmental objectives must be carefully considered. This is important because of the possible cost implications of a long-term management policy based on intervention; the general desirability of creating or restoring a sustainable habitat; and the need to avoid undesirable consequences (e.g. increased erosion or deposition) elsewhere in the estuary or along the coast.

6.3.3 **Sustainability criteria, in particular, are of vital importance if habitat creation or restoration initiatives are to succeed. It is not an objective of this study to promote the creation of habitats which subsequently require as much maintenance as the flood defence structures which preceded them.**

6.3.4 The study demonstrates that there are dozens of sites throughout England and Wales where flood defences have failed and the land formerly protected against flooding has reverted to various types of coastal habitat. Very few such sites have been properly documented, yet the information which could be collated from photographic records and discussions with local conservationists could be invaluable for future decision-making in respect of the retreat option. **It is therefore recommended that research be undertaken to identify a series of sites where the necessary information is likely to be available, albeit in a somewhat subjective form, and to establish and compare rates of habitat development or habitat change. The physical, biological and chemical controls on the nature and extent of ecosystem development could then be evaluated, and a database would ultimately be established against which future retreat options might be assessed.**

6.3.5 Experience, in the United States in particular, has demonstrated that a key factor in successful habitat creation/restoration initiatives is a careful prior appraisal of the situation and, if appropriate, well researched design undertaken by suitably qualified personnel. The physiology of a created site, its biodiversity and its long-term sustainability will then determine its eventual success. The development of the soil physiology will, in many cases, affect the rate and extent of vegetation colonisation. If the soil invertebrates, algae and other organisms, nutrients and structure are not properly established, vegetation growth will be inhibited. Similar problems will be experienced if physical processes are not fully effective. **A key to successful habitat creation, from a biological as well as a physical viewpoint, is understanding and re-establishing natural processes, and then allowing enough time for the habitat to develop.**

6.3.6 **Physical Considerations**

The coastal environment is dynamic and the mechanisms at work are powerful. Particularly on exposed coasts, the coastal process regime will need to be understood if habitat restoration/creation opportunities are to succeed and are not to cause problems up or downstream. The physical characteristics which are likely to be of greatest importance in the development and control of sustainable coastal habitats are waves; tidal currents; sediment regime; surges; elevation; grade; drainage; and site size.

6.3.7 **Biological and Chemical Considerations**

In addition to these physical parameters, a number of biological and chemical parameters must also be assessed, and possibly controlled, if a more environmentally desirable habitat is to be restored or created. The major biological considerations associated with the retreat option include the proximity of similar sites and the related availability of soil fauna, and also the preferred method of establishing vegetation cover. Primary chemical parameters relate to soil chemistry and structure, and the quality of the water entering and leaving the site.

6.3.8 A great deal of practical research has been carried out, notably in the United States, into the potential beneficial uses of dredged material in habitat creation and restoration. In general terms, these materials simply provide a substrate on which to work. A number of further factors must, however, be considered in terms of the testing and use of materials and the monitoring of sites if it is proposed that contaminated or potentially contaminated dredged materials be used.

6.3.9 For most of the coastal habitats mentioned in Section 6.2.3 above, tables have been prepared setting out the primary physical and biological requirements for the successful restoration or creation of that habitat. Where records exist, however, it is clear that some coastal habitats will take up to 20 years or more to become properly established and hence "successful".

6.3.10 In Great Britain, although we can learn a great deal from overseas experience, some experimentation will be required simply to establish which management techniques are likely to be most successful. **If the country is to sustain its coastal ecological resource in the face of rising sea levels, it would therefore be prudent to explore opportunities for creation and restoration sooner rather than later.**

6.4 <u>Assessment and Evaluation of Retreat</u>

6.4.1 Various retreat strategies can be identified, ranging from the do-nothing option, through a minimum intervention approach to the implementation of engineering works to create a desirable habitat. In a true do-nothing strategy, the sea defence is abandoned and no further action of any kind is taken. The way in which the site evolves over time is left entirely to natural forces. Managed retreat, on the other hand, covers a variety of different potential options with the common aim of restoring or creating "desirable" habitat, landscape or amenity features.

6.4.2 The identification of potential retreat options should take into account not only technical viability but also the environmental desirability of the restored or created habitat. A mixture of ecological and landscape criteria should therefore form the basis for identifying restoration and creation priorities, and then for assessing and evaluating potential options.

6.4.3 The appraisal process for managed retreat will therefore frequently involve more than one stage. The ecological and landscape criteria will generally be used first, to screen and assess potential options. A more formal evaluation within an overall cost-benefit analysis (CBA) framework should then be carried out using non-monetary and/or monetary techniques. The type of technique chosen will depend on the nature of the impact and the most suitable assessment approach.

6.4.4 Coastal habitats provide benefits which correspond to three different categories of value held by individuals towards environmental goods: use values (associated with the benefits gained from use of the environmental resource, along with option values which relate to the desire of an individual to maintain the ability to use the resource in the future); bequest values (the preservation of the environment so that future generations may also have the option of use); and existence values (the values which result from an individual's altruistic desire to assure the availability of a good or service for other individuals and for future generations).

6.4.5 It is important that both use and non-use values are taken into account in the assessment of any particular project. If an analysis only assesses the values related to direct use, a gross underestimation of the total economic benefits to be gained from any restoration or creation activities could result.

6.4.6 The application of cost-benefit analysis techniques to the evaluation of activities, including those affecting the environment, requires that all future costs and benefits are discounted. This ensures that money values are converted into comparable units and can, therefore, be added together to give an overall estimate of net benefit.

6.4.7 **Valuation Techniques**

The aim of CBA is to quantify in money terms as many costs and benefits as possible. This report identifies six potential methods for the monetary valuation of benefits associated with coastal habitat restoration and creation activities. These are methods which could be used to develop either "reference values" or "specific values". Reference values are values which are based on benefit estimates calculated for existing sites, but which are considered to be comparable to the habitat resulting from restoration or creation. Specific values are developed for the proposed restored or created resource itself, and are generally based on predictions of the functions and services that will be provided.

6.4.8 The techniques which are likely to prove most applicable to the assessment of benefits associated with habitat creation or restoration are preventative expenditure and replacement cost methods (reference values), and contingent valuation methods (reference and specific values). Only contingent valuation could be used to provide estimates of non-use related benefits including option, bequest and existence values.

6.4.9 **Future Evaluation of the Retreat Option**

There are considerable difficulties in applying monetary assessment techniques to the valuation of environmental assets such as habitat or landscape. This may limit the feasibility of valuing habitat creation/restoration initiatives and hence the reliability of any estimates generated through these techniques for input into CBA.

It is nevertheless recommended that managed retreat options should be evaluated as far as possible within a cost-benefit framework. This approach provides an indication of whether or not benefits exceed costs and has the advantage over a cost-effectiveness approach in that it takes into account the full range of environmental (habitat, conservation and amenity) implications associated with each option. Assuming that quantitative and qualitative impacts are fully considered alongside monetised benefits and cost within the benefit-cost framework, this approach will help to ensure that the most beneficial or worthwhile options are selected.

6.5 Implementation

6.5.1 A large number of organisations have an interest in the management of Britain's coastal zone. The National Rivers Authority (NRA) is arguably one of the most important of these agencies, having powers and duties in respect of both Flood Defence and Conservation, the latter under Section 8 of the Water Act 1989. The Nature Conservancy Council (now English Nature and the Countryside Council for Wales), Ministry of Agriculture, Fisheries and Food, Countryside Commission, and the local planning authorities are among the other statutory authorities with powers and duties to conserve or enhance environmental resources through designation and enforcement policies. Voluntary organisations such as the National Trust and the Royal Society for the Protection of Birds could also play a key role in the implementation of the managed retreat option.

6.5.2 Support for the principle and objectives of the retreat option from groups such as the Country Landowners Association and National Farmers Union would, however, also be desirable. Such support is unlikely to be forthcoming in the absence of an adequate compensation provision. In the long-term, if the creation of environmentally desirable coastal habitats is to become widely accepted, the issue of compensation for the landowner must therefore be both addressed and resolved.

6.5.3 **NRA's Legal Responsibilities in Respect of Conservation**

Counsel's Opinion in defining the Water Act 1989 S.8(1)(a) duty for NRA appears to offer positive support for the retreat option, where that retreat is planned and/or controlled to ensure nature conservation benefits. Counsel's Opinion states that "Attention needs to be given to its positive expression: the duty is concerned not merely with the assessment of harm but also the achievement of a better environmental result by the use of one alternative [e.g. retreat] even if the other, or others, [e.g. flood defence] are not in themselves particularly harmful to ecology or amenity" [authors' parentheses].

6.5.4 Under S.17 of the 1976 Land Drainage Act, the drainage authorities (including the NRA) have a permissive power to maintain and improve existing works and construct new works. In certain circumstances, therefore, the NRA can make a decision to abandon a defence when it reaches the end of its residual life without becoming liable to pay compensation. However, if the NRA intervenes and does something (e.g. undertaking habitat creation work in line with their S.8 duties) which actively reduces that residual life and hence the value of private land, there may be a requirement for compensation.

6.5.5 **The Role of Other Statutory Bodies**

The Nature Conservancy Council is generally supportive of the retreat option. Under the terms of the Environmental Protection Act 1991, NCC may be able to use their management agreement budget to provide funding for managed retreat in areas adjacent to sites of existing conservation interest. The NCC's ability to contribute towards individual projects may also be important, particularly in early applications of the managed retreat approach where experimentation is required.

6.5.6 The Ministry of Agriculture, Fisheries and Food has a wide range of powers and duties of direct relevance to this report. MAFF also provide funds for sea defence, tidal defence and coast protection schemes (among others) in the form of grant-aid. The managed retreat option might, in some cases, attract funding from MAFF.

6.5.7 A major new countryside initiative has been announced recently by the Countryside Commission to help to enhance and re-create valued English landscapes and habitats, whilst making them more accessible to the public. "Countryside Stewardship" offers enormous potential for the implementation of the managed retreat option. **The recreation and restoration of natural coastal landscapes and habitats could represent an appropriate application of the Countryside Stewardship objectives, but it may be necessary to amend the list of targeted habitats to specifically include coastal lowlands.**

6.5.8 Local planning authorities (LPA) have a number of flood defence, coast protection and nature conservation powers and duties relevant to the retreat option. Many LPAs regularly or occasionally carry out projects specifically to create habitats of conservation value, preferring to support site specific projects. This approach is very encouraging in respect of possible future implementation of the managed retreat option - either in areas where the LPA are responsible for the flood defences, or in support of NRA or NCC initiatives. Local planning authorities also have what is arguably a crucial role to play in enabling the option of retreat for nature conservation benefit to be implemented, because managed retreat, in some cases, might require planning permission from the LPA.

6.5.9 The role of the Crown Estates Commissioners under a retreat scenario will be important, primarily because the Crown owns all land between Mean High Water (MHW) and Mean Low Water (MLW) subject to admitted claims only. In cases where, as a result of erosion, additional areas gradually and almost imperceptibly become "intertidal", these areas are automatically taken over by the Crown. If, however, the "movement" in MHW and MLW is achieved deliberately through the actions of the NRA, District Council or other body, the situation in respect of ownership is, as yet, untested in law.

6.5.10 The voluntary agencies contacted during the preparation of this report - including the National Trust, RSPB, Wildfowl and Wetlands Trust, Worldwide Fund for Nature, Royal Society for Nature Conservation and others - have all expressed support for the principle of managed retreat for nature conservation benefits. Most of these agencies would be able to contribute towards the funding of certain retreat options using existing monies and all would be keen to become actively involved should new monies become available.

6.5.11 **The Mitigation Option**

Section 404 of the United States Clean Water Act 1972 makes provision for a thorough review of proposals which are likely to have a significant detrimental impact on wetlands. Steps are first taken to see if the proposed development project can be relocated, or if damage can be minimised to an acceptable level. If this is not possible, but a habitat creation initiative would represent an acceptable alternative, compensation in the form of mitigation (e.g. the creation of a site of at least equivalent interest elsewhere) may be required.

6.5.12 At the present time there is no parallel requirement for mitigation in Great Britain. Much British environmental "protection" relies on a largely voluntary approach to conservation, through the type of initiatives discussed above. **A mandatory requirement to minimise the environmental damage caused by waterside developments and, if this cannot be achieved, the introduction of a requirement for mitigation measures might provide an opportunity for developers in the private sector to meet some of the capital costs of the type of habitat creation initiatives discussed in this report.**

6.5.13 A fundamental problem associated with the concept of habitat creation as mitigation, however, is the risk factor. Habitat creation and restoration is not a precise science. The risks of a perceived failure, at least in the short term, can be quite high and some scientists are now arguing that it may not be possible to recreate all the characteristics of a natural wetland habitat. **It is therefore essential that a "no loss" policy is still pursued to try to protect Britain's most valuable habitats, and that habitat creation/restoration "experiments" are carried out, in the first instance, on sites with little or no existing nature conservation interest.**

6.5.14 **New Funding for Coastal Habitat Creation Initiatives**

One alternative to redirecting existing monies (as discussed above) to meet the capital and/or management costs of habitat creation or restoration projects would be to set up a new budget from which the promoting agencies could draw. This concept is already being put into practice in both the United States and Canada, where the respective Federal Governments are providing funding for habitat creation initiatives. An example of an equivalent existing budget provision in Great Britain is that associated with the Environmentally Sensitive Areas scheme, administered by MAFF. **The viability of setting up a similar budget specially aimed at funding coastal habitat creation/restoration initiatives needs to be further investigated.**

6.6 Key Recommendations

6.6.1 The conclusions of this study indicate that carefully planned, managed and monitored habitat restoration and creation projects could provide a means of significantly reducing the impact of recorded and anticipated coastal habitat loss. Such artificially created habitats could, however, take upwards of ten or twenty years to realise their maximum environmental value. With both the need for a period of experimentation and the possibility of future coastal habitat losses due to increased rates of sea level rise in mind, it is therefore recommended that NRA, NCC (now English Nature and CCW), Countryside Commission, DoE and other appropriate bodies :-

- **promote an active consideration of the potential benefits of the managed retreat option at an early stage in the decision-making process for all non-urban sea and tidal defence schemes (Sections 3.1 and 4.6);**
- **ensure that habitat creation and restoration opportunities are considered not in isolation but as part of an integrated approach to coastal management (Sections 2.3.5 and 5.3.5);**
- **initiate, wherever possible, programmes for monitoring coastal processes and ecological changes to help to ensure that data is available for future decision-making (Section 2.3.5);**
- **carry out research to establish the lessons which can be learned from sites where defences have failed in the past (Section 3.2) and use this information in the future assessment of the retreat option;**
- **undertake a series of pilot projects to test the practical application of the framework identified in this report (Section 3.2.4);**
- **implement a study aimed at producing a set of technical guidelines for the managed retreat option (Section 3.5);**
- **examine the possibility of extending the Countryside Commission's "Countryside Stewardship" scheme to incorporate explicitly coastal habitat creation and restoration initiatives in low-lying areas (Section 5.3.4);**

- **investigate the need for the modification of existing funding mechanisms to enable agencies to fund managed retreat initiatives;**

- **investigate the need for additional funding for managed retreat through the establishment of a new "coastal habitats" budget (Section 5.6).**

6.6.2 This study draws extensively on experience from the United States. It therefore seems appropriate to conclude this report with a quote from Titus (1991). His message is directed at America. The spirit of that message, however, applies equally to Great Britain and probably to many other nations, and not only under a scenario of sea level rise. Man has the ability to destroy the coastal environment irrespective of whether or not sea levels rise. He also has an opportunity to prevent that loss.

"... it is urgent to implement a policy, not because there is an impending catastrophic loss of wetlands but because we may miss the opportunities to inexpensively prevent an eventual catastrophic loss if we do not act soon ..... It is difficult for Americans to imagine an area the size of Massachusetts or larger gradually being abandoned to allow coastal ecosystems to migrate inland. But is it any easier to accept a world in which these ecosystems are lost as we invest ever increasing sums to hold back a rising sea?"

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APPENDIX A1.1

PROJECT INVESTMENT APPRAISAL

PROJECT INVESTMENT APPRAISAL

1. R & D Commission - CONSERVATION F

Topic - Conservation

Project Title - Environmental opportunities under a scenario of climate change and sea level rise

Proposed No. F01.41 Project Number.

Classification of R & D - Applied research with specific aims

2. Project Leader - Dr Andrew Brookes, Senior Technical Officer, NRA Thames Region, Kings Meadow House, Kings Meadow Road, Reading RG1 8DQ — Tel: 0734 535712, Fax: 0734 393301

3. Research Contractor - Posford Duvivier Environment, Rightwell House, Bretton Centre, Peterborough PE3 8DW — Tel: 0733 334455, Fax: 0733 262243

Contract Signatory - to be appointed

Project Manager - Ms Jan Brooke

4. Contract Details

Review and recommendations

Start Date 01.10.90
End Date 31.03.91

5.0. Objectives

5.1. Overall project objective

To develop a methodology which ensures that the potential environmental opportunities associated with sea level rise are properly identified, assessed and evaluated.

5.2. Specific objectives

The project will include the following objectives:-

a). to define the likely scale of the problem and hence the scope of the study

b). to review the objectives and status of ongoing research dealing with both the implications of climate change and with habitat creation/ restoration techniques

c). to review the likely implications of both sea level rise and other possible coastal changes likely to be associated with greenhouse warming

d). to ascertain the likely nature of environmental opportunities (and limitations) in low-lying areas of England and Wales; in particular, to identify and investigate possible habitat creation opportunities for areas where the maintenance of existing sea defence structures/ standards will no longer be economically viable

e). to determine, in principle, the technical viability of any enhancement, restoration or creation options identified in (d) above

f). to establish the economic principles involved in terms of the likely costs and benefits of the options identified; to identify a methodology by which these might be assessed

g). to define the legal situation, in particular the constraints likely to be imposed upon the National Rivers Authority in respect of the 'retreat' option

h). to determine the possible funding arrangements of technically, economically and legally viable options i). to identify subject areas in which further research may be required

j). to identify critical sites at which problems in justifying continued defence are likely to arise in the near future

k). to identify environmental agencies and other organisations likely to have an interest in the study

l). to investigate appropriate methods of data storage for possible subsequent use on Geographical Information Systems (GIS) in studies relating to the impacts on nature conservation interests of climate change and sea level rise

6. Background

Although predictions for both the rate and extent of rise of sea level and the extent of any increase in storminess resulting from climatic change are still unconfirmed, it is widely forecast that sea level will rise as a result of global warming over future decades. Various studies are underway to identify specific problems, including those reported by the Inter-governmental Panel on Climate Change (IPCC). Under a scenario of sea level rise it is anticipated that continued expenditure on maintaining existing sea and tidal defences for areas of land will become increasingly difficult to justify. Indeed in some low-lying agricultural areas the economic justification of this type of scheme is already very difficult. An option in these circumstances is to "do nothing" and allow retreat from the existing line of defence.

In cases where the "do nothing" option is examined it should be recognised that there are a number of alternatives to simply abandoning the land in question to the sea. Considerable opportunities exist in such areas for the development of environmental resources through a process of 'managed' retreat. It may be viable to promote the creation of nature conservation assets, the provision of amenity/ informal recreation facilities, and the enhancement of landscapes.

A methodology is therefore required to ensure that the potential implications of sea level rise are properly identified, assessed and evaluated. A consistent and coordinated approach will ensure that creation and enhancement opportunities are maximised and that the loss of critical sites is avoided wherever possible.

6.1. Context

There are a number of research projects and operational investigations either completed or currently being funded by the National Rivers Authority that will need to be considered in the context of this project, particularly where these relate to environmental opportunities. The project will be deemed to be complimentary to this work and will not duplicate it.

Within the Flood Defence Commission there are several projects concerned with the the design of coastal and estuarine works/ structures. Topic C7 is concerned with the response to climatic change and includes a project on the sensitivity of different types of sea defence structure to changes in mean sea level and storm wave height. Project C7.1 specifically deals with the "Economic appraisal of the consequences of climatic-induced sea level rise". Project C6.2 "Saltings as sea defence" should also be considered since saltings could be both a defence against sea level rise and a consequence. There are numerous projects within the Conservation Commission which are relevant, including the project on restoration and protection of grazing marsh; restoration of the Norfolk Broads by bio-manipulation; the coastal wildlife database; studies on the conservation value and ecological status of the Welland and Witham estuaries etc. There are links to other Commissions, including the work by WRC on 'Climatic change and its potential effect on UK water resources'. There are also a number of operational investigations either being carried out or completed in the Anglia Region, including the Sea-defence Management Study.

There are several projects being undertaking independently of the National Rivers Authority by bodies such as the Ministry of Agriculture, Fisheries and Food, Department of Environment and Countryside Commission. MAFF are funding the University of East Anglia Hunstanton to Felixstowe Study. Research has been or is currently being carried out by the Universities of Durham and East Anglia, amongst others. Both the Natural Environment Research Council and European Community fund projects in these areas.

Guidance produced by this project will be nationally applicable. The project will also be vital to other British environmental agencies who require a positive and proactive strategic response to sea level rise in order to ensure that such opportunities are identified and maximised.

7.0. Strategy

7.1. Method

Although essentially a desk exercise extensive consultation and liaison will be undertaken with sponsoring agencies and other concerned bodies as appropriate. This will include:-

a). a literature search and review. An extensive review of relevant work on climatic change, sea level rise, economic, political, social and environmental consequences, and management strategies. To include previous work in North America, European experience (eg. Dutch) and previous or ongoing work in the UK (eg. Tees Estuary, Cleveland; Anglia Region). Consultation is required with concerned individuals in each of the 10 NRA Regions and with staff in other organisations (eg. by means of a questionnaire). Identification on a regional scale of sites of existing nature conservation interest and areas of low-lying agricultural land

b). assessing available literature and contacting leading researchers and workers in the field. An appraisal of research which aims to justify in economic terms the continued protection of 'key' sites of existing environmental interest (ie. sites at which sea level rise could lead to the degradation or loss of valuable/ designated assets)

c). a review of changes which include increased storminess and saline intrusion. Various reports will be appraised in this respect, including the Inter-governmental Panel on Climate Change (IPCC) report due later in 1990

d). assessment of the types of creation and enhancement opportunities (based on experience in UK and elsewhere) to include:-

- salt marsh regeneration/ creation
- tidal mudflat and intertidal habitat development
- sand dune creation/ restoration
- other 'soft' engineering options
- fish nursery areas/ angling benefits
- informal recreation/ amenity provision (ie. footpaths)
- opportunities for the promotion of formal recreation
- any other relevant opportunities

The types of opportunities will cover 'real world' examples wherever possible, such as those already identified in the UK (eg. Wessex/ Anglia), Europe (eg. Netherlands) and North America (eg. Maine; North Carolina). The project will also cover those areas where, at present, there are no sea defence structures but where it may be advantageous to allow the land to flood in the future in order to create new habitats. The "do nothing" option will also be appraised

e). assessment of the technical viability of options given in (d) above

f). investigation of the costs of restoration/ replacement/ creation; calculation of management and other engineering costs. Review of techniques available for the economic evaluation of environmental benefits

g). consultation to establish the legal situation. However this cannot be done in isolation from a consideration of the social and political sensitivity of proposals to abandon land. This will need to be undertaken with the advice of NRA staff.

h). consultation/ interviews with relevant officers

i). literature review etc. will indicate areas requiring further research

j). identification of critical sites through consultation with engineering/ conservation staff and data collection exercise

k). consultation to establish which organisations/ individuals have an interest in the study, indicating the nature of the interest, and listing these

l). investigation of appropriate forms of data storage including the types of data (map-based and alpha numeric) which will be recorded. The GIS aspects (if applicable) will take due account of recommendations from the NRA's GIS working group, R&D Topic Area G3 and the NRA's I.T. Strategy)

7.2. Monitoring

The project will be multi-funded and each funding agency will be represented on the Steering Group. The NRA will be the head commissioner and the Project Leader will chair the Steering Group.

The Steering Group will appraise the objectives of the project, satisfy itself as to the deployment of funds, the arrangements for payment of the Contractor, review progress, receive and approve the draft and final reports and make recommendations for future phases.

Project monitoring to be undertaken by the Project Leader. Project contacts will be established in each NRA Region as appropriate for reference/ advice/ review as follows:-

a). Project Leader/ Topic Leader/ Regional Project contacts to review draft report (guidance and recommendations) based on the desk study

b). Project Leader/ Topic Leader/ Regional Project contacts to decide if research should progress to any subsequent stages based on recommendations of the initial study

8. Targets and timescales

Desk study including guidance to be completed and reviewed before March 1991. Draft report available by mid February 1991, final report by late March 1991. In addition the following meetings/ key dates are programmed:-

Mid November 1990	- Steering Group Meeting
Late December 1990	- Steering Group Meeting
Early January 1991	- Submission of ideas for further phases of work (as appropriate)
Mid February 1991	- Production and distribution of draft report
Mid March 1991	- Steering Group Meeting prior to final report; further discussion of way forward
Late March	- Presentation of results

9. Outputs

a). Draft report - One per consultee, 15 copies for the NRA, one copy per steering group member and one top copy

b). Final report - 10 copies plus one top copy

10. Costs

Phase I study: fixed fee of £33,000 plus VAT.

Funding. It is anticipated that the funding of Phase I will be:-

NRA	15000
DOE	10000
CC	4000
NCC	4000
	£33000 plus VAT

11. Benefits

a). there is considerable concern about the environmental implications of both sea level rise and the continued deterioration of defence structures. By developing an effective management strategy to counter these problems, preservation, creation and enhancement opportunities for the environment can be maximised. This will be of benefit not only to managers in the NRA but also other environmental agencies such as the Department of the Environment

b). the project will review the present situation to highlight deficiencies and make recommendations for further work on the implications of sea level rise

c). collaborative project between National Rivers Authority, Department of Environment, the Nature Conservancy Council and Countryside Commission

12. Assumptions and Risks

A valuable project to be undertaken by a qualified contractor. Costs and programme of work are most likely to be adhered to. The project relies on effective consultation/ liaison with interested parties. Response from the 10 NRA Regions can be prompted through the Project/Topic Leaders.

13. Overall Appraisal

A valuable and worthwhile project with very practical results which can be applied across the 10 NRA Regions potentially affected by sea level rise or continued deterioration of defence structures. Direct relevance to external organisations. Any risks are outweighed by the potential benefits.

Dr Andrew Brookes
5 October 1990

APPENDIX A1.2

LIST OF ORGANISATIONS AND INDIVIDUALS CONTACTED

LIST OF CONTACTS

Name	Organisation	Office	Post
*Mr. A. Merritt	Avon Wildlife Trust	Bristol	Conservation Officer
Mr. S. Hodgison	Britsh Trust for Conservation Volunteers		Conservation Director
Mr. P. Fox	British Association for Shooting and Conservation	Wrexham	Head of Conservation
Ms. P. Sneddon	Cambridge University	Geography Department	
Mr. T. Badman Mr. G. Barrow Mr. J. Dyke	Centre of Environmental Interpretation		 Landscape Architect
*Ms. J. Begg	Cheshire Conservation Trust	Northwich	Reserves Officer
Dr. R. Warrick	Climatic Research Unit, UEA	Norwich	
Mr. T. Allen Ms. J. Feline Mr. N. Holladay Ms. L. Leeson Mr. R. Ward Mr. J. Worth	Countryside Commission	Cheltenham Cambridge Cheltenham London Yorkshire and Humberside Cheltenham	
Mr. T. Burton	Council for the Preservation of Rural England		Senior Planner
*Mr. P. Kirkland	Cumbria Wildlife Trust	Ambleside	Assistant Conservation Officer
Dr. O. Pilkey	Duke University	Durham, North Carolina, USA	Professor
Mr. D. King	Dennis King Associates	Washington D.C., USA	Director
Ms. F. Christie Mr. J. Corkindale Dr. J. Fisher Mr. J. Winpenny	Department of Environment	London London London London	 Economist

Name	Organisation	Office	Post
Ms. N. Lavigne	Environment Canada	Montreal, Canada	Co-ordinator, State of the Environment
Mr. R. Fischman	Environmental Law Institute	Washington	
*Dr. C. Miles	Essex Wildlife Trust	Colchester	Conservation Officer
*Ms. J. Harper	Gwent Wildlife Trust	Monmouth	
Mr. C. Cuthbert	Hampshire County Council		Recreation Department
*Mr. C. Chatters	Hampshire & Isle of Wight Naturalists Trust	Romsey	Conservation Officer
*Mr. A Cooper	Herts. & Middlesex Wildlife Trust	St. Albans	
Dr Alan H Brampton	Hydraulics Research Ltd	Wallingford	
Mr. B. McWilliams	Irish Meteorological Service	Dublin	Deputy Director
Dr. L. Boorman	Institute of Terrestrial Ecology	Monks Wood	
*Mr. M. Crick	Lincolnshire & South Humberside Trust for Nature Conservation	Alford	Conservation Officer
Dr. S. Gubbay	Marine Conservation Society	Ross-on-Wye	Conservation Officer
Mr D Ayres	Ministry of Agriculture, Fisheries and Food	Taunton	Regional Engineer
Mr. B. Edwards		London	Fisheries IIA
Mr. S. Lockwood		Conwy	Fisheries
Mr. C. Northener		London	Estates Division
Mr. R. Purnell		London	Chief Engineer
Mr. Reegan		London	Food and Environment Protection Act
Mr. I. Ward		London	Environmentally Sensitive Areas
Mr. P. Whitehead		London	Environmentally Sensitive Areas
Mr. T. Yates		London	Flood Defence Division

Name	Organisation	Office	Post
Mr. P. Cook	Consultant	Lincoln	Former MAFF Regional Engineer
Mr. J. Burgon	National Trust	Cirencester	Chief Advisor on Nature Conservation
Mr. J. Harvey		Cirencester	Advisor on Coast and Seaside
Ms. C. Howard		Cirencester	Chief Advisor on Nature Conservation
Mr. R. Jarman		Cirencester	Ecologist
Ms. T. Bennett	Nature Conservancy Council	Peterborough GBHQ	Coastwatch Officer
Mr. S. Bilsborough		Peterborough GBHQ	Economist
Dr. A. Brown		York	Senior Officer
Ms. F. Burd		Peterborough GBHQ	
Dr. T. Cadwalladr		Cardiff	Regional Officer
Mr. A. Deadman		Blackwell	Deputy Regional Officer
Dr. P. Doody		Peterborough GBHQ	Chief Scientist Directorate, Coastal
Ms. J. Forbes		Taunton	ARO
Mr. M. Felton		Peterborough GBHQ	Head, Land Use Policy
Mr. C. Fuller		Aberystwyth	Deputy Regional Officer
Dr. C. Gibson		Colchester	ARO
Mr. R. Gomm		Taunton	Deputy Regional Officer
Mr. R. Hamilton		Colchester	Senior Officer
Mr. B. Harrison		York	Warden Humber Wildfowl Refuge
Dr. M. Labern		Peterborough (East Region)	Regional Officer
Mr. C. Lumb		Blackwell	ARO
Mr. J. Morley		Norwich	Deputy Regional Officer
Mr. G. Radley		Peterborough	Sand Dune Survey
Dr. R. Rafe		Peterborough EHQ	Policy Officer
Mr. P. Sargeant		Truro	ARO
Dr. M. Smith		Bangor WHQ	Head Science and Policy (Wales)
Ms. H. Stace		York	ARO
Mr. C. Tubbs		Lyndhurst	Senior Officer
Mr. R. Wolton		Okehampton	ARO
Mr. S. Warman		Truro	ARO
Mr. J. White		Ame	ARO

Mr. D. Alsop	National Rivers Authority	Wessex	Flood Defence
Mr. K. Annand			Information Technology
Mr. J. Ash		Anglian	Operations
Mr. R. Bailey		Severn-Trent	Flood Defence
Mr. T. Barber		Wessex	Flood Defence
Mr. C. Birkes		Northumbria	Flood Defence
Dr. A. Brookes		Thames	Project Leader
Ms. K. Bryan		Severn-Trent	Conservation
Mr. G. Bull		Exeter	Flood Defence
Mr. M. Child		North West	Flood Defence
Mr. A. Clark		Northumbria	Flood Defence
Mr. D. Cragg		North West	Conservation
Mr. M. Diamond		North West	Conservation
Mr. A. Driver		Thames	Conservation
Mr. Q. Gray		South West	Solicitor
Mr. B. Hatton		South West	Flood Defence
Mr. A. Heaton		Severn Trent	Conservation
Mr. D. Hickey		Severn Trent	Conservation
Mr. J. Hogger		Northumbria	Conservation
Mr. J. Hounslow		Thames	Conservation
Mr. R. Howell		Welsh	Conservation
Mr. R. Horrocks		Wessex	Flood Defence
Mr. A. Hunter-Blair		Anglia	Flood Defence
Ms. L. Jenkins		Wessex	Conservation
Mr. K. Jeynes		Yorkshire	Flood Defence
Mr. P. Johnson		Thames	Flood Defence
Mr. D. Leggett		Anglian	Flood Defence
Mr. T. Linford		North West	Operations
Mr. G. Llewelyn		Head Office	Research and Development
Mr. R. Mains-Smith		Severn Trent	Flood Defence
Mr. D. Martin		Southern	Flood Defence
Mr. J. Morgan		Southern	Conservation
Mr. K. Nash		Welsh	Flood Defence
Mr. C. Newton		Warrington	Flood Defence
Dr. P. Nicholson		South West	Conservation
Dr. K. O'Grady		Head Office	Conservation
Dr. D. Prigmore		Anglian	Conservation
Mr. J. Pygott		Yorkshire	Conservation
Ms. A. Rogers		Head Office	Technical Assistant
Mr. D. Rook		Yorkshire	Flood Defence
Mr. N. Stevens		Wessex	Flood Defence
Mr. B. Tinkler		Wessex	Flood Defence
Mr. R. Venables		Thames	Research and Development
Mr. M. West		Southern	Flood Defence
Mr. I. Whittle		Head Office	Flood Defence
Mr. T. Widnall		Welsh	Flood Defence

Name	Organisation	Office	Post
Dr. R. Hobbs	Norfolk Naturalists Trust	Norwich	
Mr. P. Williams Mr. P. Goodwin	Philip Williams Associates Consulting Hydrologists	San Francisco, California, USA	Director Principal
Mr. G. Alcock Mr. P. Woodworth	Proudman Oceanographic Institute	Birkenhead Birkenhead	
Mr. G. Jan Verkade Mr. R. Misdorp	Rijkswaterstaat	Delft, Netherlands Hague, Netherlands	
Dr. C. Steel	Royal Society for Nature Conservation	Lincoln	Conservation Officer
Mr. R. Buisson Dr. P. Rothwell Dr. G. Thomas Dr. M. Clarke	Royal Society for the Protection of Birds	Sandy Sandy Sandy South East	Conservation Planning (Water) Coastal Policy Head of Ecology Conservation Officer
Ms. J. Zedler	San Diego State University	California, USA	
Mr. B. Batha Mr. J. Blanchfield	San Francisco Conservation and Development Commission	California, USA	Wetlands Biologist
Mr. L. G. Buck Mr. I. Townend	Sir William Halcrow & Partners	Swindon Swindon	
Mr. J. B. Edmondson	South Central Planning & Development Commission	Louisiana, USA	Executive Director
Dr. M. Clark Ms. J. Davenport Mr. C. Hill	Southampton University	Dept. of Geography Dept. of Geography Dept. of Geography	Consultant Scientist Research Scientist Research Scientist
Mr. T. Collins	Spurn Heritage Coast Project		
Dr. C. Beardall	Suffolk Wildlife Trust		

Name	Organisation	Office	Post
Mr. J. Titus	US Environmental Protection Agency	Washington D.C., USA	Sea Level Rise Co-Ordinator
Mr. A. Col-King	Ulster University	Dept. Maritime Geography	
*Ms. J. Smith	Ulster Wildlife Trust	Belfast	Assistant Conservation Officer
Dr. I. Shennan	University of Durham		
Mr. R.K. Turner	University of East Anglia	Norwich	Senior Lecturer
Mr. E. Moselman Mr. G. Oude-Essink	University of Technology	Delft, Netherlands Delft, Netherlands	
Mr. Stuurman	Institute of Applied Geoscience	Delft, Netherlands	
Dr. M. George	Formerly NCC	Norwich	Regional Officer
Dr. N. Hulton	University of Edinburgh - Department of Geography	Edinburgh	
Dr. W. Carter	University of Ulster	Coleraine	
Mr. M. Ounsted	Wildfowl and Wetland Trust	Slimbridge	Director of Conservation Developments
Dr. M. Havard	Worldwide Fund for Nature	Godalming	Marine Officer

* **Contacted indirectly through RSNC**

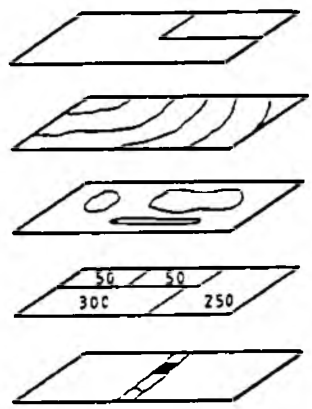
APPENDIX A1.3

THE ROLE OF GIS

APPENDIX A1.3 THE ROLE OF GIS

A1.3.1 Geographical Information Systems, with their capacity to store and map spatial information, are well suited to investigating the impacts of sea level rise.

Figure A1.3.1



1. Administration Boundaries
2. Contours/Bathymetry
3. Existing habitats
4. Crop/land value data
5. Sea Defences, e.g. from Sea Defence Survey

One of the key facilities offered by most GIS software is the capacity to overlay layers of different thematic information (Figure A1.3.1).

Most GIS packages can also perform various automated calculations. Determining areas within boundaries is one important example. By overlaying maps 1. and 2. this would, for instance, enable the area below the 5m contour in a particular district to be identified.

Many GIS packages also offer more complex calculations and statistical-analysis facilities, with the potential for ecological, hydraulic or economic analysis in the context of sea level rise. Algorithms can be constructed which link stored data on land values, house types and service line distribution together with topography. This enables various "what if" scenarios to be tested, calculating the range of economic costs associated with different levels of flood. This approach is currently being investigated as part of the MAFF study on the Economic Implications of Sea Level Rise on the South Coast, carried out by the GeoData Institute of Southampton University (see Table A1.3.1). This project is still at the experimental stage but the approach has been advanced through to implementation stage elsewhere, notably in Dade County, Florida (Pryjomko, 1990).

In the latter project, a three dimensional terrain model has been mounted on the ARC/INFO GIS, giving contours at increments of one foot. Future sea levels have been modelled at six inch increments and overlaid with population distribution, urban land use, infrastructure and agriculture data. Estimates of the financial loss resulting from progressive sea incursions have then been calculated.

A1.3.2 In developing the GIS role further, experiences from other projects utilising computerised analytical techniques in the coastal zone can provide guidance. Modelling the economic and biological damage from oil spills uses systems analysis techniques, ecological and economic models, and data storage structures that can be adapted for sea level rise investigations (e.g. Grigalunas and Opaluch, 1990). Coastal Zone Management is another major focus for computerised analysis. The Louisiana Coastal GIS Network (LCGISN) is a coastal management project where, in a State that is suffering 40% of the USA's land loss, research is underway to enable the networking of relevant databases throughout Louisiana to provide a clearer picture of environmental changes that are taking place and why (David, 1990).

A1.3.3 The prioritisation of habitats for restoration or creation could also be carried out using GIS, given information on the extent and change of relevant coastal ecosystems. It might be shown, for example, that 90% of reedbeds, 60% of sand dunes and 50% of saltmarsh had been lost since a specified baseline date in a particular country. Reedbed creation might then be identified as the main priority for habitat creation and the possible locations for creating reedbeds could then be determined via a search of the sites, identified by the NRA, where maintenance of defences is currently under scrutiny.

It is clear that GIS has the potential to play a major role in sea level rise projects. The main restriction is the lack of availability of information in an appropriate digital format with associated spatial coordinates (e.g. national grid, UTM, latitude/longitude).

There is a recognised need for coordinated effort in the collection of appropriate coastal data (Clark, personal communication, 1990). The volume of data required is beyond the capacity of any one body. The need for coordination, however, is essential to ensure that accuracy is maintained, effort is not wasted by unnecessary duplication, and that the data is collected in a format which is both transferable and appropriate to the use of GIS technology.

A1.3.4 The most expensive aspect of GIS is the transfer of data from traditional sources (maps, reports) onto the computer. Any capture of data onto the computer should therefore be undertaken in such a manner that it can be used by GIS technology at some stage. This will inevitably also require an acceptance of some form of data sharing agreement, such as that being promoted by the GeoData Institute. At present this group are pursuing a regionally based approach whereby contributors of data have access to pooled computerised information held in a "system free" format (i.e. available in all the major computer compatible forms).

An interim measure towards pooled computerised information would be the establishment of a detailed record of all digital data held by organisations, as well as their immediate plans for further data capture. Coordination of effort must be made to ensure that spatial attributes are applied to data, even when its use is intended primarily within a more standard tabular database. Point data can be quite simply referenced by a grid coordinate. Spatial areas or complex linear features are less simple but equally essential. Where they correspond to a fixed boundary line then reference to that would be applicable. Otherwise an indicative spatial reference should be used, such as the coordinate of the centroid of the area. The range of information is such that data formats and structures cannot be universally applied. However, accurate spatial and temporal references should be linked to all digital data no matter what system it is to be stored on. The problem of data exchange, given a willingness to share, is less of a problem than data capture, and is likely to become easier with time.

A1.3.5 By way of demonstrating the potential of this approach, current GIS and database work being undertaken by a range of agencies, which could potentially contribute to a retreat-for-conservation component of a coastal GIS, has been reviewed. The results of this exercise are shown in Table A1.3.1.

A1.3.6 **Recommendations in Respect of the Role of GIS**

A wide range of coastal information, much of which relates to sea level rise, is currently held on database and GIS by various academic, commercial and government organisations. There is a clear need for an inventory of these systems to be compiled, identifying in detail the attributes stored on each, the restrictions on accessibility to the data, and the potential compatibility of the various systems. Following this exercise a pilot study should then be undertaken, drawing on a range of experience both in Great Britain and overseas, to begin to combine all possible database and GIS information. An appropriate, unified means of storage, manipulation and display should then be investigated in order to produce guidelines for an integrated approach to coastal zone management using GIS as a primary tool.

Table A1.3.1 GIS and Database Projects of Relevance to Sea Level Rise

Organisation	Database/ GIS	System	Purpose	Information Contents	Status	Reference	Title
NRA, Anglian Region	GIS	Intergraph	Sea defence management	25 different datasets covering geomorphology, protected areas, ecology, recreation, infrastructure, jurisdiction, wind and wave climate, etc. All related to national grid coordinates. Previously on textual data-base currently being trans-ferred to GIS.	Pilot	NRA (1990)	Anglian Sea Defence Management System
NRA, Thames Region	GIS and Database	GFIS and SPANS	Sea defence management	Urban and rural land use, habitats, protected areas land values, etc. plus similar to above.	Under develop-ment	NRA (1990)	South Coast Sea Defence Management System

Organisation	Database/ GIS	System	Purpose	Information Contents	Status	Reference	Title
NRA	Database	Fox pro (?)	Inventory of wildlife resources associated with NRA defences	Ornithological and botanical data referenced to 500m stretches of coastline in NRA Anglian Region where NRA are responsible for sea defences.	Recently started	Prigmore D., NRA, Personal Communi-cation (1991)	Coastal Wildlife Database
NCC	Textual Database	Advanced Revelation	Estuaries management	Estuarine wildlife, conservation status, Birds of Estuary Enquiry, National Wildfowl Counts and human activities. Details spatially related to estuaries only. Some annotated field maps on archive.	Current	NCC (1991)	Estuaries Review

Organisation	Database/ GIS	System	Purpose	Information Contents	Status	Reference	Title
NCC	Textual Database	In-house	Habitat inventory	Coastal habitats, land use, and waters edge human activities. Compiled on 1:10000 maps, with key features put on in text form into database, with spatial reference to 1km squares of national grid.	Current	NCC (1990)	Coast-watch
NCC	GIS	Intergraph	Saltmarsh change	Saltmarsh monitoring between 1973 and 1988/89	Current	NCC (1990)	Saltmarsh Change in Essex and Kent
NCC	GIS	Intergraph	Irish Sea management	Coastwatch data, biblio-graphy, important and threatened conservation areas, etc.	Current	NCC (1990)	Irish Sea Project

Organisation	Database/ GIS	System	Purpose	Information Contents	Status	Reference	Title
NCC	Database	COSMOS Revelation	Saltmarsh inventory	Archive of conservation status and details of saltmarsh plant communities. Spatially referenced centre points for each marsh using national grid coordinates.	Completed	NCC (1989)	Saltmarsh Survey of Great Britain

Organisation	Database/ GIS	System	Purpose	Information Contents	Status	Reference	Title
NCC	Database and GIS	Advanced Revelation and Intergraph	Sand dune inventory	Sand dune communities using National Vegetation Classification categories spatially referred by national grid coordinates. Community also mapped at 1:10000, being transferred progressively on to Intergraph. Started in 1987 and due for completion in 1992.	Current	NCC (1990)	Sand Dune Survey of Great Britain
NCC	Textual Database	Advanced Revelation	Shingle inventory	Shingle communities using National Vegetation Classification categories spatially referenced by national grid coordinates.	Near completion	NCC (1990)	Shingle Survey of Great Britain

Organisation	Database/ GIS	System	Purpose	Information Contents	Status	Reference	Title
CEC	GIS	Arc/Info	Dredging license management	British Geological Survey core sample data, service lines, dredging areas, bathymetry, and Admiralty features, at scales from 1:5000 to 1:200000.	Near comple- tion	Posford Duvivier (1991)	Aggregate Resource Manage- ment System

Organisation	Datsbase/ GIS	System	Purpose	Information Contents	Status	Reference	Title
NRA	Database	DataEase	Sea defence management	National survey of sea defence structures including sand dunes, levels of service, properties and area at risk, plus geomorph-ological data, referenced to national grid coordinates. Phase 1 has been completed on NRA owned defences. Phase 2 covering local and district authorities and Phase 3 for private defences are both underway. Phase 4 on tidal defences due to start Spring 1991.	Current	NRA (1991)	Sea Defence Survey

Organisation	Database/ GIS	System	Purpose	Information Contents	Status	Reference	Title
SCOPAC	Database	In-house	Biblio-graphy	Bibliography material relating to coastal processes	Current	Court (1991)	Coastal Sediment Database
RSPB	GIS	Datascape	Assessment of impacts on wild-life of human activities in UK estuaries	Waters edge and adjacent land use, ecological data, habitats and water based activities, covering a total of 60 variables. A national study of 3 years duration.	Under develop-ment	RSPB (1990)	Estuaries Inventory Project
BTO	Database	Prime	Monitoring of waders	Monthly infor-mation on wader numbers, referenced to estuaries, estuary sections, or count points 1967 onwards	Current	BTO (1991) unpublished data	Birds of Estuary Enquiry

Organisation	Database/ GIS	System	Purpose	Information Contents	Status	Reference	Title
WWT	Database	Prime	Monitoring of wild-fowl	Monthly count information on wildfowl numbers referenced to estuaries, estuary sections or count points such as reservoirs. 1967 onwards.	On-going	WWT (1991)	National Wildfowl Count
DoE	Graphical Database	GIMMS	Coastal planning	Protected areas, etc.	Current	C. Hrynkiewicz, DoE, personal commun-ication (1991)	Directory of the North Sea Coastal Margin
MAFF	GIS	PC-based In-house	Broadscale North Sea management	Protected areas, outfalls, dredging, water quality, bathy-metry, etc. UK-wide coverage.	Current	J. Ramster, MAFF, personal commun-ication (1991)	Digital Marine Atlas Project

Organisation	Database/ GIS	System	Purpose	Information Contents	Status	Reference	Title
Directorate North Sea of the Dutch Public Works Department (Rijkswater-staat)	GIS	Possibly SPANS	Coastal data management and modelling system	Water quality, a range of other biolog-ical data, climatic information, jurisdictions, oil hazard analysis, eutrophication, dredging, between Straits of Dover in the South and the 58th degree latitude in the north. Project running 1988-92	Proposed	Adam Col-King (personal commun-ication 1991)	Manage-ment Analysis North Sea (MANS)
Marine Information Service (MARIS) Netherlands	Database	In-house	Commercial data bank	Water quality, physical oceanography, bathymetry, sea bed features, geology, ecology, etc.	Current	As above	Marine Infor-mation on the North Sea

Sources: Neil Pallister, NRA, personal communication (1991)
Fiona Burd, NCC, personal communication (1991)
Katherine Howard, NRA, personal communication (1991)
Tony Britton, NRA, personal communication (1991)
Amanda Rogers, NRA, personal communication (1991)
Debbie Prigmore, NRA, personal communication (1991)

APPENDIX A2.1

REVIEW OF RECENT AND ON-GOING RESEARCH OF RELEVANCE TO THIS STUDY

Review of Recent and On-Going Research of Relevance to this Study

Project	Contracted To	Funding and/or Supervising Agency
A. HABITATS		
Basic saltmarsh processes in Essex marshes in relation to predicted sea level rise	ITE - Dr. L. Boorman Monks Wood	NRA, EC, ITE, Soil Survey
Monitoring saltmarsh changes using satellite imagery.	Environmental Research Centre - University of Durham	NRA/Halcrow
Comparative studies of saltmarsh processes - assess changing patterns in the production and exchange of organic matter and exchange of mineral nutrients across the zones from mudflat to reclaimed marsh. 1990/92.	ITE - Monks Wood	NERC/EC
Studies of saltmarsh erosion in Essex. Production of maps showing changes in the area of saltmarsh vegetation, and tables showing the tidal regimes the saltmarsh plant species can withstand. 1987/92.	ITE - Dr. L. Boorman Monks Wood	Anglian Water Authority/ NRA
Saltings as a sea defence - to review research previously undertaken, and to study selected methods of saltings generation. 1990/92.	Halcrow	NRA
Restoration and protection of grazing marsh - investigate and model the recovery of soil, water and nutrient factors when arable land is returned to pasture also to produce a conservation strategy for dykes. 1990/93.	Wye College	NRA
Sand dune studies in East Anglia - studies on the vegetation communities on the North Norfolk coast. 1985/91.	ITE - Monks Wood	NERC

Project	Contracted To	Funding and/or Supervising Agency
Beach Feeding - provide guidance on the acceptable type, size and gradation of material for beach nourishment, including economic considerations. 1990/91.	MAFF and Crown Estate Commissioners	NRA
Protection of Britain's wetlands under national law and international agreements.	University College, London	WWF
B. IMPACTS OF CLIMATE CHANGE AND SEA LEVEL RISE		
Beach development due to climate change.	Hydraulics Research	NRA
Evaluation of tidal return periods in relation to climate change.		NRA
Sea level change and coastline response - changes in patterns of accretion and erosion with different rates of sea level change.	Environmental Research Centre, University of Durham	EC
Identifying areas and extent of land uplift and subsidence.	Environmental Research Centre, University of Durham	EC
Impacts of sea level rise - the use of GIS in management requirements and modelling; including coastline retreat and the environmental, social and economic aspects.	Environmental Research Centre, University of Durham	EC
Effects of sea level rise upon water resources - implications on surface and groundwater.	WRC	NRA
The Greenhouse Wales Project - to look at the implications of climate change (including sea level rise) for land and water resources in Wales.	UWIST, Cardiff	NRA, IoH, Met Office, Welsh Water

Project	Contracted To	Funding and/or Supervising Agency
Climate change, sea level rise and the English and Welsh coast. To study and predict the effects of sea level rise on coastal habitats in England and Wales. 1989/93.	ITE, Monks Wood	NERC
Modelling the effects of climatic change in species distribution. To predict species distribution at equilibrium with a changed climate and the dynamics of dispersal and population change for selected species. 1990/93.	ITE, Monks Wood	NERC, DoE
Effect of climate change and its implications for water resources. 1990/92 (Extension of DoE programme on climate change research).	Institute of Hydrology	NRA, DoE
Increasing storminess with the greenhouse effect.	UEA/CRU, Halcrow	
Climate change affecting Ireland - different issues (forestry, agriculture, fisheries, sea level rise).	DoE - Ireland (Republic) and University of Ulster	DoE
C. SEA DEFENCE STRUCTURES		
Sensitivity of sea defence structures to greenhouse effect - hydraulic performance in relation to sea level rise and storminess, and proposed methods of improving performance. 1990/91.	Hydraulics Research	NRA
Estimating Manual - examine data to estimate construction costs and develop manual for project appraisal and design of defence structures. 1990/91.	WRC	NRA

Project	Contracted To	Funding and/or Supervising Agency
Investigation of alternative methods of coast protection - to investigate coast protection methods that are effective but also safeguard geological features of interest. 1988/90.	Hydraulics Research	NCC
Current awareness review - examine relevant information on climate change research and the implications for sea defences - assess the European situation.	WRC	NRA
Unit costs for sea defence works - especially for progressive raising of defences and new constructions both inland and seaward of existing defences.	WRC	NRA
D. ECONOMIC		
Benefit/cost study on the value of coastal areas - investigate the values placed on low lying coastal areas and identify priorities for protection or sacrifice of coastal areas in a rising sea level scenario.	UEA and Middlesex Polytechnic sub contracted to WRC	NRA
Economic appraisal of the consequences of climate induced sea level rise - to examine the economics of alternative sea defence options in response to sea level rise, through case studies on the Anglian coastline. 1990/92	UEA - Mr. K. Turner	MAFF, NRA
Economic appraisal of the consequences of climate induced sea level rise - to examine the economics of alternative sea defence options in response to sea level rise, through case studies on the Southern coastline. 1990/92.	University of Southampton	MAFF, NRA

APPENDIX A3.5.1

TECHNICAL MANUALS FOR HABITAT CREATION AND RESTORATION

Table A3.5.1 Manuals and other Publications dealing with the Technical Details of Habitat Creation and Restoration

Authors & Date	Title & Notes	Publishers
Allen, H.H. & Webb, J.W. (1983)	Erosion Control with Saltmarsh Vegetation	Reprinted from the Proceedings of the Third Symposium on Coastal and Ocean Management. ASCE/San Diego, California, USA.
Allen, H.H., Webb, J.W. & Shirley, S.O. (1984)	Wetlands Development in Moderate Wave-Energy Conditions	Reprinted from the Proceedings of the Conference Dredging "84", Waterway, Port, Coastal and Ocean Division ASCE, Florida, USA.
Brooks, A. (1979)	Sand Dunes - A Practical Conservation Handbook	British Trust for Conservation Volunteers, Wallingford, UK.
Burgess, N.N. & Hirons, G.J.M. (1990)	Management Case Study - Techniques of Hydrological Management at Coastal Lagoons and Lowland Wet Grasslands on RSPB Reserves.	Royal Society for the Protection of Birds, Sandy, UK.
Countryside Commission for Scotland (1982-88)	Vegetation Management Coastal Vegetation Sheets:- 5.2.8 (1988) Sand Fencing Strained Constructions 5.2.7 (1988) Timber Panel Fencing 5.2.6 (1988) Brushwood Sand Fencing 5.2.5 (1988) Sand Fencing 5.2.4 (1982) Sand Stabilisation by Thatching 5.2.3 (1982) Sand Stabilisation by Spraying 5.2.2 (1987) Reseeding of Dune Pastures 5.2.1 (1985) Dune Grass Planting	Countryside Commission for Scotland, Perth, Scotland.
Coppin, N.J. and Richards, I.G. (1990)	Use of Vegetation in Civil Engineering	Construction Industry Research and Information Association, London, UK.
Environmental Advisory Unit (1989)	Review of Coastal Revegetation Techniques	EAU, Liverpool University, UK.

Authors & Date	Title & Notes	Publishers
Environmental Laboratory (1978)	Wetland Habitat Development with Dredged Material : Engineering and Plant Propogation.	US Army Corps of Engineers. Waterways Experimental Station, Vicksburg, MS, USA.
Gale, J.G. & Williams, P.B. (1988)	Integrating Tidal Wetland Restoration with Coastal Flood Basin Design : The Example of Shorebird Marsh, Corte Madera, California.	John M. Tettemer & Associates Limited; Philip Williams & Associates Limited, In : Proceedings of the National Wetland Syposium Urban Wetlands. June 1988, Oakland, California, USA.
Haltiner, J. & Williams, P.B. (1987)	Hydraulic Design in Salt Marsh Restoration.	Philip Williams & Associates, San Francisco, California, USA.
Kenworth, W.J., Fanesca, M.S., Hamziak, J., & Thayer, G.W. (1982)	Development of a Transplanted Seagrass (Zostera marina) Meadow in Back Sand, Carteret Country, North Carolina.	In: Cole D.P. Proceedings of the 7th Annual Conference on the Restoration and Creation of Wetlands.
Knutson, P.L., Allen, H.H., & Webb, J.W. (1990)	Guidelines for Vegetative Erosion Control on Wave Impacted Coastal Dredged Material Sites. *Chapters 3-6 evaluate the vegetative stabilisation alternatives for dredged material disposal areas using salt marsh plants.*	US Army Corps of Engineers. Waterways Experiment Station, Vicksburg, MS, USA.
Landin, M.C., Webb, J.W. & Knutson, P.L. (1989)	Long Term Monitoring of Eleven Corps of Engineers Habitat Development Field Site Built of Dredged Material 1974-87. *Chapters 2-12 discuss the technical aspects of eleven sites developed on dredged material.*	US Army Corps of Engineers, Vicksburg, MS, USA.
Morrison, J. & Williams, P. (1989)	Warm Spring Marsh Restoration	Philip Williams & Associates, San Francisco, California, USA.
Newbold, C., Honnor, J. and Buckley, K. (1989)	Nature Conservation and the Management of Drainage Channels.	Nature Conservancy Council, Peterborough, UK.

Authors & Date	Title & Notes	Publishers
San Francisco Bay Conservation and Development Commission (1986)	Guidelines for Enhancement and Restoration of Diked Historic Baylands.	SFBCDC, San Francisco, California, USA.
Saucier, R.T., Calham, C.C., Engler, R.M., Patin, T.R., & Smith, H.K. (1978)	Synthesis of Research Results Dredged Material Program - Executive Overview and Detailed Summary. Tech. Report D5-78-22. *Pages 105-150 summarise case studies of aquatic habitats developed on dredged material.*	US Army Corps of Engineers, Waterways Experimental Station, Vicksburg, MS, USA.
US Army Corps of Engineers (1976)	Dredging: Environmental Effects and Technology. Part 1. *Knutson, P.L. - Development of Intertidal Marshlands upon Dredged Material in San Francisco Bay.* *Holloway, L.F. - Biological Aspects of Marsh Development on Dredged Material.* *Reinold, R.J. - Creation of a South Eastern United States Saltmarsh on Dredged Material.*	Proceedings of World Dredging Conference 7th, San Francisco, California, USA.
US Army Corps of Engineers (1989)	Beneficial Uses of Dredged Material. *Chapters 4,5,7,8 discuss habitat development on dredged material in various aquatic habitats.*	US Army Corps of Engineers, Vicksburg, MS, USA.
US Army Corps of Engineers (1989)	Engineering and Design - Environmental Engineering for Coastal Protection. *Chapter 6. Non-structural Alternatives (saltmarsh creation).*	US Army Corps of Engineers, Vicksburg, MS, USA.

Authors & Date	Title & Notes	Publishers
US Army Corps of Engineers	Environmental Effects of Dredging. Technical Notes Volume II. *EEDP-07-01 (1986) Building, Developing and Managing Dredged Material Islands for Bird Habitat.* *EEDP-07-02 (1988) Wetlands Created for Dredged Material Stabilisation and Wildlife Habitat in Moderate to High Energy Environments.*	US Army Corps of Engineers Waterways Experiment Station, Vicksburg, MS, USA.
Williams, G. & Lewis, G. (1984)	Rivers and Wildlife Handbook: A Guide to Practices which further the Conservation of Wildlife on Rivers.	Royal Society for the Protection of Birds, Sandy, UK and Royal Society for Nature Conservation, Lincoln, UK.
Zedler, J.B. (1984)	Saltmarsh Restoration - A Guidebook for Southern California.	California Sea Grant College Program, University of California, USA.

APPENDIX A3.5.2

REVIEW OF INTERNATIONAL HABITAT CREATION AND RESTORATION INITIATIVES

Table A3.5.2 Examples of International Habitat Creation and Restoration Initiatives

i. Sand Dune Habitats

Location/Habitat	Brief Description	Cost	Success	Reference
Portrush, Co. Antrim, Northern Ireland. Natural beach/dune system low sediment supply therefore sand conservation is essential.	Need for foredune restoration following degradation by recreation pressure. a. 1969/70 - brushwood fencing, thatching and planting. b. 1973 - dune was regraded, planted with marram and mulched, except for the seaward edge.		a. Largely unsuccessful because fences too widely spaced, lack of sediment to trap and inability of marram grass to grow on steep slopes. b. Successful. Good, stable accumulation, good marram growth.	Wilcock et al (1977)
Lincolnshire, UK (Mablethorpe to Skegness); Norfolk, UK (Holkham Gap to Wells) Sand Dunes	Foredune creation by kidding to extend present dunes seaward. Trenches are dug and filled with brushwood providing a brushwood structure to trap and accumulate sand.		Successful foredune creation.	Anglian Regional Meeting
Sefton, Merseyside, UK Sand dunes	Dune stabilisation by planting of vegetation and fencing. Sand trapping fences collect blown sand in the summer months and release sand back to the beach in winter.		Successful in some areas, but at Ainsdale NNR, dune stabilisation by afforestation led to a lowering of the water table and the loss of some slack communities.	Houston and Jones (1987). North West Regional Meeting. Doody (1989b)

Location/Habitat	Brief Description	Cost	Success	Reference
Camber, Sussex, UK. Small bay dune system associated with shingle spit formation. Abundant sand supply.	1967 - Shoreline fencing to recreate dune followed by planting of marram. Inner dunes bulldozed to smooth contours and stabilised by hydraulic seeding.	£100,000 Capital Costs. Annual budget at 1977 was £6,000	Within 4 years the system was under control. By 1980 a coastal dune up to 6m high had been created and the shoreline had advanced 5-10m seaward.	Pizzey (1975) Ranwell and Boar (1986)
East Lothian, Scotland. Medium sized bay dune system which presently has a low sand supply.	1960's - buckthorn brushwood and wooden palings were used to build a 3.6m high coastal dune. This was planted on the seaward side with lyme-grass and on the landward side with marram. Blowouts were contoured and planted with marram.	1968-69 £10,500 1969-79 £23,000 1979 + £24,000	Successful - marram stablised sand on the created foredune ridge.	Ranwell & Boar (1986)
Braunton Burrows, Devon, UK. Sand dunes.	Planting of marram to trap sand and rebuild foredunes. Hessian supported on wire netting with wooden fence posts to protect dunes. Also, construction of sea buckthorn traps checks wind in its passage and allows sand accumulation on both sides.		Growth of foredunes via sand trapping deprived inner dunes of their sand supply and the middle ridge lost sand where it was still unprotected.	Kidson & Carr 1961, cited in Quinn (1977)
Rosslare, Wexford, Surfers Paradise and Noosa Bay, Queensland, Australia. Sand dunes.	Beach feeding associated with plans to trap sand. Dune-grass plantings on the backshore and coastal dunes.		Not known.	Ranwell & Boar (1986)

Location/Habitat	Brief Description	Cost	Success	Reference
Hart Warren SSSI, Cleveland, UK. Sand dunes.	Sand fences were erected to trap sand and stabilise the dunes.		Small dunes have been formed and planted with marram.	Urban Wildlife News (1990)
Pendine Sands, Carmarthen Bay, Wales, UK. Sand dunes.	Rock mounds placed at base of dunes.		Checked wave action, encouraged sand deposition, raised beach level and lowered gradient.	Colquhorn 1969, cited in Quinn (1977)
Goerre, Netherlands. Sand dunes.	Dune reinforcement was carried out by importing sand to create and reinforce dunes.		Successful as a sea defence and also fitted in to the natural environment due to careful planning.	Jong and Visser (1983)
Terrebonne Parish, Louisiana, USA. Sand dunes.	Barrier Island dunes susceptible to erosive forces of sea, due to loss of sand supply. i. Timbalier Island - 350m experimental sand fencing, vegetational stabilisation, and the building of 1-2m high dunes. ii. Grand Isle - sand placed directly on crest of barrier island dune.		Withstood 1985 hurricanes by preventing "overwash" and breaching. Acting as a sediment source for the beach.	Davis and Gorman, (1983) Penland et al (1987)

Table A3.5.2 Examples of Habitat Creation and Restoration Initiatives

ii. Marsh Habitats

Location/Habitat	Brief Description	Cost	Success	Reference
Altamaha River, Georgia, USA. Brackish marsh.	3 acre brackish water marsh was established on sandy dredged material.		Cordgrass formed a dense lush mass of vegetation and visually the marsh was identical to other marshes in the vicinity.	Landin et al (1989) Saucier et al (1978)
Bolivar Peninsula, Galveston Bay, Texas, USA. Saltmarsh.	9 acre saltmarsh established on sandy dredged material, with severe to moderate erosion.		Sandbags, breakwaters and erosion control matting proved to be effective methods in protecting the marsh. Smooth cordgrass survived at intertidal elevations while saltmarsh cordgrass invaded the upland site.	Landin et al (1989) Saucier et al (1978)
South San Francisco Bay, California, USA. Saltmarsh.	Marsh was developed in an old 10 acre salt pond on confined dredged material.		The site was planted with Pacific cordgrass, Pacific glasswort and pickleweed. It took 11 years to achieve total plant cover.	Landin et al (1989) Saucier et al (1978)
Apalachicola, Florida, USA. Saltmarsh.	A small marsh development project on poorly consolidated fine grained marine sediments in an area subject to long wind fetches. <u>Spartina</u> sp. were planted.		<u>Spartina</u> sp. is stabilising. The saltmarsh, fish populations and other estuarine habitats have been improved by the formation of tidal channels and tidal pond.	Landin et al (1989) Saucier et al (1978)

Location/Habitat	Brief Description	Cost	Success	Reference
Texas, USA. Saltmarsh	Developed marsh on dredged material in moderate to high wave-energy environments. Breakwater was used to protect the planted marsh sprigs. Erosion control mats and plant-rolls were also used.	Planting tech-niques ranged from $48 to $242 per linear metre for a marsh 20m wide in 1988.	Still experimental.	US Army Corps of Engineers (1988)
Lower Mississippi River, Louisiana, USA. Saltmarsh.	Unconfined dredged material placement to elevate shallow bay bottoms to allow natural growth of emergent marsh.	$1.50 to $3.00/cu. m (1987).	Resulted in the development of 2000 ha of man-made intertidal marsh.	Landin et al (1989)
Warm Springs Marsh, San Francisco, USA.	Embankment protecting deep borrow pit deliberately breached in 1986 in area of high suspended sediment content. Bunds used to reduce effect of wave action in areas of 3m tidal range.		Several years of monitoring demonstrate very rapid siltation and development of fringing vegetation.	Personal Communi-cation; Philip Williams Associates, San Francisco; 1990
Haywards Shoreline, San Francisco, USA. Marsh.	Complex system of culverts and control weirs to maintain shallow breeding habitat for birds.	$550,000	Partially successful. Plant colonisation was slower than anticipated. However, the site attracts large bird populations to rest and feed.	Personal Communi-cation; Philip Williams Associates, San Francisco; 1990
Galveston, Texas, USA. Marsh.	Site protected with temporary sandbag breakwater to protect young plants.		After 10 years, breakwater began to fail. Structure has now gone but a healthy marsh remains.	Personal Communi-cation; Philip Williams Associates, San Francisco; 1990

Location/Habitat	Brief Description	Cost	Success	Reference
Shooters Island, New York, USA. Marsh.	Breakwater created out of rubble, dredged fill placed behind breakwater.		Significant habitat improvement in dredged and badly eroded location.	Personal Communication; US Army Corps of Engineers; (1990)
Bogue Banks, North Carolina, USA. Saltmarsh.	Golf course eroding at a rate of 7.0m/year following large scale clearance. Sea wall was too costly, so planted 0.5m strip of vegetation (Spartina though to Juncus).		Developed into full marsh community 30m wide. Only erodes during storms.	Personal Communication; Prof. O. Pilkey, Duke University, Durham, USA (1990)
Maryland, USA. Saltmarsh.	Experimental "soft" stabilisation along shore. Rock revetment with salt marsh planted behind. Latter depends on water splashing over.		Not known.	Personal Communication; Prof. O. Pilkey, Duke University, Durham, USA (1990)
Essex, UK. Saltmarsh.	Spartina transplants within Schleswig-Holstein type polders or with groynes.		Largely experimental. Varying degrees of success.	Mascall 1987 cited in EAU (1989)
South-East USA. Saltmarsh.	Planting of Spartina sp. on dredged material to create saltmarsh habitat.		Both Spartina species showed a very good response in terms of marsh establishment.	Reinhold (1976)
North Carolina, USA. Saltmarsh.	The stabilisation of dredge spoil and the establishment of a new tidal marsh on the North Carolina coast.		Spartina marsh developed from seed and from transplanted seedlings to give complete cover within two growing seasons.	Woodhouse et al (1972)

Location/Habitat	Brief Description	Cost	Success	Reference
Lancashire, UK. Saltmarsh.	Stabilisation of intertidal flats with Puccinellia thrown onto high level sand flats on transects normal to shore on the Ribble Estuary, Lancs.		Clods took root and saltmarsh developed which has since been subject to land claim.	Barron, J. (1983) EAU (1989)
San Francisco, USA. Saltmarsh.	San Francisco Bay, Alameda Creek. Construction of substrate using dredged material and planting of saltmarsh species Spartina and Salicornia.	$26,000 per ha 1975 prices.	The planting and monitoring of replicate test plots in an unconfined area has affirmed that dredged material is a suitable sub-strate for the propagation of intertidal vegetation in San Francisco Bay.	Knutson (1976)
Southampton Water, UK. Saltmarsh.	Spartina transplants to areas of marsh damaged by persistent oil pollution.		Not known.	Dicks (1977)
Hampshire, UK. Saltmarsh.	Farlington Marshes, Langstone Harbour. Improvement of sea defences in 1979-80, using thick Reno mattresses, covered in mud dredged from in front of the embankment.	Work done by southern Water Authority, Southamp ton	Saltmarsh plant communities have developed in the sheltered and transitional sections.	Lewis et al (1984)

Location/Habitat	Brief Description	Cost	Success	Reference
Muzzi Marsh, San Francisco, USA. Saltmarsh.	Mitigation work for dredging ship channel and constructing Larkspur Ferry Terminal. Breached the dyke and flooded dredged spoil disposal area behind.		Successful growth of small plants. Work was completed in 1981. By 1987 the site was densely vegetated but only following extensive regrading exercise.	San Francisco Bay Conser-vation and Develop-ment Commiss-ion (1988)
Benicia Marina Marsh, Benicia, USA. Saltmarsh.	The City of Benicia proposed creating an 18.6 acre tidal marsh to improve marina water quality. Excavation completed in 1977. The area supports diverse habitats including an open water channel.		Dense stands of bulrushes, pickleweed, cattail and saltmarsh grass plants colonised the sites naturally.	San Francisco Bay Conser-vation and Develop-ment Commiss-ion (1988)
Sulphur Spring Creeks, Benicia, USA. Marsh.	Returned an 11.3 acre seasonal wetland to tidal action.		Unsuccessful. Plans failed to include elevations, appropriate plants and details of channels to allow tidal action. Therefore only the highest tides reached the sites.	San Francisco Bay Conser-vation and Develop-ment Commissi on (1988)

Location/Habitat	Brief Description	Cost	Success	Reference
Brittany Coast, France. Marsh restoration.	Experimental plantings of Halimione portulacoides, Juncus maritima, Puccinellia maritima, Spartina anglica and Triglochin maritima to restore salt marsh that was damaged or destroyed by the Amoco Cadiz oil spill and subsequent clean up operations.		Survival and growth of transplants of Puccinellia and Halimione were better than with those of the other three species.	Restoration of habitats impacted by oil spills. J. Cairns, A.L. Buikema.
Corte Madera Shorebird Marsh, Redwood High, School Marsh, San Francisco, USA. Marsh.	Marsh plain; through from pristine marsh to artificial tidal marsh. Used as flood storage basin in winter; complex water control structures requiring continuous management. Islands created for bird habitat.		Mostly very successful. However, breaching at one site led to a loss of habitat because of an insufficient sediment supply and exposed location. Establishing vegetation cover on islands was difficult.	Marin Audubon Society (1987)

Table A3.5.2 Examples of Habitat Creation and Restoration Initiatives

iii. Other Coastal Habitats

Location/Habitat	Brief Description	Cost	Success	Reference
North Carolina, USA. Island for Birds.	Construction of two islands out of dredged material for sea birds and aquatic biota. Planting of smooth and saltmarsh cord-grass. Similar islands have been developed in Alabama, Florida, Maryland, Texas and Louisiana.		A marsh developed and benthic organisms thrived. Terns and skimmers nest on the islands.	US Army Corps of Engineers (1988)
Gaillard Island, Alabama, USA. Island from dredged material.	Island of silty and dredged material; interior containment pond of 250-300ha of shallow water.		Seabirds and pelicans nest successfully on the island.	Landin et al (1989)
North Carolina, USA. Island habitats.	Dredged material islands provide isolated, relatively predator-free habitats which are heavily used by colonies of nesting seabirds and wading birds.		It was reported that approx. 83% of the colonial sea birds nesting in North Carolina in 1973 used dredged material islands.	Smith (1976)
Dorset, UK. Artificial islands.	Artificial islands have been created in the lagoon on Brownsea Island, Dorset.	Costs from National Trust or DTNC	The islands support breeding terns.	Personal Commun-ication; Dorset Trust for Nature Conser-vation (1991)
Florida, USA. Spoil islands.	Tampa Bay, Florida. Proposed construction of spoil islands using maintenance dredgings.		Not known.	Limoges (1976)

Location/Habitat	Brief Description	Cost	Success	Reference
Dorset, UK. Artificial islands.	Poole Bay, Dorset. BP proposal to build artificial island for offshore oil exploration using dredged fill material.	£150-200 million		Smith (1990)
North East, USA. Intertidal mudflats.	Pumped dredged material onto rocky beach, creating intertidal flats.		Commerical clam and worm beds established naturally.	Personal Commun-ication; US Army Corps of Engineers (1990)
Le Havre, France. Mudflats.	Proposed creation of artificial mudflats along channel sides to provide fish, shellfish and bird habitat and a natural water purification facility.	6.45 million French Francs (1989)	Not known.	Cellule de Suivi du Littoral Haut Normand, (1989)
Chesapeake Bay, USA. Oyster beds.	25000m^3 dredged material placed subtidally, capped with dead oyster shells for lining to settle on.		Good settlement rate. Oysters harvestable in third year.	Personal Commun-ication; US Army Corps of Engineers (1990)
Suffolk, UK. Brackish and freshwater lagoons; reedbeds and grazing marsh.	Proposed in 1988. Trimley marshes, Suffolk Development. Brackish and freshwater lagoons surrounded by reedbeds and grazing marsh will create a valuable nature reserve.	Suffolk Wildlife Trust	The 208 acre created reserve has proved successful.	Beardall et al (1988)
Titchwell, Norfolk, UK. Fresh and brackish water habitats.	An area of tidal saltmarsh was converted into fresh and brackish habitats using seawall, dam and sluice construction.	Total cost of defences was £125,000 in 1986 prices.	By regulating salinity and water levels the bird diversity has increased in all seasons.	Sills and Becker (1988)

Location/Habitat	Brief Description	Cost	Success	Reference
Yuzhny Port, USSR. Artificial shallow bank.	Concentrated soil dumping for construction of Yuzhny Port.		Soil dumping resulted in the formation of an artificial shallow bank, where the water warms up, is well lit and there is no shipping. As a result the soil dumping site has become a most productive area of the sea.	International Bulk Journal (June, 1990)
Swinefleet, River Ouse, Yorkshire, UK. Reedbeds.	Common reed was planted to trap silt and help prevent scour. Rhizome clumps were planted at MHW.		Once established the reed grew into the area below MHW.	Lewis et al (1984)
Norfolk, UK. Reedbeds.	■ River Bure, Thurne mouth - asphalt matting to rear of low level piling.	£260/m (1985)	Good reed growth after third season.	Brooke and Ash (1988)
	■ River Thurne - asphalt matting laid to grades bank of 1:4 slope.	£160/m (1985)	Difficulties establishing reeds below MHW. Floats used to prevent grazing by wildfowl.	
	■ River Bure, Upton Mill - Three dimensional plastic grid.	£220/m (1986)	Wash damage and loss of backfill experienced.	
	■ River Ant - asphalt matting laid to graded bank of 1:3 slope.	£105/m (1987)	Early signs of success.	

Location/Habitat	Brief Description	Cost	Success	Reference
Netherlands. Artificial seaweed.	Experiments using polypropylene fronds secured to a mattress and laid in 5-15m of water.		The artificial substrate accreted 0.35m of sediment within the first 3-4 weeks and retained this fill over four years. Fronds were especially successful in stabilising tidal gullies and inlet channels.	Carter (1988)
Oregon, USA. Clam flats.	Dredged material disposal site developed as commercial Clam Bed.		Habitat suitable for clams has been inadvertently produced by the disposal of dredged material.	Smith (1976a)
Florida, USA. Mangrove.	Three mangrove species have been naturally and artificially propagated on disturbed soils including dredged material.			Smith (1976a)
Essex, UK. Rock pools.	Rock pools built into groynes to provide positive contribution to the amenities of the coast. Proposal by local council, Clacton on Sea, Essex.		It is possible that there may be problems with sand-scour.	Marine Conservation Society (1988)
Suffolk, UK. Brackish Lagoons.	RSPB reserve, Havergate Island. Conversion of grazing marsh into brackish lagoons.		Created an exceptional habitat for breeding waders, wildfowl and terns.	Beardall et al (1988)

APPENDIX A3.5.3

REVIEW OF BRITISH HABITAT CREATION AND RESTORATION INITIATIVES

Table A3.5.3 Examples of British Habitat Creation or Restoration Initiatives by NRA Region.

Region: Anglian

Location and Habitat Type	Restoration (R) or Creation (C)	Details
Hamford Water *Saltmarsh*	R	Old Thames barges and pumped sediment have been used in an attempt to increase elevation to a level suitable for saltmarsh development.
Horsey Island, West Mersea, Ray Island, Deal Hall, Wallasea Island *Saltmarshes*	R	Various groynes, and fencing and channelling techniques have been used to encourage accretion and protect saltmarshes. Also some planting of cordgrass.
Levington Lagoon, River Orwell *Lagoon system*	C	Suffolk Wildlife Trust manage dredged material disposal site as a lagoon system, piping in fresh and salt water as required.
Sales Point; Dengie *Saltmarsh*	R	Construction of various types of groyne to encourage accretion and elevate the land to a level suitable for saltmarsh development. Use of old Thames barges (filled with mud and topped with aggregates) as breakwaters to reduce wave energy.
Shotley Marshes *Saltmarsh*	R	Suffolk Wildlife Trust built a series of chestnut stake and brushwood groynes to encourage accretion and therefore protect saltmarshes along 300m of coast.
Trimley, River Orwell *Freshwater lagoon system*	C	Suffolk Wildlife Trust created a 208 acre freshwater marsh and lagoon system behind a sea wall. Total cost £250,000.
Cleethorpes *Sand dunes*	R	Standard dune stabilisation including planting buckthorn.

Location and Habitat Type	Restoration (R) or Creation (C)	Details
South bank of Humber *Lagoons*	C	LTNC and others creating and managing lagoons as habitats for birds. Some successes. Some failures may be due to lack of appropriate food for waders. Difficulties achieving correct water levels.

Region: **North West**

Location and Habitat Type	Restoration (R) or Creation (C)	Details
Morecambe Bay *Saltmarsh*	R	Restoration was carried out following the removal of sea washed turf.
Piel Channel, Barrow *Saltmarsh*	R	Damaged saltmarsh was restored by turf transplants.
Pilling and Cockerham Marshes *Saltmarsh*	R	A new sea defence structure caused a decrease in salinity which threatened a resident natterjack toad population. NRA pumped sea water into the area to increase the salinity. This was not too effective and a more vigorous attempt is planned in the future.
Roosecoat Sands, Barrow Docks *Lagoon*	C	Aggregate was excavated to create a borrow pit which now forms a large, fully tidal marine lagoon.
Sandscale Haws, Duddon Estuary *Sand dunes*	R	Planting of dunes with marram.
Sefton Coast *Sand dunes*	R	Restoration by planting, fencing, etc.
South Walney *Lagoons*	C	Extraction of gravel was followed by a lagoon creation initiative by the Cumbrian Wildlife Trust.

Region: **Severn Trent**

Location and Habitat Type	Restoration (R) or Creation (C)	Details
Frampton Breakwater to Hock Ditch *Marsh; brackish wetland*	C (proposed)	Managed retreat back to secondary line of defence to create habitat for wildfowl.
Blacktoft Sands *Lagoons*	C	Lagoons, reedbeds, etc created outside main defence but inside training wall.

Region: **Southern**

Location and Habitat Type	Restoration (R) or Creation (C)	Details
Camber Sands *Sand dunes*	R	Chestnut paling windbreaks, planting and fertilising as part of a dune restoration project produced a very successful initiative.
East Head, Chichester Harbour *Sand dunes*	R	Brushwood fencing and trapping of windblown sand were successful until coast protection works reduced sediment supply.
Elmney *Wet meadows*	C	Managed flooding of existing meadowland aided by RSPB management agreement.
Farlington Marshes *Scrapes*	C	Naturalists Trust - water manipulation to create new pools using pre-18th century pattern of tidal creeks. Local Nature Reserve.
Newtown Harbour *Scrapes*	C	Naturalists Trust Scrape. Sunk into saltmarsh.
Normandy Marsh *Wetland*	C	Creation of wetland site where incursions into brackish lagoons occurred. Borrow pit habitats were provided as mitigation for engineering works.
Pagham Harbour *Shingle Island*	R	Rebuilding of Tern island using imported shingle.

Location and Habitat Type	Restoration (R) or Creation (C)	Details
Rye Harbour *Scrapes*	C	Wader pools/scrapes created using dredged material and then lined.
Thorney Deeps *Scrapes*	C	Scrape creation
Titchfield Haven *Scrapes*	C	Series of scrapes below MHWS; freshwater marsh habitat in dammed area.
West Solent *Shell beach*	R	Hampshire and IOW Naturalist Trust successfully rebuilt shell beach along front of Spartina marsh, using groyne system, to recreate Tern breeding area.

Region: **South West**

Location and Habitat Type	Restoration (R) or Creation (C)	Details
Penhale and Hayle Dunes *Sand dunes*	R	Bulldozing, netting and hydroseeding to stabilise the dunes as part of major rehabilitation programme.
Isles of Scilly	R	Stabilisation and rebuilding of boulder beaches breached in 1989/90 storms on St. Marys, Bryher and St. Agnes.

Region: **Welsh**

Location and Habitat Type	Restoration (R) or Creation (C)	Details
Burry Inlet *Scrapes*	C	Creating wetland scrapes at WWT reserve on saltings in front of sea defences.
Gwent Levels *Mudflats*	C (proposed)	Proposed barrage across Cardiff Bay will cause a loss of mudflats. By breaching a sea wall a small area of upper mudflat will be created on a grazing marsh by Cardiff Bay Development Corporation at an approximate cost of £5 million.
Gwent Levels, Rumney Great Wall *Saltmarsh*	R	Saltings in front of the seabank have had blockstone placed at the edge. In 1988 temporary fences were placed to reduce tidal action and encourage silt to settle on the foreshore, creating saltmarsh.
Newborough Warren, Morfa Harlech, Aberdovey, Dee, Oxwich. *Sand dunes*	R	Stabilisation of dunes at all sites has been assisted by NRA as dunes serve as natural sea defences.

Region: **Wessex**

Location and Habitat Type	Restoration (R) or Creation (C)	Details
Blakes Pools *Lagoons*	C	Creation of wetland/open water areas in former borrow pits by Avon Wildlife Trust.
Bridgwater Bay, Stert Peninsula *Lagoons and scrapes*	C	Creation of wetland scrapes, lagoons, etc by Avon Wildlife Trust.
South of Clevedon *Saltings*	R	Attempts at regenerating saltings following set back of flood defences, but problems possibly because too dry in summer.
Somerset Levels *Reedbeds*	C	Reedbed planting by Somerset Trust for Nature Conservation.

Region: **Yorkshire and Northumbria**

Location and Habitat Type	Restoration (R) or Creation (C)	Details
Beacon Ponds, Spurn Point *Lagoons and reedbeds*	C	Lagoons and reedbeds produced using sluices to control high tide flooding inside the sea wall, but problems achieving good water level control.
Hauxley *Tidal brackish wetlands*	C	Wildlife Trust using tidal sluices to manage former open-cast sites as controlled brackish water habitats.
Various sites in Northumbria *Sand dunes*	R	Dune stabilisation including brushwood and marram planting.

APPENDIX A4.3

MONETARY VALUATION TECHNIQUES

A.4.3 MONETARY VALUATION TECHNIQUES

A.1 Overview

Section 4 of the main report provided brief summaries of six economic valuation techniques which were identified as being most relevant to the assessment of retreat options. These were:-

- change in productivity;
- preventative expenditure and replacement costs;
- damage costs avoided;
- travel cost techniques;
- contingent valuation methods;
- energy analysis approaches.

Each of these techniques is reviewed in more detail below, including an overview of the basic approach, potential for valuation of retreat, past applications and advantages and disadvantages.

It should be noted that discussion of past applications often gives the values estimated by a particular study. All information on parameters relevant to these estimates are given where possible but, in many cases, references did not provide details of, for example, discount rates used and/or time horizon adopted for discounting. The values are presented here for illustrative purposes only.

A.2 Change in Productivity

A.2.1 The Approach

Where there is a market for the goods or services involved, estimates based on the value of changes in productivity can be used to derive values representing the benefits or costs of changes in environmental quality or resource availability.

The change in productivity approach is based on determining the physical impacts resulting from actions affecting the environment. Market prices are used to value the physical changes, with benefits equal to the value of increased output and costs equal to the value of decreased output. There are three basic steps to application of this method:-

- identification and prediction of potential direct and indirect productivity effects stemming from a proposed action;
- determination of the "correct" prices to be used; and
- estimation of the value of the changes in productivity, where this involves combining information on predicted physical effects and on prices.

Prediction of productivity effects resulting from a particular action can be carried out through research either in the field or in a laboratory or through the use of statistical regression techniques. Care must be taken to ensure that any changes in level of output predicted stem directly from the impacts on environmental quality or availability and that these are wholly attributable to the action in question.

It is also important that the predictions represent the marginal productivity of the wetland or habitat area. This is one of the greatest difficulties in applying this method. The effects of human effort must be separated from the effects on output due to changes in the quality or availability of the system. Separating these effects is complicated in practice as data is based on total effects as reflected by harvests or other such variables. Determining the effects of environmental changes can be further complicated by the highly interrelated nature of different aspects of wetland or coastal habitat systems. Failure to separate out the different effects, however, may result in over-estimation of the contribution of the wetland or different wetland characteristics to productivity.

The second step involves determining the prices, or values, to be attached to changes in output. As used above, the term "correct" prices refers to price levels where the impact of subsidies or any other factors which may have distorting effects are removed. Additionally, any changes which might take place in the market structure (i.e. changes in supply) as a result of the productivity changes need to be taken into account in the determination of "correct" prices.

A.2.2 Potential for Valuation of Retreat

With regard to the valuation of benefits stemming from habitat restoration or creation activities, this method could be used to value changes in agricultural productivity (including reeds, sedge and willow production), effects on fisheries and shell-fisheries and effects on any other dependent industries such as water supply. Estimates of productivity levels for different types of habitat could form the basis for predicting expected productivity for the various managed restoration or creation options. The gain in productivity under restoration/creation would then form the measure of benefit accruing from the managed retreat option.

However, the predicted gains must be gains that would actually be realised. In other words, gains in fish/shellfish productivity would have to be of benefit to fisherman for these values to be attributed validly to the restoration/creation works.

A.2.3 **Past Applications**

Studies have been undertaken in the US to determine the value of wetland areas to commercial fisheries. A study carried out by Batie and Wilson (as reported in Shabman and Batie, 1988) derived a value for Chesapeake Bay wetlands for oyster production. Regression analysis techniques were used to determine the relationship between oyster harvests and wetland acreage, controlling for other variables affecting harvests. The predicted contributions of wetland area to oyster harvests varied widely, with marginal productivity values per acre ranging from $11 to $1,400. Although the study represents a valid application, the results were affected by limited information on the relationship between wetlands and oyster harvests.

A number of other US efforts to estimate the economic value of biological productivity and other natural functions have resulted in per acre estimates exceeding a hundred thousand dollars (see Shabman and Batie, 1988). These estimates, however, generally have little validity in economic terms as they are not based on estimates of the value of the functions that the wetland actually provides, but on estimates of their capacity to provide certain functions if called for. Frequently, inappropriate prices have been used and the costs associated with providing the services have been neglected.

Within the UK, change in agricultural productivity was used as one component in the estimates of benefits related to the Aldeburgh Sea Defence Scheme (Turner et al., 1990). The impacts of potential flood damage of marsh areas and saline intrusion in terms of changes in crop yields were estimated for irrigated and non-irrigated crops. The difference between the pre and post breach gross margins was then used as the value of flood protection services.

A.2.4 **Advantages and Disadvantages**

The change in productivity method is useful for valuing changes in environmental quality or availability when the impacts are on goods and services for which markets exist. This means that only use-related benefits can be measured by this method and total economic benefits would therefore be under-estimated if only this method was relied on for valuation purposes.

It is, however, a straightforward method given that markets do exist and that prices can be adjusted to reflect "correct" prices. The resulting estimates may also be considered more reliable than those derived from other techniques which use surrogate or hypothetical market data.

The key limitation to the use of this method is that it necessitates good information on the relationship between environmental conditions and productivity. These relationships are rarely well established and making the link between cause and effect will require modelling work or the adoption of relationships developed in other studies. For example, the relationship between habitat characteristics and fish nursery potential is highly complicated and scientific uncertainty may make it difficult to determine how environmental changes would affect harvests.

A.3 Preventative Expenditure and Replacement Costs

A.3.1 The Approach

The preventative expenditure and replacement cost methods are related techniques for placing a value on a change in environmental quality or the loss of an environmental service.

The preventative (or defensive) expenditure approach is based on using actual expenditures incurred by individuals or a governmental body to determine the value or importance placed on a particular environmental good or service. In applying this approach, demand for environmental damage mitigation is viewed as a surrogate demand for environmental protection. That is, the willingness to accept the costs of mitigating adverse environmental effects is interpreted as the value of the benefits of a certain level of environmental quality.

The replacement costs approach is based on the principle that the work which would be incurred to restore the environment to its original state provides an estimate of the value of the environmental good or service threatened with damage or loss. Thus, through this approach, potential expenditures serve as a means of placing a value on previously unvalued functions (such as those provided by a wetland area).

Related to the replacement costs approach is the idea of mitigation works or shadow projects. A shadow project is one which compensates for the damages caused by a particular development by providing an environmental resource of equal or greater value. This may occur in a different location or even vary in nature from the damages caused. The costs of the "shadow project" can be used to place a minimum value on the damages caused.

A.3.2 Potential for Valuation of Managed Retreat

Within the valuation framework outlined in Section 4.3.3 of the main report, the preventative expenditure method could be used to provide "reference" values. Expenditure undertaken to prevent damage to existing coastal habitat areas could be used to provide estimates of the value of the areas protected. This site-specific data could then be used to develop estimates of value for different types of habitat areas. These values would provide second best estimates for restored or created wetland or habitat areas.

The replacement cost or "shadow project" approaches could also be used to place a value on restored/created habitats. In this case, the estimated costs of any management works would serve as the estimate of value; decision makers would then be left with using their own judgement as to whether or not the benefits gained would be greater than or equal to these costs.

However, the use of values generated through any of these techniques would have to be undertaken with care and treated very much as rough guides or second best only.

A.3.3 Past Applications

Several UK studies (such as that carried out for the Aldeburgh Sea Defence Scheme) have used payments made by MAFF to farmers under the Environmentally Sensitive Areas (ESA's) programme as measures of the value attached to low intensity versus high intensity agriculture. These payments represent a type of preventative expenditure.

The replacement costs approach has been used to value flood control and water quality enhancement functions and services. It also has been used to value the costs of replacing the groundwater recharge services provided by wetlands with other water supplies. There is considerable debate, however, about these applications as the relationship between wetlands and aquifers is uncertain.

One of the more widely quoted studies is that carried out by Gosselink (1974) into the water quality treatment capabilities of southeastern tidal marshes. This study argues that, due to the denitrification and nutrient removal capabilities of these marshes, they provide a form of natural tertiary treatment. The value of these services were estimated on the basis of the costs of replacing them with construction of a tertiary treatment facility. The estimated cost of such a facility was about $123,500 per hectare.

The replacement costs technique has also been used to value non-commercial species such as birds or rare fish. In estimates of the environmental damage resulting from an oil spill in Chesapeake Bay in the US, quotes were obtained from commercial breeders and biological firms to place a value on the costs of replacing lost birds. The average estimated cost was $30 per bird (Cohen, 1986).

Within the UK, the replacement costs approach was used as part of the cost-benefit analysis carried out for the Aldeburgh Sea Defence Scheme (Turner et al., 1990). Costs of purchasing and renovating a "replacement" Martello Tower were used as an estimate of the value of losses that would occur with a breach of the defences. Similarly, the costs of replacing yacht and sailing clubs with a new marina were used to value the loss of these facilities in the event of a breach.

The shadow project concept has been applied in the US to development of many wetland areas. For example, in the San Francisco Bay area, any development on wetlands must be compensated for by creation of wetland areas of a similar size and quality or by other environmental enhancement measures.

A.3.4 Advantages and Disadvantages

Preventative expenditure and replacement cost methods are straightforward and easily applied techniques, requiring data that is generally readily available. They are useful methods where the environmental change in question involves physical effects which are well perceived.

The preventative expenditure approach is based on the assumption of perfect substitutability of one good for another. If defensive expenditures are perfect substitutes for reductions in the level of pollution effects experienced, then an individual can effectively purchase the optimal amount of quality through defensive outlays. In practice though, perfect substitutability is rare. Thus, these expenditures form approximations of the minimum value to be placed on the good or service.

There are also likely to be several modes of averting behaviour and in many cases more than one mode will be used at a time. In these cases, the analyst must identify and measure the reductions in all modes if benefits are not to be underestimated.

Both the preventative expenditure and replacement cost methods provide lower limit estimates of benefits gained. Individuals will commit resources only if their subjective estimates of the benefits to be gained are at least as great as the costs. Observed expenditure therefore provides an indirect measure of the benefits as perceived by the individual. But because the willingness to incur costs is constrained by ability to pay, observed expenditures will be lower than levels that would otherwise occur.

Both methods also assume that the existing system is optimal. The question of the optimal level of environmental quality or services is not addressed by the preventative expenditure method; and current levels of expenditure may not be correct as they are based on incorrect subjective valuations of the benefits gained by the defensive measure. Similarly, the replacement costs method assumes that if the environmental good were removed or changed, then those currently benefitting from the good would replace all lost aspects. If beneficiaries were not willing to replace all aspects, then the values derived through this method would be greater than the benefits as indicated by willingness-to-pay. Conversely, if beneficiaries were willing to replace all aspects, then the value derived may be an underestimate of the true benefits.

Underlying both methods is the assumption that no secondary benefits are associated with the expenditures. If secondary benefits do arise, then these methods will over-estimate the value of the benefits provided by the environmental asset. For example, flood control works built to protect or maintain a given environmental habitat area (such as the Norfolk Broads) must not provide any other benefits for the costs of those works to be taken as the value of the habitat area protected. This will clearly not be the case in many instances as other benefits related to agriculture and recreation activities will also exist.

Finally, the replacement costs and shadow project methods both assume that re-creation of an environmental system is possible. As has been discussed in previous sections, however, this is a doubtful assumption when applied to wetland and coastal habitat creation as it may only be possible to partially recapture the value of goods and services provided by such natural areas.

A.4 Damage-Costs Avoided

A.4.1 The Approach

Related to the above methods is the use of damage-costs avoided as a measure of the value of a given function or service provided by a natural system. The concept underlying this approach is that the value of an environmental good or service is equal to the costs of damage to property or other assets which would occur if that good or service did not exist. The approach is most applicable to valuation of the physical functions and services of wetlands or habitat areas, where these provide benefits to individuals.

A.4.2 Potential for Valuation of Managed Retreat

This approach could be applied to valuation of flood protection or flood water storage, shoreline protection, erosion control and water quality enhancement benefits. It could be used to develop reference estimates for existing areas but, due to the site-specific nature of such estimates, they would be of limited reliability and validity when applied to managed retreat opportunities.

Development of values specific to enhancement and creation could also be undertaken using this approach. This would require prediction of the level of a particular function or service that would be provided by the enhanced or created service. The method would then provide an estimate of the benefits related to the creation activities (the "specific valuation" approach).

When using this approach, however, care should be taken to ensure that the value generated is not an over-estimate. For example, if the service or function could be provided by physical engineering works at lesser expense, then the costs of those works (the least-cost substitute) should be taken as the value of the environmental service, not the damage costs avoided.

A.4.3 Past Applications

There have been a number of past applications of this approach to the valuation of wetland functions and services. Most of these have been related to flood protection benefits. The approach has also been used to value the damage costs stemming from loss of water supplies resulting from the destruction of wetlands.

One of the better US illustrations of how this method has been used in the past, is given by work carried out using Corps of Engineers property damage estimates for different levels of flooding associated with wetland loss in the Charles River Basin in Massachusetts (Thibodeau and Ostro, 1981).

Using hydrologic data the Corps of Engineers predicted increased flooding levels given different levels of loss of the total wetland area. This information was combined with data on existing development and property values to predict the annual monetary loss given various amounts of reduction in wetland storage capacity. Under natural conditions (i.e. the existing situation) annual losses were calculated at about $467,000 rising to $3,193,000 with a 40% loss.

Thibodeau and Ostro extrapolated from this data to develop estimates of the losses that would occur if the entire wetland area were lost. Taking the Corps' estimates that the wetland provided 75% of the natural storage capacity of the basin, they predicted that total loss of the wetlands would produce expected annual flood damages of nearly $18 million, an increase of more than $17 million from the existing situation. On a per acre basis this equalled an annual average damage-costs avoided estimate of about $2,000. Discounted in perpetuity, the present value per acre was found to be $33,000 and this value was accepted as the flood control value of an acre of wetland in the basin.

Although this is one of the more valid applications of this method, concerns remain over the following assumptions. The extrapolation of damage costs assumes that property values in areas additional to those looked at by the Corps are similar to those considered in the Corps estimates. It also assumes that the 60% of wetland not considered in the hydrologic studies undertaken by the Corps provide the same services as the 40% initially considered. Finally, no discussion was given of the costs associated with the engineering works necessary to provide the same services.

A.4.4 Advantages and Disadvantages

The damage-costs avoided approach is a relatively easily applied method. It can only be applied, however, to cases where the "damage" can be valued in terms of market prices. Thus, if relied on as the only measure of benefit, the total benefits associated with the area are likely to be underestimated as non-use related benefits cannot be valued.

Most applications of the method involve consideration of systems where the protected area is heavily characterised by man-made structures or has high values related to agricultural productivity, etc. For example, wetland applications generally have associated with them highly developed downstream or upstream areas. If there were little man-made development or low value agricultural use, the values generated by this technique would be low, although this may be an appropriate valuation of the service provided.

A.5 Travel Cost Method

A.5.1 The Approach

The travel cost method places a value on an environmental good, generally related to recreational activities, by using the costs of consuming the service as a proxy for price. The approach is based on the concept that people spend time and money travelling to recreational sites and that these expenditures, or costs, can be treated as revealing the demand for the site. These costs are assumed to be equivalent to an overall entry price to the environmental good.

The travel cost method involves developing a demand function for the site in question, relating visitation rates to the costs of travel and/or entry price for the site. The method can be used to determine the value attached to recreational activities at a single site, or to determine how changes in environmental quality would affect demand and therefore the valuation placed on a given site.

The method assumes that recreation is a divisible good and that a set of individual demand functions can be developed for different sites where quantity (number of visits) is a function of prices, incomes, travel costs and other characteristics such as quality. The number of visits to a particular site will also depend on the attributes of competing sites; thus as quality changes at one site, demand will change for other sites. This change in demand provides the measure of benefits resulting from the change in quality.

The general procedure followed in applying the travel cost method can be summarised as follows (Freeman, 1979):

i. The area around the site or area in question is divided into contours of equal travel distance for the purpose of measuring travel costs to the site.

ii. Visitors are surveyed to determine their zones of origin and to gather data on journey times, direct travel expenses, and socio-economic characteristics (such as income, education, etc).

iii. Visitation rates are calculated for each zone. These may be expressed either as visits made by a given individual (visits per annum) or visits from a given zone (visits per capita).

iv. A demand function is developed for the site, relating visitation rates to the costs of travel. The costs of travel are assumed to form the "entry price" for the site. Regression analysis techniques are used to determine the relationship between visitation rates and travels costs, socio-economic characteristics, etc.

The functional relationship used in the regression analysis will take a form based on the following:

$$V_ij = f(P_j, D_i, C_i, t_i, h_i, Q, M_i)$$

Where:

V_ij	number of visits by individual i to site j
P_j	vector of entry fees to the various sites
D_i	vector of distances from residence of individual i to the various sites
C_i	unit travel cost of individual i
t_i	vector of travel times to the various sites for individual i
h_i	opportunity cost of travel time for individual i
Q	vector of services of the various sites (quality, etc)
M_i	money income of individual i

v. The results of the regression analysis provide the basis for developing a demand curve for visits to the site. Once the demand curve has been estimated the effect on demand of, say, raising the entry fee to the site, or of changes in quality can be determined. Through this process a second stage demand curve is developed which provides an estimate of consumer surplus.

vi. Dividing estimated consumer surplus by the number of visits to the site gives a figure for average consumer surplus per visit for those surveyed. By combining this figure with estimates for the total number of people visiting a site (in a given time period) an aggregate estimate of value, as measured by consumer surplus, can be calculated.

A.5.2 Potential for Valuation of Managed Retreat

In the valuation of habitat creation or restoration activities, the value attached to an existing site of similar characteristics could be used to provide a "reference value" for restored or created areas. For example, the type of approach adopted in recent work undertaken by the Forestry Commission could be used develop these values (see 5.3). The reliability of this would, however, be questionable as the method is site-specific and a number of assumptions would have to be made concerning key variables such as visitation rates and the quality and nature of the created habitat.

Theoretically, the travel cost method could also be used to derive a value for a restored or created resource such as those developed under a managed retreat option. In practice though, its use in this manner may not be feasible. It would require that the sites where creation or restoration works were to take place already receive visitors for whom demand functions could be developed. This may not always be the case. Even where it is the case, current demand levels may not provide a good indication of future demand if the restoration or creation activities are to provide considerable improvements in quality. Further, data on sites of similar quality to that predicted for the created habitat areas would have to be included in the regression analysis.

A.5.3 **Past Applications**

The travel cost method has been used extensively in the United States, with some studies valuing the recreational services (e.g. fishing, hunting, bird watching, photography, walking, etc.) provided by wetland or coastal habitats. One example of such an application is that carried out for wetland areas in Terrebone Parish, Louisiana. A survey of recreational users was undertaken to determine willingness to pay to preserve the areas for recreational use. Questionnaires were placed on all vehicles parked at twenty seven boat launch facilities at different times during the year, including both weekdays and weekends. Out of over 7,800 questionnaires placed in this manner, only 1,126 were returned for a response rate of just over 14%.

Seven concentric rings of 35 mile increments were then constructed around the area. The study found that use of the wetland areas was highly localised with 78% of respondents coming from ring 1 and 98% from rings 1 to 3 (this localised use may invalidate the results of this study, and the relatively low values found for habitat are attributed to this factor). Total costs of travel time for the typical user group were used to measure the value of the resource. These costs were estimated to be about $27 (1985 values) for the typical user group. Aggregating these over Terrebone Parish (zones 1 to 3), provided a value of about $6 per acre per year, or $46 when discounted at 8% in perpetuity.

Earlier US studies include those carried out by Kreutzwiser, and Miller and Hay (as reported in Shabman and Batie, 1988). Kreutzwiser calculated travel costs for Long Point Marsh on Lake Erie, where the wetland uses included nature viewing, photography, fishing, waterfowl hunting, canoeing and camping. The overall estimate of consumer surplus for the marsh was $191,361. Miller and Hay related hunter success to wetland acreage. Hunter participation was estimated as a function of habitat, socio-economic variables and travel costs. A 10% loss in waterfowl habitat was then assumed. Consumer surplus estimates of $29 per day of hunting were assumed, based on previous study results, and these were combined with the above model to calculate the average value for hunting at this site to be $82.00 per acre of habitat. This per acre value is unique to the assumption of a 10% loss in habitat.

Within the UK, no applications of the travel cost method to recreation services provided by wetland or coastal habitats have been documented. Use of the method has generally, been fairly limited but includes the valuation of nature reserves and forest recreation. A recent study carried out for the Forestry Commission (Benson and Willis, 1990) indicates, however, how the method can be used to derive an overall demand function for a given environmental asset.

Forestry Commission estate land was divided into fourteen clusters of districts, where lands incorporated into each district were considered to share common characteristics. A representative site was selected from each district and visitor surveys were carried out to produce estimates of recreational benefits. The results of these surveys ranged from £1.34 to £3.31 per site, with an average of £2 per person over all sites. District managers were then asked to provide "guesstimates" on the number of visitors and this data together with monitoring data were used to estimate total figures for each site. Site-specific results were then combined with the visitation rate estimates for all estate sites to develop a total value for open-access recreation. Total value was calculated at £53 million (1988 values) with an average value of £47 per hectare.

A.5.4 Advantages and Disadvantages

The main advantage of the travel cost method is that it relies on using observed behaviour. This gives the resulting values greater credibility than those derived from methods such as contingent valuation which depend on stated responses to hypothetical situations, or from indirect approaches based on engineering costs. It is a valuable approach at a site-specific level where areas are visited by a broad range of people specifically for recreational purposes and where adequate data on the characteristics of the area and the users are available.

On the negative side, data requirements for the travel cost method are considerable. Information is required on number of visitors, place of journey origin, duration of journey, direct travel expenses, value of travel time, socio-economic characteristics, and population for different zones. Where the aim is to predict how changes in quality would affect demand, information is also needed on the costs of travel to other substitute sites and on current site "quality" characteristics.

There are also a number of modelling and other assumptions which need to be considered when applying the method. A particular concern relates to the type of functional form to be adopted. Economic theory provides no guidance on whether the demand relationship should be linear, log-linear or take some other form, yet results may be sensitive to the form used. Further, care must be taken in comparing results of different applications as comparability will depend on the functional forms specified.

The travel cost method assumes that all users would get the same total benefit from use of the site and that the people in a given zone would make the same number of visits at given entry fee. There is no reflection of the quality of the recreation experience, unless congestion is specifically controlled for in the demand model. It is also assumed that people know how much enjoyment will be gained when deciding to take the trip.

In general, no recognition is made that travel to the site might form part of the benefits associated with the experience or that some trips may be multi-purpose. In the case of multi-purpose trips, assigning all the benefits to one site would result in an over-estimation as some of these benefits should be apportioned to other sites visited. This problem can be dealt with through either of two approaches. The first is to exclude multi-purpose users (known as "meanderers") from estimation of the visitation demand function and then to assume when calculating consumer surplus that these users value the site on average as highly as purposeful users. The second approach is to ask multi-purpose users to weight the relative importance or value of their trip to the site in question as compared to other sites.

There is considerable debate over what type of approach should be adopted for estimating the costs of distance travelled and the value of travel time. Some analysts base the costs of distance travelled only on fuel costs as these represent marginal costs. Others take the full costs of motoring including insurance, depreciation, etc as the basis. The difference in the estimates resulting from the two approaches could be significant. Similarly, in terms of the valuation of time, if individuals are giving up working time in order to visit a site, then the wage rate is the appropriate price as it represents opportunity cost. If recreation time is not at the expense of wage earnings, then this may not be the right value. In this case, the opportunity cost of other foregone activities might provide a more valid measure.

Determining how quality should be represented in the analysis can also pose analytical difficulties. The relationship between the recreational service provided and the change in habitat quality will have to be established. The units defined for measuring changes in quality should also be in a form that is easily understood by individuals using the site. Studies have shown wide discrepancies between objective expert measures of environmental quality and what users perceive and value. Given this problem, applying the method to gradations in quality may be complicated.

Statistical problems with the method stem from the fact that only data for visitors to the site are recorded. No information is provided on what determines whether an individual visits a site or not, nor on the entry fee at which visits would not occur.

Finally, the estimation of benefits relies on the concept of consumer surplus. This rules out direct comparability with valuation techniques such as contingent valuation which are based on the concept of willingness to pay. In studies where the travel cost method is complemented by methods such as contingent valuation, the travel cost estimates should provide upper limit indications of willingness to pay. On the other hand, the travel cost method also provides minimum estimates of benefits in the sense that it omits option and existence values, as well as any values attached to the good by those who never actually visit the site.

A.6 Contingent Valuation Method

A.6.1 The Approach

Contingent valuation methods (CVM) are direct approaches toward the valuation of environmental goods. The methods consist of asking individuals what they would be willing to pay (or willing to accept by way of compensation) for a specified change in quantity or quality of an environmental good or service. The contingent valuation approach is appealing because it can be applied to a wide range of environmental issues and in almost any context. It is the only valuation method which can be used to derive estimates for option, bequest and existence values.

The first step in the contingent valuation (or expressed preferences) approach is the establishment of a hypothetical market for the environmental good in question. A sample of individuals (taken to be representative of the population of concern) are then questioned to determine the amount they would be willing to pay (or accept). The hypothetical or contingent market used should be as close as possible to a real market and should include the good itself, the institutional setting for its provision and the financing instrument (taxes, local community charge, entrance fee, etc.) that would be used. The sample surveyed should be familiar with the good and with the financial instrument (also referred to as the payment vehicle). They should represent a range of views on the issue of concern. Thus, if across-the-board values are needed, the sample should not be confined to a local population or users of a particular good as the values derived from these groups may not be representative of social values.

In addition to information on what individuals would be willing to pay (or accept), the surveys must also collect data related to socio-economic characteristics. This includes information on income, education, etc. This socio-economic data helps check the reliability of survey responses.

Surveys can be carried out using either direct interview techniques or bidding games:

- **Direct interview techniques** involve asking people to state what they would be willing to pay for a change in quantity or quality of an environmental good. The respondent may be given a "starting point" relating to current expenditure levels on the good, expenditure required for protection of quantity or quality, or some other relevant form of expenditure. Direct survey techniques can be carried out either through personal interviews, postal surveys, or telephone surveys.

- **Bidding games** are much more complicated. These involve setting out the contingent market for the respondent and describing how quantity or quality would be changed. The interviewer then sets a starting point bid and asks the respondent whether he would be willing to pay that amount for a specified improvement in environmental quantity or quality. This process is repeated until the interviewer finds the respondent's maximum willingness to pay. Conversely, this approach can be used to find the minimum willingness to be compensated.

Bidding games must be carried out through personal interviews but can take a range of forms. The interviewer can vary the process described above by using a reference device to determine when a respondent is indifferent between two outcomes. Alternatively, a trade-off analysis approach can be taken which involves determining the trade-offs the respondent is willing to make between changes in the quantity/quality of the environmental good and some other good (such as a lump sum payment).

The results of the survey are then analysed to determine an average willingness to pay per person. These figures are extrapolated to calculate the total value of the good or service to the whole population. This analysis will include the use of statistical regression analysis techniques to test the reliability of the responses and to test for potential bias in the results.

Because of the hypothetical nature of contingent valuation surveys, there are a number of potential sources of bias which need to be recognised and taken into account in both the design and evaluation of the survey.

- **Design bias**: The amount and quality of information, or the sequence in which it is provided may influence an individual's response to the questions. Similarly there are a range of different financing instruments or payment vehicles which can be used in the survey (taxes, community charge, entrance fees, special fund). Individuals may be more sensitive to one type of payment vehicle (such as taxes) than another, and it may be important to include more than one type of vehicle in the surveys to tests for this problem. The last form of design bias relates to the use of a starting point bid, which may lower or raise the individual's response. Again this can be tested for by using two different starting points and comparing the resulting bid levels.

- **Hypothetical bias**: Individuals are not likely to be familiar with placing a monetary value on environmental goods and some may find it difficult (due to the artificial nature of the question) or be unable. Further, if individuals know that no real payment is involved they may respond in an irresponsible manner. Respondents should therefore believe that their answers will affect the environmental change in question.

- **Operational bias**: Operational bias stems from a lack of consistency between the hypothetical market and the market in which actual choices are made. It is important therefore that the market be established so as to be as realistic as possible.

- **Strategic bias**: This bias arises from what is known as the "free-rider" effect. It is difficult to exclude people from enjoying an environmental good, and if an individual believes that he will benefit regardless of his actions then he may not reveal his true willingness-to-pay.

A.6.2 **Potential for Valuation of Managed Retreat**

As noted above, contingent valuation methods provide the most flexible means of deriving economic values for non-priced goods. Values can be developed which represent the total value of environmental resources such as wetland habitats, where this includes both use and non-use benefits. Its potential for application to the problem of valuing retreat options which benefit nature conservation is, therefore, greater than is the potential for any of the other techniques. Contingent valuation could be used to derive "reference" values, but could more usefully be used to predict values for specific retreat options.

Application of CVM to the valuation of habitat creation benefits will require that considerable attention is paid to the design of the survey instrument to ensure, for example, that individuals are given a clear understanding of the difference between natural evolution and evolution following restoration or creation works. Studies carried out in Canada found that the method could be applied most reliably to wetlands which had been the subject of considerable press attention or which were well known due to proximity. There was also a general lack of public knowledge about the differences between the functions and services provided by different types of habitat, and these may have had significant effects on survey results (Bardecki, 1988).

Similarly, considerable thought will have to be given to the population to which the survey sample should apply. Should only local and non-local visitors from the area surrounding the site be included in the survey as these are the individuals most likely to make use of the created area for recreational and other purposes? Or is the issue one of creating national resources using national funds, in which case the sample should be representative of the general population?

A.6.3 **Past Applications**

There have been a number of applications of contingent valuation methods in the UK. These include valuation of forest recreation, river quality improvements, coastal and beach amenity, and habitat creation.

Studies undertaken by the Middlesex Polytechnic Flood Hazard Research Centre between 1987 and 1990 used contingent valuation methods to determine the recreation benefits of coast protection. In particular, the studies focused on beach protection as this was considered to form the "front line" defence of the coast. Two surveys were carried out in 1988 and 1989 covering eleven coastal sites in England, and 1300 beach and promenade users. The aim of these surveys was to determine the economic losses likely to be associated with the loss of recreation through beach erosion at a particular site. The results of the surveys indicate values attached to beach and recreational experiences ranging from £3.60 to £10.50 per person visit. The economic losses from beach erosion and hence a degradation of recreational experiences were estimated to be about £4.37 on average per person visit.

Contingent valuation was also applied to the valuation of recreation assets in the cost-benefit analysis of the Aldeburgh Sea Defence Scheme (Turner et al, 1990). In this study, visitors to the Aldeburgh Sea Wall and Orford Quay were surveyed. Efforts were made in the development of the survey questionnaire to reduce bias problems. For example, hypothetical bias was minimised through the provision of information on local sea defences, tax and rates contributions, and environmental assets in the area. Payment vehicle bias was reduced by using taxes as the payment mode and an iterative bidding approach was adopted to reduce starting point bias. Strategic bias problems were recognised as a potential problem, but were considered to have had minimal impact on the results.

From the survey, three categories of individuals were identified: locals; non-locals who viewed the site as providing unique benefits; and non-locals who felt that equivalent alternative sites existed. For the latter category, the loss of the wall and its environs would not result in an economic loss as they could visit alternative sites without loss of enjoyment. They would, however, have to travel further on average to reach these alternative sites, and the costs associated with this travel were estimated. This cost data was combined with average per person willingness to pay estimates for the first two categories and data on the number of group visits per category to estimate the overall value for the recreational benefits of maintaining the status quo situation (i.e. preventing major change).

Similar work has also been carried out for Thames Region NRA with the aim of valuing the habitat creation benefits associated with riverine flood defence works. The findings of this riverine study should be valuable to the development of the contingent valuation method to the valuation of coastal habitats.

A.6.4 Advantages and Disadvantages

The main advantages of contingent valuation methods are that they are based on deriving maximum willingness-to-pay (or willingness to be compensated) and are flexible. The other key advantage is that, unlike the other techniques, contingent valuation can be used to derive option, bequest and existence values.

The key disadvantage lies in the hypothetical nature of the survey instrument and the potential biases which might consequently be introduced into the analysis. These problems are, however, related to survey techniques in general and considerable effort is being put into finding methods of reducing them. If these problems are controlled for, the results of CVM studies should provide valid and reliable benefit estimates. Tests can be carried out using statistical techniques to check reliability and the results can be compared to those derived through other techniques (although this will only provide a weak indication of reliability due to differences in the concepts underlying the techniques).

A second disadvantage arises from the level of resources that may be required in these studies. These requirements will depend on the number of people to be surveyed and the survey method, whether through postal surveys, personal interviews, bidding games, etc. In general postal surveys will be less costly, but savings must be traded against not having an interviewer present to help respondents answer what may be difficult and complex questions.

There is also considerable debate caused by the asymmetry observed between willingness to pay and willingness to accept estimates. Economic theory indicates that an individual should be indifferent between these two measures, but past studies have indicated that responses differ, sometimes significantly.

Finally, the question of whether or not individuals think in terms of a total "environmental budget" has also been gaining importance with regard to contingent valuation methods. The environmental budget is that proportion of disposable income which an individual is willing to spend on environmental protection/conservation. Some researchers claim that when answering questions on willingness-to-pay, individuals' responses reflect not only the value they attach to the good in question, but to their environmental budget as a whole. This results in the over valuation of willingness to pay, and thus of benefits gained. The degree to which this is a problem is not known. Careful framing of surveys, including questions on membership of environmental groups, for example, may help control for this problem.

A.7 Energy Analysis Approach

A.7.1 The Approach

The energy analysis approach is based on the principle that there is a fixed relationship between the energy embodied in a product and its market price. The method looks at the total amount of energy captured by a system and uses this as an estimate of its potential to do useful work for the economy. Once the level of energy embodied in a system is determined, the energy measurement is translated into money terms using a conversion factor that relates money (in the form of prices) to energy.

For a wetland or coastal habitat system, the Gross Primary Productivity (GPP) of the ecosystem is used to provide an index of the energy captured by that system. GPP provides a measure of the solar energy that is used by plants in the system to fix carbon into organic molecules. This primary production forms the life support for all of the plants and animals in that system which, in turn, also regulate water flow, sedimentation, etc. GPP therefore provides a measure of the energy inputs to the ecosystem. The energy value related to GPP is then converted into money terms, which provides an estimate of the total value of the wetland or coastal habitat system.

At a simplified level, the steps involved in the approach can be described as follows (Costanza, 1988):

i. Either through field measurements or laboratory experiments, the GPP of the natural system is determined. In the case of habitat creation, this would involve determining GPP for both the existing system and the restored or created system. These estimates are generally produced in terms of carbon fixed or heat equivalent energy content of the carbon.

ii. The GPP measurements are then converted to fossil fuel equivalents on the basis of the fuel efficiency of the ecosystem as compared to other fossil fuel sources.

iii. The fossil fuel equivalent estimates are then converted into monetary values using an economy-wide ratio of economic value per unit of energy (i.e. the ratio of Gross National Product to total economy energy use, as measured in fossil fuel equivalents).

GPP is generally measured by an analysis of gas exchange which detects carbon dioxide concentrations in different plants (or oxygen for aquatic plants). The estimates are stated in grams of carbon or calories of plant biomass per unit area per unit time.

This measure is then converted into fossil fuel equivalents either by determining the amount of energy needed to upgrade biomass to fossil fuel (e.g. through biogas), or by considering the relevant number of calories of biomass that would have to be burned to produce the same amount of electricity as a given quantity of fossil fuel (e.g. oil or coal). Either method provides an indication of the "energy quality factor" of biomass relative to fossil fuel. An approximate average value is .05 Cal biomass/1.0 Cal fossil fuel, indicating that it is 20 times less energy productive than fossil fuel.

A.7.2 Past Applications

The energy analysis approach has been applied to a number of different wetland sites in the United States. One example is given by work carried out for Louisiana wetlands and aquatic habitats (Costanza, 1988). Table A.7.1 provides estimates of GPP and of the loss in value for conversions of wetlands from marsh to open water systems. In preparing these calculations the following assumptions were made: a conversion factor of 0.05 coal equivalent kcal/GPP kcal was used; and the economic value per unit of energy was assumed to be 15,000 coal equivalent kcal per US$ (1983). As there are 4,047 m2/acre, the estimated economic value per acre per year is:

$$(0.05 \times 4047)/15000 = 0.013.$$

As can be seen from Table A.7.1, the estimated economic value of losses incurred from the transformation of marsh to open water resources are $6,700 for salt marshes, $10,602 for brackish marshes, and $6,400 for fresh marshes. If the process were reversed, in other words the conversion was from an open water resource to marsh, these values would represent the benefits gained from the restoration or creation of the marsh areas.

Table A.7.1 GPP and Economic Value Estimates for Louisiana wetlands and marine habitats

Habitat Type	Gross Primary Production (kcal/m2/yr)	Annual Equivalent Value ($) ($/acre/yr)	Net Marsh to Aquatic Change in Annual Value ($/acre/yr)	Present Value at 8% Discount Rate ($/acre)
Salt Marsh	48,000	624		
Salt Aquatic	6,600	86	538	6,700
Brackish Marsh	70,300	914		
Brackish Aquatic	5,100	67	847	10,602
Fresh Marsh	48,500	630		
Fresh Aquatic	9,300	121	509	6,400

Updating the above figures to 1990 terms gives values of $8,800, $13,900 and $8,100 per acre for the three marsh types respectively. These results compare to those found in other studies carried out for Florida and the Gulf of Mexico (unsourced reference, updating work by Gosselink and Costanza). A general wetland value for Florida was found to be $209,100 (1990 values). The valuations for the Gulf of Mexico involved further work on salt marshes, brackish marshes and fresh marshes; the values estimated in this study were $10,000, $14,600 and $10,000 (in 1990 values) respectively for the different marshes.

A.7.3 Advantages and Disadvantages

With regard to the valuation of restoration or creation activities, the energy analysis approach could be applied to most proposals and would provide a means of valuing the enhanced or new habitat. Proponents of the method claim that it has advantages over other valuation techniques in that it provides a comprehensive valuation. Detailed listing of the specific functions and services being provided by a given area and the subsequent valuation of each of these is not required. It is not clear, however, whether this comprehensiveness applies only to use related benefits, or whether it is considered also to include non-use benefits.

The comprehensiveness of the approach may also result in an over-estimation of values, as not all of the functions and services provided (as measured by energy) may be either useful or valuable to society. Given this, the approach should be considered to provide an upper bound estimate of value.

A further problem with the approach is that, unless detailed analysis is carried out for each site, application of general GPP estimates will not account for inter-dependencies between habitat types, nor for differences in productivity within the same habitat type. All salt marsh, for example, is assumed to have the same GPP, regardless of site-specific conditions or the nature of adjoining land uses.

The strongest argument against the use of the embodied energy approach, however, concerns the derivation of the prices used to convert the measure of energy into a monetary value. The approach is based on the assumption that prices for all goods are tied to the amount of energy required to produce that good. Although there is undoubtedly some relationship between market prices and embodied energy, prices also reflect a number of other considerations. Thus, inputing a good's value on the basis of energy alone (or calorific value) will provide an incorrect valuation.

APPENDIX B1.1

POTENTIAL CASE STUDY SITES FOR FURTHER INVESTIGATION OF THE MANAGED RETREAT OPTION

Table B1.1 Potential Case Study Sites for further Managed Retreat Investigation, by NRA Region

Region: Anglian

AREA	NOTES
Foulton Hall Point/Dovercourt/adjacent areas	Managed retreat to high ground in an area currently used for agricultural production could be used to extend the area of saltmarsh. Land elevation and the possible need to maintain the sea wall in some form as a breakwater are likely to be critical issues.
Ray Pits Farm/adjacent areas	Generally a sheltered estuary site although some crosswalls may be needed to reduce exposure. Retreat may be possible along the stretch from Canewdon to South Fambridge but the implications of retreat for seawalls using refuse as infill should be fully considered.
Queens and/or Kings Marshes, Lower Deben	Existing agricultural habitat of no nature conservation interest, but area might present an opportunity to develop high level saltmarsh and associated habitats.
Benacre, NNR	Natural shingle wall protecting a brackish lagoon. Shingle ridge is breaching with increasing frequency and the implications of a retreat policy might therefore be investigated.
Norfolk Broads	Several self-contained flood compartments on the rivers Yare, Waveney, Bure, Ant and Thurne were identified as potential candidates for retreat by a recent University of East Anglia Study (Brooke and Turner, 1989). Marsh and/or reedbed habitat might be created and reversion to grazing marsh might be encouraged in other areas if flood defence standards are lowered.
Cley Bank	RSPB reserve currently protected by a managed shingle ridge. The implications of failure might be investigated.
Holkham Bay	Area of grazing marsh and arable land currently protected by a semi-natural sand dune. Retreat may allow saltmarsh or grazing marsh to develop.

AREA	NOTES
Winterton	A sand dune has grown up on top of seawall. Latter has recently been re-exposed, and the implications of a managed retreat could be investigated.
Winteringham Ings	Retreat could offer opportunities to develop borrow pits into intertidal lagoons and feeding areas.

Region: **North West**

AREA	NOTES
Ribble Estuary, SSSI Banks Marsh (south side) Freckleton Pool (north side)	Two embankments exist where a private landowner built an embankment seaward of the existing NRA defence. Loss of these embankments would give nature conservation benefits, but the land is of high agricultural value.
Pilling/Cockerham	Retreat would present an opportunity for the land to revert back to saltmarsh. The area used to be a tidal saltmarsh until it was enclosed by the Pilling-Cockerham sea defence embankment in 1981.

Region: Severn Trent

AREA	NOTES
Upper Humber/Lower Trent - Alkborough Flats - Whitton	Wetland bird habitat could be created to add to existing areas of mudflat, reedbed and associated habitats in the Upper Humber Estuary. Warping may be required to raise land levels and encourage transition from arable land through grazing to saltmarsh.
Morton Bend	Wetland habitat creation opportunities may exist within meander if bend is removed to ease navigation.
Broomfleet	Area owned by Associated British Ports could provide opportunity for setting back defence line and creating habitat on existing agricultural land.
Beckingham Marshes	Possible habitat creation (e.g. fresh/brackish marsh) on land owned by NRA. Defences must, however, be retained in some form to maintain flood storage function.
Frampton breakwater to Hock Ditch	Retreat project underway adjacent to Wildfowl and Wetlands Trust Reserve at Slimbridge. Negotiated arrangement involving NRA, landowner, WWT and NCC. Elsewhere in this area, however, defences are being maintained to protect geese feeding grounds.

Region: **Southern**

AREA	NOTES
Dungeness	Southern side of Dungeness promontory may be a candidate for retreat; a secondary tidal defence already exists over part of the length.
Isle of Grain	Island in the tidal area of the Thames estuary. The area floods every one in ten years and reversion from arable to grazing marsh could be encouraged.
East side of Newhaven, Seaford and Denton, Ouse Estuary	Area has an obvious cliff to retreat to near the tidemill. Area of shingle where retreat would have implications for geological interest. Saline intrusion could, however, affect the recharge to an aquifer used by the Mid-Sussex Water Co.
Bracklesham Bay	Could create an intertidal area whereby Selsey Bill would become an island again. A long cross wall would, however, need to be built.
Beaulieu Estate, Beaulieu Estuary (west side)	Past flooding on Gins Marsh estate has shown this to be a potential site for managed retreat. The wall is privately owned by the Beaulieu Estate, however, and is therefore not the NRA's responsibility.
Hayling Island	Opportunities for retreat and habitat restoration may exist in and around the Hayling Island area.
Thorneybrook	East side of Western Yar Estuary where the agricultural land regularly gets flooded by salt water anyway, may offer opportunities for habitat creation.

Region: South West

AREA	NOTES
River Camel	Much of this area is already of interest for birds. Also important saltmarsh habitat. NCC would be willing to allow bank failure and envisage significant nature conservation interest being developed. The area is in agricultural use with few properties, but is protected by private defences.
Exe Estuary	Large estuary embanked at the top at Exminster Marshes. Land on both sides of the estuary is owned by British Rail. The land between the railway and the embankments, now largely in agricultural use, but retains significant interest for wading birds.
River Clyst	Tributary of the River Exe. The NRA have responsibility for the banks which frequently overtop onto the agricultural land. The head of the estuary is tidal with some freshwater flooding. Retreat would provide significant opportunities for wetland/marsh habitat creation.
River Fal	At the top end of the estuary saltmarsh (with a full transition through to woodland) has developed over outwash from china clay pits. There may be scope for further habitat creation in the estuary, possibly using china clay waste as a substrate.
Isles of Scilly	Low lying coastal dune and boulder beach habitats of high nature conservation interest. Already suffering from storm damage and saltwater incursion. There is, however, a need to protect valuable farmland and water supply aquifiers.

N.B. Other possible case studies for further investigation of the benefits and disadvantages of the retreat option in the South West region might include sites on the Axe and Tamar Estuaries, at Marazion marsh (where some nature conservation agencies might wish to see the defences maintained to protect the existing freshwater habitat), and at Braunton Marshes behind an extensive dune system.

Region: **Wessex**

AREA	NOTES
Bridgwater Bay and Parrett Estuary	Opportunities may exist along this narrow estuary for retreating from the present line of defence to create wetland areas (e.g. at Pawlett Hams). The creation of high tide roosts might also be investigated as existing sites are likely to be affected by sea level rise.
Porlock Bay	Shingle ridge thinning and breaching with increasing regularity. Retreat options might include creation of brackish marsh, with reedbeds where there is strong freshwater influence. Control structures may be required to maintain water levels and prevent drying out at low tide.
Portishead and Gordano Valley	Existing National Nature Reserve may be under threat from development. Implications of retreat should be investigated alongside protection options.
Blue Anchor to Lilstock	Retreat may be a possibility in this area currently protected by a gabion wall built in the 1960s.

N.B. At other sites NRA (Wessex Region) are actively investigating options for setting embankments back up to 40m for engineering purposes (stability). Habitat creation and restoration could be/is being explored on these areas.

Region: **Welsh**

AREA	NOTES
Gwent Levels	Scope for retreat where the predominantly grazed agricultural land is backed by a railway line.
Newport - east side near Llanwern	The area east of the railway in the vicinity of the "new" Severn crossing offers retreat possibilities. Currently protected by sea defences, the agricultural land is under some development pressure but would present excellent habitat restoration/creation opportunities.
Pentwyn Pools	The NRA favour retreat in this area.

Region: **Yorkshire and Northumbria**

AREA	NOTES
Holy Island	Retreat and/or a reduced defence standard could lead to further beneficial habitat changes.
Kilnsea	Retreat to the old secondary defence line (Easington Bank) could give scope for development of grass marsh, reedbeds and saltings. Water level control would, however, be required.
Hauxley	Enhancement of former opencast sites at the rear of the dune system could produce significant nature conservation benefits.
Tees Estuary	Habitat creation may be possible on a site within the industrial part of the estuary which is zoned for development but not yet developed. A secondary line of defence does exist but the standard is unknown.
Sunk Island	Currently owned by the Crown Estate Commissioners, Sunk Island could provide valuable opportunities for mudflat/saltmarsh creation and restoration.
Druridge Bay/Hauxley	Bay area which would present a suitable area for retreat. However, the need to maintain the integrity of opencast operations in the hinterland would be a key consideration.
Northumbrian Dunes	In some areas, particularly where tidal flooding already takes place, habitats could be encouraged that are of greater conservation value than the existing rough grazing. Sluice gates could be installed at tidal water inlets to increase the extent and duration of inundation.