The Conservation of Nationally Important Marine Geoscience Sites: a feasibility study

Part 1: Reports A1 to A6

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Overview

The six reports A1 to A6 represent the fulfilment of the first stage of a feasibility study evaluating the value, and site selection methodology, of conserving offshore sites of geological and geomorphological interest. The feasibility study was undertaken by the Centre for Applied Marine Science, part of the School of Ocean Sciences, University of Wales Bangor on behalf of the Joint Nature Conservation Committee Contract Number F90-01-600. These six full reports follow the earlier preliminary report summarising the conclusions and recommendation contained herein. It should be noted, however, that in the case of Report A3 and Report A6, the conclusion and recommendations made in this final draft differ to those originally suggested in the preliminary document.

The marine environment around the United Kingdom is characterised by many geological and geomorphological features and dynamic processes not found above the level of low tide. Marine specific processes act to generate landforms for which little evidence exists terrestrially. In addition, geological structures and sediments exposed on land are continued offshore and show, in some cases different features, or established characteristics better, than their terrestrial counterparts. Importantly, the continental shelf around Britain has been witness to considerable changes in sea-level throughout the Quaternary period linked to glacially influenced changes in global marine water volumes. As such, much of the sedimentological and environmental evidence attesting to conditions during marine low-stands now lies within the subtidal zone. Given this range of geodiversity, and the great advances made by the current terrestrial Geological Conservation Review (GCR) in conserving Britain's Earth heritage, there is a clear case for a marine geoscience conservation programme to enable protection of important offshore sites now and in the future. Any such initiative will, however, be made difficult by the dispersed and fragmentary nature of marine geological datasets. If a conservation programme is to conserve a range of sites that are truly representative of the marine environment then there is a clear and pressing need for directed research to be conducted in support of such an initiative. Report A1 reviews the benefits of marine Earth science conservation and assesses what gains in knowledge could be achieved by instigating a marine geoscience conservation programme and which subject areas may benefit the most. It also assesses the amount of information available to support such an initiative.

Research is especially needed to determine the susceptibility of different sites to threats specific to the marine environment. Given the dynamic nature of the continental shelf, threats to site integrity can act to cause degradation remotely, perturbations to sediment transport pathways and wave-current dynamics resulting in site degradation at a distance from the damaging activity. This is especially the case where large scale seabed construction or sediment extraction is taking place. Report A2 analyses the potential threats facing marine Earth heritage sites in the context of site dependency on active marine processes and their susceptibility to far-field effects.

Existing coastal geomorphology GCR sites represent a special case in terms of their conservation value as, although they are defined as being above low-water, they are dependent to a considerable degree on process operating in the marine environment for their evolution and maintenance. In analysing the fifteen coastal geomorphology GCR sites within the Irish Sea Basin, is noted that those depositional features highly dependent on sediment supply from offshore or alongshore would derive the greatest potential benefit from possible GCR site boundary extension into the submarine environment. However only for a very few sites, even within those categories, does a sufficient case exist for such boundary extension as many sites suffer from a lack of data regarding sediment sources and their dependency on offshore oceanographic dynamics. Without sufficient data it is impossible to make an accurate assessment of the potential benefits of GCR site boundary extension subtidally. Especially in the case of complex dynamic assemblage sites where landforms currently conserved under the GCR represent purely the subaerial components of dynamic interlinked landform systems, there does exist a case for extending boundaries below low water to encompass the whole landform assemblage rather than just conserving part. Report A3 examines the case for coastal geomorphology site GCR boundary extension into the marine environment on site-by-site basis using the Irish Sea as an example.

If a programme of marine geoscience conservation is to be undertaken, it needs to be based on a well reasoned site selection rationale constructed around certain fundamental principles of Earth heritage conservation. In examining the existing principles and methodology of the Geological Conservation Review, it is considered that those existing principles and approaches broadly apply in a marine context with only little alteration. However, given the dynamic nature of the marine environment, the potential scale of some bedforms, their reliance on far-field processes and the tendency for complex interacting bedform systems to develop, a modified site classification scheme is proposed to that of the GCR. A "nested sites" approach is suggested accommodating individual sites of low dependency on processes operating in their environs, active sites highly dependent on processes operating in their environs, and larger dynamic systems or geotopes. Features are conserved either as spatially constrained first-order sites of high conservation status, or nested within larger second-order lower status conservation zones. It is considered that this approach is the most appropriate given the action of far-field threats, enabling truly representative conservation of the highly varied geodiversity found within our waters, whilst at the same time keeping the potential for conflict of interest to a minimum. It is also suggested that a numerical approach be integrated into site evaluation and selection. Such an approach would be more transparent and was favoured by many of the consultees, being considered less subjective and qualitative than the existing site selection methodology. Report A4 provides an assessment of the validity of applying the GCR criteria to selecting sites in the offshore area as well as recommending a rationale for site selection.

As stated, the lack and variability of suitable data in support of a marine geoscience conservation initiative is perhaps the greatest obstacle to the initiation of such a programme. In Report A5, however, an analysis of relevant data sources is conducted. A list of selected data sources including brief descriptions is included in Annex 2.

Based on the methodology recommended in Report A4, the existing GCR thematic blocks can broadly be applied to the marine environment. However, there exists a need for four new, marine specific, thematic blocks, these being regionally defined Marine Geomorphology blocks. In addition, several existing blocks (regional coastal geomorphology blocks, mass-movement, regional Quaternary blocks) require redefinition to include subtidal and marine aspects if they are to be applicable offshore. Report A6 provides an outline of the new thematic blocks and proposes modifications to existing ones.

Recommendations

Report A1:

Recommendation A1.1

Based on the benefits that a programme of marine geoscience conservation would bring, it is clear that there is both a need and a desire for such measures. Such a conservation programme would be a logical extension of terrestrial Earth heritage conservation schemes, representing a far wider range of geological and geomorphological phenomena than a purely terrestrial programme.

Recommendation A1.2

Any proposed conservation scheme would have to be concerned exclusively with Earth heritage and geodiversity. Any site selection rationale that evaluates sites on a combination of non-geoscience criteria would probably result in the omission of sites important purely for their Earth heritage value. However, any programme must also be able to form a component of a larger, more holistic, approach to marine habitat management necessary for the successful conservation of our seas for future generations.

Recommendation A1.3

Given the fundamental access problems posed by the remote and submarine nature of sites, any marine geoscience conservation programme must include approaches to overcome this in potentially new and novel ways not necessarily applicable terrestrially. Such approaches may include improved access to site data, documentation and sample materials in ways that would compensate for sites only being accessible to a small minority with sufficient research resources.

Recommendation A1.4

There exists an urgent need to increase dramatically public awareness in earth heritage and geodiversity. Nowhere is this more apparent than in the offshore environment where public awareness of marine habitats has increased but knowledge and understanding of the nature and value of offshore geology and processes is markedly lacking. Any marine geoscience conservation programme must include, as a fundamental component, wide ranging initiatives to increase public awareness of marine Earth heritage.

Recommendation A1.5

An active programme of research into marine geology and geomorphology in support of any site selection rationale is required if a conservation programme is to represent sufficiently the diversity of features, deposits and processes in the marine environment. Given the spatial variability in existing data, such a research programme is necessary both to identify potential features for inclusion and to assess their value as conservation sites. This active research programme should form a fundamental part of a conservation scheme.

Report A2:

Recommendation A2.1

The evaluation of potential threats must be conducted on a site-by-site basis rather than applying a generic approach to threat assessment. In the case of soft sediment integrity sites, especially active ones, close attention must be paid to threats to the sediment and water dynamics on which those sites are critically dependent. For this to be successful, it is envisaged that this will require modelling of sediment supply and hydrodynamics and the response of bedforms or bedform fields to changes in those parameters.

Recommendation A2.2

It is essential that in order to reduce the potential for any conflict of interests, any programme of marine geoscience conservation must be conducted in close partnership with other continental shelf users. Close cooperation and continual consultation is especially important with those stakeholders whose activities may represent potential threats to site integrity. Consultation with industry organisations, such as the British Marine Aggregate Producers Association, the International Cable Protection Committee, the United Kingdom Offshore Operators Association and the British Wind Energy Association, along with licensing authorities and statutory bodies would be essential.

Recommendation A2.3

A framework for international cooperation needs to be investigated to enable the realistic conservation of sites within the UKCS dependent upon processes operative outside UK jurisdiction. Such a management approach may be available through the European Union or may require agreements with individual nation states.

Report A3:

Recommendation A3.1

For a limited number of Irish Sea GCR coastal geomorphology sites, there appears sufficient justification for the extension of existing site boundaries into the subtidal environment, these sites being:

- Ainsdale, Merseyside
- Ynyslas, Ceredigion
- Newborough Warren, Ynys Môn
- Morfa Dinlle, Gwynedd

Broader categories that contain sites that could potentially benefit from boundary extension are:

- Sandy Beaches & Coastal Dunes
- Sand Spits & Tombolos
- Complex Coastal Assemblages

Recommendation A3.2

For the remainder of Irish Sea GCR coastal geomorphology sites where it is demonstrably of little benefit to extend existing GCR site boundaries into the subtidal environment, or where a current lack of instrumental and modelling data available for sites makes a valid assessment of such benefits impossible, offshore threat mitigation and conservation would be better accommodated as part of integrated coastal and estuarine management programmes.

Recommendation A3.4

In the case of complex landform systems that span both marine, intertidal and terrestrial environments (such as spits, bars and barrier islands) there does exist a strong case for boundary extension to include the submarine extension of those features and processes integral to that landform/bedform system. For sites selected to illustrate the operation of physical processes, the exclusion of their submarine components seems unjustified.

Recommendation A3.5

The desire to extend existing subaerial coastal geomorphology GCR sites, where justified, into the submarine environment is greatly hindered by a lack of instrumental and numerical modelling data. In order to implement effectively a marine boundary extension initiative, further research into the vast majority of sites must be taken if accurate assessments of the benefits of boundary extension are to be made and new submarine site boundaries delineated.

Recommendation A3.6

It is recognised that the above conclusions apply only to sites on the Irish Sea coast. Coastal geomorphological sites outside this region should also be reviewed on a site by site basis.

Report A4:

Recommendation A4.1

A site selection rationale based on a two-tier nested conservation zone approach and using the existing GCR criteria as its basis represents the most inclusive approach to marine geoscience site conservation. 1st order conservation zones equivalent to existing GCR SSSIs would recognise individual features or bedform fields. 2nd order conservation zones of a less prescriptive nature would cover the territory adjacent to protected sites where deemed necessary to maintain far-field processes critical for site integrity.

Recommendation A4.2

1st order conservation area boundaries will largely conform to the spatial limits of features in question using criteria currently employed for delineating terrestrial sites. 2nd order conservation area boundaries will require, in most cases, further research to define the extent and coverage of processes and sediment transport pathways that are critical for the maintaining the integrity of features within first-order zones. Furthermore, 2nd order conservation areas will also be used to define geotope system, not necessarily centred on core 1st order sites.

Recommendation A4.3

The GCR criteria will be equally effective in selecting areas for conservation at geotope scales as well as at the individual site level. However, individual sites and geotope systems must be assessed separately, selection being based on two separate but similar, parallel and interlinked selection rationales, one for individual sites, one for site assemblages or geotopes.

Recommendation A4.4

Numerically grading sites according to site selection criteria would be desirable to improve the transparency and objectivity of the site selection process. Grading would take place at the level of the GCR thematic block or network, the highest scoring sites being conserved. Sites could change their grade value over time due to new research, site degradation etc. Grading would work on a site by site basis but also at the geotope level. Geotopes and individual sites would have to be graded separately.

Report A5:

Recommendation A5.1

Any programme of marine geoscience conservation must be developed in parallel with, or be preceded by, an in-depth and wide ranging data compilation exercise, Given the fragmentary nature of much of the data necessary to support a conservation programme such a study would be a significant undertaking beyond the scope of this report.

Recommendation A5.2

Access to certain important data-sets will probably take the form of commercial transactions between data curators (BGS, DTI, Hydrographic Office, hydrocarbon companies). Where such data is essential for the support of a robust conservation programme such commercial data should be procured.

Recommendation A5.3

Access to, and use of, the BGS offshore geological and geomorphological database currently being prepared by the Geophysics & Marine Geoscience group at BGS Murchison House, Edinburgh should be sought as a matter of priority.

Report A6:

Recommendation A6.1

Given the fundamentally different range of geological elements and geomorphological features and processes encountered in the marine environment, there is a need for new thematic blocks within the existing GCR geomorphology category, these being:

- Marine Geomorphology of the North Sea
- Marine Geomorphology of the English Channel & Celtic Sea
- Marine Geomorphology of the Irish Sea
- Marine Geomorphology of the Hebrides Shelf & Rockall Area

Marine geology sites should be those not forming subtidal elements of coastal systems and thus not being considered under redefined coastal geomorphology blocks.

Recommendation A6.2

The geographically defined Quaternary blocks should be extended to include the marine areas of the UKCS adjacent to, and extending from, them. The exact geographical delineation between blocks should be based on the Quaternary history of those regions in order to maintain coherency.

Recommendation A6.3

The definition of the three coastal geomorphology GCR blocks needs to be expanded to include elements of coastal systems currently below low water.

Recommendation A6.4

The definition of the mass-movement GCR block needs to be broadened to include submarine mass-movement processes and landforms of the shelf edge and continental slope.

Recommendation A6.5

Geotope areas should be subdivided into environmental/genetic categories for ease of intercomparison. Five provisional categories are suggested: Estuarine, Longshore, Island Archipelago, Tidal Strait, and Shelf Slope systems.

Recommendation A6.6

The forthcoming BGS catalogue of UKCS marine geological and geomorphological features, if accessible by the JNCC, could form the basis of a site categorisation hierarchy

Report A1 The value of conserving marine geoscience sites

A1.1 Introduction

The territorial waters of the United Kingdom, from mean low water to the outward limit of the United Kingdom Continental Shelf (UKCS) as defined under section 1(7) of the Continental Shelf Act 1964 (including additions up to 2001), occupy around 985,180 km^2 of sea floor (Figure A1.1), ranging in depth from shallow subtidal continental shelf environments of a few metres, to deep oceanic abyssal plain in excess of 3,000m water depth. Comparing this to the UK terrestrial environment (including Northern Ireland), covering 244,820 km^2 with a vertical range from sea-level to 1,344m, it becomes apparent that the marine realm represents a markedly larger, and altitudinally more varied zone than that currently above sea-level.

This subtidal territory is also characterised by large scale marine geomorphological processes active throughout the UKCS leading to the evolution and maintenance of geomorphic features from the micro to the mega scale and active sedimentary bodies not found in the terrestrial environment. Given the scale and breadth of the Northwest European continental shelf, much of which falls within UK territorial waters, processes and active bedforms occurring on the shelf represent some of the best examples in the world, and in some cases, are unique. Also included within the UKCS are areas of continental slope and rise where sediment transfer from the shelf to the deep ocean results in characteristic classic suites of sedimentary and erosive features.

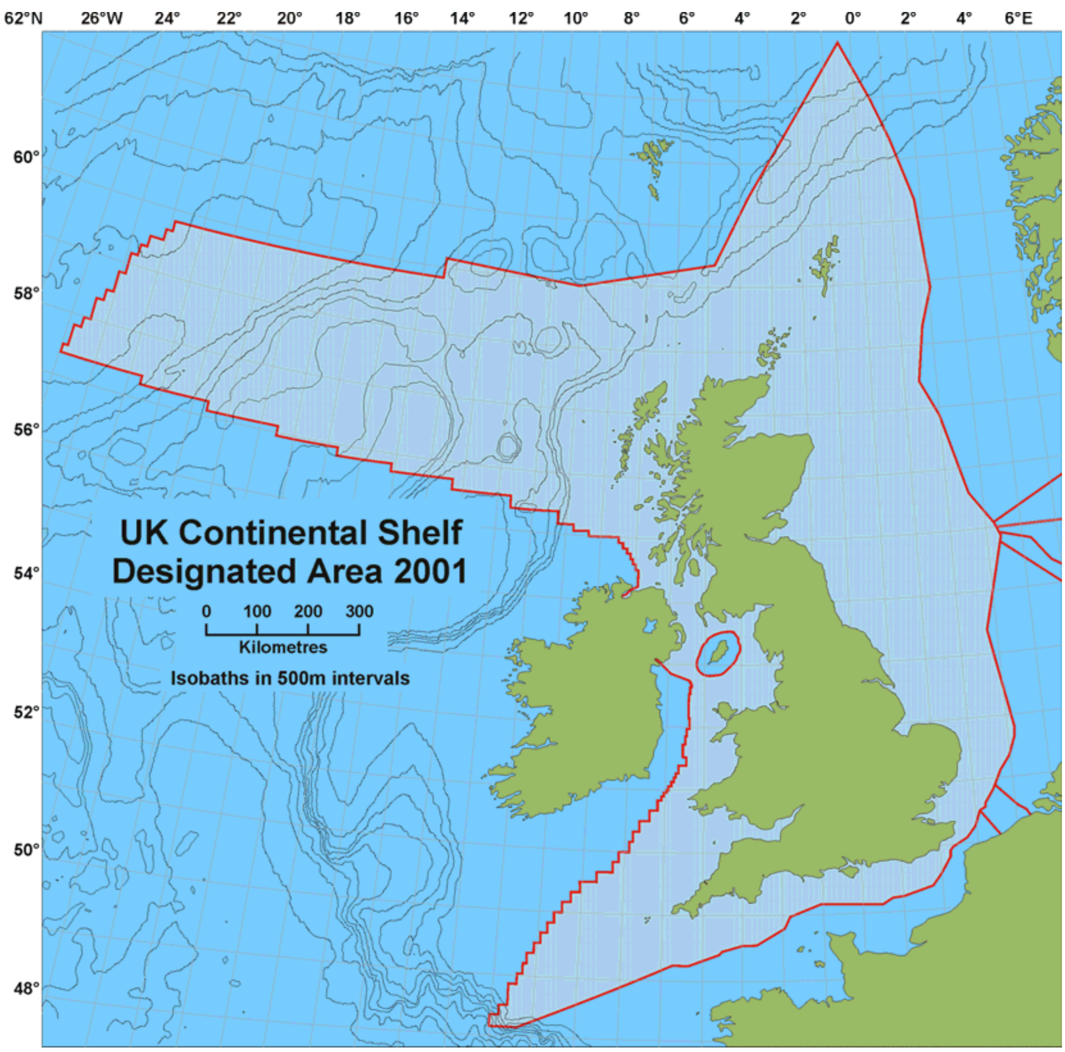


Figure A1.1 *Offshore bathymetry of the UK Continental Shelf. Bathymetric data supplied by Online Map Creation (http://www.aquarius.geomar.de/omc/omc_intro.html)*

Furthermore, the continental shelf (of which much of the UKCS occupies) has been witness to marked and repeated large scale environmental changes throughout the Cenozoic with phases of subaerial exposure and inundation linked to eustatic changes in global sea-level caused by the advance and retreat of northern hemisphere ice-sheets (Lowe & Walker, 1997). As such, the Northwest European continental shelf bears the signatures of past cycles of environmental change in the form of relict landforms and sediment bodies relating to periods of subaerial exposure, ice-advance, deglaciation and marine inundation. Often such features occur at scales larger than those preserved in the modern subaerial environment, and, under favourable conditions, sedimentary sequences are more continuous and complete than their terrestrial counterparts.

Also present within the UKCS are outcrops of lithologies not currently exposed above modern sea-level (Figure A1.2), along with geological structures and lithologies that whilst occurring subaerially, may be better represented in the marine environment.

As such, the marine environment around the United Kingdom is one characterised by important and active geomorphological processes not found within the terrestrial environment. It has been shaped by dramatic environmental changes, in places, more so than the terrestrial landmass. It also represents an area more extensive than the subaerially exposed UK with the outcrops of lithologies and geological structures not exposed on land.

In researching this report a broad range of groups and individuals with potential interests in such a marine geoscience conservation programme were consulted along with those

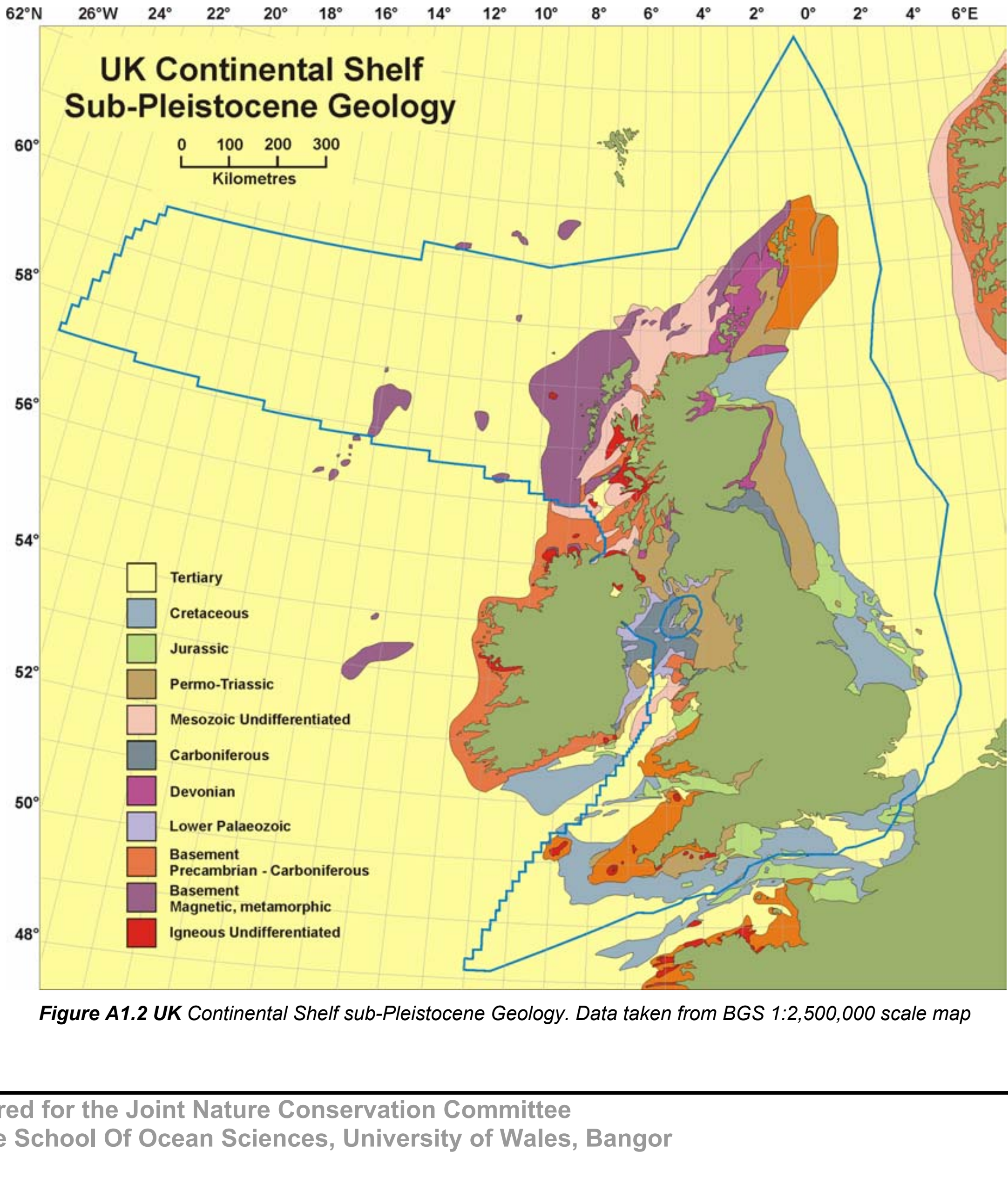


***Figure A1.2 UK** Continental Shelf sub-Pleistocene Geology. Data taken from BGS 1:2,500,000 scale map* specialists within the marine geosciences community whose particular fields of research would provide valuable contributions to the width and depth of this feasibility study. Such groups include university research departments, geological surveys, government agencies and statutory authorities, commercial organisations and academic societies. A full list of consultees is included in Annex 1.

A1.2 Key Benefits

The broad justifications for conserving earth sciences sites are the same for the marine environment as they are for sites on dry land. The premise that we need to preserve our Earth heritage for future generations (NCC, 1984,1990, Pearce, 1989, Wilson *et al*., 1994) and in doing so maintain the resources necessary for continued and future research (Allen *et al*., 1989) applies beneath the waves as much as it does terrestrially.

However, features and processes operative in the marine environment suffer from the problem of accessibility requiring a large infrastructure and budget to study and research them. Bedforms and outcrops are rarely directly accessible except by diving and submersible. More often remote sampling and imaging techniques are used such as coring, dredging, ROVs, sonar and seismic surveys. The result is that the user community is restricted to those with the infrastructure and budget large enough to undertake research into, or exploitation of, these resources, and so forms a markedly smaller group compared to those who consider themselves stakeholders in terrestrial geology and geomorphology.

Users of marine geoscience conservation sites fall into two of the five principal categories outlined by the former Nature Conservancy Council (NCC, 1990):

- professional researchers and Earth scientists in industry
- students and staff in higher and further education

Generally excluded from marine geoscience sites by the problems of accessibility are users in the remaining three NCC (1990) categories:

- school pupils and teachers
- amateur groups and collectors
- members of the general public

Despite these problems, the six themes outlined by Ellis *et al.* (1996) regarding the heritage value of sites and their need for conservation are still applicable, albeit with some qualifications. The six topics being:

- the international significance of Earth heritage sites
- exceptional Earth Heritage sites
- Earth science research
- environmental forecasting
- Earth heritage sites in education and training
- Earth heritage as a cultural and ecological resource

Each of these six themes will be addressed with reference to the marine environment.

A1.2.1 International significance of marine geoscience sites

Whilst many of the early great advances in geological thinking were made based on the study of British terrestrial sites, the study of the geology of the surrounding seas has, never the less, added significantly to geological understanding. Especially in terms of the active and relict geomorphological features found across the shelf and on the continental slope, there are many sites that could be considered of international importance. Some sites constitute the underwater extension of classic, internationally important, intertidal features such as the gravel beach of Chesil Beach, the cuspate foreland of Dungeness and the Spurn Head spit system at the mouth of the Humber.

Other active features include those of international importance that are not the extension of intertidal sites such as the fields of gas pockmarks and cold seeps in the North Sea.

Further features are relict such as Sarn Badrig, Sarn Cynfelyn and Sarn y Bwlch extending out from the coast in Cardigan Bay, these features representing medial moraines formed between piedmont ice lobes extending from the Cambrian Mountains during the last glacial period.

A1.2.2 Exceptional marine geoscience sites

The diverse geology and bedforms found in the seas around the UK include many sites of national or international importance due to their exceptional nature. Some sites may represent more commonly occurring features such as Nash Bank, a banner bank in the Bristol Channel that is a classic example of its type and has been studied in much detail (Stride, 1982; Stride & Belderson, 1990). Whilst such features may be relatively common, this site is considered an exceptional example.

Other sites may be exceptional due to their unique nature. Haig Fras, a sea-mount on the shelf some 120km west-northwest of the Isles of Scilly is a unique example of a drowned granite landscape. Sidescan sonar and submarine photography reveal evidence of a glacially scoured and possibly wave cut platform on its flanks with a suite of classic subaerial granite tor features forming the multiple summits of this bathymetric high now some 30-70m below sea-level. Furthermore, the granite itself is markedly different in age and mineralogy to that of Lands End and the Isles of Scilly with which it is commonly associated.

Both classes of site are exceptional for different reasons, representing rare and irreplaceable constituents of global Earth heritage. Unique and exceptional sites of this nature, when presented with possible threats to their integrity would benefit greatly from conservation measures.

A1.2.3 Marine Earth science research

When compared with the terrestrial United Kingdom, the geology of, and geomorphological processes operative in, our marine environment have been subjected to far less research than their counterparts on land, primarily due to their submerged and inaccessible nature.

Because of this, there exists wide scope for further research, especially in the understanding of dynamic systems across the shelf and the transfer of sediment over the shelf edge. Furthermore, an increased understanding of the geology and geomorphology of the offshore zone is essential if the history of the insularity of the British Isles from the rest of Europe and its consequences for the development and evolution of British flora and fauna is to be advanced (Preece, 1995).

Continued research based on relatively undisturbed sites also has economic implications. The implementation of deep-water hydrocarbon extraction technologies and the exploitation of gas hydrate deposits requires an understanding of the geology and geomorphology of the shelf and slope based on the study of previously pristine sites especially given the potentially unstable nature of parts of the deeper continental shelf and slope. The continued development of new and innovative techniques, technologies and ideas in both industry and academia is critically dependent on the existence of, and access to, a resource of marine Earth science sites.

A1.2.4 Environmental forecasting

The marine environment represents a vital resource for understanding past and present environmental change. Due to the high magnitude changes in sea-level during the last glaciation (as much as 120m lower 18,000 years ago (Fairbanks, 1989)) the continental shelf and slope of the UK posses both landforms and sediments relating to periods of subaerial exposure and/or shallowing conditions. Evidence for extensive glaciation across the shelf is also present along with now flooded river channels and lake beds that were formally found in this drowned landscape. Like those found within the intertidal zone, submerged forests and peats outcrop subtidally, again testifying to former lower sea-levels.

These sediments and landforms can provide a record of both long and short term environmental change, their study generating the baseline data with which to assess the rate and magnitude of modern climatic and environmental variability and the influence of anthropogenic disturbance within these cycles.

A1.2.5 Marine geoscience sites in training and education

Whilst the geosciences represent a substantial and important component of the National Science Curriculum between the ages of 5 and 16, opportunities for field studies, which form an integral part of many course, are severely limited by the obvious physical problems of directly accessing marine sites. Schools have formed the largest single user of terrestrial Geological Conservation Review (GCR) sites (NCC, 1990), this fact being a major justification for the conservation of sites, but this group is likely to be excluded from directly visiting marine sites due to their remote and inaccessible nature.

Fieldwork forms an essential component of any Earth sciences based university degree course with students being almost entirely dependent upon currently protected and conserved terrestrial geoscience sites for their training in field techniques (NCC, 1990). To varying degrees, any Earth science subject is field based and so requires access to such sites for students to gain the hands-on practical experience necessary. In addition, many of those students go on to use those skills gained in the field professionally in industry and academia. However, the majority of universities do not have the resources or finances available to include field study of marine sites as part of their graduate and masters courses. Whilst geoscience subjects are widely taught in UK universities, the number offering curricula with a dominantly marine component (e.g. marine geology, geophysics, physical oceanography) is very small, restricted to institutions with the infrastructure to provide a viable field component. Currently around four universities offer marine based geoscience courses, a number which is likely to increase (statistics from UCAS website).

Clearly the benefit to schools, colleges and universities of conserving marine geoscience sites is markedly less than the conservation of terrestrial sites due to the noted problems of access. However, whilst access may be restricted by the remote nature of such sites and the large infrastructure required to work at these localities, the study of data derived from them, even if the site has not been visited by those pupils or students, forms a vital component of their education. Be it in the form of access to archived sediments and core materials, the use and manipulation of geophysical and sedimentological data, or the use of such sites, based on research carried out by others, as teaching examples, the conservation of marine geoscience sites would have a direct and important benefit to the teaching of Earth science subjects at all levels.

A1.2.6 Marine Earth heritage as a cultural resource

Many amateur groups and collectors use and visit terrestrial Earth science sites either as leisure time activities or as part of research and education. However few, if any, outside industry or academia have the opportunity to visit important marine localities. Such users depend heavily on terrestrial geoscience sites (NCC, 1990), their activities contributing to research and education as well as forming an important leisure industry. However, they are largely excluded from the offshore environment due to the inherent access difficulties.

Many marine sites may also be of archæological interest, and whilst suffering from the same problems of access as the geology, would be of value above and beyond their Earth heritage content. Such archæology would include shipwreck locations, important for their historic and archæological value but also as potential marine and war grave sites. In addition, there is potential for considerable interface between the geoscience and archæological communities in regard to the conservation and study of Holocene deposits that could contain archæologically significant remains. The occurrence of artefacts and structures (such as "Sea Henge" on the coast of East Anglia) in mid-Holocene intertidal peats and the documented recovery of archæological remains from trawls over the subtidal peats of Dogger Bank (Long *et al.*, 1988) strongly suggests that many less well studied Holocene deposits now in the subtidal environment may be of archæological significance. Even without archæological finds, data from such sediments can provide the vitally needed environmental contexts within which to understand archæological and historical activities in the vicinity.

For the general public at large however, the opinion of many concerned with marine geoscience research and conservation is that the marine environment suffers from the problem of being "out of sight, out of mind". Whilst the terrestrial landscape of the British Isles, controlled largely by the geological and geomorphological features within and beneath it, has been the subject of song, poetry and prose throughout the ages, being a source of regional and national identity that has engraved itself upon the national consciousness, the bathymetry of the waters around these islands has, for the most part, been an object of myth and superstition, if it has been acknowledged at all. Man's relationship with the offshore zone has been more concerned about the sea and what is in it rather than what its bottom looks like.

The problems of access, both directly to sites and to information regarding them, is at its most acute when examining potential benefits to members of the general public. User communities outside industry, academia and special interest groups are very small. Recreational diving and amateur fishing are perhaps the main leisure time uses of shallower water sites of geological interest, and, especially in the case of diving, could see significant benefits from their conservation. However, whereas terrestrial sites are in general open to the public and complemented by geological trails, site information boards, visitor and field centres, museums, show caves and mines, such infrastructure and activities would be financially prohibitive and cater to only a small number of potential users in the marine environment. The greatest challenge lies in overcoming such problems of remoteness and bringing the value of marine sites as an important cultural aspect of Earth heritage to a general public that has only basic knowledge of, or places little cultural value on, the geology and geomorphology of the offshore zone. The conservation of marine geoscience sites may offer such an initial opportunity.

A1.2.7 Marine Earth heritage as an ecological resource

The use of substrate as an indicator of ecosystem structure is common practice in marine ecology where such habitats cannot be directly sampled. Substrate can be used as a guide to species assemblage composition as a means of highlighting key communities for conservation. Such an approach is based on the fundamental interrelationships between geology, geomorphology and ecosystem where maintaining the integrity of the substrate and the existing hydrodynamic and sediment regimes goes a long way to conserve the ecological community which has developed upon it.

The conservation of marine Earth heritage sites would thus have significant ecological benefits for the marine life inhabiting those localities. The limitation of activities threatening the geological and geomorphological integrity of sites would, especially in regard to benthic habitats, directly benefit marine ecosystems resulting in less anthropogenic disturbance, mechanical damage, resuspension of sediment and overall habitat degradation.

It is likely that a large number of key geoscience sites will also fall within the boundaries of sites important for marine ecology and biodiversity such as many of the terrestrial Sites of Special Scientific Interest (SSSIs) encompass both GCR and biological Nature Conservation Review (NCR) sites. However marine geoscience sites, whilst in nearly all cases benefiting marine benthic communities, may not always correspond with important habitats. Separate and distinct, but mutually complementary, programmes of marine geoscience and ecology conservation would be required if the full benefits to both are to be felt.

A.1.2.8 Summary

The conservation of marine geoscience sites would have benefits both for those involved in the marine geosciences themselves and for others in the broader user community. However, due to the inherent problems of accessing remote and submerged features, the benefits of conservation would be felt to the greatest extent by those involved in research be that within the industrial or university sector. Those without the necessary infrastructure and/or funds to access those sites such as schools, amateur groups and the general public would benefit less.

Groups, activities or sites receiving major benefits include:

- internationally important sites
  - stratotype sites
  - sites important in the development of key theories
- exceptional sites
  - unique sites
  - “classic” examples of more common features
- marine geoscience research
  - industry and academia
  - new theories and techniques
  - new technologies
- environmental forecasting
  - past environments
  - sea-level change
  - climate change
- education & training
  - selected university courses
- cultural resource
  - archæology
  - maritime history
  - sport diving
  - recreational fishing
- ecological resource
  - substrate conservation
  - benthic habitat conservation

Groups or activities receiving lesser benefits include:

- education & training
  - university geoscience courses
  - school & colleges
- cultural resource
  - amateur groups & hobbyists
  - general public

A1.3 Potential knowledge gains

A programme of marine geoscience conservation has the potential to encourage and stimulate research in a variety of Earth science fields either in direct support of a conservation programme or as a consequence of access to, and interest in, protected marine geoscience sites.

A1.3.1 Key Earth science beneficiaries

Given the fundamentally dynamic nature of the sea floor and the predominance of both active and relict bedforms, features of interest due to their solid geology will probably form a minority in a list of sites for inclusion in a programme of conservation. Therefore, the Earth science subject areas benefiting the most from such a programme would reflect this overall dominance of active and relict geomorphological sites and often unconsolidated Cenozoic sediments.

Primary benefits would probably be felt in geomorphological and dynamical research where the conservation of key sites would aid in the research of dynamic processes and bedform behaviour and evolution. It is likely that many sites would be active geomorphological ones, requiring as a condition of their conservation, and resulting from their subsequent protection, a greatly increased understanding of their behaviour and development and of the sediment supply and dynamics necessary for their existence.

Equally, subjects concerned with Cenozoic environmental change and the evolution of the British Isles, in particular during the Quaternary, would also benefit considerably. Much of the continental shelf and slope is dominated by relict inactive bedforms and sediments that testify to former sea-levels, climates and sediment regimes. Evidence for subaerial exposure of the shelf, under climatic conditions at variance with those at present, in the form of submerged peats, fluvial and lacustrine systems, and periglacial landforms, is found at many localities. Large areas of the UK seabed also show evidence of extensive glaciation with both sediments and landforms indicative of grounded ice sheets, glacimarine and glacifluvial conditions. Marine features developed during periods of lower sea-level such as the tidal sand ridges in the Celtic Sea and features relating to the subsequent flooding of the shelf such as drowned beach deposits and submerged bar and spit systems have also been recognised but the interpretation of many of these bedforms remain controversial. In particular, the direct evidence for the evolution of insularity of the British Isles and its consequences for the floral, faunal and archæological development of these islands now lies in the offshore zone.

A programme of marine geoscience conservation would also be of considerable benefit for those concerned with environmental forecasting. The very real fears of anthropogenic induced sea-level rise and global climatic change need to be seen in the context of naturally occurring fluctuations in the Earth system. Without high quality baseline data on long term environmental change, much of which is derived from the study of sediments and landforms in the offshore zone, such human impacts on climate and sea-level cannot be properly assessed. In addition, in order to make accurate and reliable predictions of future environmental change and the economic, social, cultural and ecological consequences of such developments, a detailed advanced understanding of the dynamic relationships between land, hydrosphere and atmosphere is necessary. Also essential is an appreciation of the complex interaction and interdependency of processes operative in those realms.

A1.3.2 Summary

The benefits of a programme of marine geoscience conservation would be experienced across the whole range of Earth Science disciplines. However, the greatest benefits would be experienced in the fields of marine geomorphology, physical oceanography and dynamics, Quaternary science, and environmental modelling and forecasting. Solid, hydrocarbon and structural geology, along with marine geophysics, and related fields more reliant upon the study of subsurface features by remote sampling and imaging technologies would receive less benefit from such a conservation programme.

A1.4 Data availability

The availability of data, both in terms of spatial coverage and quality, needed to support a programme of marine geoscience conservation, is highly variable and fragmented. Detailed high quality site specific data exists for some locations whilst other areas may be considered data-poor. The patchy nature of data availability reflects the research interests of the different UKCS user communities.

In terms of widespread coverage of the whole of the UKCS, the British Geological Survey (BGS) and UK Hydrographic Office (UKHO) have access to, and curate, the most useful data sets. The BGS has mapped the surface and geology and sediments of the whole of the UKCS and publishes this mapped data along with detailed reports of the geology of the UK sector including the results of boreholes, seismic surveys, magnetic and gravitational anomalies. In addition they maintain an archive of all borehole and core sediments and logs taken as part of their mapping initiative. The UKHO, as the chief charting agency of the Admiralty, maintains a highly accurate, detailed, and up-to-date bathymetric database for the whole of UK waters.

However, more specific data, on the level of individual sites, is highly variable. Where areas are of interest for hydrocarbon exploration, large amounts of detailed high quality data have been generated including three-dimensional seismic surveys, side scan sonar records and borehole and core sampling. However, much of this data was gathered commercially at a cost to the petrochemical companies and may also be of a commercial sensitive nature. Thus very little of this data is in the public realm.

The aggregate industry also has access to highly detailed data in the form of sediment cores, shallow geophysics and sidescan sonar. However, such morphological and stratigraphical mapping is constrained to the limited sites of interest to the aggregate industry and concerns sites already (or soon to be) subjected to active commercial removal.

Perhaps the largest volume of data is that gathered by universities and other research establishments. This is also the most fragmented and variable (both spatially and in terms of quality). Data sets range from basin-wide studies to investigations of specific bedforms and geological outcrops, reflecting the differing priorities of externally funded research programmes, university research aims, and the interests of individual researchers.

The problem of data variability is further compounded by the inherent problems of access and the large infrastructure required in conducting research offshore. Especially in the case of universities, data coverage of the nearshore area is much greater than the open shelf, the shelf edge and beyond due to the physical and financial constraints placed on exploration. This is not so true of commercial operations, however the focus of their research (hydrocarbon, aggregate) tends to be in highly specific areas. The result is that some areas have been subjected to detailed high intensity study whilst for other regions, data coverage is sparse.

Based upon consultation undertaken as part of this feasibility study, a picture of data coverage can be attempted. Nearshore, the best high intensity data coverage is to be found along the south coast of England, particularly in the south east, and along the east coast. Data coverage decreases further north and west. Nearshore data coverage for the Scottish coast, in particular the Western Isles and sea lochs is particularly sparse with a few exceptions.

In terms of the open shelf data is highly variable. Within the North Sea highly detailed data sets exist in areas of hydrocarbon interest as well as those areas studied by universities. Data coverage in the southern North Sea is relatively good, but decreases northwards (except for hydrocarbon regions). The English Channel and Western Approaches have been studied in some detail, but here too, data coverage decreases westwards towards the shelf edge. The Celtic and Irish Seas have also been subjected to ongoing investigation and data coverage within these regions is good, especially in the Irish Sea, with coverage decreasing southwards. The shelf around north west Scotland has not been studied in as much detail and data sets remain patchy.

As regards the shelf edge and oceanic regions within the defined UKCS, data coverage along the shelf edge of the North Sea is high and improving steadily due to commercial investigations by hydrocarbon exploration companies. Much of this data, however, is not yet in the public domain. Over the shelf edge data coverage again becomes highly variable.

Given the highly variable and patchy nature of data coverage within the UKCS and the importance of having a universal, high quality geological and geomorphological database for all of the UK waters if a marine geoscience conservation initiative is to succeed, there is a clear and pressing need for further, wide scale, investigation of the geology, geomorphology and dynamics of the shelf. Such new research could form an intrinsic part of, or be motivated by (through the mechanisms of the research councils), any proposed conservation programme. The patchiness of data coverage encountered in the UKCS is a serious problem and one that needs to be addressed if a marine geoconservation programme is to conserve sites that truly represent the diversity of the geology and geomorphology encountered in our waters.

A1.5 Summary & Recommendations

It is recognised that the conservation of subtidal sites of nationally important geoscience interest would be wholly in keeping with the concepts of geodiversity and Earth heritage conservation. To quote from §A1.2:

> *The premise that we need to preserve our Earth heritage for future generations (NCC, 1984,1990, Pearce, 1989) and in doing so maintain the resources necessary for continued and future research (Allen et al., 1989) applies beneath the waves as much as it does terrestrially.*

A programme centred around the conservation of marine geoscience sites would have distinct geodiversity benefits in the protection of internationally and national important and unique features and deposits. The research benefits of such a programme would be considerable and would be most strongly felt by those in the geomorphological, dynamical, Quaternary and environmental forecasting and modelling communities. However, whilst conserved sites would also represent important educational, cultural and ecological resources, their accessibility to those outside industry and research universities would be limited due to the inherent problems of access posed by such marine locations. There is thus a need and an opportunity to improve the accessibility to site information to help overcome the physical difficulties of site access.

The availability of data to support such a programme is however spatially variable in its volume and quality. Such data patchiness presents problems in devising a workable site selection rational with some areas of UK waters benefiting from good data coverage and others having been largely neglected. Whilst this does pose potential problems, it may also act as a stimulus for future research, in support of a marine earth science conservation programme, directed at those areas under-represented in the over all data coverage of the UK marine environment.

This report, in addressing the value of conserving marine geoscience sites, the key benefits and research gains such conservation may bring and the availability of data to support such a conservation programme makes the following recommendations:

Recommendation A1.1

Based on the benefits that a programme of marine geoscience conservation would bring, it is clear that there is both a need and a desire for such measures.

Such a conservation programme of would be a logical extension of terrestrial Earth heritage conservation schemes, representing a far wider range of geological and geomorphological phenomena than a purely terrestrial programme.

Recommendation A1.2

Any proposed conservation scheme would have to be concerned exclusively with Earth heritage and geodiversity. Any site selection rationale that evaluates sites on a combination of non-geoscience criteria would probably result in the omission of sites important purely for their Earth heritage value.

However, any programme must also be able to form a component of a larger, more holistic, approach to marine habitat management necessary for the successful conservation of our seas for future generations.

Recommendation A1.3

Given the fundamental access problems posed by the remote and submarine nature of sites, any marine geoscience conservation programme must include approaches to overcome this in potentially new and novel ways not necessarily applicable terrestrially. Such approaches may include improved access to site data, documentation and sample materials in ways that would compensate for sites only being accessible to a small minority with sufficient research resources.

Recommendation A1.4

There exists an urgent need to increase dramatically public awareness in earth heritage and geodiversity. Nowhere is this more apparent than in the offshore environment where public awareness of marine habitats has increased but knowledge and understanding of the nature and value of offshore geology and processes is markedly lacking.

Any marine geoscience conservation programme must include, as a fundamental *component, wide ranging initiatives to increase public awareness of marine Earth heritage.*

Recommendation A1.5

An active programme of research into marine geology and geomorphology in support of any site selection rationale is required if a conservation programme is to represent sufficiently the diversity of features, deposits and processes in the marine environment. Given the spatial variability in existing data, such a research programme is necessary both to identify potential features for inclusion and to assess their value as conservation sites. This active research programme should form a fundamental part of a conservation scheme.

Report A2 Potential threats facing marine geoscience sites

A2.1 Introduction

Marine geoscience conservation sites face a wide range of potential threats to their integrity. Some of these threats are the same as those faced by terrestrial sites whilst many are specific to the marine environment. In addition, sites also face threats to accessibility due to exclusion zones around submarine installations.

The majority of sites that would form the basis of any marine geoscience site conservation programme would be active and inactive geomorphological sites, classed as *integrity* sites under the Earth Science Conservation Classification (ESCC) (NCC, 1990). *Exposure* sites defined as exposures of rocks or sediments that may be far more extensive below surface (NCC, 1990; Glasser, 2001) would be numerically less common given the predominance of integrity sites in the marine environment.

A2.2 Integrity sites

Integrity sites can be subdivided into two constituent categories depending on whether the landforms and their constituent deposits are still currently active or if, under the present dynamic and sediment regime, they are static or relict features. These two categories are not, however, mutually exclusive and some features may be undergoing active development in some parts whilst being inactive in others. For example tidally generated linear sand ridges currently active above a critical waterdepth threshold may be inactive in their lower margins below that depth having formed under earlier, lower sea-level regimes.

Other currently static or relict features may become active due to both natural and/or anthropogenic modification of tide-current-sediment regimes in their vicinity. Likewise, active process sites may themselves become inactive if conditions leading to their development and maintenance change. Whilst local and regional scale modification of dynamical processes that could result in such a phase change from active to inactive states and *vice versa* could be both naturally (e.g. major storm scour and sediment mobilisation, migration of channels within estuaries) or anthropogenically induced (e.g. aggregate dredging, major constructions), predicted rises in global sea-level could result in the widespread modification of both active and inactive marine features, especially in the case of those close to dynamic and sedimentological threshold values.

A2.2.1 Static geomorphological sites

Static or relict geomorphological features in the marine environment are those that are irreplaceable if destroyed or degraded (Glasser, 2001). They may constitute features of erosion or deposition or complex interrelated assemblages of both. Such sites in the offshore zone would typically include glacial and glacimarine landforms such as moraines (Foster, 1970; Stoker & Holmes, 1991), eskers (*sensu* Noormets & Floden, 2002) kettle holes, sea lochs and iceberg ploughmarks (Stoker *et al.*, 1994; Dowdeswell *et al.*, 1996; Weaver *et al.*, 2000) periglacial features such as pingos and patterned ground (*sensu* Hequette & Man, 1986); submerged fluvial landforms (Gibbard, 1995; Antoine *et al.*, 2003; Bourillet *et al.*, 2003); subaerial features such as tors (e.g. Haig Fras: Evans, 1990); features relating to former shallower conditions such as the tidal sand ridges of the Celtic Sea (Bouysee *et al.*, 1976; Pantin & Evans, 1984; Belderson *et al.*, 1986); relict features on the shelf edge and continental slope (Knutz *et al.*, 2001; Bourillet *et al.*, 2003) and features relating to the Holocene inundation of the shelf such as submerged beaches and cliff lines (Donovan & Stride, 1975) and drowned coastal barriers and inter-bar channels.

Also included within the category of inactive integrity sites must be included unconsolidated deposits of a finite and limited nature. Unlike exposure sites, they may lack surface expression but are not extensive subsurface. Such deposits may only be accessed by remote sampling but due to their fundamentally limited extent, unconsolidated nature and frequent proximity to the seabed surface (a few metres) such deposits must be considered as integrity sites. Such sites may include deposits such as submerged peats and organic clays, lake deposits and marine deposits containing high-resolution environmental records.

Potential threats faced by static relict integrity sites reflect the nature of sediments in which the are formed. Relict erosive features formed in resistant lithologies such as roches moutonneés, submerged wave cut platforms and tors will be at less risk of erosion by the disruption of the local current and sediment regimes than features such as iceberg ploughmarks and moraines formed of unconsolidated sediments. Likewise such soft sediment landforms would be at greater risk from navigational dredging, aggregate extraction and destruction caused by major constructions. However, both categories are inactive landforms and thus lack the capacity to regenerate and recover from even small scale degradation and damage.

Erosional and depositional features in both consolidated and unconsolidated sediments face a number of common threats. Threats to sites include activities directly damaging the site, or by activities causing indirect site degradation due to changing the local sediment and hydrodynamical regimes, the damaging activity often taking place some distance from the site. Some threats however are specific to the nature of the sediment or the erosional or depositional origin of the feature.

Furthermore, the role of benthic communities in the stabilisation of unconsolidated sediments must not be overlooked. Activities resulting in the degradation and destruction of such communities could result in increased sediment erosion and irreversible degradation and destabilisation of that relict feature.

Major direct threats

The principal potential direct threats faced by inactive geomorphological integrity sites at present and in the near future include aggregate extraction; mineral exploitation (dredging for placer deposits, manganese nodule collection); navigational dredging, fishing damage (trawl scour); large scale construction (wind farms, hydrocarbon structures, tidal barrages, breakwaters, piers and harbours); local scale construction (pipes, cables, fibre optics); sediment dumping (dredge waste, sewage disposal); disposal of structures (hydrocarbon structures e.g. Brent Spar, planned scuttling of ships); and collision damage and sediment resuspension by shipping.

Lesser direct threats

Lesser direct threats include damage by recreational activities (diving, pleasure craft); irresponsible research activities (coring, dredging, grab sampling); military use; and fisheries and aquaculture (sediment resuspension, construction, loss of fishing gear).

Indirect threats

Indirect threats, *i.e.* site degradation due to activities occurring outside the limits of that site, are those that disrupt the sediment budget of a site and/or the dynamical regime of that area. Such activities may result in increased erosion of that feature or increased sedimentation, infilling and burial.

Such indirect threats are the same as those major direct threats which could result in the modification of the seabed system beyond the immediate zone of impact. In addition, however, are terrestrial and intertidal activities which would have consequences for the conservation of marine inactive geomorphological integrity sites by influencing sedimentation and the dynamics of the offshore zone.

These additional indirect threats include coastal protection schemes (‘hard’ – concrete structures, groynes and ‘soft’ – offshore berm approaches); cliff stabilisation; beach replenishment; land reclamation; river and estuarine management schemes; and increased/decreased fluvial sediment and water volume inputs.

A2.2.2 Active geomorphological sites

Potential active marine-process geomorphological sites could be used to illustrate the diverse range of processes and resulting bedforms that are found in UK waters. Such sites would be by definition dynamic and so dependent on the maintenance of sediment budgets and tide-current regimes that result in their formation and evolution. However, such features, due to their dynamic nature, have a greater capacity to regenerate and repair degradation after direct damage. This capacity to do so is entirely dependent upon the nature of the sediment and the hydrodynamical environment. However, the maintenance of a viable benthic community typical to that substrate could well be essential for the conservation of the feature in question given the interrelationship between bedforms, physical processes and habitat. Active geomorphological sites would include, like their inactive counterparts, erosional and depositional features as well as composite assemblages. Features would include pockmarks and hydrocarbon seeps; submarine canyons, deep sea fans and continental slope mass movement features; tidal scours depressions, lag deposits, ebb tide deltas and flood tide ramparts; active bedform fields including sand waves, dunes, sand sheets and ripples; inter-barrier tidal channels; banner banks; the submarine extension of spits, bars and tombolos; and the active submarine aspects of fjords and sea-lochs.

Major direct threats

Given the ability of many dynamic active sites to regenerate, albeit dependent on sediment type and energy environment (Hall, 1994; Hall *et al.*, 1994; Kaiser *et al.*, 2002), such sites may be able to sustain higher levels of disturbance than inactive features. For an activity to pose a major direct threat to the integrity of an active process geomorphological site it would have to have an impact above and beyond the ability of the active system to regenerate. Such activities may involve the wholesale complete or near complete removal of a feature or suite or related features.

Such direct threats that could lead to permanent site degradation resemble those experienced by inactive sites but of sufficient magnitude that given the energy environment and sediment type of a site damage inflicted by such activities would be permanent either through a single event or continued activity. These threats include aggregate extraction; mineral exploitation; navigational dredging, fishing trawl damage (highly sediment dependent); large scale construction; sediment dumping; and the disposal of marine structures and shipping.

Lesser direct threats

Some activities that may result in major degradation of relict sites either as single incidents or through cumulative and repetitive action may pose less serious threats to active site integrity due to the variable ability of such sites to regenerate. The seriousness posed by threats of this category would be dependent on the nature of the site in question. As long as any disturbance is within the magnitude and intensity ranges of naturally occurring processes, recovery times for a site will be small. Where those background parameters are exceeded recovery times will be significant and site degradation may even be permanent.

Indirect threats

Active marine geomorphological conservation sites are wholly dependent upon the maintenance of the processes whose actions they serve to illustrate. Whilst the resulting landforms of erosion or deposition may be spatially constrained (or where mobile and ephemeral, their formation zone can be delineated) the processes on which such features are dependent may be operative over areas considerably larger than that occupied by the bedforms. Any disruption of those processes such as modifications in rates and sources of sediment supply and changes to the pattern of current and tidal activity within the wider environment of that bedform may have an adverse effect on the integrity of a site. In coastal areas, disruption of an active coastal circulation cell would represent a profound but indirect threat to the integrity of sites within that cell.

Indirect threats to active marine geomorphological sites are similar to activities included under the heading of major direct threats that could result in modification of sea-floor morphology processes beyond the area of immediate impact. Major additional indirect threats include coastal protection schemes (‘hard’ – concrete structures, groynes and ‘soft’ – offshore berm approaches); cliff stabilisation; beach replenishment; land reclamation; river and estuarine management schemes; and increased/decreased fluvial sediment and water volume inputs. All of the above have the potential to profoundly modify sediment circulation and dynamical processes within circulation cells.

A2.3 Exposure sites

Exposure sites, defined by NCC (1990) as sites where structures and deposits that may be extensive sub-surficially and thus otherwise accessible only by remote sampling are exposed locally on the surface. Whilst the subsurface continuation of that deposit is almost certain to posses similar attributes to those apparent in the surface exposure, the deposit or structure is not available for study other than at that site. Whilst in the terrestrial environment such sites are represented by quarries, cuttings, cliffs, outcrops and mines, and form the numerical bulk of all scheduled GCR sites, offshore, such features are likely to be in the minority given the scarcity of natural outcrops relative to active and inactive geomorphological sites.

Exposure sites would be composed almost entirely of natural outcrops on the seafloor. Such sites may, in addition, be of interest as integrity sites for their geomorphology such as the Haig Fras granite (Evans, 1990).

It is envisaged that most of these sites would be focused on features within the solid geology rather than in unconsolidated sediments. Threats faced by such sites would be those resulting in the degradation of the exposure either through erosion or burial. Whilst site erosion is a serious site management issue and results in the permanent loss of aspects of that site, site burial does not destroy the features of interest. Direct activities at the site would probably pose the largest potential threats, whilst indirect activities causing changes in sediment and current dynamics would probably have a lesser impact. It is, however, conceivable that future commercial activities in the marine environment may lead to the production of artificial exposures with a different associated suite of potential threats than natural exposures.

Major direct threats

The principal present and future potential direct threats to the quality of exposure sites include mineral extraction (submarine mining and quarrying); navigational improvements; fishing damage (trawl scour); large scale construction (wind farms, hydrocarbon structures, tidal barrages, breakwaters, piers, marinas, harbours and land reclamation); sediment dumping (dredge waste, sewerage disposal); disposal of structures (hydrocarbon structures e.g. Brent Spar, planned scuttling of ships); and collision damage by shipping.

Lesser direct threats

Lesser direct threats are similar to those faced by inactive geomorphological integrity sites and include damage by recreational activities (diving, pleasure craft); irresponsible research activities; military use, and local scale construction.

Indirect threats

Activities acting remotely that could lead to the degradation of exposures are likely not to be the primary threats faced by exposure sites. Such threats include the consequences of activities listed under major direct threats but acting outside their zones of primary impact. Additional activities would be coastal protection schemes (‘hard’ – concrete structures, groynes and ‘soft’ – offshore berm approaches), cliff stabilisation, beach replenishment, and land reclamation.

A2.4 Spatial variability of threats

The degree to which activities and processes act to threaten site integrity vary both spatially and temporally throughout the marine environment. The severity posed by such threats is dependent upon economic activity, population density, and environmental setting. Key activities including trawling, aggregate extraction, hydrocarbon exploitation, wind farm development, cable and fibre optic installation, and tidal and wave energy developments are distributed widely throughout the UKCS, their intensity and spatial distribution being dependent upon these variables.

A2.4.1 Fishing

The frequency and intensity of bottom trawling varies according to substrate, water depth, target species, season and weather (Jennings *et al.*, 1999). Different fishing technologies also result in greater or lesser sediment disturbance (Kaiser *et al.*, 2002) with heavy gears such as shellfish dredges, rock-hopper otter trawls and heavy flatfish beam trawls resulting in the greatest disturbance.

Data for the North Sea (Jennings *et al.*, 1999) suggest that fishing effort in the North Sea has increased by approximately 27% between 1977 and 1995 with the otter trawls making up most of the fishing effort. Spatially, the areas subjected to the highest intensity of trawling in the North Sea (otter and beam trawls) occur off the coasts of Yorkshire, Northumbria and southeast Scotland, as well as along the southern coast of the Moray Firth. High intensity zones also occur in the central North Sea and Dogger Bank region, the Thames Estuary, and far southern North Sea.

A2.4.2 Aggregate extraction

Aggregate extraction is confined to suitable sediments found in commercially viable settings. As such, major areas of extraction tend to occur near centres of population with high demand for building aggregates. Principal areas of exploitation include a zone between the Humber and Wash, an East Anglia and Thames Estuary zones, Solent and eastern Channel zones, a

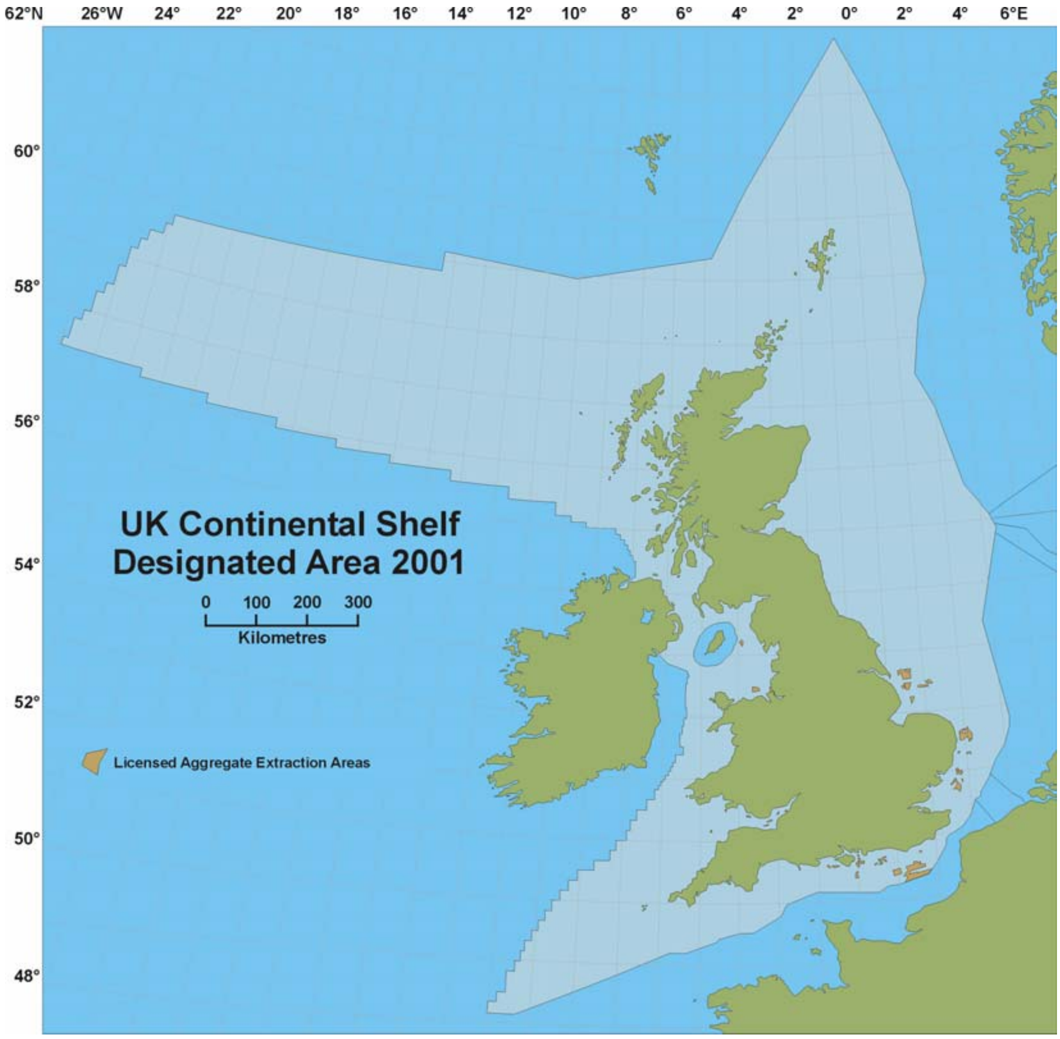


Figure A2.1 *Licensed Aggregate Extraction Areas. Data supplied from BMAPA*

Bristol Channel zone, and Liverpool Bay and Cumbria zones (Figure A2.1). At present according to BMAPA statistics (BMAPA, 2002) dredging licences cover 1,700 km2 equating to 0.12% of the UKCS. On average, 15% of the total licensed area is dredged per year.

A2.4.3 Hydrocarbon exploitation

The major centres of hydrocarbon extraction occur in the North Sea, with the major oil fields following the North Sea graben from 56°N to 62°N and from 1°W to 4°E (within the UKCS). An extensive gas field occurs in the southern North Sea between 53°N and 55°N. Small scale oil and gas fields also occur in Morecambe and Liverpool Bays and the Irish sector of the Celtic Sea. Within, and extending beyond, the main hydrocarbon regions exists a considerable pipeline network, mostly conveying gas products to terrestrial terminals (Figure A2.2).

A2.4.4 Wind farms

Under the first round of government licensing, consents for seventeen wind turbine developments were issued, the first in April 2002. Round 1 sites are restricted to a maximum of 30 turbines covering a site of no more than 10km^2 (DTI, 2002) The seventeen sites (Figure A2.3) are all within the UK 12 nautical mile territorial waters limit with the majority of locations confined to Liverpool and Morecambe bays, the Thames Estuary, and the Wash – East Anglia coast region. Other sites occur of Teesside, Northern Ireland and in the Bristol Channel and Solway Firth.

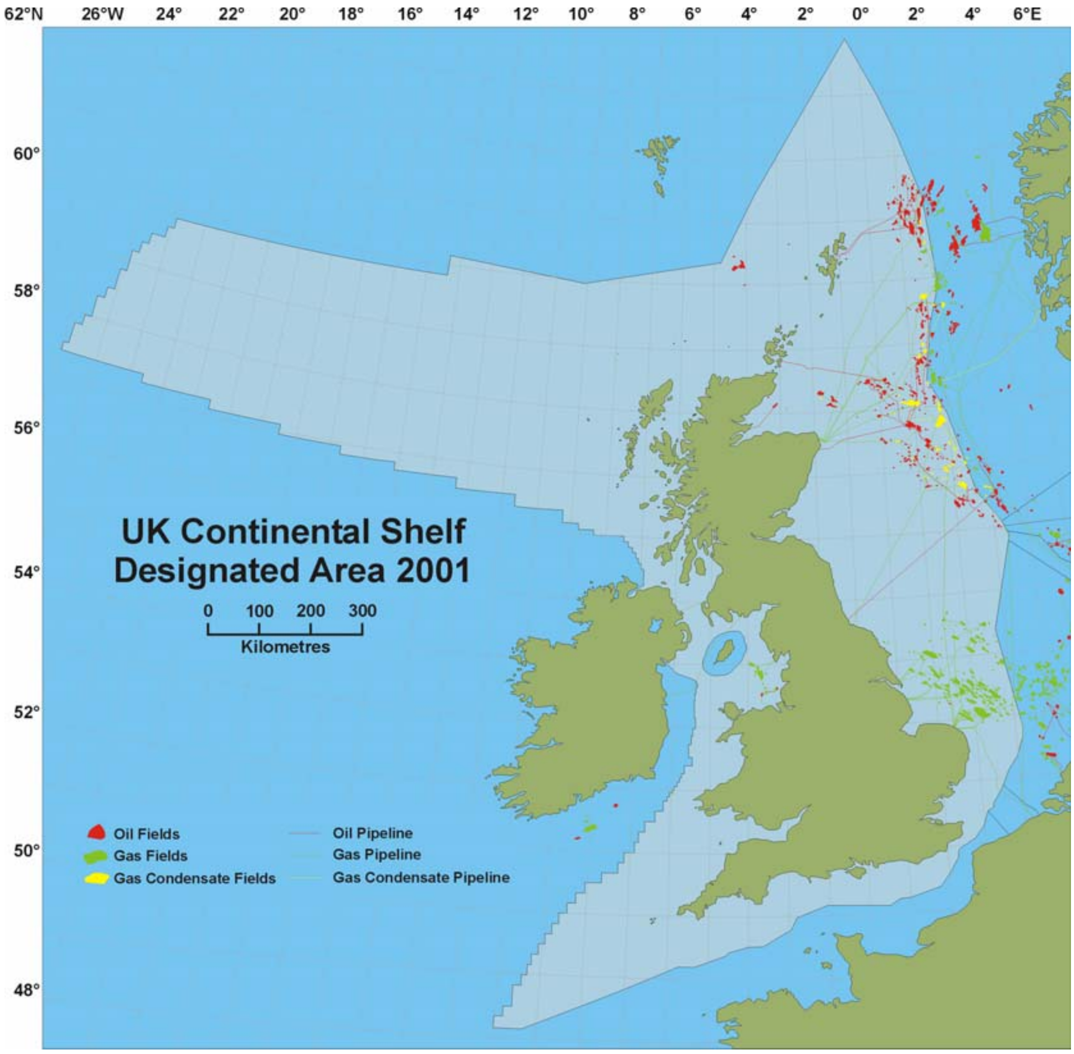


Figure A2.2 *UK Continental Shelf hydrocarbon infrastructure. Data sourced from DTI*

Licensing Round 2, announced in July 2003, proposes three strategic areas for development, these being the Northwest, Thames Estuary and Greater Wash zones (Figure A2.3). it is envisaged that wind turbine developments within these areas will be considerably larger than those licensed in Round 1. Round 2 developments could involve sites in excess of 100 wind turbines. Round 2 sites will be excluded from a minimum 8km strip from the shoreline, extended to 13km in particularly sensitive areas. In addition, certain shallow water regions within the Greater Wash strategic area will also be excluded. The three strategic areas include sites beyond the 12 nautical mile territorial waters limit, requiring new legislation to enable renewable energy generation within the UKCS. It is envisaged by the Government that future licensing rounds will expand the wind turbine infrastructure still further.

In addition to the wind turbine developments themselves (including exclusion zones), there will be the need for cable connection to the UK National Grid representing a further integrity threat above and beyond that of the wind turbine structures themselves.

A2.4.5 Cables and fibre optics

The UKCS is criss-crossed by a large number of submarine cables either resting directly on the sea floor or entrenched into unconsolidated sediments (Figure A2.4). Exclusion zones of up to 500m can be designated around cables, preventing access and further research of bottom features within that zone. In addition, entrenching of cables can directly damage or destroy active and relict integrity sites. The seafloors of the English Channel, Western Approaches and Irish Sea are crossed by particularly dense cable networks. This is most pronounced of the coasts of Lands End and the Lizard in Cornwall.

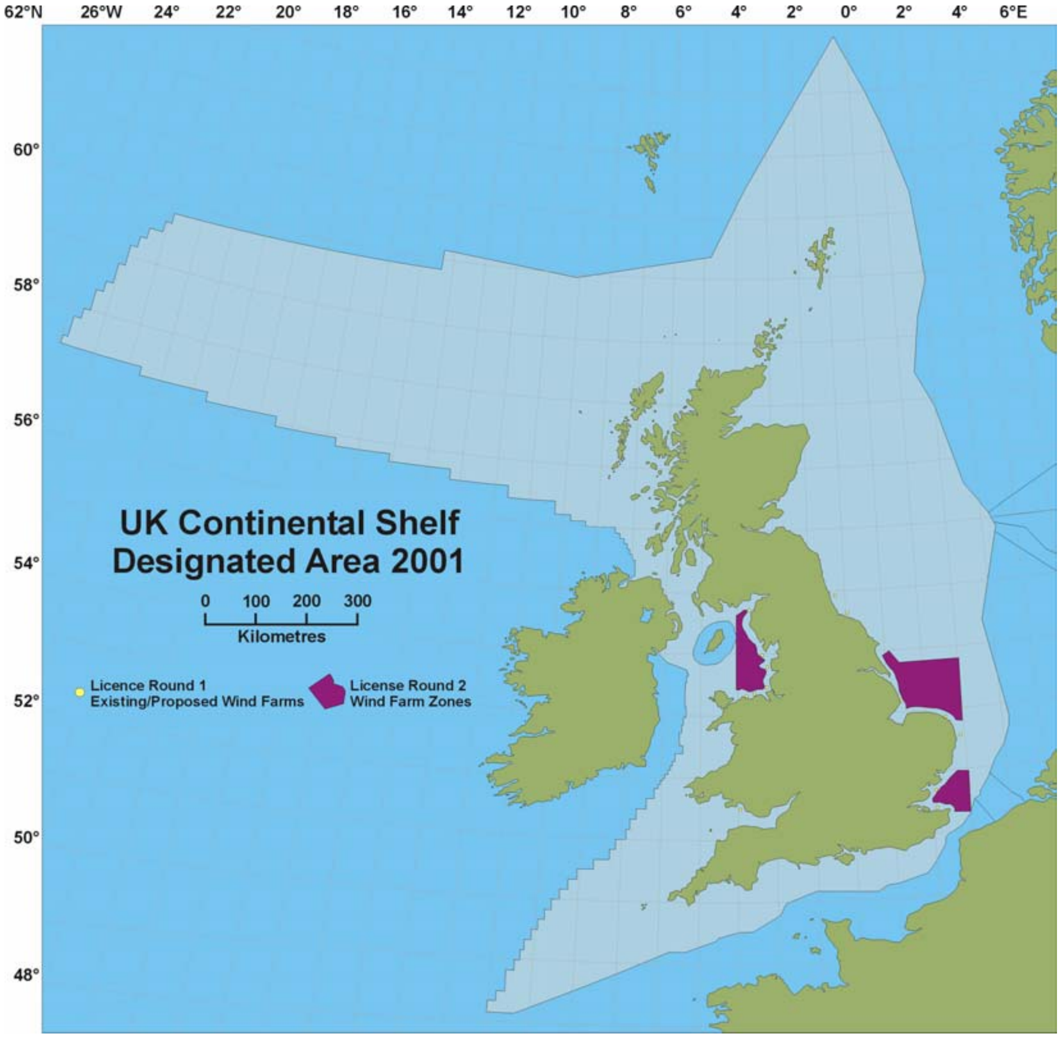


Figure A2.3 *UK Continental Shelf Licensing Round 1 and Round 2 wind turbine development areas. Data from Crown Estates and DTI*

A2.5 International Issues

Especially in the case of active geomorphological integrity sites which are critically dependent on processes operating in, and sediments derived from, areas significantly more extensive that that occupied by the individual bedform or bedform fields, possible conservation issues may arise that do not apply to terrestrial UK active integrity sites. Active features on the continental shelf may be dependent on processes operating in, and sediments derived from, waters outside UK jurisdiction. A management framework for such sites needs to be investigated as important sites may not be realistically conservable if those processes acting outside UK waters cannot be maintained.

A2.6 Summary & Recommendations

The division of potential features into active and inactive integrity, and exposure, sites enables the assessment of threats to be placed in a more structured context. All sites face potential threats acting both immediately at the point of impact of that disruptive activity and by activities taking place remotely by the modification of sediment dynamics and sediment pathways.

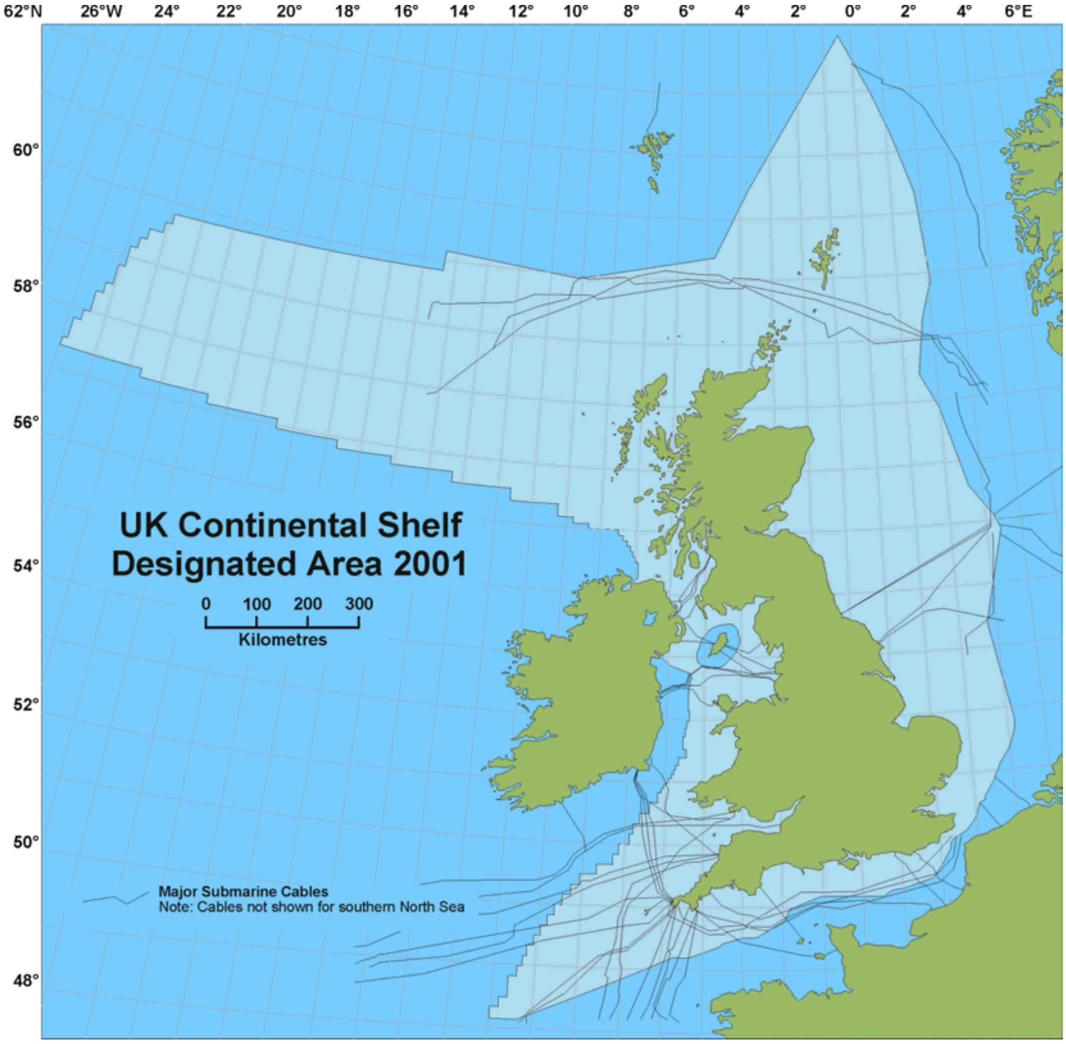


Figure A2.4 *UK Continental Shelf offshore cable network. Data taken from UKHO chart No.:2 British Isles*

Exposure sites are likely to be able to sustain the highest levels of disruption as most of these sites will be in extensive bodies of lithified materials. The primary potential threats posed to such sites are activities acting directly on sites resulting in degradation of, or access restriction to, exposures such as large scale construction and burial.

Active geomorphological integrity sites would be able to sustain variable levels of direct disturbance according to the magnitude and intensity of such disturbance and the nature of the sediments and dynamics resulting in that feature's maintenance and evolution. Given the dependence of such sites on dynamic processes and sediment pathways operating over large areas, the primary potential threats faced by such sites include both the direct degradation and destruction of sites along with the remote modification of sediment supply and circulation dynamics. Activities resulting in these kinds of potential threats would include aggregate extraction, large scale offshore construction, navigational dredging and coastal defence measures.

Static geomorphological sites, mostly comprised of Quaternary sediments are characterised by their inability to sustain even moderate levels of disturbance and degradation. Sites face both direct threats to their integrity such as trawl damage, construction, aggregate extraction and indirect remote threats leading to a change of current and sediment regime in a similar fashion as active integrity sites.

Threats faced by sites show marked spatial variability in their intensity and magnitude. Potentially damaging activities such as aggregate extraction, hydrocarbon exploitation, cable and pipeline installation and wind turbine construction are not evenly distributed across the continental shelf but are constrained by both physical and socio-economic factors. However, it is these activities with the greatest potential to result in site degradation that already are subject to strict governmental licensing control. Individual activities that pose, of themselves, lesser threats, but are not as strictly regulated, may result in greater site damage due to their cumulative effect.

Recommendation A2.1

The evaluation of potential threats must be conducted on a site-by-site basis rather than applying a generic approach to threat assessment.

In the case of soft sediment integrity sites, especially active ones, close attention must be paid to threats to the sediment and water dynamics on which those sites are critically dependent. For this to be successful, it is envisaged that this will require modelling of sediment supply and hydrodynamics and the response of bedforms or bedform fields to changes in those parameters.

Recommendation A2.2

It is essential that in order to reduce the potential for any conflict of interests, any programme of marine geoscience conservation must be conducted in close partnership with other continental shelf users. Close cooperation and continual consultation is especially important with those stakeholders whose activities may represent potential threats to site integrity. Consultation with industry organisations, such as the British Marine Aggregate Producers Association, the International Cable Protection Committee, the United Kingdom Offshore Operators Association and the British Wind Energy Association, along with licensing authorities and statutory bodies would be essential.

Recommendation A2.3

A framework for international cooperation needs to be investigated to enable the realistic conservation of sites within the UKCS dependent upon processes operative outside UK jurisdiction. Such a management approach may be available through the European Union or may require agreements with individual nation states

Report A3 Extension of existing coastal geomorphology GCR sites into the marine environment with reference to the Irish Sea

A3.1 Introduction

Under the current Geological Conservation Review, coastal geomorphological sites demonstrating landforms and processes active within the intertidal zone or supratidal features dependent on those marine processes are conserved as Sites of Special Scientific Interest. These sites include features such as hard and soft rock cliffs, shingle beaches, sandy beaches and coastal dunes, sand spits and tombolos, machair, saltmarshes, and complex coastal assemblages.

All of these landforms are dependent to some degree on processes acting in the marine environment. Sediment supply, either onshore or alongshore, is critical for the maintenance of many of the constructive coastal geomorphological features such as sand spits and saltmarshes, whilst active erosion is necessary for the maintenance of active undegraded cliffs in both hard and soft sediments.

If a programme of marine geoscience conservation is to be instigated, there is potential for extending the existing inter- and supra-tidal coastal GCR sites subtidally. In extending site boundaries below low water, it is envisaged that greater protection can be granted to the processes on which the integrity of the site in question is dependent. In addition, if an integrated approach to geodiversity and its conservation is to be achieved, coastal landforms must be viewed as complex systems spanning the intertidal zone and extending both supra- and sub-tidally. Conserving only part of the active landform above low water fails to represent the whole system and thus is not truly representative of the full range of geodiversity found on and around the British Isles.

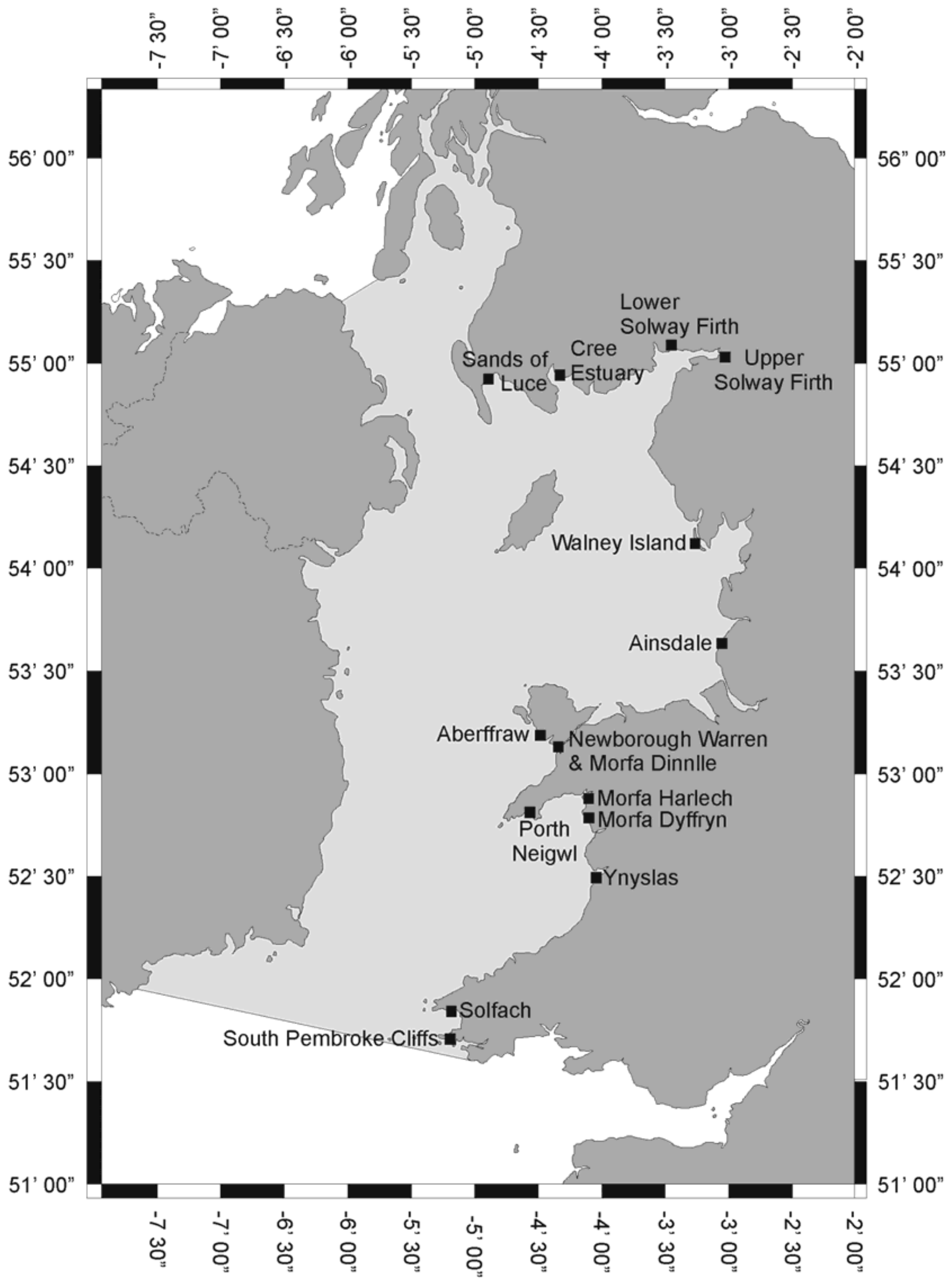
However, in order to undertake an assessment of the benefits of site extension below low water, sufficient data for each site must be available in order to determine the dependency of that site on offshore processes and the extent to which that bedform or those critical processes extend subtidally. This feasibility study therefore examines, on a site by site basis, the existing coastal geomorphology GCR sites along the British Irish Sea coast in order to assess the degree to which they would benefit from site extension below low water, and if sufficient data is available to support such site extension proposals.

Fifteen coastal geomorphology GCR sites are found along the British Irish Sea coast, from the Mull of Kintyre to Linney Head (Figure A3.1), and can be grouped according to their geomorphology:

- **Hard & Soft Rock Cliffs**
  - Porth Neigwl, Gwynedd
  - Solfach, Pembrokeshire
  - South Pembroke Cliffs, Pembrokeshire
- **Sandy Beaches & Coastal Dunes**
  - Luce Sands, Dumfries & Galloway
  - Ainsdale, Merseyside
  - Tywyn Aberffraw, Ynys Môn
- **Sand Spits & Tombolos**
  - Walney Island, Cumbria
  - Morfa Harlech, Gwynedd
  - Morfa Dyffryn, Gwynedd
  - Ynyslas, Ceredigion
- **Saltmarshes**
  - Solway Firth: Lower Solway, Dumfries & Galloway
  - Solway Firth: Upper Solway marshes, Dumfries & Galloway
  - Solway Firth: Cree Estuary, Dumfries & Galloway
- **Complex Coastal Assemblages**
  - Newborough Warren, Ynys Môn
  - Morfa Dinlle, Gwynedd

In the following report, each site is assessed according to its dependence on offshore processes and the benefit of subtidal boundary extension, with particular reference to integrity threat mitigation. In addition, assessments are made of the amount of data available to support any proposed extension. Site descriptions are adapted from those short citations of scientific interest prepared for each site as part of the GCR review process.

JNCC GCR Irish Sea Pilot Study Area
including Irish Sea Coastal Geomorphology GCR sites



Area boundaries defined as Mull of Kintyre, Argyll to Fair Head, County Antrim; coast of Northern Ireland to Median Line: Median Line to line between Mine Head, C. Waterford and Linney Head, Pembrokeshire: from Median Line to Linney Head: Linney Head, Pembrokeshire along coast to Mull of Kintyre, Argyll

Figure A3.1 *Irish Sea British coastal geomorphology GCR sites*

A3.2 Hard & Soft Rock Cliffs

The maintenance of active cliff slopes in both hard and soft sediments is dependent on continued erosion at the cliff base. Naturally occurring or anthropogenic changes in sediment supply and advection, wave direction, amplitude and fetch can lead to changes in erosion rates or even to net sedimentation at the cliff base. Where sediment derived from cliff erosion is delivered to adjacent beaches, both the processes governing the erosion of those cliffs and the subsequent transport and circulation of the derived sediment must be maintained if site integrity is to be preserved.

A3.2.1 Porth Neigwl, Gwynedd

Porth Neigwl is a major example of a cliff-beach system in which the planform of the beach is controlled by a dynamic relationship between south-westerly swell and waves and the resistance of the backing cliffs, composed predominantly of Devensian till. The lower beach is formed mainly of sand, whereas the upper beach is dominated by cobbles and shingle, derived mainly from erosion of the cliffs. A common feature of the beach is a series of bars on the lower beach which are aligned at an acute angle to the beach itself. The site is important both as a member of a suite of major beaches dominated by south-westerly swells and because it appears to depend entirely upon the supply of sediment from erosion of the cliffs which back the beach and to have no relict source or component within the beach sediment budget. It is unusual amongst west coast beaches in having no associated dunes and is a good example of a high energy beach system.

The main control on continued site integrity as regards the subtidal environment is maintenance of the current south-westerly orientated wave regime. As beach sediments are supplied wholly from the erosion of the backing till cliffs the influence of offshore sediment circulation is considered slight (JNCC, *in prep.*). However, subtidal sediment removal might result in advection of beach sediments offshore faster than resupply by cliff erosion resulting in changes in beach planform and increased rates of cliff retreat.

However, insufficient data exists to accurately assess the response of the site to changes in wave regime or offshore sediment dynamics. In addition, there is little current threat of large-scale sediment extraction in the vicinity of the site. It is thus considered that, based on potential integrity threats, there is little scope for GCR boundary extension below low water at this site. Management of the site's offshore environs would better be accommodated within an integrated coastal management plan.

A3.2.2 Solfach, Pembrokeshire

Solfach is an important site for coastal geomorphology, providing a classic small-scale example of a ria. The site includes not only the present ria but also the adjacent Gwada valley, the floor of which has been almost entirely infilled with alluvial sediments. The proximity of the two features provides a contrast between rates of sedimentary infill and resulting morphologies. Slope-over-wall forms surround both the present and former rias, which are cut into a near-horizontal surface at an altitude of about 60 metres above sea-level.

The features are both former subglacial meltwater channels incised into the surrounding bedrock surface during periods of lower sea-level. The valleys were subsequently inundated during the Holocene marine transgression with sedimentary infill following. The Gwada valley is almost totally infilled with alluvium whilst a small alluvial delta occurs at the head of the Solfach ria. At low water gravel, mud and sand are exposed in the ria associated with alluvial delta development. More marine intertidal forms occur in the lower reaches of Solfach, including intertidal rock platforms (JNCC, *in prep.*). A three phase model is proposed for the morphological development of the feature with initial fluvial incision of the valley producing the gentle upper slopes followed by rapid down cutting either fluvially to a lower base level than present during periods of high discharge (glacial / periglacial melt water) or due to subglacial discharge (Goudie & Gardiner, 1985) during the last glacial period. Differential infilling of the two valleys occurred with a greater volume of sediment delivered to the Gwada. Inundation occurred around 6,000 yr BP (Goudie & Gardiner, 1985).

Given the fundamentally relict nature of most of the Solfach morphology, the low dependence on offshore sedimentary and dynamic processes, and the limited impact inundation has had upon cliff development, there is little justification, in terms of integrity threat mitigation, for extending GCR boundaries below low water at this site. The combined inundated Solfach–Gwada valley does, however, continue subtidally. There is thus a case for boundary extension into the marine environment to include its subtidal extension. Such boundary extension is desirable if both the intertidal and subtidal components of this flooded fluvial (glacifluvial) system are to be conserved, being representative of the influence of sea-level upon fluvially generated coastal landforms.

A3.2.3 South Pembroke Cliffs, Pembrokeshire

The site at South Pembroke Cliffs contains some of the best examples of coastal rock cliff forms in Britain. Formed mainly in massive Carboniferous limestones, the cliffs include exceptional examples of the development of geo, stack, cave and arch features. Faults and other weaknesses have been exploited to produce such well-known features as the Green Bridge of Wales, Elegug Stacks and the Huntsman's Leap. The importance of this site is enhanced by the retreat of the coastline into an area of karstic landforms. Thus, the combined effects of solution, collapse and marine erosion have produced an intricate and geomorphologically important assemblage of landforms.

The main controls on landscape evolution at this site appears to be the exploitation by marine erosion of structural discontinuities within the Carboniferous limestone (Guilcher, 1958; John, 1978). The coastal geomorphology exhibits a strong structural control, with erosional exploitation of faults, bedding and shear planes as well as the erosion and exhumation of karstic features (Steers, 1969; John, 1978). Marine erosion continues to be highly active at this site, dominated by south-westerly storm waves. Cliff fall is very common and represents an important mechanism of delivering sediment into the intertidal zone and maintaining active coastal retreat. Solutional activity of the limestone is also very important (Steers, 1969; John, 1978).

Literature regarding this site is limited, however it is apparent that apart from maintaining the current wave climate at this site, the South Pembroke Coast GCR would benefit little from boundary extension into the subtidal zone. Such an extension would be unjustified in terms of threat mitigation as well as for site inclusivity (including whole features that span subtidal and supratidal environments). Potential threats to wave direction, magnitude and fetch would best be managed as part of a wider coastal management plan.

A3.3 Sandy Beaches & Coastal Dunes

Sandy beach and coastal dune systems are highly dependent upon intertidal and nearshore sediment dynamics for their continued maintenance and evolution. Onshore or alongshore sediment transfer is a function of wave climate and tidal behaviour directly linked to nearshore submarine morphologies which critically control intertidal beach bedforms and the degree to which beach and dune system are prograding or eroding.

A3.3.1 Luce Sands, Dumfries & Galloway

The key site of Luce Sands, situated to the south of Stranraer between the Mull of Galloway and Burrow Head, is the largest and most complex system of beach and dunes in the south of Scotland. A rich variety of contrasting dune morphology lends to the site much of its interest and distinctiveness - low parallel foredunes, high transverse dunes displaying signs of recent severe erosion, and a complex area of older dunes resting on raised beach ridges and showing signs of severe erosion in the past. The degree of development of dune slacks is also worthy of note in a Scottish context. The dynamic relationships between these individual components are as yet imperfectly understood, but are likely to be of considerable significance. The beach is also unusual in being well-nourished by an apparently continuing supply of sand from offshore, transported through the North Channel and then into Luce Bay.

The complex has been (and continues to be) characterised by high rates of sediment delivery, initially as gravel resulting in a multi-ridged gravel strandplain, supplanted by sand regime producing a wide sandy beach and dune system as sea-levels have fallen at this site through the Holocene (Single & Hansom, 1994). Sediment is driven into Luce Bay by unidirectional waves, infilling the bay head. The contributing area for onshore sediment movement is large, the 9m isobath being some 3km offshore, whilst the floor of the bay is composed of large accumulations of unconsolidated glacigenic sands and gravels, relatively easily transported by wave activity (Single & Hansom, 1994). In addition, the bay functions as a significant sediment trap for material transported by longshore drift southwards along the Rhinns of Galloway coast, then being transported northwards along a major flood channel on the bay's western side (Mather, 1979).

The dune system is currently increasing along much of its length (JNCC, *in prep.*) as a result of the well-nourished sediment conditions. However, erosion is taking place at its western margin due to flank erosion around recent inappropriate coastal protection works (Single & Hansom, 1994).

The dependency of Luce Sands on the continuing high rates of sediment delivery derived from the mobilisation of offshore relict glacigenic sediments and the longshore transport of material from the Rhinns of Galloway coast is acute. Disruption of these sediment sources could cause considerable readjustment of beach morphology and dune development. However, without detailed modelling of sediment transport pathways and the response of the dynamic system to large-scale disruption, it is unclear exactly how sensitive the Luce Sands site would be to changes in sediment delivery, and at what scale such disturbances must operate in order to adversely effect site integrity.

Furthermore, the extension of site boundaries in order to encompass the whole of Luce Bay down to the 20m isobath (region dominantly floored by sandy sediment) would require an addition of 275km^2 to a site currently covering 24.9km^2. Despite the relatively large size of the existing site, it seems difficult to justify a site extension of this scale (*ca.* 1104%).

It is thus considered that without further research and modelling of the Luce Bay sediment transport system and its response to induced perturbations there is insufficient data to justify the extension of the site's GCR boundaries into the offshore zone. It seems likely that only major disruptions to the offshore sediment regime caused by construction or sediment extraction could result in significant changes in the sediment budget of the bay. At this stage, it is therefore recommended that the offshore extension of the Luce Sands GCR site be better managed as part of a coastal management plan as opposed to an extension of its GCR boundaries.

A3.3.2 Ainsdale, Merseyside

Ainsdale is an important site for coastal geomorphology, in particular for the large sand dunes and the multiple sand bars that occur on the foreshore. Although much of the shoreline is undergoing erosion, there are relatively stable bar features in the intertidal zone where sediment transport is probably alongshore. Many different bedforms are represented on the foreshore and have been studied in much greater detail than similar features elsewhere.

Much has been published regarding the intertidal and dune geomorphology, palaeogeography, sea-level change, and offshore oceanography of the Merseyside and south Lancashire coast and, as such, Ainsdale is perhaps the best documented site along the Irish Sea coast.

Initial sand migration is considered to have commenced between 4.6 and 4 ka BP followed by coastal dune formation *ca.* 4 ka BP. Sand accumulation continued, interrupted by marine transgressions around 3500, 2335, 1795-1370 and 800 radiocarbon years BP (Innes & Tooley, 1993). This was followed by a recent erosional phase beginning around the start of the twentieth century and continuing today (Greswell, 1937: Pye & Neal, 1994).

Greswell (1937) showed that the beach morphology and intertidal bedforms (ridge & runnels) are dependent on the mean wave direction and size. At Ainsdale there is a dominant westerly component to wind, westerly waves being most common and having the greatest fetch. Major storm waves also originate from the west. This westerly wave component provides the overall control on the intertidal macro morphology. Waves arriving obliquely to coast are not fully refracted, thus longshore drift acts north-eastwards north of Formby Point, and south-eastwards south of Formby Point.

Greswell (1937) suggested that sediment supplying Formby and the adjacent coast was supplied from sources offshore and subsequently transported by longshore drift north and south. Greswell (1937) surmised that erosion at Formby Point post-1900 was the result of the interruption of the onshore supply of sediment, longshore drift removing more sediment than was being delivered from offshore. Beach lowering caused by this interruption in sediment supply resulted in erosion of the dunes. Greswell (1953) suggested that this reduction in sediment supply was due to dredging of the Mersey Bar.

However, whilst seabed drifter studies (Halliwell & O'Connor, 1973) illustrate a residual onshore drift in Liverpool Bay, Parker (1975) suggests that sub-beach surface erosion of Quaternary sediments represents the main sediment source, not sediments derived from offshore. Parker (1975) did not explain why the change from a prograding to an eroding system occurred.

Numerical modelling undertaken by Pye & Neal (1994) (and Pye & Smith, 1988) suggest that the erosional trend beginning around 1900 was the result of a number of coincident factors. A higher than average frequency of westerly storms around 1900 is considered to have initiated erosion. This erosional pattern was reinforced by the construction of training walls along the Mersey and Ribble estuaries with associated dredge spoil dumping resulting in altered bathymetries. The consequence was a significant increase in wave focusing at Formby Point due to marked changes in wave refraction and beach dynamics caused by the engineering of the estuaries. Training works concentrate flows in the main channels resulting in the shallowing and infilling of subsidiary channels. The Formby Channel disappeared by 1965 after building of the Mersey walls from 1909-1939. They found no evidence, however, for a decrease in sediment supply from offshore.

It is clear, then, that this site is highly influenced by changes in bathymetry offshore resulting in changes in wave focusing and refraction. In the last hundred years this has lead to a shift from net accretion to net erosion at Formby Point, but is not due to any decrease in the amount of sediment advected shoreward from reservoirs offshore.

Of all the Irish Sea coastal geomorphology GCR sites Ainsdale has the strongest case for boundary extension off shore given the large amount of literature attesting to its dependence on offshore dynamics. It is also within the environs of this site that the Burbo offshore wind turbine development (licensing Round 1) is being constructed as well as being adjacent to the DTI's offshore wind turbine licensing Round 2 North West strategic area. The effect changing bathymetry, due to channel training and dredge spoil dumping, during the nineteenth and twentieth centuries has had on the Ainsdale site is clear. Further changes in bathymetry, in part related to wind turbine construction may further adversely effect the wave and sediment dynamics at this site.

However, in order to delineate effectively subtidal site boundaries and to provide an effective case for boundary extension, further detailed oceanographic field research and numerical modelling is urgently required. After such study, it may prove that management of the offshore adjacent to Ainsdale is better accommodated as part of a coastal management plan. However, Ainsdale currently remains the strongest candidate for offshore boundary extension.

A3.3.3 Tywyn Aberffraw, Ynys Môn

Tywyn Aberffraw is an important site for coastal geomorphology. It comprises an area of blown sand and dunes occupying a confined valley site. Because of the physical constraints, there is little possibility of sand entering the bay from alongshore and the bounding cliffs supply little material to the beach. Tywyn Aberffraw offers an excellent opportunity for the study of beach and dune relationships in an area of restricted sediment supply, both from the beach and within the site. A further important feature is the relative isolation of individual grey parabolic dunes upon a sand plain, a landform assemblage that has few comparable equivalents in England and Wales.

The beach at Aberffraw is around 300m wide and composed almost entirely of sand. Due to the small size of the beach and its enclosure by surrounding headlands only waves approaching from a narrow range of directions (south to WSW) can reach the beach and only waves from the southwest undergo no refraction. South-westerly waves have a fetch in excess of 4000km (JNCC, *in prep.*). The offshore zone (as opposed to an alongshore source) is considered to be the main sediment source due to the restriction of longshore drift by the adjacent headlands (Robinson, 1980).

There seems little justification for extending site boundaries into the subtidal environment at this site given its low dependence on longshore sediment supply and a lack of data regarding potential offshore sediment sources. Any major changes in bathymetry offshore could adversely effect the dynamics of approaching waves. The potential, however, for such threatening activities that would result in major bathymetric changes (such as major engineering works, sediment extraction and dumping) is considered, at this site, to be low and thus does not warrant site extension on the basis of potential integrity threats.

A3.4 Sand Spits & Tombolos

Sand spits and tombolos are highly dependent upon longshore sediment transfer and the refracting and focusing of nearshore waves for their maintenance and evolution. Changes in nearshore bathymetry or in longshore sediment supply due to anthropogenic action can have considerable adverse effects on site integrity.

A3.4.1 Walney Island, Cumbria

The two sites at Walney Island represent the distal features of a barrier island. There are few examples of this type of feature in Britain and Walney Island is exceptional in being the product of erosion and reworking of glacial sediments, rather than coastal deposition. The spits at Walney Island are important in several respects: 1) They represent the distal features of the offshore bar and occur in a macrotidal location; 2) They differ in both form and sediments - North End Haws is fed by sandy sediments in the intertidal zone and has small dunes on its surface, whereas South End Haws comprises mainly shingle with limited dune development; 3) They are associated with scars (boulder- and cobble-dominated areas of the intertidal zone) which are a characteristic form of this coast. The sites at Walney are important both in their own right and for comparative studies with other barrier island-type features.

The Southern Haws Point Spit is fed by a southerly drift of sediment derived from the erosion of till cliffs that form most of the western side of Walney Island. Sediments are dominantly gravelly. Beyond the distal end of the spit, strong tidal currents have developed a large channel and are capable of advecting away finer the components of the sediment (JNCC, *in prep*.). The Northern End Haws Spit is dominated by much sandier sediments derived from a northerly drift from the eroding till cliffs of western Walney Island. The distal end of the spit is broad and is marked by dunes resting on a shingle base adjacent to a wide sandy intertidal area (JNCC, *in prep*.).

Accretion on the southern spit results primarily from sediment transport from the seabed (Phillips, 1969) thus changes in offshore bathymetry and removal of sediment through aggregate extraction will have consequences for spit development (JNCC, *in prep*.). Transfer from the seabed is controlled by the tidal stream assisted by the prevailing westerly waves. Contrasting ebb and flood circulation patterns are encountered in Morecambe Bay, but both act to transport sediment into intertidal areas where it can be delivered to the southern spit by longshore drift (Phillips, 1969). Accretion of the northern spit is, however, poorly understood with a northerly drift counter to the dominant southerly longshore sediment transfer occurring (Steers, 1946). The relationship between the northern spit and the adjacent dune complex at Sandscale Haws and the extensive sand flats of Duddon Sands is also poorly understood and requires further research (JNCC, *in prep*.).

There is a possible case for GCR boundary extension in association with the southern spit on Walney Island given its proven dependence upon offshore dynamics and sediment supply, however further research is required to assess the full dependency of the site on these offshore processes and the degree to which perturbation of those dynamics may result in site degradation. The case for boundary extension is hindered in the north by a marked scarcity of data. It is considered here, therefore, that further detailed oceanographic research, numerical modelling, and potential threat analysis is needed before an accurate assessment of the desirability of boundary extension can be fully undertaken.

A3.4.2 Morfa Harlech, Gwynedd

Morfa Harlech is an important site for coastal geomorphological studies. It comprises a major cuspate foreland, in which the alignment of a sand beach and dunes at an acute angle to former cliffs has encouraged extensive sedimentation. The beach and dunes form a narrow fringing system in the south but widen northwards into several subparallel ridges. Morfa Harlech is a classic landform. It is also significant for the relationship of the ridges to wave energy inputs from local rivers and the seabed. While progradation has been prevalent, there is also some localised erosion, both at the proximal end near Harlech and at the distal end of the spit. Although movements of sand along the spit towards its distal end have contributed in part to its extension across the Afon Glaslyn, changes in the position of the river channel have contributed both to the growth and erosion of the spit. Morfa Harlech is largely unaffected by interference with littoral sediment transport, and is part of a suite of beaches largely aligned to Atlantic swell within the Irish Sea.

The spit is considered to be very close to equilibrium with the dominant prevailing south-westerly wave regime. There appears to be very little net sediment transport alongshore, the spit's alignment being strongly influenced by the position of the main estuary channel of the Afon Glaslyn (JNCC, *in prep*.). Sediment supplying the spit is probably derived from the extensive glacigenic deposits flooring Cardigan Bay with additional material supplied by sands within the estuary (fluvial origin including additions from intensive nineteenth and twentieth century mining waste) (JNCC, *in prep*.).

Whilst it is suggested that the spit is dependent upon offshore sediment sources and is aligned to prevailing and dominant south-westerly waves little geomorphological work has been conducted at the site, and no oceanographic investigations have been undertaken. It is considered therefore, that there is insufficient data to assess accurately the need for boundary extension at this site. However, given the lack of any major potential threat to the site's integrity at present, there appears little need for boundary extension as a means of threat management. Conservation of the wider environs around the site is probably better achieved as part of a coastal management plan rather than within extended GCR boundaries given the current shortage of data.

A3.4.3 Morfa Dyffryn, Gwynedd

Morfa Dyffryn is an important site for coastal geomorphological studies. The feature developed as a spit extending across the mouth of the Afon Artro, but today it links the morainic hill of Mochras to the mainland, following diversion of the river to its present course in the early nineteenth century. Near its southern end, Morfa Dyffryn comprises a narrow fringing beach of shingle, cobbles and sand upon which there are low dunes. Northwards, the dunes are wider and higher, enclosing large slacks. At Mochras, the shoreline is formed of low till cliffs and a beach dominated by cobbles and boulders. This provides protection to the distal part of the beach against wave attack from the north-west. The dunes contain fine examples of dune migration and much of the change within the beach-dune system involves internal adjustments. There is no evidence of any significant supply of sand from either the north or south. Although superficially similar to Morfa Harlech, Morfa Dyffryn shows many differences in detail and forms an important member of a suite of west coast sandy beaches aligned towards south-west swell from the Atlantic.

The Morfa Dyffryn spit is linked morphologically to Sarn Badrig, one of a number of submarine southwest trending morainic features on the floor of Cardigan Bay. Sarn Badrig acts to influence wave refraction and sediment supply and provides a promontory against which the low-water beach has become aligned (JNCC, *in prep*.). The main sources of sediment appears to be from the seabed offshore rather than by longshore drift or from the adjacent estuary (Moore, 1968).

Like nearby Morfa Harlech the spit is dependent upon offshore sediment sources and is aligned to prevailing and dominant south-westerly waves. Little geomorphological work has been conducted at the site, and no oceanographic investigations have been undertaken. Again, it is considered that there currently exists insufficient data to accurately assess the need for boundary extension at this site. Like Morfa Harlech, given the lack of any major potential threat to the site's integrity at present, there appears little need for boundary extension as a means of threat management. Conservation of the wider environs around the site is probably better achieved as part of a coastal management plan rather than within extended GCR boundaries given the current shortage of data.

A3.4.4 Ynyslas, Ceredigion

Ynyslas is an important site for coastal geomorphological studies. It is a good example of a sand spit built upon a partly gravel base. The southern part comprises a shingle ridge with some sand accumulation on top. The central part is dominated by vegetated dunes, while the northern (distal) end forms a low sand flat with small, isolated vegetated dunes. The behaviour of the spit relates not only to sediment transport northwards but also to patterns of water movement within the Dyfi estuary. In total, the site is significant for geomorphological studies of estuarine sedimentation and the links between this and estuary mouth processes of spit development.

Longshore supply of sediment to the spit from the till cliffs to the south at Borth is considered to have been the main source of material from which the spit developed. This supply, however, is now limited due to the construction of a large groyne field extending northwards from Borth. Reworking of sands between the dunes and beach, the transfer of sediment between dunes, sand flats, banks and beaches, and the spits gravel base are considered the main reasons for its continued stability (JNCC, *in prep*.).

This site appears to be a relatively stable one (JNCC*, in prep.*) despite the reduction in longshore sediment supply. The spit recovers quickly after storm erosion, the dunes acting as a sediment reservoir. Sand is also circulated at the northern distal end of the spit with sediment being blown from the dunes over wide sand flats. Sand is subsequently transported by current action across the intertidal and shallow subtidal banks to be deposited offshore whereafter it is returned to the beaches (JNCC, *in prep*.).

The site appears to be highly dependent upon patterns of water circulation in the adjacent Dyfi estuary and, to a lesser extent, upon the northward longshore drift in Cardigan Bay (JNCC, *in prep*.). There is a case for the extension of existing GCR boundaries below low water to encompass the adjacent shallow subtidal banks and estuarine environment of the Dyfi that play such an important rôle in sediment cycling and spit maintenance.

There currently, however, appears little threat to these environments and further research into sediment transport pathways, the response of the system to perturbations in nearshore morphologies, and the likelihood of potential threats is required if a robust case for boundary extension is to be made.

A3.5 Saltmarshes

Saltmarsh development is fundamentally linked to tidal range, sea-level change, and the sediment dynamics within estuaries. In particular, changes in the position of flood and ebb channels can result in marked saltmarsh erosion and accretion. The rôle played by biogenic elements is also very important.

A3.5.1 Upper Solway Firth (south shore), Cumbria

The Upper Solway flats and saltmarshes are classic estuarine marshes which exhibit outstanding geomorphological features. Creek systems in various stages of development are found on the saltmarshes and exhibit a widely spaced dendritic system on Burgh, Rockcliffe. Saltpans are found on the marshes and take several forms. The saltmarsh erosion edge is well-developed on the Upper Solway marshes and the saltmarshes also exhibit the finest examples in the British Isles of marsh terraces believed to be formed by the processes of creek migration and isostatic uplift.

The upper Solway saltmarshes are composed dominantly of fine grained sand of a marine offshore provenance (Marshall, 1962) with probable additions from the reworking of adjacent isostatically raised Holocene deposits. The largest marsh of the upper Solway is Rockliffe Marsh between the Esk and Eden estuaries. Both northern and southern ends of the marsh have shown significant recent expansion in response to migration of the Esk and Eden channels away from the marsh edges. Continued isostatic uplift in the region is also considered to result in the creation of larger low energy flat surfaces suitable for saltmarsh development. The marshes of the upper Solway have been subjected to cyclic episodes of erosion and accretion, due primarily to changes in channel position and rate of sea-level change (JNCC, *in prep*.). Due to low energy conditions prevalent in the upper Solway, marsh erosion is attributed mainly to shifts in river channels (Marshall, 1962).

There appears little justification for extending GCR boundaries at this site due to the limited influence of offshore processes in maintaining site integrity. The area is little effected by human interference (JNCC, *in prep*.), the natural fluctuation in channel position being the primary control on marsh development. It is thus considered that no boundary extension is necessary at this site.

A3.5.2 Cree Estuary, Dumfries & Galloway

The marshes of the Cree Estuary demonstrate particularly well the geomorphological features of the estuarine-type of saltmarsh. The creek system is dendritic, and saltpans are distributed over all marsh levels. The saltmarsh has developed recently, and independently of the Solway Firth complex.

The Cree estuary acts as a sediment sink with a generally unidirectional wave climate encouraging sediment influx with little removal. The exact provenance of sediments within the estuary and flanking saltmarshes has not been determined (JNCC, *in prep*.) although the outer Solway appears to be the major source. A significant fluvial source is also suggested by the increasing volume of mud within the Cree estuary. Whilst much of the present channel has been embanked, its position is considered to be the main local control on saltmarsh development. Deflection by land-claim embankments of the main Cree channel to the east has encouraged saltmarsh development on its western bank.

As the integrity of the Cree saltmarsh system is primarily controlled by the position of the main channel of the River Cree, itself in turn partly controlled by boulder groins and embankments, there is little justification for extending the existing GCR boundaries beyond their present limits into the subtidal zone at this site.

A3.5.3 Lower Solway Firth (north shore), Dumfries & Galloway

The saltmarsh morphology and evolutionary development of the Solway marshes have been extensively researched. The marshes are important geomorphologically for the development of creeks, saltpans and distinct terraces on the saltmarsh surface which may be a response to isostatic uplift and changing sea-levels. Old creek patterns can be traced on the raised beaches along the Solway Firth; this gives evidence for the existence of extensive saltmarshes in the estuary in the past. Nationally, the Solway marshes are a key site for the study of saltmarsh morphology and evolution.

The Solway Firth is a macrotidal system, with the ebb tide running longer and flowing at a lower velocity than the flood. Areas of sandbanks retard the flood peak at successive locations upstream contributing to a pronounced tidal asymmetry. Net sedimentation within the estuary is enhanced due to the slower ebb currents being less able to transport sediment than the stronger flood (Comber *et al.*, 1994). The inner Firth acts as a sediment trap, with a unidirectional wave regime (south-westerly Irish Sea wind waves and refracted Atlantic swells) with little seaward escape of sediment (Perkins & Williams, 1966). Sediments within the saltmarsh are dominantly sand with an offshore marine provenance.

The Caerlaverock marsh situated adjacent to the Nith estuary in the upper Solway has been subjected to a cyclic pattern of erosion and accretion in three phases between 1829 and 1962 (Steers, 1973). Erosion during the 1920s has been attributed to the construction of a railway viaduct enhancing accretion on the opposite bank of the Firth (Marshall, 1962). Attempts to improve the channel's navigability probably resulted in significant extension of the Caerlaverock marsh (Steers, 1973). The complex pattern of rapid erosion and accretion at Caerlaverock has been attributed to a number of factors (JNCC, *in prep.*). The progressive easterly migration of the main channel of the Nith, accelerated by dredging and spoil dumping, has resulted in marsh accretion on the western bank and erosion on the eastern. The western side is also more sheltered, with the marsh edge on the eastern bank of the Nith being subjected to erosion via toppling failure of large sediment blocks during high tide storm events. Saltmarsh to the east of the River Nith shows a well developed creek pattern with creek development (down cutting and headward extension) combined with soft sediment deformation into the creeks resulting in a lowering of the marsh surface. The saltmarshes of the Solway are also heavily grazed, both by domestic cattle and migratory geese causing damage to the vegetation cover and lowering resistance to erosion. Sea-level rise may also be contributing to a trend towards erosion.

Given the dependency of the lower Solway Firth saltmarshes on natural variations in the position of estuarine channels, exposure to the prevailing wave conditions, grazing by wildfowl, and sea-level fluctuations, there appears little justification for GCR boundary extension below low water, especially as the majority of the Firth is exposed at low tide. The influence that anthropogenic activity within the estuary has have on marsh integrity is noted (dredging, dredge spoil dumping, bridge building), however, it is considered here that such activities are infrequent and the saltmarsh shows rapid readjustment to these perturbations. The mitigation of potential threats such as these in the future would be better managed as part of a coastal or estuary management plan as opposed to a GCR boundary extension.

A3.6 Complex Coastal Assemblages

Coastal assemblage sites are those defined under the Geological Conservation Review as possessing a wide diversity of outstanding coastal features that together form an integrated coastal system. As such, these sites come closest to the concept of the “geotope”.

The two coastal assemblage sites on the Irish Sea coast occur at the south-western end of the Menai Strait and owe their existence to interaction of longshore sediment transfer, wave refraction by offshore sediment bodies and tidal dynamics at the mouth of the Menai Strait. Residual flow in the strait is to the southwest (Harvey, 1968) with tidal flow being markedly ebb dominated. The result is the significant ebb tide delta structure of Caernarfon Bar. A flood tide rampart has also developed at the entrance to the strait immediately west of Morfa Dinlle.

A3.6.1 Newborough Warren, Ynys Môn

Newborough Warren is an important site for coastal geomorphology, notably for studying the effects of waves and currents on beach development. It comprises a major coastal dune system whose form is controlled by the Menai Straits to the east, Afon Cefni to the west and Ynys Llanddwyn, which divides the shoreline between Malltraeth Bay and Llanddwyn Bay. There are large expanses of both active and fixed dunes, although many of the latter have been forested. South-east of Ynys Llanddwyn, parts of the dunes are cliffed and experience net sediment deficit, while sand is transported eastwards towards a spit which extends (in association with an artificial breakwater) to Abermenai Point. In Malltraeth Bay, the dunes attain altitudes in excess of 30 metres above sea-level, resting upon, and masking, the rock outcrop of Ynys Llanddwyn. North-westwards, the beach extends into extensive intertidal sand flats in the Malltraeth estuary. The dune forms at Newborough Warren are varied in character and provide an excellent range of features of many different ages.

The spit at Abermenai Point is aligned normal to the dominant and prevailing wave regime and has seen the construction of an artificial breakwater (now much degraded) after breaching in 1868 and 1889 (Robinson, 1980). The easternmost part of Abermenai Point thus represents the former distal end of the spit. The spit continues to grow eastwards along the line of the former breakwater with sand carried by longshore drift from the west to reconnect with its former distal end (JNCC, *in prep.*).

There is evidence for considerable deepening of Caernarfon Bay since the mid eighteenth century with a progressive onshore movement of the shallow water seabed profile. The onshore transport of sand is considered the source for the extensive dune fields of Newborough Warren and Newborough Forest (JNCC, *in prep.*). Sediment derived from tidal streams at the mouth of the Menai Strait rather than sand delivered by longshore drift is considered to be the reason for the continuing stability of the recurved end of Abermenai Point (Robinson, 1980). Little work has been done on the offshore and nearshore sediment transport pathways and dynamics though the complex interaction between tidal dynamics and bedforms in Caernarfon Bay and associated with the mouth of the Menai Strait is clear. The exact source of sediment maintaining spit development and dune accretion also requires further investigation (JNCC, *in prep.*).

There is no current major offshore threat (e.g. construction, aggregate extraction) facing the integrity of the Newborough Warren coastal assemblage site. Given the complex interaction of tidal dynamics and offshore sediment bodies noted above, however, and the fundamental interlinkage between spit development, ebb tide delta, longshore drift and onshore sediment transfer, there does exist a case for extending GCR boundaries into the subtidal zone to fully encompass the whole tidal-strait mouth system of which the dunes and spit are but the subaerial expression. However, sufficient data to support a well justified and robust case for boundary extension is currently lacking and further research is required.

A3.6.2 Morfa Dinlle, Gwynedd

Morfa Dinlle, which forms the southern side of the western mouth of the Menai Strait, comprises a complex area of coast undergoing erosion together with shingle ridges and dunes. At Dinas Dinlle, low cliffs about 25 m in height expose folded and faulted Devensian glacigenic sediments that provide evidence for a possible advance of the Late Devensian ice-sheet. The sediments of the cliffs are also important in providing evidence that helps elucidate the development of the western end of the Menai Strait. Marine erosion of glacial deposits south of Dinas Dinlle has supplied a heterogeneous mix of sediments to the mainly north-eastwards moving drift system along Pen Llŷn. At the northern end of the cliffs the coast has been reinforced to protect the Marine Hotel. A single shingle ridge extends north from Dinas Dinlle for about 2.5 km, and has been protected, since 1976, by gabion mattresses along the ridge crest between Dinas Dinlle and the airfield. In places the lower seaward face of the ridge has been undermined leading to collapse of the gabions. The low-lying area between Dinas Dinlle and Morfa Dinlle village is believed to have been formed by deposition of gravel ridges, but these have been obliterated by construction of the airfield. Morfa Dinlle itself comprises a series of shingle ridges capped in parts by low sand dunes.

Little research has been conducted into the character and dynamics of Morfa Dinlle, but like the adjacent Newborough Warren coastal assemblage site, it is fundamentally linked to the tidal dynamics associated with the south-western mouth of the Menai Strait and longshore drift processes acting within Caernarfon Bay. Development of shingle ridges at Morfa Dinlle suggests sediment delivery vastly in excess of that potentially available from cliff erosion and longshore drift alone. Recycling of sediment due to shoreward migration of the ridge system extending from Dinas Dinlle to Morfa Dinlle may represent another source along with material derived from the adjacent seabed. The complex topography of the north-eastern end of Morfa Dinlle at Fort Belan has been attributed to the spit feature being cored by morainic deposits.

Like the adjacent Newborough Warren and Abermenai Point there is no current major offshore threat facing the integrity of the site. However, when taken with the assemblage site on the opposite side of the Menai Strait, Morfa Dinlle and the Newborough-Abermenai dunes and gravel ridges represent components of an integral system of international importance documenting the sedimentary and morphological response to rising Holocene sea-levels and the opening of the Menai Strait Pethick, 1997). As stated in the Coastal Geomorphology GCR volume (JNCC, in prep.):

> *The relationship between the mouth area of an estuary* [or tidal strait] *and its tidal dynamics is central to an understanding of estuarine management and, owing to the loss or destruction of comparable sites elsewhere, the Morfa Dinlle-Abermenai sites provide a unique opportunity for research into this complex interaction of open coast and tidal geomorphology.*

A case for boundary extension at this site, or as part of a unified Morfa Dinlle-Abermenai subtidal GCR extension initiative (perhaps forming part of a geotope approach to marine geoscience conservation including the whole or significant parts of the sub- and inter-tidal Menai Strait), is particularly strong. The international importance of the current GCR sites and their rôle as components of a larger complex and dynamic tidal strait mouth system spanning the subtidal, intertidal and supratidal realms makes this one of the strongest candidates for submarine boundary extension.

A3.7 Conclusions

The case for extending existing coastal geomorphology GCR site boundaries into the subtidal environment is highly dependent on the availability of site specific data, particularly in regard to sediment sources and transport pathways, tidal and wave dynamics, and the long term evolution of those sites. In addition, an assessment of potential threats faced by those sites, acting in the offshore zone, must also be taken into account.

The majority of the Irish Sea coast sites discussed above suffer from a lack of both instrumental and numerical modelling data regarding their dependence on offshore and nearshore processes. This makes accurately assessing their reliance on these processes and thus the benefits of extending their existing GCR boundaries into the subtidal environment extremely problematic. Given that areas below low water are not explicitly covered by the Sites of Special Scientific Interest (SSSI) system by which current GCR sites are conserved, the need for quality data to support a robust justification for site extension and a change in the legislative framework for site conservation is acute. It is, nevertheless, apparent that some site categories would benefit more than others from site boundary extension. It must, though, be stated that boundary extension cannot be justified for all sites within those categories due to a low threat to integrity posed by potential offshore activities, a low dependence on offshore processes, or, as in the majority of cases, insufficient data to support a robust justification of boundary extension.

Those categories *benefiting little* from boundary extension due to their inherent low dependency on subtidal processes and sediment dynamics that can be effectively conserved by such extension measures are detailed below, including their constituent individual sites found on the British Irish Sea coast:

- **Hard & Soft Rock Cliffs**
  - Porth Neigwl, Gwynedd
  - Solfach, Pembrokeshire
  - South Pembroke Cliffs, Pembrokeshire
- **Saltmarshes**
  - Solway Firth: North Shore, Dumfries & Galloway
  - Solway Firth: Upper Solway marshes, Dumfries & Galloway
  - Solway Firth: Cree Estuary, Dumfries & Galloway

In such cases, any potential threat to site integrity acting subtidally would be best managed as part of an integrated coastal or estuarine management plan.

Categories potentially *benefiting* from boundary extension include the following. However, as stated, not all sites within these categories (on the Irish Sea coast at least) can be proved to benefit from boundary extension. In this case a generic approach to extension cannot be taken, rather a site-by-site analysis. This is however hindered by lack of available data. Categories benefiting from extension are listed below. Sites within these categories for which their exists justification for such boundary extension are marked in bold type:

- **Sandy Beaches & Coastal Dunes**
  - Luce Sands, Dumfries & Galloway
  - **Ainsdale, Merseyside**
  - Tywyn Aberffraw, Ynys Môn

- **Sand Spits & Tombolos**
  - Walney Island, Cumbria
  - Morfa Harlech, Gwynedd
  - Morfa Dyffryn, Gwynedd
  - **Ynyslas, Ceredigion** (with further research)

- **Complex Coastal Assemblages**
  - **Newborough Warren, Ynys Môn**
  - **Morfa Dinlle, Gwynedd**

It is apparent that the sites within the above categories not highlighted as benefiting from boundary extension cannot be accurately assessed due to insufficient data. If more research data was available it is envisaged that further sites would be added to the list of those for which sufficient justification for boundary extension exists.

All the categories that contain sites potentially benefiting from submarine GCR boundary extension are those that are highly dependent upon the onshore and longshore transport of sediment and the complex dynamical interaction between tide, waves and bedforms subtidally and intertidally. It is the conservation of these processes and sediment dynamics in the subtidal environment in order to mitigate against potential site integrity threats that represents primary justification for boundary extension where the reliance of a site on those offshore processes is demonstrable.

However, especially in the case of complex coastal assemblage sites (as well as some sand spit and tombolos), features currently conserved at GCR sites represent only the subaerial components of larger complex dynamical systems. If the principles of conserving Britain's geodiversity are to be adhered to, such systems need conserving *in their entirety* both above and below low water as being representative of the broad range of dynamic morphosedimentary systems active around the UK. The opportunity to extend sites to encompass their whole submarine extent rather than the limited and piecemeal conservation of their current subaerial components would represent a major advance in geoconservation, overcoming the arbitrary intertidal barrier over which sediments can move. Few sites now currently exist where either their terrestrial or marine components have not been in some way degraded. Those that still exist (many of which whose subaerial elements are conserved at GCR sites) should be conserved in whole rather than in part.

A3.8 Summary & Recommendations

Coastal geomorphology represents the interface between processes operative in both the marine and terrestrial environments such that active integrity sites within this border region are dependent upon dynamical and sediment process in the marine environment as well as subaerial processes such as mass movement and aeolian activity in the terrestrial zone. It is the dynamic balance between processes operating in both environments and acting on a range of different lithologies and sediment types that leads to the development of the wide range of coastal landforms seen around the UK.

Coastal geomorphology sites included in the terrestrial GCR do not currently extend below mean low water. Whilst representing the subaerial expression of these landform systems, they do not include within their boundaries the integral marine processes and bedforms that form fundamental components of such systems. However the degree to which individual sites within the Irish Sea (pilot study) area are dependent on offshore processes and sediment transfers is extremely difficult to quantify given the marked lack of published data on the subject. There appears a lack of instrumental data on the scale necessary to elucidate the influence of offshore processes effectively for all fifteen Irish Sea GCR coastal geomorphology sites, along with a lack of numerical methods of sufficient resolution to model sites at the necessary local and regional scale required. For a number of sites, however, there appears a justifiable case for boundary extension. With access to improved and higher resolution data, the justification for boundary extension at these sites would be more robust, and it could be demonstrated that other sites could benefit from such an initiative for which there is presently insufficient justification for boundary extension. These sites are:

- Ainsdale, Merseyside
- Ynyslas, Ceredigion
- Newborough Warren, Ynys Môn
- Morfa Dinlle, Gwynedd

Based on a general understanding of the different categories of sites and the limited literature published on them, the broader categories of coastal geomorphology features within which sites could benefit from boundary extension are as follows:

- Sandy Beaches & Coastal Dunes
- Sand Spits & Tombolos
- Complex Coastal Assemblages

The above categories that contain sites potentially benefiting from submarine GCR boundary extension are those that are highly dependent upon the onshore and longshore transport of sediment and the complex dynamical interaction between tide, waves and bedforms subtidally and intertidally. Not all sites within those categories, however, can be proved to benefit from boundary extension and whilst the above categories are a guide to which sites might benefit from extension, a generic approach is not advised. Rather, a more specific site-by-site analysis is required to establish which sites would benefit most from boundary extension and for which sites sufficient data exists to justify such extension.

Categories likely not to contain sites potentially benefiting from boundary extension are:

- Hard & Soft Rock Cliffs
- Saltmarshes

Some individual sites within these categories may, however, benefit from extension. The classification of the above as not containing sites for which sufficient justification for boundary extension exists is based upon an assessment of Irish Sea sites. Sites within these categories outside the Irish Sea Basin may benefit from such a boundary extension initiative.

It is considered therefore, that based both on the assessment of potential offshore site integrity threats and the occurrence of complex interacting landform (where essential parts of those systems are expressed subtidally as in the case of spit, bar and barrier features), there exist a clear and justifiable case for boundary extension to include the whole bed/landform system. As existing GCR geomorphological integrity sites are used to demonstrate dynamic process active in the environment, the extension of site boundaries to include processes not covered in the terrestrial environment is wholly justified. However, for the majority of sites there exists insufficient data to assess accurately their dependency on offshore processes other than making broad qualitative observations. In such cases it is thus difficult to analyse the degree to which sites would benefit from boundary extension. In addition, in those cases where boundary extension is considered necessary and/or justified, the lack of sufficient site-specific data may weaken such cases.

In these circumstances where it can be proved that sites will benefit little from boundary extension or were insufficient data is available for accurate assessment, offshore conservation would be better accommodated in coastal and estuarine management strategies.

Recommendation A3.1

For a limited number of Irish Sea GCR coastal geomorphology sites, there appears sufficient justification for the extension of existing site boundaries into the subtidal environment, these sites being:

- *Ainsdale, Merseyside*
- *Ynyslas, Ceredigion*
- *Newborough Warren, Ynys Môn*
- *Morfa Dinlle, Gwynedd*

Broader categories that contain sites that could potentially benefit from boundary extension are:

- *Sandy Beaches & Coastal Dunes*
- *Sand Spits & Tombolos*
- *Complex Coastal Assemblages*

Recommendation A3.2

For the remainder of Irish Sea GCR coastal geomorphology sites where it is demonstrably of little benefit to extend existing GCR site boundaries into the subtidal environment, or where a current lack of instrumental and modelling data available for sites makes a valid assessment of such benefits impossible, offshore threat mitigation and conservation would be better accommodated as part of integrated coastal and estuarine management programmes.

Recommendation A3.4

In the case of complex landform systems that span both marine, intertidal and terrestrial environments (such as spits, bars and barrier islands) there does exist a strong case for boundary extension to include the submarine extension of those features and processes integral to that landform/bedform system. For sites selected to illustrate the operation of physical processes, the exclusion of their submarine components seems unjustified.

Recommendation A3.5

The desire to extend existing subaerial coastal geomorphology GCR sites, where justified, into the submarine environment is greatly hindered by a lack of instrumental and numerical modelling data. In order effectively to implement a marine boundary extension initiative, further research into the vast majority of sites must *be taken if accurate assessments of the benefits of boundary extension are to be made and new submarine site boundaries delineated.*

Recommendation A3.6

It is recognised that the above conclusions apply only to sites on the Irish Sea coast. Coastal geomorphological sites outside this region should also be reviewed on a site by site basis.

Report A4 Marine geoscience site selection rationales

A4.1 Introduction

The existing terrestrial Geological Conservation Review (GCR) selection rationale is based upon five fundamental components (Ellis *et al*.,1996) which address the broad scientific, cultural, philosophical and practical needs of Earth heritage conservation. These components are :

- International importance of site
  - time interval stratotypes
  - boundary stratotypes
  - biozone type localities
  - chronozone type localities
  - outstanding landforms
  - rock, mineral & fossil typesites
  - historically important localities
- Exceptionality of site
  - unique, rare, special features
  - nationally important
- Representativeness of site
  - sites that best represent those features, events, processes fundamental to UK geological history
- Minimum number of sites to be representative
  - minimum duplication between sites
  - minimum number of sites necessary to demonstrate topic of interest
- Research value of site
  - *geologically* important sites
  - history of past, or potential for future, important research
- Practically conservable
  - Sites can be conserved in a practical sense

Such an approach, evaluating sites using the above criteria as a basis for assessment, has been particularly successful in a terrestrial context where the vast majority of GCR sites (2,704 of a total of 3,000) are exposure or inactive integrity sites. Nationally only 296 features are considered as active geomorphological integrity sites.

The above approach is strongly site based, evaluating features as discrete discernable units, easily definable, and independent of the surrounding landscape system. However, alternative, non site-specific approaches exist.

The concept of the “geotope”, adapted from the conservation biology term biotope, refers to a distinct landform assemblage as opposed to individual features or sites within that assemblage. The term was first introduced by Sturm (1994) as being a distinct part of the geosphere of exceptional Earth science interest above that of the surroundings.

A geotope may thus represent an active landform assemblage of interacting and interrelated components, or processes, found within a larger area than the level of the site as defined by the GCR methodology. A geotope may also encompass a region of closely associated or concentrated relict geological or geomorphological features, or an area with both inactive and active integrity components along with exposure features forming a discrete land system.

At the larger scale where such discrete landform assemblages, as defined by the geotope approach, represent components of a larger morphodynamic system, an even wider view can be taken and the landscape regarded as a functioning systems hierarchy of geotopes and sites. An example of a geotope might be a coastal spit system, including within it the spit head, bar and tombolo features above low water and submarine features such as its subtidal extension, ebb tide deltas and tidal scour features (considered as individual sites using a site based rationale) A landscape or seascape system could also include this spit system assemblage within a larger system at the scale of an estuary including fluvial elements, saltmarsh and mudbank features, intertidal morphological features, dune and coastal barrier sites and relict and exposure sites within the estuarine environment.

This report thus aims to evaluate such site-based, geotope, and landscape systems in the context of a programme of marine geoscience conservation and to propose a suitable rationale for the marine environment.

A4.2 Site-based versus systems approaches

The geological, geomorphological and dynamic character of the UK offshore region differs markedly from the terrestrial environment. Many of the features found within the UKCS are specific to the marine realm and are dependent on marine-specific processes. Features also face threats specific to, or of greater intensity in, the subtidal zone. Any site selection rationale must therefore specifically address the features, processes and threats peculiar to the marine environment, whilst at the same time allowing the rigorous selection of sites based on the wider justifications of Earth heritage conservation. In addition, such a rationale must be broadly compatible with, and complementary to, the existing terrestrial GCR programme if the full range of British geological and geomorphological features and processes (supra- and sub-tidal) are to be represented.

A4.2.1 Threats and selection rationales

The potential for far-field effects to have deleterious consequences for site integrity is particularly acute in the marine environment where the majority of potential conservation sites are relict or active integrity features composed of erodable unconsolidated sediments. This presents a considerable challenge to any site selection rationale, requiring consideration of processes and sediment transport pathways active over large distances and areas. Any rationale must also address direct threats to site integrity acting on, or in the immediate vicinity, of that feature.

Site-based approaches

Assessing features using a site-based rationale where site boundaries can be easily and clearly defined represents a valuable approach to mitigating near-field and direct threats acting to degrade site integrity. By defining small (relative to geotopes and seascapes) discrete units around important features, within which potentially damaging activities are strictly controlled or prohibited, enables sites to be protected from direct threats whilst minimising potential conflicts of interest. In such a case, the conservation "footprint" of a feature is small and thus the area in which conflicts of interest with other marine stakeholders can arise is limited.

However, given the spatially limited extent of site boundaries, a marine geoscience conservation programme designed around a site-based selection rationale would fail to sufficiently protect sites from the detrimental consequences of far-field effects. Threats to site integrity, acting over considerable distances by disrupting existing patterns of sediment supply and tide-current processes (see Report A2), could be initiated outside site boundaries. Such activities have major potential far-field consequences for site integrity, more so in the marine environment where many active geomorphological sites are not as topographically constrained as they are terrestrially. Given this failure to mitigate against such remotely acting threats that are a fundamental characteristic of the marine environment represents a major shortcoming of any GCR-style site-based selection rationale. The adoption of purely this class of methodology would leave many sensitive sites open to considerable far-field threats to site integrity. However, where applied to sites of only limited vulnerability to far-field indirect threats such as hard rock exposures and some relict integrity features, this approach still represents a valuable conservation tool.

Geotopes & landscape/seascape systems based approaches

The medium-scale geotope and large-scale seascape system approaches represent the conservation of bedform assemblages along with the surrounding environment on which they depend for sediment supply and the operation of wave-wind-current processes. Consequently such approaches infer the designation of larger areas of seafloor as conservation areas than the more spatially limited site-based approach. Thus the conservation "footprint" of these areas is much larger than GCR-style individual sites. This raises greater potential for conflicts of interest with other marine users.

The benefits of such approaches are that by restricting, or prohibiting, activities potentially threatening to site integrity over a larger area outside the physical boundaries of those features on the sea floor, the ability to manage far-field indirect threats is greatly increased. Given the size such conservation zones would have to cover to include the process and sediment "catchment area" of a bedform or bedform field, the consequent potential for conflicts of interest is severely increased, especially in high use zones such as the Severn Estuary-Bristol Channel, Wash, north-eastern Irish Sea and southern North Sea. Such a rationale may prove unworkable at a level where sufficient protection of sites from activities potentially harmful to their integrity can be justified given other uses for those designated areas. Whilst a lower level of threat mitigation based on control and management rather than prohibition may well be workable at

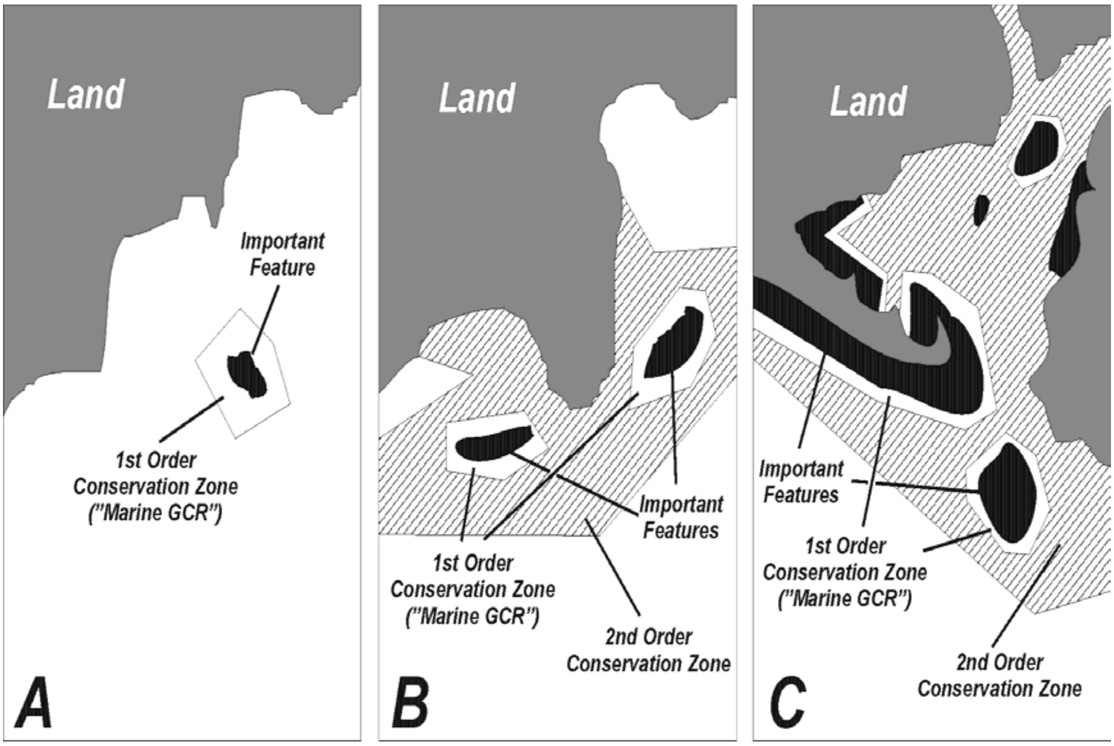


Figure A4.1 *Nested conservation zones.* ***A****) Exposure site requires only 1st order "marine GCR" conservation zone.* ***B****) Active integrity site requiring both 1st order conservation of feature and a wider zone of 2nd order conservation to mitigate against far-field effects disrupting sediment pathways and dynamics.* ***C****) Complex association of sites as part of a geotope approach. Individual sites fall within 1st order conservation zones nested within a larger second-order zone. Some features are not included in 1st order zones as they fail to fulfil national minimum number and representativeness criteria but are included in the second-order zone as they are an intrinsic part of the overall system.*

such a scale, and may well be sufficient to prevent or restrict site degradation due to far-field effects, such an approach would afford little protection from near-field or direct threats.

Thus, though geotope and seascape system approaches present clear advantages over site-based selection rationales in terms of mitigating against remotely acting far-field threats, the potential for conflicts of interest is significantly greater and the protection afforded against threats acting *directly* on site integrity is lessened.

Nested sites approach

In an attempt to overcome the drawbacks inherent in both methodologies, whilst preserving their benefits, there appears to be scope for a hybrid rationale that uses aspects borrowed from both the site-based and geotope/seascape-systems approaches. Such a combination methodology is termed here the "nested sites" approach (Figure A4.1).

Using the site-based approach, only the smallest units (individual features, bedforms, bedform formation fields where features are ephemeral) that can be easily delineated would be included as sites, with equivalent status to terrestrial GCR sites and afforded the same level of threat protection. In the case of exposure sites or integrity sites of only limited vulnerability from remotely acting threats, such conservation measures would be sufficient given the low dependency of such features on far-field processes and sediment dynamics.

However, when considering dynamic features dependent on the operation of processes or sediment transport pathways acting over larger areas, a combination approach would be of greater benefit in terms of threat mitigation. A defined "marine GCR site" constituting the bedform, bedform field or sediment unit would form the core of a geotope that would extend to include the wider adjacent area whose conservation would help mitigate against far-field effects causing dynamical and sedimentological changes to the bedform system. The core zone would posses a high level conservation status whilst the outer "geotope" zone would posses a lower status. Thus by using this nested site approach sufficient protection is given to the particular feature from direct threats by prohibiting certain activities within the inner zone, and from far-field threats by controlling and managing potentially threatening activities in the outer zone. The potential for conflict of interest is reduced by taking a workable management approach whilst at the same time maintaining high levels of site integrity.

At the seascape scale, a system conserved under the nested sites approach would be composed of a number of first-order marine "GCR site" features, nested within a zone of second-order conservation status similar to the nested geotope approach. Again, such a methodology has the benefit of maintaining individual site integrity within first-order marine "GCR site" boundaries whilst mitigating against key potentially damaging activities and far-field effects within the surrounding second-order conservation zone.

A4.2.2 The GCR criteria below low water

The six criteria used by the current GCR programme in site selection (see §A4.1) were devised with reference to the terrestrial environment, and form the fundamental basis of British Earth heritage conservation and a key expression of the underlying justification behind such conservation programmes. However, they may not be wholly applicable to the geology, geomorphology and morphodynamic processes characteristic of the subtidal zone given the specific nature of these aspects offshore. Furthermore, some may be more applicable to a site-based selection rationale as opposed to geotope, seascape and nested site systems.

Each of the six criteria are examined with reference to their applicability in the marine environment as well as their value as part of differing site selection rationales.

International importance

The concept of international importance being a key criteria for site conservation, be that feature recognised as an international stratotype, important type site, and outstanding landform or for its science history value, forms one of the principal tenets of Earth heritage conservation and is considered equally applicable in the marine environment as it is on land.

Sites of international importance occur within the marine environment (e.g. the subtidal and offshore extension of Chesil Beach) and thus such a criterion should be recognised in any site selection rationale. The fact that such sites are submarine does not reduce their international importance, nor does the scale of the feature or the conservation methodology applied. The international importance criteria is equally applicable to individual sites selected using a GCR-style site-based approach as it is for geotopes, seascapes and nested-site methodologies. However, quantifying such a subjective concept as international importance may become more difficult as the scale of the site or site-system used is increased. A consideration of international importance is, though, critical and should form the primary component of any marine site selection rationale.

Exceptionality

Nationally exceptional sites possessing unique, rare or special features also occur both terrestrially and subtidally. Exceptionality forms the second component of the GCR criteria and, like international importance, also reflects the fundamental principles of Earth heritage conservation.

Exceptionality, as a site selection criterion, is equally applicable below low water as it is above and should form a key component of any marine site selection rationale. Like international importance, however, there may arise problems of quantifying exceptionality especially in the case of larger scale site conservation approaches.

Representativeness

Fundamental to the approach taken by the GCR is the concept of representativeness, forming the systematic back-bone to the terrestrial site selection methodology. The approach is founded on the principle that any selection rationale should aim to include a sufficient range of sites to illustrate the diversity of Britain's geological heritage, including aspects both unique and commonplace. It thus forms a vitally important tool in conserving Britain's geodiversity.

There is no reason why such an important concept should not be applied below low water as it is above. There is nothing inherent in the marine environment that make such an approach unworkable. However, the concept of representativeness (and the closely allied minimum number concept) works most effectively as a site selection criteria at the level of individual well defined sites of limited extent such as those that form the existing GCR network. It becomes more difficult to apply the representative principle when using site selection approaches that rely on the conservation of site assemblages as blocks rather than individual sites. In such a case the potential for duplication of individual sites within and between geotopes and seascapes may fail to fulfil the site-based representative criterion. However, when applied at the level of the geotope rather than the site, there is no apparent reason why representativeness should not be a viable concept. The whole geotope or bedform system must be assessed according to its representativeness rather than the individual features that occur within it.

A nested site methodology would also be founded on the concept of representativeness but such a two tier approach would allow representativeness to be assessed on both an individual site level and that of the larger geotope. A potential nested site geotope might thus score highly in terms of representativeness for the overall system, but might be composed of high-scoring first-order "GCR-style" sites as well as lower scoring features that have not been given first-order status but still form fundamental components of the geotope.

Such a fundamental concept of representativeness must be included within any site selection rationale, but would work best within a multi-level nested sites approach.

Minimum number

Critical to the concept of representativeness is the criteria that, at an operational level, there should be a minimum of duplication between sites. Such an approach is designed to reduce conflicts of interest and keep site numbers to a practically conservable number whilst at the same time maintaining representative examples of the different aspects of British geodiversity.

Again, simply because features occur in the submarine environment does not mean that such a concept cannot be applied. However, like representativeness, such an approach is most suited to a site-based selection approach where individual sites can be delineated, categorised, researched and assessed, and a minimum representative number chosen for conservation. The potential for the duplication of individual features when using larger scale geotope and seascape approaches could easily result in the inclusion of many similar sites between and within such conservation areas.

A two tier nested sites approach would, however, go some way to overcome this problem. Where a site-based approach and a larger geotope system run in parallel a minimum number of representative individual sites would be selected along with a minimum representative number of geotopes or seascape systems. The result would be a structured two tier nested system with first-order "GCR-style" conservation zones nested within larger second-order geotopes or seascape systems. Some component features would not be given first-order conservation status as they represent duplication of that category of site. However, they, would be included within the second-order conservation zone as they form fundamental components of the overall geotope.

Research value

Whilst not expressly a key component of the GCR site selection rationale, preference is given to sites that have received detailed study in the past, have the potential for future research, and have played an important rôle in the development of earth sciences (Ellis *et al.*, 1996).

Such an approach can be applied to both site-based and geotope methodologies. It would, however, be most successful when integrated into a nested sites rationale where the research value of both the overall geotope and its constituent elements would be assessed both independently and as a whole.

Given the marine environment and the paucity of data for some areas of the offshore environment, the research value of many sites may be difficult to quantify in individual cases. Many nationally and internationally important and exceptional features may not have been studied in much detail, likewise classic representative examples may have had little work conducted on them. It may be the case that given the logistical problems of undertaking submarine research those features of which most is known may be the most accessible rather than the best preserved or most representative. Thus relying too heavily on research value as a selection criterion may result in the omission of certain key features from any site selection programme. However, when integrated with the other selection criteria it still represents a valuable concept for assessing site conservation value within the marine environment.

Conservability

The operational criterion of conservability is applicable both to terrestrial and marine sites. Sites that cannot be practically conserved should not be included in any conservation programme.

In the marine environment it can be argued, however, that many features cannot be practically conserved on a limited site-only basis as the threats posed by transmitted far-field effects acting outside the immediate vicinity of that feature cannot be mitigated against. Likewise, a large area of high level conservation status such as a geotope may not be realistically conservable due to acute and irresolvable conflict of interest issues and the need for other potentially harmful activities to continue within that area.

The nested sites approach may resolve some of these issues by affording core sites high levels of conservation whilst mitigating against far field threats by nesting sites within larger lower status conservation zones. Such lower status zones would either be around individual sites or site systems to help conserve sediment supply and dynamics or comprise larger scale geotopes and seascape systems composed of bedform assemblages.

Further conservability issues are raised by sites dependent on processes operating outside the UKCS. For sites in this category to be practically conserved requires international agreement (see § A2.4). Similarly, if sufficient legislation is not in place to allow site conservation within the UKCS but outside the 12 nautical mile territorial waters zone sites within 12 nm of the coast but dependent on process operative outside this limit may also not be realistically conservable.

The variability of natural processes also presents threats to site integrity which may render some sites ultimately unconservable. Assessing the susceptibility of sites to such complex interacting processes, including global sea-level change, is, however, difficult and requires a recognition of the timescales of which some sites have existed and for how long into the future they should be practically conservable for.

Site conservability is an important practical criterion and should be applied to any marine site selection rationale. Sites or geotopes must be practically conservable if any conservation programme is to be successful in the mid to long term.

A4.2.3 Geotopes, seascapes and nested site systems: other advantages and disadvantages

The larger scale geotope, seascape and nested site selection approaches possess significant threat-based benefits and drawbacks and the varying potential for conflict of interest issues to arise (§ A4.2.1). In addition to this threat-based analysis, larger scale area-based approaches also have other marked advantages and disadvantages when compared to the traditional side-based methodologies in terms of representativeness and geodiversity.

Such approaches allow the study of complex interaction of geomorphic and geodynamic processes within site assemblages and thus represent a greater potential for future advances in understanding than do geomorphic sites conserved in isolation. The large scale of geotope areas also has positive implications for applying a more holistic approach to marine conservation in general. Larger areas probably represent more viable and integrated marine habitats as well as containing within their borders potential marine archæological sites. In addition they form larger systems that may be conceptually easier for the general public to grasp rather than individual sites whose conservation value can be perceived to be rather specific and esoteric.

However, the large scale of such geotope and nested-sites approaches may present specific management problems. Simply put, there is a larger region being conserved requiring greater resources do to so effectively. Larger areas may also present greater problems of policing. Especially in the case of nested-site zones, specific policing issues could arise where certain activities are prohibited within first-order core conservation sites whilst permitted with control within the surrounding second-order area. Disputes as to which side of the core site boundary activities were occurring would be likely, however this may be equally probable using a purely site-based approach. Lastly, lack of data may also be a problem in defining effectively the boundaries of larger site assemblages and process and sediment “catchments” of dynamic sites. Data paucity may also make justifying large scale conservation rationales difficult.

A4.3 Delineating Boundaries

The existing GCR programme requires site boundaries to correspond to the *minimum area* required for continued conservation of those features of interest, drawn on an Ordnance Survey 1:10,000 scale base-map (Wimbledon *et al.*, 1994; Ellis *et al.*, 1996). Defining this minimum area in the marine environment, especially given the dependency of active integrity sites on complex processes active over large areas, may prove more difficult than defining the limits of terrestrial exposure sites.

A4.3.1 Process boundaries and catchments

Effective site boundary delineation requires an understanding of marine processes and an appreciation of the dynamical and sedimentary "catchment" of a feature. Furthermore, it requires an assessment of the level of threat faced by a site and the degree to which such threats decrease in severity with increasing distance from the feature of interest. To do this effectively requires the integration of quality field and modelling data, which for many potential marine sites does not currently exist. Thus for any marine conservation programme to be successful, it is imperative that a research programme in support of the conservation initiative be undertaken parallel to, or as a constituent part of, that initiative (see § A1.3, Recommendation A1.5).

Such a need to define robustly site boundaries based on firm scientific data applies equally to both individual sites and geotope limits. In the case of a nested sites approach it is envisaged that core first-order site boundaries would approximately correspond to the physical extent of that feature on the sea floor. Where features are ephemeral, the area defined will correspond to the established area of development of those features, i.e. the bedform field. Where dynamic features appear to be migrating, core site boundaries must be flexible allow for movement of the feature over time. In the case of particularly sensitive sites, 500m exclusion zones for certain potentially threatening activities (e.g. trawling) similar to those currently found around marine installations, may be required, extending beyond the defined limit of that site or included within the site boundary.

Defining the limits of second-order conservation zones or geotopes requires an understanding of sediment transport and dynamics and the sediment and process "catchment" of an active feature or assemblage of features. Boundaries should be drawn around the minimum area required based on such an understanding as well as an appreciation of the decline in threat severity at increased distance from features or feature assemblages.

A4.3.2 Charting

Once defined, boundaries should be drawn on Hydrographic Office (HO) marine charts at a scale sufficient to show in detail the site boundaries and any exclusion zones necessary. HO charts vary in scale depending on the area covered. If it is considered necessary to map site boundaries at a standardised scale, the production of specific bathymetric charts based on surveyed data or data purchased from the HO will be required for some sites where suitable charts do not currently exist. This will be especially true of areas offshore away from well charted estuaries and coastal areas.

A4.4 Recommended Marine Site Selection Rationale

Based on the above evaluation of the different site selection rationales, and including the benefits and drawbacks of each approach in terms of threat mitigation, boundary definition and fulfilment of the existing GCR criteria, this report recommends the adoption of a two-tier nested-sites approach as a working site selection rationale for a marine geoscience conservation programme.

A4.4.1 Two-tier nested sites approach

A two-tier nested-sites approach (Figure A4.1) combines the benefits of both site-based and geotope based systems whilst going a long way to overcome the deficiencies of such approaches when applied in a marine setting. In effect it represents an extension of a modified form of the existing GCR approach into the offshore environment, superimposed upon a geotope marine conservation approach.

A4.4.2 First-order conservation sites

Fundamental to this nested-sites methodology is the concept of the core first-order site. First-order core sites are classified and assessed along established site-based criteria and are afforded the highest level of conservation status similar to existing terrestrial GCR sites. Such core sites would be composed of individual features considered worthy of conservation and site boundaries would approximate to the physical boundaries of those features. In cases where features are particularly sensitive to certain threats, site boundaries may be extended to include a suitable exclusion zone (e.g. 500m used for marine structures). These core first-order conservation zones would be of limited extent and form the basis for a marine geoscience conservation programme. They would strongly resemble existing GCR sites in their assessment, classification, conservation and publication. Core sites composed of exposure and integrity sites would form the basis of individual sites, geotopes and seascape systems.

A4.4.3 Second-order conservation zones

The second component of this two-tiered nested-sites approach is the second-order conservation zone within which first-order sites are nested. Whereas the first-order sites are characterised by high conservation status, including the prohibition of harmful activities acting directly on site integrity, second-order zones would be marked by a lower conservation status allowing greater use of the area by other stakeholders and based on a more general management rather than prohibitive approach.

The aim of designating second-order conservation zone status to the seabed surrounding sites is threefold.

1) Where individual sites are dependent upon wider sedimentary and dynamic processes, protection is afforded from far-field threat transmission.

2) Conservation status can be afforded to larger complex systems and bedform assemblages, i.e. geotopes and seascape systems, composed of a number of interacting elements.

3) The lesser conservation status of these zones based on a more management-orientated approach reduces inherent increases in the potential for conflicts of interests as site size is expanded.

Second-order zones, where used to designate geotopes, would be subjected to similar selection criteria as individual first-order core sites. However, such selection, assessment, classification, conservation and publication would be conducted at the level of the geotope rather than the individual site.

Thus second-order conservation zones would form the basis of a programme of geotope and active integrity site conservation on which first-order conservation sites are superimposed. In effect this represents the simultaneous enaction of two parallel, but fundamentally linked, approaches to marine geoscience conservation. This two-pronged approach results in a conservation methodology far more robust and defensible in terms of scientific value, threat management and geodiversity representativeness. In an environment dominated by processes and sediment dynamics acting over large areas and by complex interacting assemblages of bedforms, such a two-tier approach is superior to either one of its components enacted independently.

A4.4.4 Tripartite approaches to dynamics

Based on the two-tier principle, sites can be divided into three categories based on an assessment of their dependency on, or threat posed by, changes in local and regional sediment and tide-current dynamics. These categories are:

- Independent sites
- Nested sites
- Geotopes

A4.4.5 Independent sites

Features independent of modern sediment supply and dynamics, and at low risk from far-field threats, can be conserved as core first-order sites without needing to be nested within a larger second-order conservation zone (Figure A4.1). As such, these sites would resemble existing terrestrial GCR locations.

The majority of sites in this category would probably be exposure sites formed in solid geology as well as robust integrity sites at low risk from far-field effects. Independent sites would not form components of the larger systems considered for conservation under second-order zonation unless they fell within the boundaries of geotope systems.

A4.4.6 Nested sites

Where features are highly dependent upon active sediment and tide-current dynamics for their maintenance and evolution and/or are susceptible to potential threats (due to unconsolidated nature etc.) acting over large distances from the feature, a nested sites approach should be taken (Figure A4.1).

The individual feature, or features, would be conserved within first-order core conservation sites like those used for independent sites. Such sites would be nested within a larger second-order conservation zone designed to maintain sedimentary and dynamic conditions currently pertaining in that area. This second-order zone does not, however, represent a geotope and is not assessed as such. Rather, it is designed to safeguard the process essential for the maintenance of the site which it surrounds.

The majority of sites in this category would be integrity sites. An inactive integrity site formed in unconsolidated sediment would benefit as changes in the dynamical regime within a radius of that site could lead to site degradation and damage. Such sites might include relict moraines, moribund tidal sand ridges or iceberg scour marks. Active integrity sites would benefit as geodynamical process essential for their evolution, maintenance and development would be maintained. Such sites might include sand wave fields, banner banks or active tidal sand ridges.

A4.4.7 Geotopes

Where complex interacting and/or interrelated associations of features (both exposure and integrity type) occur, such areas can be conserved under a geotope rather than a site-based approach. The whole area defined as the geotope would be afforded second-order marine conservation zone status. Such geotopes would be assessed independently of individual sites, but according to the same criteria. These criteria would be applied at the level of the geotope to distinguish between geotopes rather than at the site or component feature level.

It is likely that geotopes of second-order conservation status will have nested within them first-order sites considered worthy for conservation independently of the overall geotope system (Figure A4.1). Given that geotopes will be subject to the same criteria as individual sites, internationally important or exceptional geotopes are likely to contain internationally important or exceptional components. However, geotopes will also contain features that form fundamental components essential for the integrity of that geotope but which have not be granted first-order conservation status as they do not fulfil the minimum number criteria applied at a site specific level. In other words more valuable examples of that particular feature may be found outside that specific conserved geotope.

Second-order conservation zone geotopes could include: significant estuaries and embayment such as the Solent, Wash, Humber, Severn and Thames; complex sea lochs, tidal straits and island systems such as the Isles of Scilly, the Menai Strait, Firth of Lorne – Loch Linnhe, and shelf edge/continental slope systems including canyon-fan associations, mass movement elements, and along slope deposits and transport features.

A4.4.8 Numerical site assessment

The existing site GCR selection methodology, based upon a review process aiming to shortlist potential sites for inclusion within the conservation programme, received marked criticism from a number of consultees. Whilst the method of literature searching, draft site list preparation, documentation, and peer review were broadly accepted, it was considered that the process lacked transparency and was highly subjective. In particular, it was felt that selection based purely on a written site summary, and written justification for their inclusion, biased the selection process in favour of features about which the best prose had been written rather than those sites that were inherently better suited for conservation.

Whilst such criticism may be unjustified given the rigorous peer review process potential sites are subjected to, this perception of subjectivity and lack of transparency needs to be addressed. Any site selection process will always, by definition, contain subjective elements. It is considered, however, that there is scope for a more open and objective site selection approach that forms part of the established site selection review mechanism.

The concept of numerically grading biotopes and ecosystem elements as a means to evaluate their conservation potential is an established technique. It is suggested here that such an approach can be adapted for use in a marine site selection programme and that it can be integrated into, rather than replacing, a site assessment process similar to that used in the GCR.

Both individual sites and geotopes would be subjected to numerical assessment using the six key assessment criteria:

- International importance
- Exceptionality
- Representativeness
- Duplication (Minimum number)
- Research value
- Conservability

Each site or geotope would be awarded a numerical value under each of these headings. Sites or geotopes gaining the highest total scores would be the most favoured candidates for conservation. Site/geotope grading would be conducted at the level of categories equivalent to GCR thematic blocks or networks (see § A6.2) in order to prevent shortlist being dominated by particular categories of sites.

The grading process remains subjective and the level at which sites are graded according to each criteria will have to be adjusted so that manifestly important sites consistently score the highest. However, once a workable numerical grading system has been established and integrated into a marine site selection methodology resembling the current GCR approach such a process should be more transparent and objective. It also has the advantage that as new sites are suggested or others become degraded or redundant over time, their new value and subjective "rank" can easily be calculated.

A4.4.9 Structured selection rationale

In addition, the current GCR programme was criticised by consultees as being composed of often disparate thematic blocks, the review blocks and networks having evolved on an apparently *ad hoc* basis rather than constructed systematically. By devising a workable site selection rationale *before* considering a list of potential sites or thematic conservation review blocks, a structured, top-down, hierarchical approach to site categorisation is achievable.

A4.5 Summary & Recommendations

The existing terrestrial GCR site selection rationale works well in the terrestrial environment where most sites are exposure or inactive integrity sites and where boundaries can effectively be drawn around discrete elements. Even in the case of active integrity sites, within the terrestrial environment such landform systems are often topographically or lithologically constrained.

Alternative systems proposed for application to marine sites are those of the "geotope" or "seascape" and the "nested-sites" approach. Such approaches include often dynamic features requiring the maintenance of processes necessary for their development that operate within areas considerably larger than the extent of that particular bedform or bedform field, or the conservation of a wider area containing a dynamic association of interacting and/or genetically linked features and processes of both exposure and integrity type.

Given the scale of geomorphological processes within the marine environment, the site based approach currently used by the GCR is of limited value in conserving offshore sites. This approach is best applied to limited extent marine exposure sites at risk from few potential threats and around which boundaries can easily be drawn.

Geotope or seascape approaches would be more applicable to active geomorphic features and feature assemblages granting mitigation of far-field and distance acting threats. However, to be workable and avoid excessive conflicts of interest, such conservation would have to be based on a dominantly management-orientated approach and may thus not afford individual sites within those systems sufficient direct protection.

The nested-sites approach offers a combination of the two above rationales affording high conservation status to core sites whilst extending lower level second-order conservation status to the surrounding seafloor on which those sites are dependent. This has the benefit of maintaining individual site integrity within first-order core site boundaries whilst mitigating against key potentially damaging activities and far-field effects within the surrounding second-order conservation zone.

The six GCR site selection criteria apply equally well to limited extent marine sites as they do to terrestrial sites. Even in the case of a nested conservation zone approach applied to an individual active feature, such criteria are still applicable as they would apply to the core feature rather than the surrounding seafloor. However, due to the paucity of data for some areas of the offshore environment, the research value of sites and geotopes may be difficult to quantify in individual cases. Such criteria can also successfully be applied to larger scale geotopes. To be successful, however, geotopes have to be assessed as part of a parallel and linked site selection process separate from that used to assess individual sites. Thus the nested approach represents the combination and parallel operation of both site-based and geotope rationales.

Defining conservation-area boundaries would be relatively easy for exposure sites that are non-mobile and independent of external processes. Boundaries would take into account spatial extent of that exposure and variations in site quality/degradation as well as conflicts of interest with other potential users. Likewise, for active and inactive integrity sites where a zonation approach is used, the first-order conservation zone boundaries will probably coincide with the physical boundaries of individual features or bedform fields in question. However, defining the outer limits of second-order conservation zones may prove problematic given the lack of numerical and instrumental data available at a local level. An acceptably robust definition of second-order conservation zones will require, in most cases, further research into parameters such as sediment transport pathways, wave transformation, tidal behaviour and residual tidal currents at each integrity site as sufficient data is in most cases lacking at present.

The existing site GCR selection methodology received criticism from a number of consultees. Whilst the method of literature searching, draft site list preparation, documentation, and peer review were broadly accepted, it was considered that the process lacked transparency and was highly subjective. Whilst any site selection process will always contain subjective elements, it is considered that there is scope for a more open and objective site selection approach based on a numerical grading method using, as its basis, the six established GCR criteria. Site grading would be between similar sites and geotopes within individual thematic blocks or at the level of GCR networks. When integrated into a site selection process resembling the existing GCR methodology, it represents a far more transparent and objective approach to site selection.

Recommendation A4.1

A site selection rationale based on a two tier nested conservation zone approach and using the existing GCR criteria as its basis represents the most inclusive approach to marine geoscience site conservation. 1st order conservation zones equivalent to existing GCR SSSIs would recognise individual features or bedform fields. 2nd order conservation zones of a less proscriptive nature would cover the territory adjacent to protected sites where deemed necessary to maintain far-field processes critical for site integrity.

Recommendation A4.2

1st order conservation area boundaries will largely conform to the spatial limits of features in question using criteria currently employed for delineating terrestrial sites. 2nd order conservation area boundaries will require, in most cases, further research to define the extent and coverage of processes and sediment transport pathways that are critical for the maintaining the integrity of features within first-order zones. Furthermore, 2nd order conservation areas will also be used to define geotope systems, not necessarily centred on core 1st order sites.

Recommendation A4.3

The GCR criteria will be equally effective in selecting areas for conservation at geotope scales as well as at the individual site level. However, individual sites and geotope systems must be assessed separately, selection being based on two separate but similar, parallel and interlinked selection rationales, one for individual sites, one for site assemblages or geotopes.

Recommendation A4.4

Numerically grading sites according to site selection criteria would be desirable to improve the transparency and objectivity of the site selection process. Grading would take place at the level of the GCR thematic block or network, the highest scoring sites being conserved. Sites could change their grade value over time due to new research, site degradation etc. Grading would work on a site by site basis but also at the geotope level. Geotopes and individual sites would have to be graded separately.

Report A5 Data Catalogue

A5.1 Introduction

There currently exists no detailed national inventory of subtidal geological and geomorphological features within the UKCS. Such is database is highly desirable and would greatly aid a programme of marine geoscience conservation. Whilst large amounts of data do exist, coverage is highly variable both in terms of quality and quantity for particular sites and regions. The location and curation of relevant data and metadata sets is also dispersed and non-standardised.

A5.2 Universities & Research Departments

Universities and other research establishments hold the bulk of relevant data. Much of this material, however, is poorly catalogued and of limited availability. Universities and departments may often not be fully aware of what data they hold until certain academics retire or pass away!

The range of data held at various institutions reflects the range of interests of individuals within those institutions and can vary tremendously in spatial coverage and quality. Highly specific site data reflecting years of study of particular individual's "pet sites" can be contrasted with spatially extensive but temporally limited data sets reflecting programmes of thematic research undertaken by research groups and departments.

Access to this often unpublished material is via direct consultation with those individuals directly responsible for its gathering and curation within specific marine and geoscience departments. Copywrite issues may arise in certain cases where such previously unpublished data is used. A selected list of relevant university departments is included in Annex 2.

A5.3 Journals

Much site specific, system-orientated, and wider scale data has been published within general and specialist peer-reviewed scientific journals and is thus in the public domain. Whilst much has appeared in widely recognised and circulated publications, there exist large amounts of data appearing as papers and reports in obscure and limited circulation publications. Often such journals and proceedings are of a local or regional nature and may not be subjected to the same intensive peer review process found in the more widely recognised publications. For some sites, however, such papers and reports may represent the only sources of published data. A selected list of relevant publications is included in Annex 2. A further source includes the "grey literature" of quasi-academic and popular science publications.

A5.4 UK, EU and International Research Programmes

Data resulting from large thematic research programmes represents an important source of information required to support a marine geoscience conservation initiative. Such programmes involve collaborative research between a number of domestic and international universities, state research institutes and statutory bodies. Information arising from these programmes is released in a variety of formats including on-line metadata, papers in journals, reports submitted to the funding agencies, and as published books and reports. Publication is, however, a key aspect of the majority of these programmes.

Within the UK, the Natural Environment Research Council (NERC) is the primary funding body. For EU collaborative research programmes the European Union Marine Science and Technology initiative (EU-MAST) as part of the framework-based science funding scheme is the main managing body. Examples include the EU Ocean Margins Exchange project (OMEX) and the NERC Land Ocean Interactions Study (LOIS). The ongoing international Ocean Drilling Project, of which the UK is a full member, also represents a source of important geological information, with some of the ODP boreholes having been taken within the UKCS.

A selected list of past and present research programmes of relevance to a marine geoscience conservation initiative, along with the funding umbrella organisations is included in Annex 2.

A5.5 NERC Data Centres

The UK Natural Environment Research Council (NERC) maintains a number of data gathering and curation centres throughout the UK along with NERC funded research establishments.

Such data repositories represent important sources of marine geological, geomorphological and process data derived from NERC funded research (thematic programmes and individual grants). Examples include the British Oceanographic Data Centre (BODC) hosted at the Proudman Oceanographic Laboratory and the National Geoscience Data Centre (NGDC) managed by the British Geological Survey. Much of the data held within these repositories is available to the public but more specific information may have to be procured through commercial transactions with the NERC.

NERC-funded research institutes are also essential sources of data and expertise. Of these, Proudman Oceanographic Laboratory (POL) at Liverpool University, and Southampton Oceanography Centre (SOC) at Southampton University are the most relevant.

A list of relevant NERC data centres and funded research institutes is included in Annex 2.

A5.6 Survey Organisations

A5.6.1 The British Geological Survey

The British Geological Survey (BGS), as curator of the NERC NGDC, is a vital source of marine geoscience data and, as such, must be involved in the development of any marine geoscience conservation programme.

Much of its database is searchable on-line as part of the BGS Internet Geoscience Data Index (GDI). It also curates geological data on behalf of offshore hydrocarbon operators and the UK nuclear operator NIREX.

Most importantly, as part of the initial licensing of the UKCS for hydrocarbon exploration during the 1960s and '70s, the BGS has mapped the distribution of sediment bodies and surface and subsurface geology throughout the whole UKCS in some detail. Mapping was carried out on the basis of deep and shallow coring, grab sampling, seismic, magnetic and other geophysical techniques. Divided into twelve report areas, maps of surface sediment, Quaternary deposits and sub-Quaternary lithologies are published at a scale of 1:250,000 along with a detailed Offshore Regional Report for each region. These reports and maps should form the initial starting point for any research into potential specific conservation sites.

Whilst yet to be published, the BGS is compiling a highly detailed national database of geological and geomorphological features within the UKCS as a basis for marine habitat classification and conservation. Such a database will be far more comprehensive than anything existing previously and would form a valuable resource for any marine geoscience conservation programme both in terms of background spatial data and as a framework for site classification and selection. The database is due to be completed within twelve months. It is recommended that this database be used as a fundamental component (in perhaps modified form) of any marine conservation site selection rationale.

Whilst much of the data held by the BGS is considered to be publicly accessible, highly detailed site specific information necessary for a marine geoscience conservation programme would only be available to the JNCC via commercial transactions.

A5.6.2 The UK Hydrographic Office.

As the main gatherer and publisher of bathymetric data in the UK, the United Kingdom Hydrographic Office (UKHO) is a vital source of data in support of a marine geoscience conservation initiative. Access to detailed bathymetries is essential at all stages in the site selection process, from identifying potential sites, identifying the spatial activity of potential threats, delineating site boundaries and publishing site descriptions.

In addition, published UKHO charts carry details of potential threats to site integrity or accessibility such as cables and fibre optics, wind energy and hydrocarbon installations and navigation routeways.

The UKHO curates up-to-date high quality data along with important historical information. However, much of this is not in the public domain. Where not of a classified or restricted nature, data may only be available to the JNCC as a commercial transaction.

A5.7 Licensing & Advisory Bodies

As part of the licensing process for offshore operations such as sediment extraction, hydrocarbon exploration and exploitation, and wind energy developments, data in support of licence applications must be submitted to the relevant government agencies. Thus the Department of Trade and Industry (DTI), the Department for the Environment, Farming and Rural Affairs (DEFRA) marine consents unit

(DEFRA-MCU) and the former Department for Transport, Local Government and the Regions (DTLR) all have in their possession data valuable to an offshore marine geoscience conservation programme.

Such data is not publicly available as it represents restricted, commercially sensitive and commercially acquired information. It remains unclear if access to non-commercially sensitive data could be granted to the JNCC in support of a site selection process. Neither is it clear if this access would be a commercial undertaking conducted with the above government departments or directly with the companies who submitted that information as part of their licensing applications. However, if accessible, the data holdings of these organisations would be valuable, especially on a site specific basis. It would, though, only probably apply to sites currently being developed and thus already potentially suffering some degree of integrity degradation.

As custodians of the seafloor within the twelve nautical mile limit of UK Territorial Waters, Crown Estates is also a key link in the license-granting process and thus has access to significant site-specific datasets. Data is particularly related to aggregate extraction and wind energy developments including geological information required as part of environmental impact assessments carried out as prerequisite of the licensing process.

In addition, the marine environmental advisory, monitoring, research and consultation organisation, the Centre for Environment, Fisheries and Aquaculture Science (CEFAS), provides services in fisheries science and management, environmental monitoring and assessment, fish farming, fish health, disease and hygiene. It has access to marine environmental data that includes geological, geomorphological and dynamical information.

A5.8 Industry Sources

Industrial exploitation of the UKCS represents both the potential to generate new geological and geomorphological datasets as well as representing potential threats to site integrity. Data relating to both is essential as part of a marine geoscience site conservation programme particularly in heavily utilised areas of the UKCS such as the Liverpool-Morecambe Bay, Humber-Wash-East Anglia-southern North Sea, and Thames Estuary areas.

As part of the license application process for UKCS exploitation, and as an essential element of their commercial activities, hydrocarbon, aggregate, engineering, telecommunications and wind energy companies generate large amounts of both spatially extensive and detailed site specific data. Much of this information is commercially sensitive and not available publicly or has been commercially acquired and would be available to the JNCC only via commercial arrangements. Some basic index data, however, is available on-line, particularly that relating to offshore oil and gas. The DEAL (Digital Energy Atlas & Library) website maintained by the BGS on behalf of the UK Offshore Operators Association (UKOOA) is one such example.

Based upon consultation with the relevant bodies, it is recommended that approaches to commercial operators by the JNCC be made initially through the representative industry associations. Most have shown considerable positive interest in the development of a marine geoscience conservation programme and feel that early and continuing co-operation between them and the JNCC would be mutually beneficial. The relevant industry associations are:

- UK Offshore Operators Association
    - UKOOA
    - Hydrocarbon industries
- British Marine Aggregate Producers Association
    - BMAPA
    - Aggregate and sand excavators
- British Wind Energy Association
    - BWEA
    - Terrestrial and marine wind energy generators
- UK Cable Protection Committee
    - UKCPC
    - Submarine cable owners, operators and servicers.

A5.9 Coastal Monitoring Initiatives

The Channel Coastal Observatory is the data management and regional coordination centre for the Southeast Regional Coastal Monitoring Programme. The aim of this interdisciplinary programme is to provide a consistent regional approach to coastal process monitoring, providing information for development of strategic shoreline management plans, coastal defence strategies and operational management of coastal protection and flood defence. The programme is managed on behalf of the Coastal Groups of the Southeast of England and is funded by DEFRA, in partnership with local Authorities of the southeast of England and the Environment Agency. As such, the Coastal Channel Observatory has access to large amounts of specific nearshore geological, geomorphological and dynamical data including high-resolution nearshore bathymetries.

FutureCOAST is an annual seminar run by Department of Geography, University of Aberdeen, Scotland. FutureCOAST is concerned specifically with marine and coastal management approaches, in particular the use of geographical information systems, remote sensing and the internet in marine and coastal zone management.

A5.10 Other sources

Various other sources of data are available including those that form various local and regional geoconservation and broader conservation and marine management initiatives and organisations.

Local geological associations may have access to data regarding nearshore features within their areas. In a similar manner, local RIGS (Regionally Important Geological-geomorphological) groups may also possess relevant information and local knowledge of coastal and nearshore features and systems.

Regional conservation initiatives such as the Irish Sea Forum and the Dorset Coast Forum also represent sources of information. The Irish Sea Forum is a non-profit association made of constituent academic, research, advisory and commercial organisations. Its aim is the enhancement of the environmental health of the Irish Sea and its associated coastal features and estuaries and the sustainable use of its resources.

The Dorset Coast Forum was established in 1995 with the aim of examining the long term strategic environmental and economic issues facing the Dorset coastal zone. The Forum has access to large amounts of specific information regarding the geology and geomorphology of the coast including the submarine extension of many of the important structures into the nearshore zone. Included within their remit is joint management (along with Devon County Council, Dorset County Council) of the Dorset and East Devon Jurassic Coast world heritage site.

In addition local divers associations, as well as the national British Sub-Aqua Club, may also have particular data (or be able to contact individuals who do), including samples and photographs, relating to specific sites.

A5.11 Summary & Recommendations

No national inventory of subtidal geological and geomorphological features currently exists. Such a database is highly desirable and would greatly aid a programme of marine geoscience conservation. Whilst large amounts of data do exist, coverage is highly variable as well as its location and curation. Large amounts of site specific data is held by universities and other small research establishments. Much data, whilst in the public domain, has been published in journals and reports with only limited circulation. Likewise large amounts of relevant information is held by hydrocarbon corporations and has been submitted to the Department of Trade and Industry (DTI) as part of licensing procedures. Such data may be of a commercially confidential nature and thus not available whilst other information may only be available as part of a commercial transaction between the JNCC and the DTI or the individual hydrocarbon corporation concerned.

However, at the regional scale the British Geological Survey (BGS) curates much public access data that could form the basis of a conservation programme. Of particular importance are the BGS offshore regional reports summarising the offshore geology and geomorphology of each of the 12 primary areas of the UK Continental Shelf (UKCS). In addition, public access data curated by the BGS includes that accessible via the Internet Geoscience Data Index. Further non-public data held by the BGS may be accessed by the JNCC as a commercial transaction. The Admiralty Hydrographic Office curates both highly accurate modern and historical bathymetric and surface sediment data, again available commercially.

Other important regional public domain sources of data include the Natural Environment Research Council (NERC) LOIS (Land Ocean Interaction Study) datasets concerned with sediment transfer from river catchments to shelf edge. UK data is predominantly centred on the North Sea, curated at a number of centres throughout the UK and overseen by the NERC. Shoreline Management Plans represent another data source, promoted by DEFRA in England, the Welsh Assembly in Wales and the Scottish

Parliament in Scotland. Data is accessed through local councils. The Future-Coast (University of Aberdeen) programme and the Channel Coastal Observatory (Southampton Oceanography Centre) are sources of coastal and nearshore data.

Whilst yet to be published, the BGS is, however, compiling a national database of geological and geomorphological features within the UKCS as a basis for marine habitat classification and conservation. Such a database will be far more comprehensive than anything existing previously and would form a valuable resource for any marine geoscience conservation programme both in terms of background spatial data and as a framework for site classification and selection. The database is due to be completed within twelve months.

Recommendation A5.1

Any programme of marine geoscience conservation must be developed in parallel with, or be preceded by, an in-depth and wide ranging data compilation exercise, Given the fragmentary nature of much of the data necessary to support a conservation programme, such a study would be a significant undertaking beyond the scope of this report.

Recommendation A5.2

Access to certain important datasets will probably take the form of commercial transactions between data curators (BGS, DTI, Hydrographic Office, hydrocarbon companies). Where such data is essential for the support of a robust conservation programme such commercial data should be procured.

Recommendation A5.3

Access to, and use of, the BGS offshore geological and geomorphological database currently being prepared by the Geophysics & Marine Geoscience group at BGS Murchison House, Edinburgh should be sought as a matter of priority.

Report A6 Marine geoscience site category list

A6.1 Introduction

The existing sites-based GCR conservation approach is based upon the categorisation of sites under thematic headings known as "blocks". Such subject blocks provide the broad framework for site selection, ensuring that the differing geoscience themes can be accorded equal treatment. Sites within thematic blocks are then subsequently divided into logical groupings based upon the type of geological feature, process or event they represent. These subdivisions are known as "networks".

The two-tier nested-sites rationale recommended in Report A4 for adoption as the basis for a marine geoscience conservation programme is broadly compatible with the existing GCR concept of thematic blocks and site networks at the level of the first-order core conservation site. However, given the limited number of potential exposure sites and the numerical dominance of specifically *marine* active process integrity sites, it is considered that the majority of the existing 100 GCR blocks would not be applicable within the marine environment (or only after considerable redefinition). Due to the paucity of *geological* exposure sites offshore, many of the features classed within the stratigraphic, structural, metamorphic, igneous, mineralogical and petrological classes of blocks would simply not be encountered. Furthermore, many of the sites classed within blocks under the Quaternary and geomorphology headings may not be encountered offshore whilst other types of site occurring subtidally may not be included under the existing GCR system. Also, the existing approach, being site-based, does not allow for the incorporation of geotope type conservation zones within a categorisation hierarchy.

It is widely felt, however, that there is a need for continuity between the terrestrial GCR and a marine geoconservation programme. The terrestrial initiative is one that has worked well since its initiation during the 1970s and it is felt important by many of the consultees that marine conservation should represent an *extension* of this, rather than an alternative system. As there exists much continuity across the low-water boundary, geologically, geomorphologically and dynamically, so there should also be continuity methodologically.

It is suggested here that an approach similar to the existing GCR block and network methodology be adopted for first-order conservation sites, where necessary being broadened to accommodate the geodiversity characteristic of the UKCS. Whilst being marine specific, it enables a unity to be established between the terrestrial and marine geoconservation programmes. The present low-water mark is, in effect, an arbitrary boundary spanned both geologically and geomorphologically. Sites will be assigned into the seven primary thematic categories currently used in the GCR, these being:

- Stratigraphy
- Structural & Metamorphic Geology
- Igneous Petrology
- Mineralogy
- Palaeontology
- Quaternary Geology & Geomorphology
- Geomorphology

Geotopes would be considered under a parallel but separate system. Candidate geotopes would be divided between broad categories reflecting different classes of morphodynamic or bed/land-form assemblage systems. Such categories represent an adaptation of the GCR block concept for inclusion within a geotope conservation approach.

A6.2 1st Order Conservation Sites: Stratigraphy, Structural & Metamorphic Geology, Igneous Petrology, Mineralogy, and Palaeontology

Whilst the majority of terrestrial GCR sites fall into the first five categories (Stratigraphic, structural & Metamorphic, Igneous, Mineralogy, Palaeontology), within the marine environment, due to the relative scarcity of outcrops and other exposure type sites, features within these categories will be very much in the minority. It may even be likely that there exist no marine sites within the Mineralogy and Palaeontology categories due to a lack of suitable exposures (as opposed to borehole and core samples).

Given, therefore, the probable limited number of sites within the above five categories, it is considered that any marine features that do fall within these broader classes will be covered under existing GCR thematic blocks. No additional blocks are here suggested therefore. It is acknowledged, however, that in researching potential sites for conservation, new blocks under the above headings may become apparent.

A6.3 1st Order Conservation Sites: Quaternary Geology & Geomorphology

The cyclic climate changes throughout the Quaternary period have resulted in dramatic changes in the environment of the British Isles. In particular the periodic advance and retreat of glacial ice and the eustatic fall (*c.* 120m below present during the Last Glacial Maximum) and rise (*c.*8m above present during the Last Interglacial) of sea-level coupled with climatically forced changes in ecosystem composition has left a significant imprint on the geological and geomorphological make up of both terrestrial and marine Britain.

Much of the north-west European continental shelf was exposed subaerially during glacial stages due to lowered global eustatic sea-levels. These regions were subjected to geological and geomorphological processes strongly controlled by the climate of the time including the glaciation of large areas of the UKCS by fast flowing ice-streams. Beyond ice limits, periglacial processes dominated including extensive ground-ice, aeolian, fluvial, slope, and freeze-thaw action. Glacimarine conditions persisted in areas still below contemporary sea-level including water wave and current processes in formally shallower areas than present. Climatic amelioration during interglacial periods resulted in transgression of the shelf and the cyclic breaching of the Dover Strait and resulting insularity of Britain. Relict shallow water, intertidal and coastal features now below low water attest to rising interglacial sea-levels, as do inundated organic deposits. However, due to this cyclic nature of climatically forced environmental change and sea-level flux, few deposits or bedforms survive from earlier glacial or interglacial periods, the widespread marine reworking of the shelf coupled with extensive glaciation, obliterating most traces of earlier land systems. The majority of Quaternary features now below low water date from the last Devensian glaciation and the present Holocene interglacial.

Currently, the terrestrial GCR divides up Quaternary sites on a geographical basis. As the Quaternary history of different regions varies as a result of topography, latitude, altitude, the geographical devision enables the construction of coherent regional Quaternary histories with the flexibility of specific thematic networks that can span regional blocks to derive a more national integrated view. In addition to the regional Quaternary blocks there are three further specific blocks; Tufa, Holocene Sea-level, and Pollen Stratigraphy of England.

It is suggested in this report that Quaternary sites currently below low water that attest to former lower sea-levels (relict shallow water features, former intertidal features, drowned cliffs etc) be accommodated within the existing Holocene Sea-level block. It is further suggested that other Quaternary sites be accommodated within regional Quaternary thematic blocks. There exists the possibility of defining new Quaternary blocks on a marine basis such as an Irish Sea block or an English Channel block. It is felt, however, that existing terrestrial Quaternary regional blocks (e.g. Quaternary of Scotland, Quaternary of South-west England) be extended to include the marine areas adjacent to them. Whilst boundary between existing blocks may appear arbitrary, the addition of new shelf-sea blocks would only add to the number of arbitrary boundaries involved. Thus, for example, the South-west England Quaternary block would include the Western Approaches, the western English Channel, the southern Celtic Sea and much of the Bristol Channel. Likewise the Quaternary of the Thames would include the subtidal Thames estuary and much of the southern North Sea. Research will be needed to define effectively the offshore boundaries of these areas as coherent units.

A6.4 1st Order Conservation Sites: Geomorphology

The marine environment is a highly dynamic one, generating an array of constructional and erosional landforms dependent upon processes and sediment pathways acting over considerable areas. The Holocene transgression resulting in the marine reworking of large volumes of sediment deposited by fluvial and glacial processes on the shelf during Quaternary low-stands has enabled the development of large dynamic bedforms both nearshore and on the open shelf.

By their very nature, such bedforms and sediments are marine specific and thus do not fit easily into the existing terrestrial GCR blocks. Currently there exist ten geomorphology blocks, these being three regional coastal geomorphology and three regional fluvial geomorphology blocks along with a mass-movement block as well as caves and karst blocks. Whilst there are some features that would be included within the existing categories (Plymouth Sound submarine caves in the Caves block; submerged toes of active slump blocks on the Dorset coast in the Mass-movement block) the majority of marine specific features need to be included within new or modified blocks.

It is proposed here that four new blocks be defined and the definition of four of the existing terrestrial blocks be broadened to include marine features. The four new blocks proposed are:

- Marine Geomorphology of the North Sea
- Marine Geomorphology of the English Channel and Celtic Sea
- Marine Geomorphology of the Irish Sea
- Marine Geomorphology of the Hebrides Shelf and Rockall Area

The four blocks whose definition is to be broadened are:

- Mass-Movement
- Coastal Geomorphology of England
- Coastal Geomorphology of Scotland
- Coastal Geomorphology of Wales

A6.4.1 New Marine Geomorphology Blocks

The four proposed new Marine Geomorphology Blocks are defined on a regional basis. The English Channel & Celtic Sea block is defined as that area of the United Kingdom Continental Shelf as defined under section 1(7) of the Continental Shelf Act 1964 (including additions up to 2001), including territorial waters within the twelve nautical mile limit, westwards of a line drawn between South Foreland (Kent) to Cap Gris Nez (Pas de Calais), and southwards of a line drawn between St David's Head (Pembrokeshire) to Carnsore Point (County Wexford). This region includes the Bristol Channel

The Irish Sea block is defined as that area of the United Kingdom Continental Shelf as defined under section 1(7) of the Continental Shelf Act 1964 (including additions up to 2001), including territorial waters within the twelve nautical mile limit, northwards of a line drawn between St David's Head (Pembrokeshire) to Carnsore Point (County Wexford) and southwards of a line drawn between the Mull of Kintyre (Strathclyde) and Fair Head (County Antrim).

The Hebrides Shelf and Rockall Area block is defined as that area of the United Kingdom Continental Shelf as defined under section 1(7) of the Continental Shelf Act 1964 (including additions up to 2001), including territorial waters within the twelve nautical mile limit, northwards of a line drawn the Mull of Kintyre (Strathclyde) and Fair Head (County Antrim) and westwards of a line drawn from between Duncansby Head (Highland), the southernmost tip of South Ronaldsay island (Orkney), the northernmost tip of North Ronaldsey island (Orkney), Sumburgh Head (Shetland), Herma Ness (Shetland) and then drawn northwards from Herma Head to the edge of the UKCS. This are includes the Malin Sea, the Sea of the Hebrides, the Minch, the sounds and sea-lochs of the Scottish west and north coasts, the Orkney and Shetland Islands, and the continental slope, Rockall Trough and Rockall Rise within the UKCS.

The North Sea block is defined as that area of the United Kingdom Continental Shelf as defined under section 1(7) of the Continental Shelf Act 1964 (including additions up to 2001), including territorial waters within the twelve nautical mile limit, eastwards of a line drawn from between Duncansby Head (Highland), the southernmost tip of South Ronaldsay island (Orkney), the northernmost tip of North Ronaldsey island (Orkney), Sumburgh Head (Shetland), Herma Ness (Shetland) and then drawn northwards from Herma Head to the edge of the UKCS; and eastwards of a line drawn between South Foreland (Kent) to Cap Gris Nez (Pas de Calais).

The geomorphological features included within these new blocks would be those dynamical depositional and erosional features specific to the marine environment. Included would be features such as banner banks, mega-ripple and dune fields, sand wave fields and gravel banks. Also included would be tidal scour features and lag deposits as erosional features. Cold seeps and gas escape structures would be included within marine geomorphology blocks, as would deep sea and continental slope features occurring within the UKCS that are not included within a modified Mass-Movement block.

There exists a potential for overlap between the proposed new marine geomorphology blocks and the proposed modified coastal geomorphology blocks. It is considered, however, that features included within the marine geomorphology blocks would be those not directly dynamically linked to intertidal or coastal features and not constituting integral parts of coastal assemblages spanning the subtidal, intertidal and supratidal environments. Thus ebb tide deltas would not be included whereas offshore active tidal sand ridges would. Where offshore sediment bodies act as sources of sediment for coastal sites they would normally be considered as marine sites.

Networks within the marine geomorphology blocks would most likely be based around different morphological classes of feature or different morphodynamic processes acting on bedforms.

A6.4.2 Modified Mass-Movement block

It is proposed here that the definition of the existing terrestrial GCR Mass-Movement geomorphology thematic block be modified to incorporate mass-movement processes and the resulting bedforms acting in the marine environment. Given the relatively subdued topography of most of the geological continental shelf (as opposed to the politically defined UK Continental Shelf:- UKCS) the majority of mass-movement features are confined to the continental slope and shelf edge. Most marine mass-movement sites would be thus found in the far south-west of the UKCS and the sizeable north-western Rockall region (see Figure A1.1).

Marine features included within this broadened category would be those generated by turbidity flows including dendritic submarine canyons and fans, as well as large scale slide features on the continental slope.

A6.4.3 Modified Coastal Geomorphology blocks

When initially instigated, there was no framework within the GCR for including sites below the low water mark. As a result, important aspects of coastal geomorphology were neglected as they occurred below low water. Only the subaerial components of fundamentally linked dynamic coastal systems that span the marine, intertidal and terrestrial environments could be conserved. A marine geoscience conservation programme, if adopted, presents the possibility of expanding the definition of the coastal geomorphology GCR block to include subtidal elements. This more inclusive approach would enable coastal systems to be conserved more efficiently and as dynamical wholes. It is thus proposed that the three existing regional coastal geomorphology blocks (England, Scotland, Wales) be expanding to include coastal features or components of coastal systems now below low water. As addressed in § A6.4.1, however, there does exist the potential for overlap between extended coastal and new marine geomorphology blocks. Submarine features included within coastal blocks should be proved to be integral to the coastal system.

Features included within enlarged coastal blocks would include: the submarine extension of spits and bars, ebb tide deltas and flood tide ramparts, inter-barrier channels, submarine extension of active rock shore platforms, and other submarine elements of soft sediment and rocky coasts.

A6.5 2nd Order Conservation Zones: Geotopes

Geotopes, whilst being assessed using the basic criteria as individual first-order core conservation sites, must be considered under a parallel scheme to individual sites. Geotopes represent landform assemblages and large-scale interactive landform systems composed of individual elements rather than just those elements in isolation.

It is suggested that whole defined geotopes be conserved as second-order conservation zones. It is probable that within these second-order zones will be nested first-order sites. However, geotopes do not, by definition, require features considered worthy of conservation as first-order zones to be included within their boundaries. First-order sites are considered under a parallel but *separate* system to geotopes. There is no reason, however, why first-order sites should not occur within wider conserved geotopes. In fact, this report considers it highly likely that internationally important and exceptional geotopes worthy of conservation will contain internationally important and exceptional individual first-order sites equally worthy of conservation.

Whilst being considered under a separate parallel system (based however on the same principles and criteria), geotopes can still be subdivided into categories resembling GCR thematic blocks. It is suggested that five categories be proposed composed of a number of variable example elements, these being:

- Estuarine Systems
  - Saltmarsh, mud & sand flats
  - Ebb & flood channels
  - Bars & tidal deltas
  - Active bedform fields
  - Other tide-current erosive and depositional features
  - Relict features

- Longshore Systems
  - Spits, bars, barriers, tombolos
  - Headlands & embayment
  - Banner banks
  - Other tide-current erosive and depositional features
  - Relict features

- Island Archipelagos Systems
  - Inter-island channels
  - Bedform fields
  - Reefs & shoals
  - Other tide-current erosive and depositional features
  - Relict features

- Tidal Strait Systems
  - Tidal channels
  - Scour hollows
  - Saltmarshes, mud & sand flats
  - Reefs & shoals
  - Bars & tidal deltas
  - Megaripple and other bedform fields
  - Other tide-current erosive and depositional features
  - Relict features

- Shelf-Slope Systems
  - Submarine canyons
  - Fans
  - Mass-movement features
  - Turbidity flow deposits
  - Along slope transport features
  - Other turbidity and non-turbidity current erosive and depositional features
  - Undamaged gas-hydrate deposits
  - Relict features

It is envisaged that these categories may be modified, combined or added to, based on an assessment of the range of geotopes within the UKCS and the scale at which they can be realistically conserved.

A6.6 2nd Order Conservation Zones: Buffer Zones

The second-order conservation zones in which individual or multiple first-order core conservation sites can be nested are intended to provide a greater degree of protection from remotely acting integrity threats where needed. They are also intended, in the case of active integrity sites, to conserve processes and sediment supplies active at scales greater than the individual site, and that are considered essential for the maintenance and evolution of those sites.

As such, their designation is based on an assessment of the dependency of the core first-order site on, and potential risk from, these wider processes and threats. They do not need a separate selection rationale from the core site which they surround. In effect, they represent a lower grade extension of a site's conservation boundaries in order to successfully conserve that core site.

A6.6 Numerical Site Ranking

The need for a method to numerically rank potential sites as part of a site selection methodology is discussed in § A4.4.8, along with a proposed workable grading system based upon the main six selection criteria (§ A4.4). Such an approach is applicable both to individual sites as well as geotopes.

It is important, however, that site ranking take place at a suitable level within the site category hierarchy. The aim is to avoid a short list of sites suggested for conservation being dominated by one or two classes of feature. Such a scenario could arise under circumstances such as there having had been more research undertaken on a particular type of deposit or landform as opposed to others. The result would thus contradicting the principle of representativeness.

It is proposed that any such site ranking should take place at the level of the GCR network rather than at the thematic block level. Thus only like sites would be compared against each other (e.g. megaripple fields, submarine canyons, granite exposures etc.). Such an approach avoids comparing disparate sites and so does not risk certain types of features being over represented. This method can also be applied to geotopes at level of the five suggested geotope categories.

A6.7 Summary & Recommendations

Given the diverse geology, geomorphology and dynamic processes found within the UKCS and the marine-specific nature of the majority of those features and processes, the majority of the thematic blocks used in the terrestrial GCR do not probably apply. A programme of marine geoscience conservation would have to account for the fundamentally marine nature of the shelf, especially in the conservation of active integrity sites illustrating shelf sea and slope processes. However, given the successes of the terrestrial GCR initiative, the case for extending conservation to the marine environment using the existing framework is strong. It is thus recommended that the seven broad topics used by the GCR are those with which marine sites are categorised. Whilst the majority of thematic blocks within those categories will not apply, those within the Quaternary category do. In addition, with the adoption of new geomorphology blocks and the redefinition of others to include marine features the use of the current GCR categories appears the most useful subtidally.

Four new thematic blocks are proposed within the Geomorphology category, these being regionally defined Marine Geomorphology blocks. It is also proposed that the existing coastal geomorphology blocks be redefined to include coastal features below current low water and also that the existing regionally defined Quaternary blocks be extended to include Quaternary features in the marine environment adjacent to those terrestrial regions.

Geotope sites should be conserved and categories according to a separate system, but one that strongly resembles, and is compatible with, the existing GCR and its proposed marine extension.

Recommendation A6.1

Given the fundamentally different range of geological elements and geomorphological features and processes encountered in the marine environment, there is a need for new thematic blocks within the existing GCR geomorphology category, these being:

- *Marine Geomorphology of the North Sea*
- *Marine Geomorphology of the English Channel & Celtic Sea*
- *Marine Geomorphology of the Irish Sea*
- *Marine Geomorphology of the Hebrides Shelf & Rockall Area*

Marine geology sites should be those not forming subtidal elements of coastal systems and thus not being considered under redefined coastal geomorphology blocks.

Recommendation A6.2

The geographically defined Quaternary blocks should be extended to include the marine areas of the UKCS adjacent to, and extending from, them. The exact geographical delineation between blocks should be based on the Quaternary history of those regions in order to maintain coherency.

Recommendation A6.3

The definition of the three coastal geomorphology GCR blocks needs to be expanded to include elements of coastal systems currently below low water.

Recommendation A6.4

The definition of the mass-movement GCR block needs to be broadened to include submarine mass-movement processes and landforms of the shelf edge and continental slope.

Recommendation A6.5

Geotope areas should be subdivided into environmental/genetic categories for ease of intercomparison. Five provisional categories are suggested: Estuarine, Longshore, Island Archipelago, Tidal Strait, and Shelf Slope systems.

Recommendation A6.6

The forthcoming BGS catalogue of UKCS marine geological and geomorphological features, if accessible by the JNCC, could form the basis of a site categorisation hierarchy

Annex 1 Consultees

British Geological Survey
- Geophysics & Marine Geoscience Group,
  - Murchison House, Edinburgh
  - Keyworth, Nottingham

The Geological Society
- Marine Studies Group
- Environment Group

Countryside Council for Wales

English Nature

Department for Environment Food and Rural Affairs
- Marine Consents and Environment Unit

The Crown Estate

Centre for Environment, Fisheries and Aquacultural Science

Southampton Oceanography Centre

University of Durham
- Department of Geography

University of East Anglia
- School of Environmental Sciences

University of Greenwich
- Department of Earth and Environmental Sciences

University of Plymouth
- Department of Geology

University of Portsmouth
- Department of Geography

University of St. Andrews
- School of Geography and Geosciences

University of Wales – Bangor
- School of Ocean Sciences

Chester College (University of Liverpool)
- Department of Biological Sciences

British Marine Aggregate Producers Association

British Wind Energy Association

United Kingdom Cable Protection Committee

United Kingdom Offshore Operators Association

Irish Sea Forum

Dorset Coast Forum

Cheshire RIGS Group

Annex 2 Data Sources

Universities and Research Departments

University	Department	Research Interests	Website
University of Aberdeen	Department of Geology & Petroleum Geology	Deep marine clastics, Shallow marine and shelf-forming processes, Geofluids and fluid emplacement, Geochemistry and diagenesis	www.abdn.ac.uk/geology/
University of Cambridge	Department of Earth Sciences	Tectonics, Basin and crustal development, Sedimentology, Palaeobiology and palaeoecology, Environmental change, Marine geochemistry	www.esc.cam.ac.uk/
	Department of Geography	Glaciology and Quarternary Science, Coastal Processes	www.geog.cam.ac.uk/
	Cambridge Coastal Research Unit	Intertidal sedimentation, Wave Dynamics, Shoreline Management Plans	ccru.geog.cam.ac.uk/
	Godwin Institute for Quaternary Research	Quaternary Palaeoenvironments, Palaeoceanography, Glaciology	www.giqr.group.cam.ac.uk/
University of Durham	Department of Geography	Earth Surface Systems, Quaternary Environmental Change	www.geography.dur.ac.uk/
	Sealevel Research Unit	Quaternary sea-level change, Coastal evolution, Future sea-level rise	www.geography.dur.ac.uk/research/groups/sea_level/sea_level.html
	Department of Geological Sciences	Geochemistry & Petrology, Geopysics, Palaeontology, Petroleum geology, Sedimentology, Structural Geology, Volcanology	www.dur.ac.uk/geolsci.www/
University of East Anglia	School of Environmental Sciences	Coastal Processes, Environmental Earth Sciences, Ocean & Climate Modelling, Oceanography	www.uea.ac.uk/env/
University of Liverpool	Department of Earth Sciences	Earth Structure & geodynamics, Ocean, Climate & Biogeochemistry, Palaeoceanography, Palaeoecology, Palaeobiology, Sedimentaology, Stratigraphy	www.liv.ac.uk/earth_sciences/dept/ general.html
University of London Royal Holloway	Department of Geography	Environmental change, Quaternary science	www.gg.rhul.ac.uk/
	Centre for Quaternary Research	Quaternary Palaeoenvironments, Glaciology, Periglacial systems, Quaternary palaeoceanography, Sea-level change	www.gg.rhul.ac.uk/cqr/
	Department of Geology	Coastal & Estuarine Dynamics, Clastic sedimentology, Palaeoenvironments and palaeoclimates, Palaeoceanography, Clastic & carbonate sedimentation, Basin & mountain evolution	www.gl.rhul.ac.uk/
University of Plymouth	Department of Geography	Holocene sea-level, Quaternary environments,	www.geog.plymouth.ac.uk/
	Department of Geology	Micropalaeontology, Climate change, Palaeoceanography, Sedimentology basin analysis, Geomorphology, Geodynamics, Periglaciology, Neashore seabed investigations, Geoconservation	www.geol.plymouth.ac.uk/

Note: The data sources below do not represent a comprehensive definitive list, rather a selection of the main data sources that would be initially consulted as part of a marine geoscience site conservation initiative.

Universities and Research Departments

University	Department	Research Interests	Website
University of Portsmouth	Department of Geography	Fluvial & coastal geomorphology, Geoconservation, Shoreline & coastal zone management	www.port.ac.uk/departments/academic/geography/
University of Southampton	School of Ocean & Earth Sciences	Ocean circulation and climate, Upper ocean processes and biogeochemistry, Marine biodiversity and population dynamics, Sedimentary dynamics and diagenetic processes, Hydrothermal processes and ocean/crust Interaction, Marine geophysic, Palaeoceanography and palaeoenvironments	www.soes.soton.ac.uk/
University of St Andrews	School of Geography & Geosciences	Environmental change, Palaeoceanography, Ocean-climate dynamics, Glaciology, Geomorphology, Sedimentology, Marine remote sensing	www.st-andrews.ac.uk/gg/
University of Wales Bangor	School fo Ocean Sciences	Shelf sea and ocean margin physics, Marine sedimentary processes, transport and seimentation, Palaeoceanography, Quaternary marine environments	www.sos.bangor.ac.uk
University of Wales Cardiff	School of Earth, Ocean & Planetary Sciences	Palaeoceanography, Glaciology, Permafrost environments, Basin dynamics, Marine and coastal environments	www.earth.cardiff.ac.uk/
University of Wales Swansea	Department of Geography	Environmental modelling, Quaternary & Hollocene environmental change, Quaternary geomorphology	ralph.swan.ac.uk/
Imperial College	Department of Earth Science & Engineering	Sedimentary basins, Petroluem engineering,	www.ese.ic.ac.uk/

Journals

Journal Title	Speciality	Publisher	Website
Boreas	All branches of Quaternary research	Taylor & Francis	www.tandf.co.uk/journals/
Deep-Sea Research	Physical, Chemical and Biological Oceanography, Marine Sedimentology, Geology and Geochemy, Marine Biology and Ecology	Elsevier	www.sciencedirect.com
Earth & Planetary Science Letters	All branches of Earth science	Elsevier	www.sciencedirect.com
Estuarine, Coastal & Shelf Science	Saline water phenomena ranging from the outer edge of continental shelf to the upper limits of tidal zone. Multidisciplinary approach to oceanography of estuaries, coastal zones, continental shelf seas: zoology, botany, geology, sedimentology, physical oceanography, numerical models, and chemical processes.	Elsevier	www.sciencedirect.com
Geological Journal	Interdiciplinary geoscience journal covering: Sedimentology, Palaeontology, Structural Geology, Geophysics, Geochemistry, Metamorphic Geology, Igneous Geology	Elsevier	www.interscience.wiley.com
Geological Magazine	Complete spectrum of geological topics	Cambridge University Press	titles.cambridge.org/journals/
Geophysical Journal International	Solid earth geophysics topics including: seismology; tides, the Earth's gravitational field, Earth interior, crustal structure, isostasy, palaeomagnetism, geomagnetism, geotectonics, heat flow, electromagnetism, rheology and volcanology, structure and evolution of rifts, ridges, trenches, mountains, continents and oceans	Blackwell Publishing	www.blackwellpublishing.com/journals/
Journal of Geophysical Research	Separate journals adressing Earth surface processes and oceanography	American Geophsical Union	www.agu.org/pubs/pubs.html
Journal of Quaternary Science	Dedicated to Quaternary science sunbjects but including papers on broader aspects including: Archaeology, Botany, Climatology, Geochemistry, Geochronology, Geology, Geomorphology, Geophysics, Glaciology, Limnology, Oceanography, Palaeoceanography, Palaeoclimatology, Palaeoecology, Palaeontology, Soil Science and Zoology. Special issues: "The Quaternary of History of the English Channel" March-May 2003 Vol 18(3-4). "The Glaciation of the Irish Sea Basin" July 2001 Vol 16(5)	John Wiley & Sons	www.interscience.wiley.com

Journals

Journal Title	Speciality	Publisher	Website
Journal of Sedimentary Petrology / Research	Sedimentary geology including: sedimentary processes, the origin of sedimentary deposits, the workings of sedimentary systems, and the records of earth history contained within sedimentary rocks	SEPM	spot.colorado.edu/~jsedr/
Journal of the Geological Society of London	Interdisciplinary Earth sciences	The Geological Society	www.geolsco.org.uk
Marine Geology	Marine geology, geochemistry and geophysics	Elsevier	www.sciencedirect.com
Nature	International multidiciplinary sciences including all aspects of the Earth sciences.	Nature Publishing	www.nature.com
Oceanologica Acta	All oceanographical disciplines, relating to any sector of the oceans, including estuaries and brackish waters.	Elsevier	www.sciencedirect.com
Palaeogeography, Palaeoclimatology, Palaeoecology	Multidisciplinary palaeo-environmental geology journal	Elsevier	www.sciencedirect.com
Proceedings of the Geologists' Association	All aspects of geology	The Geological Society	www.geolsco.org.uk
Progress in Oceanography	Longer, more comprehensive oceanography papers, reviews and treatise. All oceanography disiplins.	Elsevier	www.sciencedirect.com
Quaternary Science Reviews	Quaternary science topics including: geology, geomorphology, geography, archaeology, soil science, palaeobotany, palaeontology, palaeoclimatology and dating methods.	Elsevier	www.sciencedirect.com
Science	International multidiciplinary sciences including all aspects of the Earth sciences.	American Association for the Advancement of Science	www.sciencemag.org/
Sedimentary Geology	All aspects of research into sediments and sedimentary rocksincluding: analytical techniques to regional or geodynamical aspects of sedimentary systems and basin analysis; subsurface analysis of sedimentary sequences, diagenesis, chemical sedimentology and numerical modelling.	Elsevier	www.sciencedirect.com

Journals

Journal Title	Speciality	Publisher	Website
Sedimentology	Whole spectrum of sedimentology, sedimentary geology and sedimentary geochemistry including: grain transport, sediment fluxes, modern and ancient sedimentary environments, sequence stratigraphy, sediment-organism interaction, palaeosoils, diagenesis, stable isotope geochemistry, environmental sedimentology.	Blackwell Publishing	www.blackwellpublishing.com/journals/
Terra Nova	Wide spectrum of the Solid Earth and Planetary Sciences including: geology, geophysics and geochemistry, and extends to the fluid envelopes (atmosphere, ocean, environment) whenever coupling with the Solid Earth is involved.	Blackwell Publishing	www.blackwellpublishing.com/journals/

Research Programmes

Acronym	Full Name	Description	Currator	Website
EU-MAST	European Union Marine Science & Technology programme	EU marine science and technology programme the aim of which is to develop the scientific and technological bases for the sustainable exploitation of marine systems and determine their precise role in global change. Research falls under four main headings, as follows : "MARINE SCIENCE" in order to understand the fundamental processes governing marine systems, including extreme marine environments (deep sea floors, ice-covered seas, etc.) and specific European areas (Baltic, Mediterranean, etc.); "STRATEGIC MARINE RESEARCH" to ensure compatibility between the exploitation and protection of marine resources. Hazards and adverse impacts liable to affect the marine environment will be identified; "MARINE TECHNOLOGY" the aim of which is to develop generic technologies for monitoring, using and protecting the marine environment (oceanographic observation, underwater communication and viewing, analysis of natural substances, development of measurement instruments, remote-controlled vehicles and benthic laboratories for deep-sea and Arctic exploration); "SUPPORTING INITIATIVES" in order to improve coordination and develop European cooperation	EU Government	http://www.cordis.lu/mast/home.html http://europa.eu.int/comm/research/marine1.html
NERC	UK Natural Environment Research Council	NERC is one of the seven UK Research Councils that fund and manage scientific research and training in the UK. NERC is responsible for overseeing earth system science: advancing knowledge of planet Earth as a complex, interacting system. NERC's work covers the full range of atmospheric, earth, terrestrial and aquatic sciences, from the depth of the oceans to the upper atmosphere, including working with international partners.	UK Government	http://www.nerc.ac.uk/
ENAM	European North Atlantic Margin	Research programme funded by EU-MAST in four rounds, currently ENAM IV. Focuses on the sediment dynamics of the European continental shelf. Good data sets derived for the UK North Sea sector Various published and on-line metadata available through EU-MAST and thr contributing bodies and institutions. The BODC houses some of the resulting data along with the Irish Marine Institute	EU-MAST	http://europa.eu.int/comm/research/marine1.html http://www.bodc.ac.uk/ http://www.marine.ie
STEAM	Sediment Transport on European Atlantic Margin	Research programme funded by EU-MAST round 2. similar objectives to the ENAM projects focussing on sediment transport dynamics using geophysical techniques. Data variously accessable through EU-MAST and the various contributing bodies and institutions. BODC and SOC house some accessibale information.	EU-MAST	http://europa.eu.int/comm/research/marine1.html http://www.bodc.ac.uk/ http://www.soc.soton.ac.uk

Research Programmes

Acronym	Full Name	Description	Currator	Website
MORENA	Multidisciplinary Oceanographic Research in the Eastern boundary of the North Atlantic	Research programme funded by EU-MAST. Objective to measure, understand and model shelf-ocean exchange in a typical coastal upwelling region of the eastern boundary layer of the subtropical ocean. This is being attained through a multidisciplinary approach aimed at the quantitative understanding of the physical, chemical and biological processes involved in the transfer of matter (including salt, particulates, nutrients, organic compounds, biomass), momentum and energy across and along the shelf, the shelf break and the slope, in the Iberian region of the European Atlantic.	EU-MAST	http://www.mth.uea.ac.uk/ocean/morena.html
OMEX	Ocean Margin Exchange	Research programme, funded by EU-MAST, aiming to gain a better understanding of the physical, chemical and biological processes occurring at the ocean margins in order to quantify fluxes of energy and matter across this boundary. Recognising the environmental significance of shelf-edge exchange and its role in global biogeochemical cycling, this MAST initiative aims to characterise the flux of carbon, nutrients and other trace elements between the open ocean and the coastal seas. Data available on-line and directly from the BODC	EU-MAST	http://www.pol.ac.uk/bodc/omex/omex.html http://www.bodc.ac.uk/
LOICZ	Land-Ocean Interactions in the Coastal Zone	A research programme under the auspices of the International Geosphere-Biosphere Programme: A study of Global Change (IGBP) of the International Council of Scientific Unions (ICSU). The overall goal of the project is to determine at regional and global scales: the nature of the dynamic interaction between land, ocean and atmosphere; how changes in various compartments of the Earth system are affecting coastal zones and altering their role in global cycles; to assess how future changes in these areas will affect their use by people; and, to provide a sound scientific basis for future integrated management of coastal areas on a sustainable basis. Includes the EuroCat project (funded by the EU) aiming to accomplish an integrated catchment/coast management and sustainable use of water resources at a catchment scale. The impacts affecting the coastal sea are linked to the human activities in the catchments by integrating natural and social sciences. Using the unifying framework of Driver-Pressure-State- Impact-Response (DPSIR), observed state changes and impacts in and on the coastal zone generated by changing material fluxes are investigated from the perspective of their individual socio-economic drivers at catchment scale. The project originates from and contributes to the global LOICZ- Basin assessment and synthesis core project. Results will assist in developing improved management solutions and strategies for key European river basins and coastal zones and contribute to the implementation and evaluation of regulatory measures such as the EU Water Framework Directive.	International Council of Scientific Unions (ICSU)	http://www.nioz.nl/loicz/

Research Programmes

Acronym	Full Name	Description	Currator	Website
SANDPIT	Sandpit	Research programme funded by EU-MAST. The overall objective of the SAND PIT project is to develop reliable prediction techniques and guidelines to better understand, simulate and predict the morhological behaviour of large-scale sand mining pits/areas and the associated sand transport processes at the middle and lower (offshore) shoreface and also in the surrounding coastal zone. The emphasis is on the role of large-scale offshore sand mining pits and areas, but the morphological behaviour of dredged channels and trenches for navigation, pipelines and telecom-cables will also be addressed. The potential use of large-scale sand banks and shoals for sand mining will also be studied. Furthermore, the ecological effects of sand mining and dredging will be evaluated and summarised. Data available on-line	EU-MAST	http://sandpit.wldelft.nl/mainpage/mainpage.htm
HOLSMEER	Late Holocene Shallow Marine Environments of Europe.	EU-MAST- Fifth Framework. The objectives of HOLSMEER are: 1. To generate high-resolution quantitative palaeoceanographic/palaeoclimatic data from NE Atlantic coastal/shelf sites for the last 2000 years using a multidisciplinary approach: 2. To develop novel palaeoclimatic tools for shallow marine settings by (i) calibrating the proxy data against instrumental datasets, (ii) contributing to transfer function development, and (iii) then to extrapolate back beyond the timescale of the instrumental data using the palaeoclimate record: 3. To investigate the link between late Holocene climate variability detected in the shelf/coastal regions of western Europe and the variability of the oceanic heat flux associated with the North Atlantic thermohaline circulation, and to compare such variability with existing high-resolution terrestrial proxies to help determine forcing mechanisms behind such climate change: 4. To lay a foundation for the identification of hazards and resources linked with, or forced by, such climate change.	EU-MAST V Framework	http://www.bangor.ac.uk/os/holsmeer/
LOIS	Land Ocean Interaction Study	Research programme funded by NERC. It aims to quantify and simulate the fluxes and transformations of materials (sediments, nutrients, contaminants) into and out of the coastal zone, extending from the catchment to the edge of the continental shelf. The main study area, embracing river catchments, estuaries and coastal seas, is the UK East Coast from Berwick upon Tweed to Great Yarmouth, concentrating on the Humber and its catchment, and to a lesser extent the River Tweed. The shelf edge study is focused on an area to the west of Scotland. Data available on-lone and from Plymouth Marine Laboratory.	NERC	http://www.pml.ac.uk/lois/index.html

Research Programmes

Acronym	Full Name	Description	Currator	Website
ODP	Ocean Drilling Project	The Ocean Drilling Program (ODP) is an international partnership of scientists and research institutions organized to explore the evolution and structure of Earth. ODP provides researchers around the world access to a vast repository of geological and environmental information recorded far below the ocean surface in seafloor sediments and rocks. ODP data is available through the Janus Web. Janus Web provides access to ODP's Oracle relational database Janus. The database contains 450 tables of ODP's marine geoscience data that are collected onboard the drillship JOIDES Resolution. The database includes paleontological, lithostratigraphic, chemical, physical, sedimentological, and geophysical data for ocean sediments and hard rocks.	NERC in the UK	http://www.oceandrilling.org/

NERC Data Centres

Acronym	Full Name	Description	Currator	Website
BODC	British Oceanographic Data Centre	Large amounts of marine oceanographic, dynamical and physical meatdata available on-line along with data products derived from Uk and international colaberations including OMEX & LOIS.	Proudman Oceanographic Laboratory, Merseyside	http://www.bodc.ac.uk/
NGDC	National Geoscience Data Centre	National archive of surface & subsurface information including: bore whole, core and grab logs, laboratory and test data, hydrocarbon, geophysical and structural datasets, Coal Authority data collection, UK NIREX Ltd data collection. On-line searchable metasata index: Geoscience Data Index (GDI) gives details of all BGS public access data coverage and products.	British Geological Survey, Keyworth & Edinburgh	http://www.bgs.ac.uk/geoindex/home.html

NERC Research Facilities

Acronym	Full Name	Descrition	Location	Website
BOSCORF	British Ocean Sediment Core Research Facility	Storage and archival facility for UK core materials	Southampton Oceanography Centre	http://www.boscorf.org/
SOC	Southampton Oceanography Centre	Major marine research institute covering: Large scale circulation and the ocean interior, The Upper Ocean, Coastal and Shelf Sea Processes, Sediments and the Benthic Boundary Layer, Plate Boundaries and Ocean Margins, Palaeoceanography and Climate Change, Systems, Platforms and Sensors, Earth System Science and Modelling. Also includes the National Oceanographic Library, Ocean Research Service (UKORS) and the NERC Research Ships Unit (RSU)	University of Southampton	http://www.soc.soton.ac.uk
POL	Proudman Oceanographic Laboratory	Major marine research institute specialising inoceanography encompassing global sea-levels and geodesy, numerical modelling of continental shelf seas and coastal sediment processes.	Bidston Observatory Birkenhead	http://www.pol.ac.uk/

Survey Organisations

Acronym	Full Name	Description	Location	Website
BGS	Britsih Geological Survey (formerly Institute for Geological Science)	UK geological mapping agency with a core programme of long-term strategic mapping, monitoring, databasing and underpinning applied research which is fully funded by the Science Budget; a partnership programme of medium-term mapping and research co-funded by the BGS from the Science Budget and by partners in the private and public sectors including the EU; a responsive programme of research undertaken in direct response to commissions from customers in the private and public sectors and funded by them. Curates large amounts of marine-specific geological information along with geophysics and marine geosciences group.	Keyworth, Nottingham and Murchison House, Edinburgh.	www.bgs.ac.uk
UKHO	UK Hydrographic Office	The UKHO is a government Trading Fund and part of the Ministry of Defence. It's primary activity is the provision of navigational products and services to the Royal Navy and the merchant marine in compliance with Safety Of Life At Sea (SOLAS) Regulations. It has a highly detailed database of bathymetric information and is the main supply of definitive bathymetric charts	Taunton	www.ukho.gov.uk

Licensing & Advisory Bodies

Acronym	Full Name	Description	Website
-	The Crown Estate	The Crown Estate owns around 55% of the foreshore (between mean high and mean low water) and approximately half of the beds of estuarial areas and tidal rivers in the United Kingdom. It also owns the seabed out to the 12 mile territorial limit, including the rights to explore and exploit the natural resources of the UK Continental Shelf, excluding oil, gas and coal.	www.crownestates.co.uk
CEFAS	Centre for Environment, Fisheries and Aquaculture Science	The Centre for Environment, Fisheries and Aquaculture Science, CEFAS, is a UK-based research and consultancy centre. They provide services in fisheries science and management, environmental monitoring and assessment, fish farming, fish health, disease and hygiene to clients around the world.	www.cefas.co.uk
DEFRA	Department for Environment Food and Rural Affairs	DEFRA is one of the primary government departments involved in licensing uses of the shlef as well as environmental protection, fisheries and science. It includes the Marine Consents & Environment Unit (MCEU). The MCEU an alliance of the Marine Environment Branch of DEFRA and the Ports Division (Casework Branch) of the Department for Transport. The job of the MCEU is to provide a central facility for receipt and administration on behalf of both Departments of applications to undertake works in tidal waters and at sea, including marine developments, offshore energy, coast defences, dredging and waste disposal. The Unit also administers certain applications on behalf of the Welsh Assembly Government which is the licensing authority in Welsh waters.	http://www.defra.gov.uk/ www.mceu.gov.uk
DTI	Department of Trade and Industry	DTI is one of the primary government departments involved in licensing uses of the shelf. It is particularly concerned with licensing hydrocarbon exploration as well as wind energy developments.	http://www.dti.gov.uk/

Industrial Organisations

Acronym	Full Name	Description	Website
UKOOA	United Kingdom Offshore Operators Association	UK Offshore Operators Association (UKOOA) is the representative organisation for the UK offshore oil and gas industry. Its members are companies licensed by the Government to explore for and produce oil and gas in UK waters. Also sponsors the UK Digital Energy Atlas & Library (DEAL) on-line data catalogue of reference information for the United Kingdom offshore oil & gas industry maintained by the BGS	www.ukooa.org.uk www.ukdeal.co.uk
BMAPA	British Marine Aggregate Producers Association	BMAPA is the representative association for the offshore aggreagte industry. Its members are companies licensed by the Government to explore and extract offshore aggregate deposits. It is also one of the constituent members of the Quarry Products Association	www.bmapa.org
BWEA	British Wind Energy Association	BWEA is the representative association for the UK wind energy industry including the offshore sector. It represents it's member companies as well as encourage wind energy research.	http://www.bwea.com/ http://www.offshorewindfarms.co.uk/
UKCPC	United Kingdom Cable Protection Committee	The UKCPC is an international forum of administrations and commercial companies which own, operate or service submarine telecommunications cables in UK waters. The principal goal of the UKCPC is the promotion of marine safety and the safeguarding of submarine telecommunications cables from man-made and natural hazards	www.ukcpc.org.uk

Coastal Monitoring Initiatives

Full Name	Description	Location	Website
FutureCOAST	FutureCOAST is an annual seminar series set up by David R. Green and Stephen D. King from the Department of Geography, University of Aberdeen, Scotland. FutureCOAST is about the successful management of the marine and coastal environment in this new Millennium. In particular, FutureCOAST events focus upon the use of Geographical Information Systems, Remote Sensing and the Internet in marine and coastal zone management	University of Aberdeen	http://www.abdn.ac.uk/geospatial/agi/future/
Channel Coastal Observatory	The Channel Coastal Observatory is the data management and regional coordination centre for the Southeast Regional Coastal Monitoring Programme. The programme provides a consistent regional approach to coastal process monitoring, providing information for development of strategic shoreline management plans, coastal defence strategies and operational management of coastal protection and flood defence. The programme is managed on behalf of the Coastal Groups of the Southeast of England and is funded by DEFRA, in partnership with local Authorities of the southeast of England and the Environment Agency.	Southampton Oceanography Centre	www.chanelcoast.org

Other Data Sources

Full Name	Description	Location	Website
Irish Sea Forum	The Irish Sea Forum is a non-profit association made of of constituent academic, research, advisory and commercial organisations with the aim of enhancing the environmental health of the Irish Sea and its associated coastal features and estuaries and the sustainable use of its resources	University of Liverpool	http://www.liv.ac.uk/~isf1/isfhome.html
The Dorset Coast Forum	The Dorset Coast Forum was established in 1995 with the aim of examining the long term stratigic environmental, social and economic issues facing the Dorset coastal zone. The Forum has access to specific information regarding the geology and geomorphology of the coast including the submarine extension of deposits and structures into the nearshore zone. Managed jointly between Dorset and Devon county councils and the Dorset Coast Forum is the Dorset and East Devon Jurrasic Coast world heritage site.	Dorchester	http://www.dorsetcoast.com/ http://www.jurassiccoast.com/
British Sub-Aqua Club	BSAC is the main sport and recreational divers club in the UK and the main governing body for the sport. It is based on a branch structure with local groups of individual members comprising BSAC branches. Many of it's members have direct experience of and interest in geological diving and have access to site-specific data including photographs and samples.	Ellesmere Port	http://www.bsac.com/
OceanNET	OceanNET is the portal for the UK Global Ocean Observing System (UK GOOS) and UK Marine Environmental Data (UK MED) action groups, both operated by the Inter-Agency Committee on Marine Science and Technology (IACMST). UK GOOS is charged with maintaining an overview of all marine observations and their application, the main focus of the action group is operational oceanography and forecasting. UK MED is a partnership between key government departments, agencies and user groups, the MED network aims to improve the accessibility and availability of UK marine environmental data.	-	http://www.oceannet.org/

Other Data Sources

Full Name	Description	Location	Website
Inter-Agency Committee on Marine Science and Technology	The IACMST maintains an overview of marine activities across Government. It encourages links between Government and the national marine community, the wider application of marine science and technology, optimum use of major UK marine facilities, training and education and international links	-	www.marine.gov.uk
Sea Search	A website set up, operated and further developed to provide an effective navigation tool to data and information sources in Europe, to oceanographic data and information, managed by European centres, and to centres in Europe with expertise and skills in oceanographic and marine data & information management.		www.sea-search.net

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