

**THE UNIVERSITY OF SOUTHAMPTON 2010-11  
FACULTY OF ENGINEERING, SCIENCE AND MATHEMATICS  
SCHOOL OF GEOGRAPHY**

**THE APPLICATION OF GIS TO MANAGEMENT  
OF OUTDOOR RECREATION AND  
CONSERVATION IN SOUTH WEST WALES**

**Stephen Quinton**

A dissertation submitted in partial fulfilment of the requirements for the degree of M.Sc. in Geographical Information Systems by Online Distance Learning.

UNIVERSITY OF  
**Southampton**  
School of Geography

## **Statement of Originality**

Except for those parts in which it is explicitly stated to the contrary, this thesis is my own work. It has not been submitted for any degree at this or any other academic or professional institution.

The copyright of this thesis rests with the author. Information derived from it should be acknowledged.

I agree that the thesis may be made available for reading and photocopying at the discretion of the Head of the School of Geography. Permission for anyone other than the author to reproduce or photocopy any part of the thesis must be obtained from the Head of School who will give his/her permission for such reproduction only to an extent which he/she considers to be fair and reasonable.

Signed.....

Candidate's name: ...STEPHEN QUINTON.....(Block Capitals)

Word Count:

## **Abstract**

Recreational pressure on coastal environments is an issue for land managers that is likely to increase in the near future. Increasing numbers of people visiting sites that would otherwise be relatively free of human interference has the potential to impact on geological features, archaeological remains and, more significantly, on flora and fauna on the coast. This study focuses on the development of coasteering sites on the Pembrokeshire Coast. This is a popular group activity involving climbing, swimming and cliff-jumping on rocky shores, often combined with an element of environmental education. Recent increases in numbers of activity providers and participants has led to overcrowding, restrictions on numbers and a resulting demand for new locations suitable for the activity. Case studies illustrating existing problems on the St. David's Peninsula are included that highlight difficulties facing the local outdoor activity industry.

A methodology for identifying potential sites has been developed based on eliminating impracticable areas based on shoreline type, accessibility and safety issues. Wilderness mapping techniques developed by Carver et al (2002) have been adapted to identify wild parts of the coastline which could be protected from this type of activity. This involves Multi-Criteria Evaluation MCE based on five, equally weighted factors. The value and use of GIS in mapping specific conservation features at various scales is also discussed in relation to this problem and an example of a preliminary analysis of one site is presented.

## **Acronyms**

<b>CASWEB</b>	<b>Census Area Statistics on the WEB</b>
<b>CCW</b>	<b>Countryside Commission for Wales</b>
<b>EIA</b>	<b>Environmental Impact Assessment</b>
<b>EN</b>	<b>English Nature</b>
<b>GIS</b>	<b>Geographical Information Systems</b>
<b>MCE</b>	<b>Multi-Criteria Evaluation</b>
<b>NT</b>	<b>National Trust</b>
<b>OS</b>	<b>Ordnance Survey</b>
<b>PCNPA</b>	<b>Pembrokeshire Coast National Park Authority</b>
<b>POCG</b>	<b>Pembrokeshire Outdoor Charter Group</b>
<b>SDSS</b>	<b>Spatial Decision Support System</b>
<b>WAG</b>	<b>Welsh Assembly Government</b>

# Contents

Author's Note and Acknowledgements

List of tables

List of figures

## **1 Introduction**

1.1 Conservation management and outdoor activities

1.2 The Pembrokeshire Coast National Park

1.3 The study areas

1.4 Coasteering

1.5 Dissertation Aims

## **2 Literature Review**

2.1 History/background

2.2 Recreation and Conservation Management issues

2.3 Legislation and Conservation

2.4 National Governing Bodies and Representative Bodies for Outdoor Recreation

2.5 GIS approaches to managing conflict between recreation & conservation

## **3 Methodology**

3.1 Study Area 1 (St. David's Peninsula) Methodology

3.2 Study Area 2 (Pembrokeshire) Methodology

## **4. Results**

4.1 Pembrokeshire Sites

4.2 Detailed analysis at Pen Anglas Point

## **5. Discussion**

5.1 Methodology for identifying suitable sites for coasteering development

5.2 Adapting Wilderness mapping

5.3 The Role of GIS within assessing suitability of sites for coasteering

## **6. Conclusion**

## **7. Appendices**

7.1 Appendix 1: Map sections used in analysis

7.2 Appendix 2: LANDMAP Visual and Sensory Landscape Mapping Methodology

## **8. References**

## **List of Tables**

- 2.1 Factors affecting tranquillity according to MacFarlane et al (2006)**
- 3.1 Factors affecting wilderness value, from Carver et al (2002)**
- 3.2 Hierarchical levels of scale used in LANDMAP visual/sensory classification**
- 3.3 Evaluation criteria for visual and sensory value**
- 3.4 Standardised values of Visual and Sensory Landscape Quality**
- 5.1 Summary of conservation features that could be mapped as part of a SDSS for development of new coastering sites.**

## **List of figures**

### **Author's Note**

The author is involved in the process of negotiating access (as a volunteer) within Pembrokeshire as the Chair of Pembrokeshire Outdoor Charter Group and the British Mountaineering Council Local Access Representative. In addition to these roles he is part of the Climbers' Club Guidebook team for Pembrokeshire and is currently writing the forthcoming guidebook to rock climbing in North Pembrokeshire. These projects have enabled the author to access detailed information which would have not otherwise been available, particularly in the areas of shoreline characteristics, 'escape routes' and presence of protected wildlife. All photographs were taken by the author unless otherwise stated.

### **Acknowledgements**

This dissertation could not have been completed without the help and support from several individuals. Firstly, I am grateful for the technical advice, support and encouragement from my tutor, Jim Wright. I am also indebted to Bob Haycock, Ant Rogers, Tom Luddington, David Jones and Powell Strong, all of whom have provided invaluable and detailed local information that has added to that of the author in producing a worthwhile study. Lastly and not leastly, my wonderful wife Jane has put up with endless hours of research and playing around with maps that could have doubtless been put to other uses.



# **1. Introduction**

## **1.1 Conservation management and outdoor activities**

Rising population pressure, climate change and increasing vulnerability of wildlife has resulted in a need for innovative management strategies to preserve our natural habitats. This is particularly the case in densely populated countries such as the UK where relatively small areas of 'natural' landscapes are crucial for wildlife conservation but also provide an important recreation resource for hundreds of thousands of people. Organisations such as National Park Authorities, English Nature (EN), the Countryside Council for Wales (CCW), the Forestry Commission (FC) and the National Trust (NT) have the task of managing sensitive areas in order to conserve nature whilst promoting opportunities for the public to enjoy the natural environment. This sometimes leads to conflicts of interest and land managers have to find ways of monitoring pressures and taking steps to reduce human impact on important natural resources. GIS is becoming used increasingly in these tasks as a means of mapping conservation interests and human pressures. It is useful in highlighting potential problems, modelling trends, analysing problems and presenting information to stakeholders.

Conflicts may arise between outdoor recreation and conservation when the volume of activity approaches and exceeds the 'carrying capacity' of the environment or creates 'unacceptable change'. The carrying capacity of any environment will vary according to activities taking place, time of year, tidal state and species present resulting in complex problems for land managers. For example, coastal habitats are important for cliff-nesting birds in the spring and seals in the autumn. Different species of birds are more or less affected by the presence of humans and seals can be tolerant of power boats but 'spooked' by kayaks and people on foot. Vulnerability to disturbance also varies greatly over small distances due to changes in geology, exposure and the resulting variation in geomorphology, flora and fauna. This study will highlight some of these difficulties and discuss possible solutions.

## **1.2 The Pembrokeshire Coast National Park**

This study focuses on management of outdoor recreation pressure in the Pembrokeshire Coast National Park in south west Wales, an area rich in wildlife that has recently been voted the second best coastal destination in the world by National Geographic Magazine (King, 2010). The area has been chosen because of a rapidly expanding outdoor recreation industry, successful marketing that is likely to result in continued growth for the foreseeable future and a well-organised management structure that involves conservationists, activity providers and landowners. Geographical Information Systems (GIS) are already being used as a management tool and their use is now developing to tackle specific management problems. This study focuses initially on the St. David's Peninsula which includes the greatest concentration of 'hot spots' (see figure 1) in the National Park but has been extended to cover the whole county in an attempt to investigate the use of GIS as part of a process of identifying new sites for commercial outdoor activity development.

Issues relating to recreational pressures are increasing as promotion of outdoor activity and adventure tourism has escalated in recent years. According to the Welsh Assembly Government (2008), adventure sports account for 8% of activities by visitors to the Welsh Coastline and publicity of adventure tourism through newspapers and television has escalated in recent years.

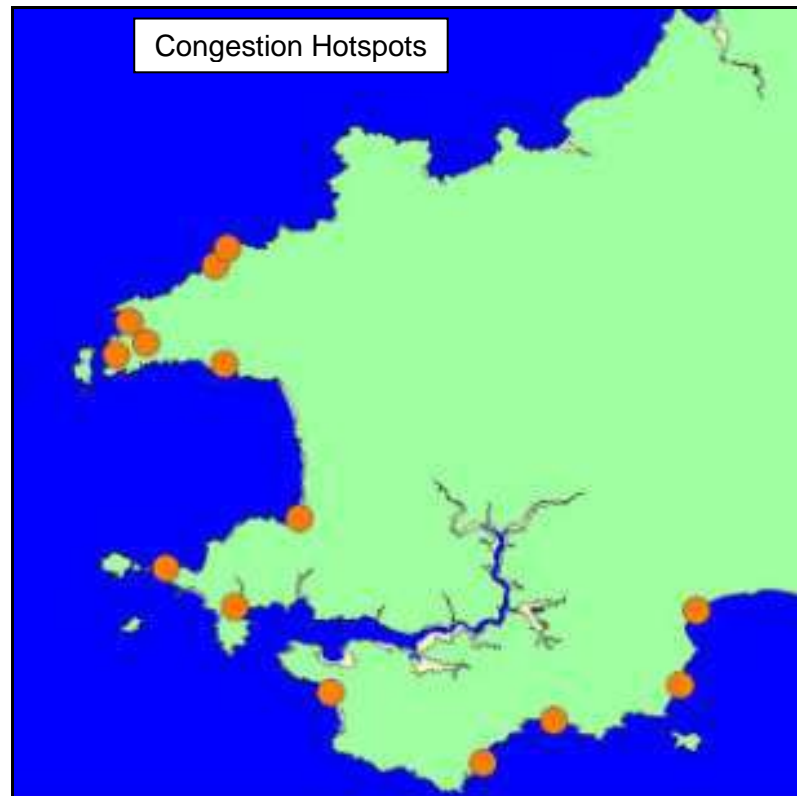
The Pembrokeshire Coast National Park Authority (PCNPA) has recently produced a draft Recreation Plan that highlights the importance of recreation in this area and also the need for management to protect this aspect of tourism. The requirements for a recreation plan are summarised as follows:

- 1. To make the most of healthy and sustainable recreation opportunities for local people and visitors.*
- 2. To make the most of limited resources and ensure that vital facilities are not lost or degraded.*
- 3. To identify desirable levels of activities for certain locations.*
- 4. To guide the provision of facilities and information which influence activities and the location of those activities.*
- 5. To provide opportunities for all those using the area for recreation to become more involved in managing activities themselves, thereby taking greater ownership of the National Park.*
- 6. To identify issues likely to affect the National Park's recreational capacity and demand in future, such as the impacts of climate change and changes in social and demographic trends.*

(PCNPA, 2010)

The sixth point forms much of the basis of this study which deals with issues connected to recreational capacity, future demand and the impacts on local businesses, local population and the environment.

The Recreation Plan also identifies a number of hotspots where large numbers of people taking part in recreational activities can cause congestion problems at certain times as shown below in figure 1.



**Figure 1.1: Congestion Hotspots in Pembrokeshire Coast National Park  
(PCNPA, 2010)**

Reasons for congestion are varied and may be linked to concentrations of holiday accommodation, restricted car parking and infrastructure issues as well as recreation facilities/environment. The impacts of congestion are also varied and include negative effects on the natural environment, degradation of the tourism value and inconvenience for the local population. Management of congestion and the need to direct people to areas where their activities are not going to be detrimental to the locality is a key concern of the National Park Authority and other landowners such as the National Trust.

Coasteering is one activity that has grown exponentially as a commercial business for local outdoor activity centres in the last 20 years and this has led to some management issues in 'honeypot sites'. The PCNPA Recreational Plan (Consultation Document) asks the following questions relating to management of this activity, many of which are addressed within this dissertation (see section 6).

- *Should we be seeking voluntary agreements to ensure that commercial coasteering does not develop in some of the wilder parts of the park?*
- *Should we be looking for agreed voluntary seasonal restrictions to be agreed as with climbing for some areas? – These might be to protect cliff nesting birds, cliff face habitats or seal pupping /moulting sites.*
- *Do we need to develop an agreed coasteering specific code of practice and resources for the growing numbers of coasteering leaders and assistants to help reconcile coasteering with conservation as has been done with gorge walking in North Wales?*
- *Should some of the most popular areas be subject to an agreed time zoning /booking system with agreed limitation on numbers to prevent overcrowding and if so how would this work?*
- *How do we influence groups coming to Pembrokeshire from away who are not with locally trained guides / members of the POC?*
- *How can we make the interpretation side of coasteering grow and encourage more the thrill from the wonders of the natural foreshore and coast?*
- *Is there a danger that public bodies find an attraction in new activities like coasteering and by supporting the activity with promotion, help to create the problems of overuse without contributing to the management and sustainable development of activities?*
- *Should public funding and promotion be focussed only on the less intrusive activities that are in Group 1 (non-intrusive activities such as walking, cycling, surfing etc.) which are the activities undertaken by the vast majority of visitors and local people?*

(PCNPA , 2010)

### 1.2.1 Selected Conservation Features of the Pembrokeshire Coast

Key elements of the natural environment within the area include birds, mammals, plants, geology, archaeological remains and the cultural/historical centre of St. David's. Important habitats consist mainly of coastal slopes, shingle, sea cliffs, sea caves and islets. The following section describes these categories of conservation features in greater detail.

#### **Birdlife**

The study area includes many sections designated as an SPA for protection of chough (*pyrrhocorax pyrrhocorax*) habitat. These birds have a permanent population in the area and nest in caves and crevices in sea cliffs. They require short cropped coastal grasslands for feeding and are vulnerable to disturbance during the nesting season and habitat loss. There are also several pairs of peregrine falcons (*falco peregrinus*) within the area which feed on smaller birds, principally rock doves also nesting within caves and chimneys on sea cliffs.



**Figure 1.2: ‘Schedule 1’ protected birds of the Pembrokeshire coast, chough (left) and peregrine falcon (right).** Photographs kindly supplied by Bob Haycock (CCW)

Ramsey Island is a Royal Society for the Protection of Birds (RSPB) reserve and is important for chough, peregrine falcons, kittiwakes (*rissa tridactyla*), guillemots (*uria aalge*) and razorbills (*alca torda*). Ravens, cormorants, oyster catchers, swallows and rock pipits are also relatively common within the study area.

### **Marine mammals**

The most obvious species of vulnerable mammal in the area is the Atlantic grey seal (*halichoerus grypus*). This species uses the caves and coves on the mainland and Ramsey Island for ‘pupping’ in the Autumn. Ramsey Island has the largest concentration of grey seals in southern Britain with hundreds of pups born every year (RSPB, 2008). Seals are most vulnerable to disturbance during the pupping season (August to December) when it is essential that female seals are able to feed pups which are left on shingle beaches and in caves. Prolonged presence of humans can prevent this and cause the death of the pup. Climbers and coastering groups should maintain a distance of 100m on open coasts and avoid climbing within the same cove as seal pups to avoid disturbance (Strong, 2010)



**Figure 1.3: Atlantic grey seal pup**

The area is also an important feeding and breeding area for the harbour porpoise (*phocoena phocoena*) which is commonly seen in the tidal stream through Ramsey Sound and off St. David’s Head.

Other species of whales and dolphins, including large groups of common dolphin, are regularly seen further off shore but are only likely to be affected by power boats and commercial vessels. There is a permanent population of bottlenose dolphin in Cardigan Bay and these can often be seen off the coast between Fishguard and Cardigan.

### **Other vulnerable mammals**

Some of the sea caves and crevices on the coast are used by bats such as common pipistrelles (*pipistrellus pipistrellus*) and greater or lesser horseshoe bats (*rhinolophus ferrumequinum* and *rhinolophus hipposideros* respectively). Greater horseshoe bats are one of the rarest species of mammals in the UK and disturbance during the winter hibernation period can be catastrophic and incur large fines under the Wildlife and Countryside Act (1981). Sections of coastline are also used for feeding by otters. Lyles (2009) suggests that 'otter havens' should be established to protect them from disturbance. There has been very little research into otter behaviour on the coast and no documented evidence of disturbance from outdoor recreation.

### **Rocky shore communities**

The intertidal zone is home to a large number of specialised species, some of which are vulnerable to the impacts of outdoor activity participants. According to Tyler-Walters, (2005) the species that are most at risk include foliose canopy forming algae (e.g. furoids), coralline turfs and barnacles. Some of these are illustrated in figure 4.11 on page ... .

### **Plants**

The area contains three main types of natural plant communities; coastal heathland, sea cliffs and inland heath areas. The inland dry and humid heathland areas such as those with the North West Pembrokeshire Commons SAC are little affected by recreation but include floating water-plantain (*luronium natans*) heather (*calluna vulgaris*) and western gorse (*ulex gallii*) heath areas. (JNCC, 2009)

Coastal heathlands include spring squill, (*scilla verna*), bird's foot trefoil (*lotus corniculatus*) and sea campion (*silene uniflora*) as well as chives (*allium schoenoprasum*) (Hurford and Evans, 2006). This plant life is one of the main attractions of the area, particularly in the spring when the flowers on the coastal heath form a spectacular pink and purple carpet.



The National Trust are managing some areas of coastal heathland through grazing by cattle and ponies in order to reduce scrub, encourage wild flower growth, and preserve habitat for chough and other wildlife.



**Figure 1.4: Vulnerable plants on the Pembrokeshire Coast: upper left; chives, upper right; spring squill, lower left; typical ledge community including rock samphire, thrift and sea campion at St. David’s Head, lower right; golden samphire.**

The sea cliffs in the area are well known for their diverse flora including the endemic sea-lavender (*limonium paradoxum*) and thrift (*armeria maritime*); the ‘flower of Pembrokeshire’. These species have managed to develop in specialised locations with minimal soil and are vulnerable to disturbance from climbers and anyone accessing the lower cliffs such as anglers and coastering groups. Golden samphire (*Inula crithmoides*) is another nationally rare plant that can be found mainly on limestone cliffs in the south of the county.

## **Geology and geomorphology**

The geological sites in this area are one of the reasons that Pembrokeshire was chosen as the location for the first coastal National Park. There are Geological Conservation Review (GCR) sites within the St. David's area at Aber Mawr (Ramsey Is.), Porthclais, Porth y Rhaw, Solva, St. David's Head, St. David's Coast, St. Non's Bay and Whitesands Bay .



**Figure 1.5: Geological Features; left; Cambrian Conglomerate at St. Non's Bay, right; folded Ordovician Sediments at Pwll Crochan**

The geology consists of Pre-Cambrian Volcanic outcrops exposed at the centre of an anticline which runs ENE-WSW through the centre of the area. This is flanked by Cambrian sandstones and mudstones and Ordovician sediments and igneous strata on the north coast. Special features include basal Cambrian Conglomerate at St. Non's Bay, the Quartz Gabbro of St. David's Head and the trilobite-rich Cambrian mudstones west of Solva.

The geology is closely related to the presence of sea caves which are identified as potentially sensitive to disturbance (Rogers, 2010). Caves typically form where fault systems intersect with sea cliffs and provide specialised environments with low light, overhangs and habitat for seals, bats, birds and marine organisms that would normally live in deeper waters. Sea caves are one of the key features protected by the Marine SAC and are significant attractions to kayakers and coastering groups.

The effects of ice ages can be seen in the boulder clay deposits at Whitesands, glacial erratics in Ramsey Sound and meltwater channels at Solva. Glacial features are one of the reasons why some of the coastal sites are designated as SSSIs but are, in general, more vulnerable to natural coastal erosion than human disturbance. Care may be required when selecting access routes to avoid damage to features in some areas.

### **Archaeological Remains**



**Figure 1.6: Penpleidiau Promontory Fort**

Many of the promontories around the coast were the sites of settlements and forts during the Bronze and Iron Ages. Today these appear as earth mounds and the remains of stone walls. Some of these sites coincide with the top of climbing locations, notably at St. Davids Head and Penpleidiau (see figure 1.6 above), just east of Craig Caerfai. They are prone to erosion from walkers and climbers as well as coasteering groups at access points if not properly managed. Within the Castlemartin Firing ranges in south Pembrokeshire, some archaeological sites have restricted access to protect the fragile remains of embankments.

### **1.3 The study areas**

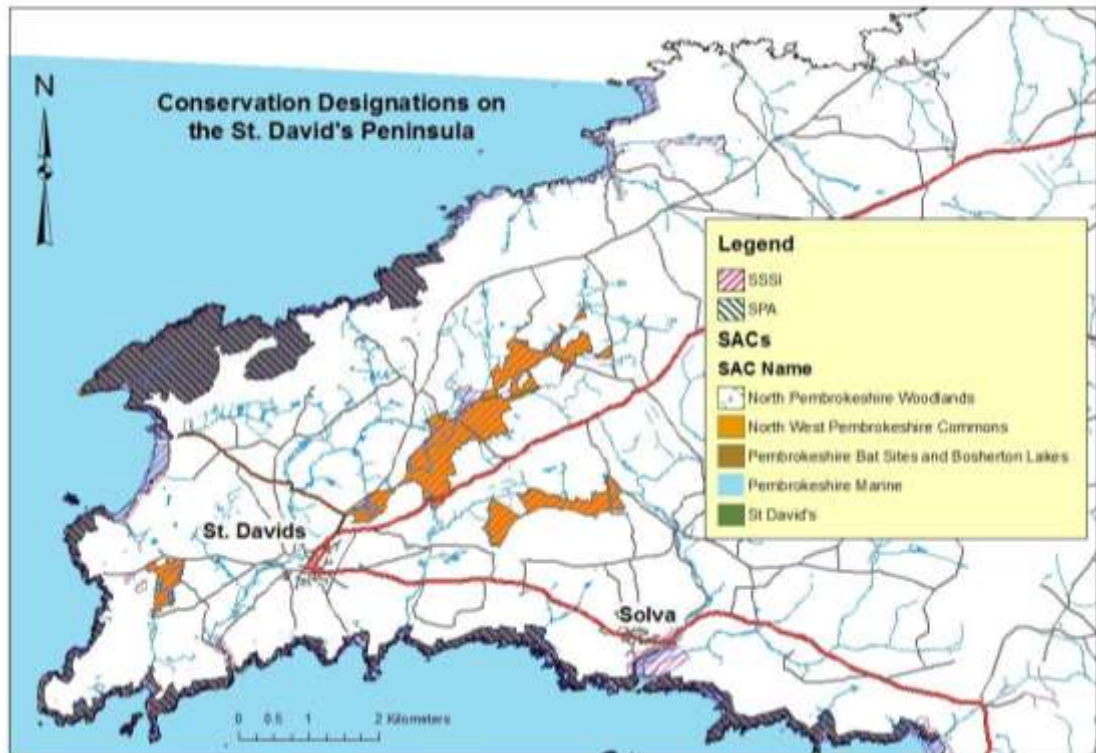
Two areas have been used for this project; firstly the St. David's Peninsula, which has been selected as a pilot area for testing methodology. This includes the most congested areas for commercial outdoor activities and has been studied previously resulting in wide-ranging and detailed information being available. Secondly, the whole of the Pembrokeshire Coast has been used to give a wider perspective and to provide a greater range of coastal environments. While the main outdoor activities and much of the conservation interests are coastal, the inland environments are included in some of the analysis as factors such as landform, infrastructure and settlements impact on accessibility and the aesthetic qualities of the coastal environment.

#### **1.3.1 Study Area 1: The St. David's Peninsula/ Penrhyn Tyddewi**

This area is part of the Pembrokeshire Coast National Park and includes locations covered by a number of further conservation designations including the Pembrokeshire Marine SAC, the North West Pembrokeshire Commons SAC, Ramsey and St. David's Peninsula Coast SPA, several SSSIs, an RSPB reserve and a number of National Trust properties.

Figure 1.7 below shows the distribution of conservation designations in the study area.





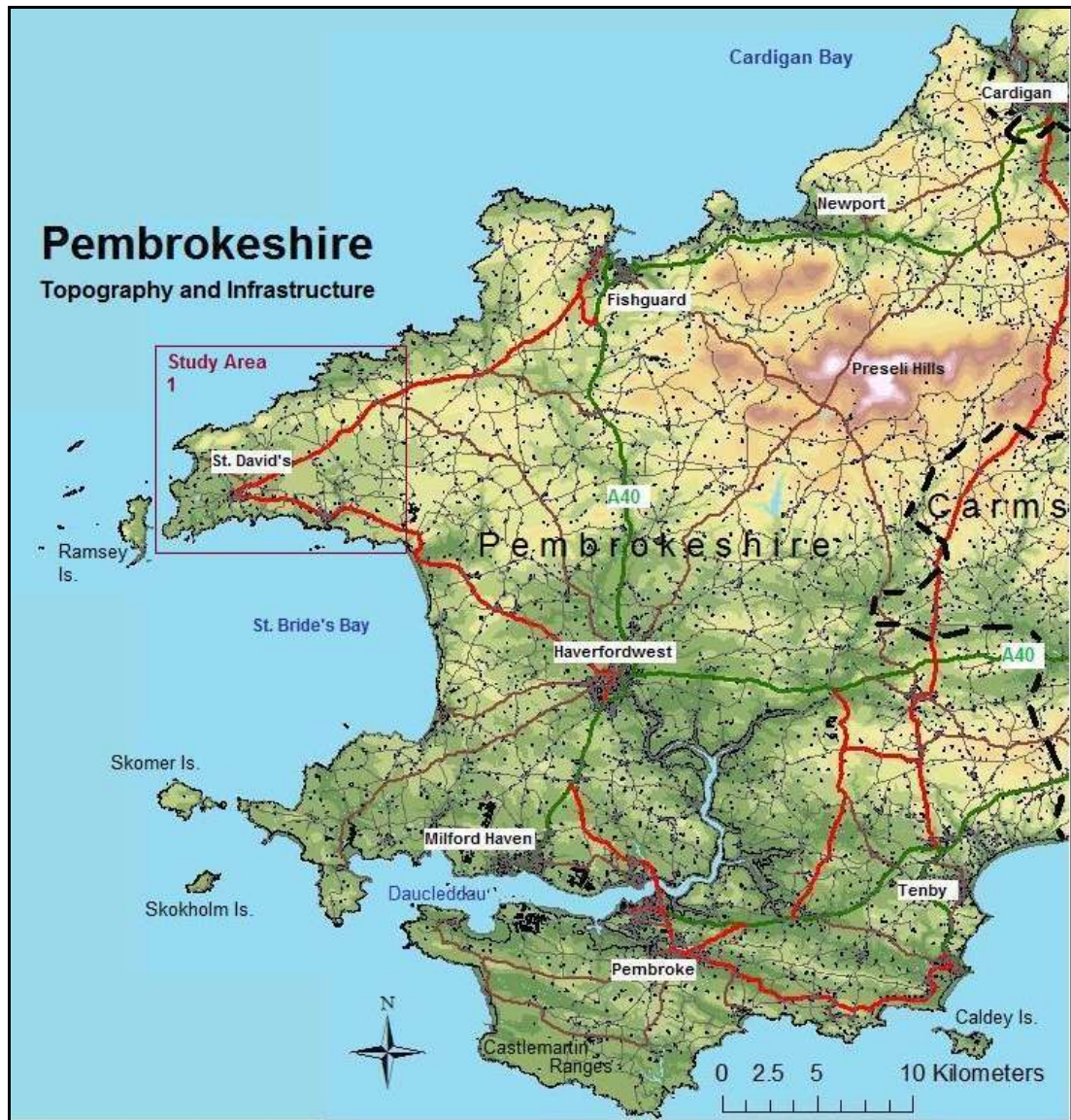
**Figure 1.7: St. David's Peninsula: Conservation Designations**

**(Note: The whole area is part of the Pembrokeshire Coast National Park)**

Map created by S. Quinton, May, 2010 for MSc in GIS

Ordnance Survey © Crown Copyright and database right 2010

### 1.3.2 Study Area 2: The Pembrokeshire Coast



**Figure 1.8: Study Area 2 - Pembrokeshire**

Map created by S. Quinton, Dec. 2010 for MSc in GIS

Ordnance Survey © Crown Copyright and database right 2010

The second study area includes the whole of the Pembrokeshire coast from St. Dogmael's near Cardigan in the north, to Amroth near Tenby in the south. This area includes a greater diversity of natural landscapes and human land-use types than the St. David's Peninsula and these are briefly outlined below:

## **Natural Landscapes**

The northern part of the county includes the Preseli Hills which rise to 536 metres as well as the rocky outcrops of Carningli near Newport and Garn Fechan west of Fishguard. A series of wooded valleys lead south from the Preselis to feed into the Eastern Cleddau, part of the drowned river valley of the Daucleddau. The coastline is dominated by extensive sections of steep cliffs but also includes some long sections of beach and several areas of salt marsh.

There are several islands just off the shore including Skomer Island which is one of only three Marine Nature Reserves in the UK. Caldey Island is owned by Cistercian monks and is maintained as a “haven of tranquillity and peace”. The off shore islands are unlikely to be developed for commercial outdoor activities due to conservation value, access difficulties and priorities for land owners.

## **Land Use Types and Industry**

The majority of the area is agricultural land but there are some significant other uses that have an impact on access to the coast. In the south of the county, there are over 25 square kilometres of Ministry of Defence firing ranges. These areas have complex access arrangements including a ban on public access (except by permits in some special cases, e.g. for rock climbers) at Castlemartin Range West. Other areas are accessible along the coastal path when no firing is taking place.

The Daucleddau estuary includes oil refineries, Liquefied Natural Gas (LNG) depots and a ferry port. Also known as the Milford Haven waterway, it is said to be the second deepest natural harbour in the world and is nationally important for importing fuel to the UK

Together with the energy sector, ports and agriculture, tourism is a major component of the Pembrokeshire economy and is continuing to grow and diversify. A recent development is the Bluestone Resort near Narberth, which provides accommodation, on-site activities and off-site trips and adventure sports. Traditional tourist destinations such as Tenby in the south east of the county, and St. David’s in the west continue to become more popular and the income from tourist expenditure provides employment for thousands of local people.

## **Selected Outdoor Recreation impacts**

The Pembrokeshire coast has been used as a location for outdoor activities for many decades with a general increase in numbers of visitors and numbers of activities since the early 1970s.

### **Walking**

The Pembrokeshire Coastal Path was opened as a National Trail in 1970 giving access to the stunning cliff scenery for thousands of walkers every year. The most popular sections show signs of moderate erosion which has been addressed by some repair work and construction of wooden steps, for example, at Porth Melgan near Whitesands. There is potential for conflicts between walkers who often visit the coastal path for unspoilt, natural scenery, and outdoor activity groups who can appear obtrusive in an otherwise tranquil environment.

### **Climbing**

Rock climbing on the Pembrokeshire sea cliffs was first developed in the 1960s. There are now several thousand listed climbs, nearly all of which are on SSSIs and many of which are within the Ramsey and St David's or Castlemartin SPAs. Because of the potential for rock climbers to access habitats where humans do not normally visit, there is the possibility of disturbance of flora and fauna. This has long been recognised as an issue and is managed by liaison between the British Mountaineering Council, land owners and the National Park Authority. Impacts include localised trampling of vegetation and associated erosion, cleaning of plants and lichen from climbing routes and disturbance of seals, birds and bats.

### **Sea Kayaking**

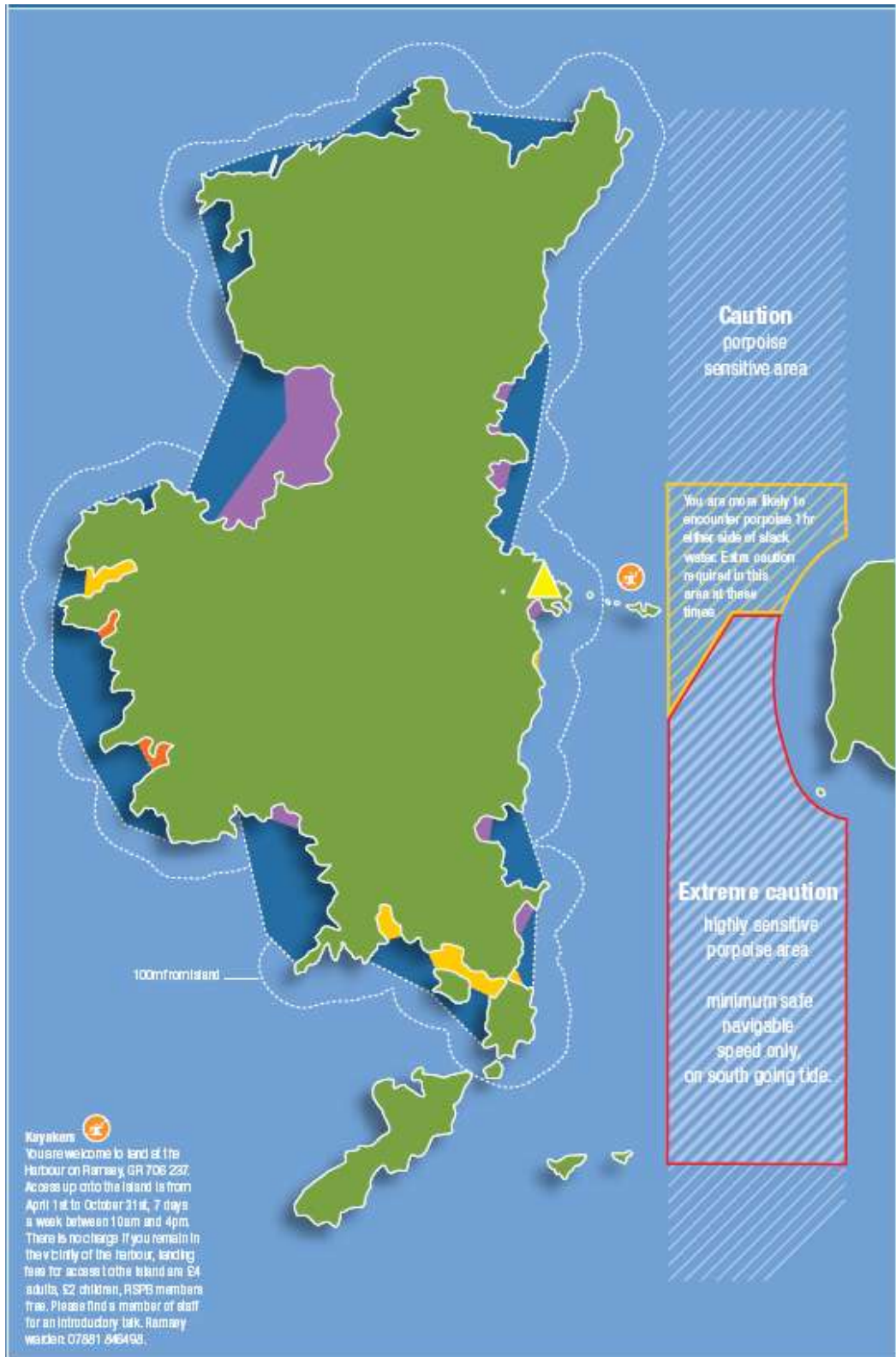
The coastline and offshore islands are also well known as an internationally important area for sea kayaking and 'play-boating'. The main attractions are a combination of sheltered coves, harbours and beaches for less experienced paddlers and challenging off-shore expeditions and a tidal white water rapid which has been the location for a World Championship kayak competition ('the Bitches' near Ramsey island). Kayaking allows people to gain close proximity to birds, seals and cetaceans in way that appears threatening to wildlife and can cause significant



disturbance. A Marine Code has been developed in an attempt to minimise the disturbance from both kayaks and powered watercraft (Pembrokeshire Marine Code, 2004, see figure 1.10 below).

### **Power Boats**

The proximity of Ramsey Island, the wildlife and amazing tidal waters has led to a number of companies running boat trips to and around Ramsey Island. The number of operators has expanded rapidly in the last 15 years and during summer holiday seasons there can be up to seven boats circumnavigating the island. This level of boating activity clearly has the potential for disturbance in several ways including; noise and disturbance of birds, seals and cetaceans, and physical contact with marine animals through high speed planing. Air and water pollution can also be a problem, particularly in large sea caves which are visited by most boat trips.



**Figure 1.9:** Extract from Pembrokeshire Marine Code leaflet showing voluntary restrictions around Ramsey Island. (Pembrokeshire Marine Code, 2004)

## **1.4 Coasteering**

Coasteering involves a mixture of rock climbing, swimming, scrambling and cliff jumping, all taking place a few metres above or below sea level (Pembrokeshire Outdoor Charter Group, 2005). Groups typically access sections of coast using the coastal footpath then descend to sea level and traverse for distances of a few hundred metres to a kilometre then return to the coast path at a suitable exit point. During the trip, group members will walk, climb, swim and jump off small cliffs into deep water. At low tide, these trips provide excellent opportunities for investigating rocky shore ecosystems as well as participating in an adventure sport. This is a relatively recently developed activity that has its roots in Pembrokeshire, being first developed by a local outdoor activity centre based in St. David's. It has rapidly developed into the most popular outdoor activity in the area and is used by virtually all of the local outdoor activity companies operating in the study area. The potential impacts of coasteering have been the subject of a number of studies including desk-based research by CCW (Tyler-Walters, 2005), field study of levels of use by Luddington (2008) and research into effects of trampling on the intertidal zone by Ponsford (2007) and Thomas (2007). The rapid expansion of coasteering has led to concern amongst land owners and managers such as the National Park Authority, the National Trust and CCW that serious harm and/or disturbance is possible to areas that are vulnerable and otherwise little-visited by humans.

In addition to organised, commercial coasteering there has been a recent growth in ad-hoc coasteering by individuals families and groups who potentially pose a more serious risk of disturbance to wildlife and the environment. Increasing ownership of wetsuits and other outdoor equipment by the general public may lead to escalation of this type of un-organised coasteering which, by definition, is difficult to control or influence and is likely to result in people causing disturbance to sensitive locations through a lack of awareness. Visiting, organised groups from outside the area may also represent a threat if they are not aware of access agreements or conservation issues at sites. One of the roles of POCG is to publicise information on protecting the coastal environment and raise awareness of these issues.

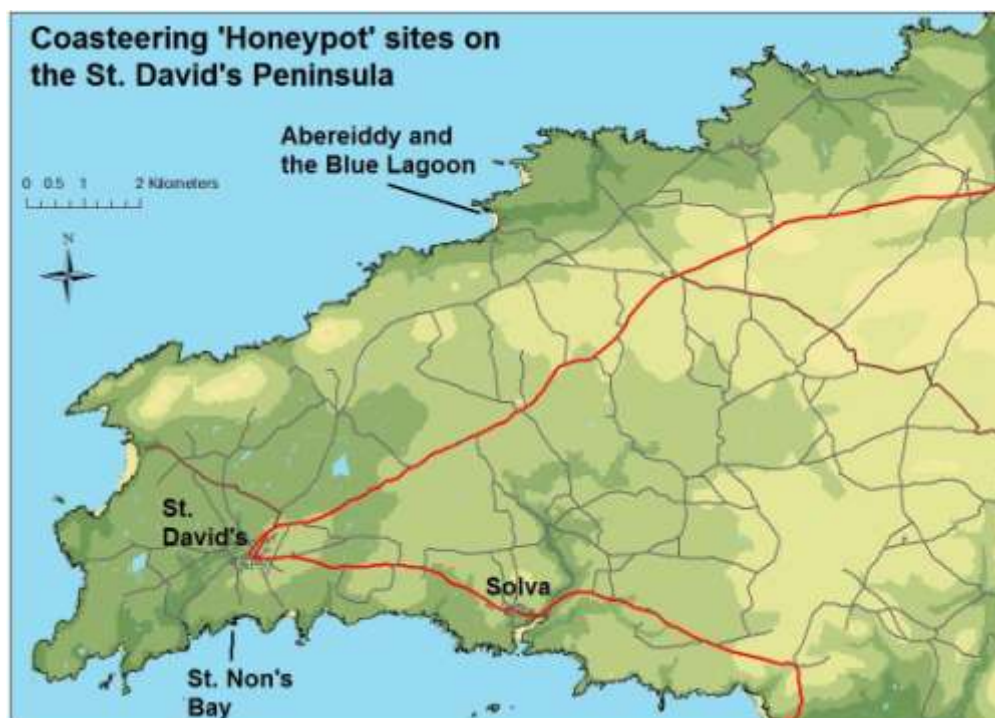
The National Trust are currently investigating the potential for new coasteering development and attempting to devise a protocol for making decisions on suitability of sites for coasteering based on conservation issues. The identification of potential new sites for coasteering forms the basis of this investigation.

There are a number of general requirements for coasteering locations, all of which are rather subjective:

- Areas of rocky shore which would generally be considered to be inaccessible for most tourists
- Sections of reasonably solid rock cliffs with deep water below
- Access points and escape routes at regular intervals
- Sites where cliff jumps into deep water are possible
- Some shelter from waves and tidal currents
- Areas of flat ledges where groups can 'gather' between more difficult sections of climbing or swimming

### **Coasteering Issues in Pembrokeshire**

Two sites in the St. David's area have been selected as case studies to illustrate the existing congestion issues and hence the demand for new areas:



**Figure: 1.10 Key Coasteering locations in the St David's Peninsula**

Map created by S. Quinton, Dec. 2010 for MSc in GIS  
Ordnance Survey © Crown Copyright and database right 2010

#### **1.4.1 Case study 1: St. Non's Bay, 1km south of St. David's**

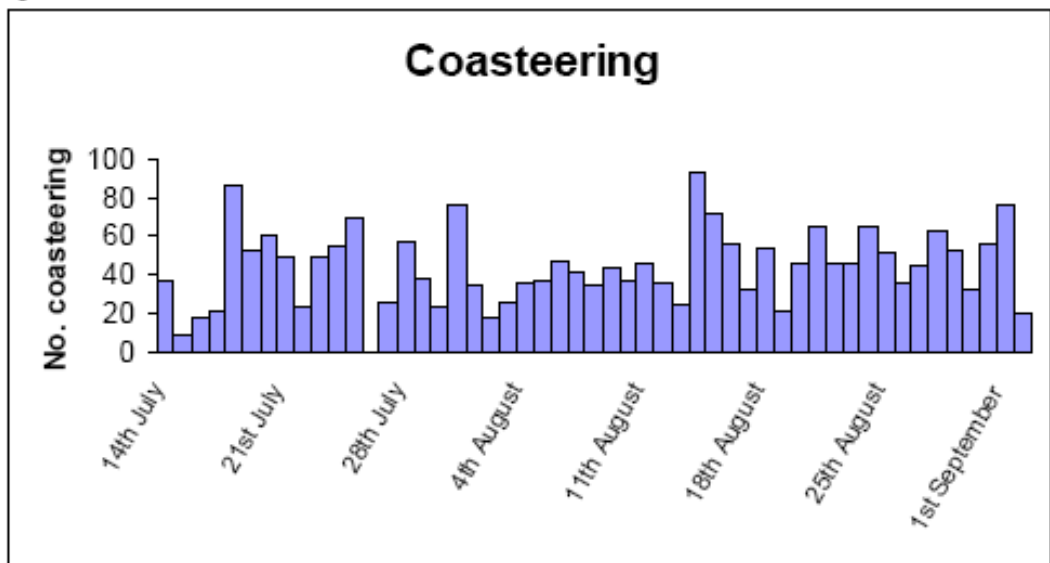
This area was one of the first to be developed for commercial coasteering and is a popular site, used in the main by one local company but also by organised groups from outside the area. There are several sections that can be suitable at different states of the tide and a number of access points. The site is considered to be one of the best locations locally due to combination of challenging climbing sections, deep water for cliff jumps, easy sections with good ledges, caves and small islets. The main limitation of this site is that it is exposed to the prevailing swell direction and can be too dangerous for commercial groups during rough weather.



**Figure 1.11 Part of St. Non's Bay, near St. David's**

This site has been studied by Luddington (2008) who recorded the numbers of clients and the visible impacts of coasteering on this stretch of coast. The chart below (figure 1.12) illustrates the intensity of use of this area which can have close to 100 people (typically 8-12 groups between 10.00am and 5.00pm) coasteering along this stretch during busy days. Recorded physical impacts were limited to erosion at on the upper parts of descent routes where informal paths have been created by coasteering groups and anglers. There were also small areas of bare rock that would have otherwise been populated by barnacles, probably due to repetitive trampling by coasteering groups.





**Figure 1.12: Numbers of clients taking part in commercial coasteering trips during the peak summer season, 2007 (From Luddington, 2008)**



**Figure 1.13 An organised coasteering group at St. Non's Bay**

This site is considered a ‘honeypot’ location which provides a suitable venue in calm to moderate swell conditions with minimal impact on the natural environment other than localised erosion and some interruption of the otherwise tranquil nature of the coast.

The exposed nature of this section of coast means that the flora and fauna have adapted to regular storm action and the ecosystem is relatively resilient. This may not necessarily be true of alternative, more sheltered locations that might be developed to allow for continued growth of the outdoor activity industry.

When conditions are rough, groups have historically moved to the second case study, Abereidid, which is a more sheltered location, 8.5 km to the north east (see below).

#### **1.4.2 Case Study 2: Abereidid and the ‘Blue Lagoon’**



**Figure 1.14: The ‘Blue Lagoon’ at Abereidid**

This site is more complex and can be even busier than St. Non's Bay. It is used as the 'default' location by several outdoor activity providers due to several key factors:

- Easy access from a car park within 50 metres of the high water mark.
- Reliable, calm conditions created by a lagoon in the old quarry.
- A good combination of easy and difficult sea level traversing, caves and cliff jumping opportunities.

Client numbers have been reported (anecdotally) as up to 170 at a time and this has resulted in a system of controls being negotiated between the landowners and outdoor activity companies during 2010-11 .

A number of factors combine to make this site a particularly interesting example of outdoor recreation management:

- The existing car park is protected by a poorly designed sea defence that is due to be removed in 2011-2012. This is likely to result in the upper beach being re-graded by storm waves and the car parking area reducing by approximately 50% within a period of a few weeks to 2 years.
- The area is partly owned by the National Trust and partly by a local farmer while the foreshore is leased from the Crown Estate by the National Park Authority.
- This is one of very few sites that are suitable for coastering in very rough weather.
- All stakeholders are willing to create a system that will allow commercial coastering to continue in a sustainable way without detracting from the nature of the location.

Negotiations are ongoing (winter 2010-2011) to develop a booking and registration system that will limit commercial organisations to a maximum of 75 clients using the area for coastering at a time. This should go some way to protecting the location from overuse but also has the effect of creating an urgent demand for an alternative venue.



## 1.5 Dissertation Aims

1. To develop a method of classifying sections of coast as suitable, or unsuitable for development of commercial coastering activities.
2. Adapt wilderness mapping techniques to a coastal location.
3. Identify the role of GIS within the process of identifying suitable locations.

The outdoor activity sector is a significant employer in the local area and has seen steady growth in demand over recent years. In order to satisfy that demand and secure employment into the next decade, there is a need for new locations to be found. Key sites first developed in the 1980s and 1990s are now close to their 'carrying capacity' and impacts of activities have, in at least one case, become unacceptable. The first aim of this study is to develop a model for narrowing down the search areas for suitable locations. This will be based on practical factors (such as accessibility and safety), protecting the wilder, more tranquil parts of the coast and minimising impact on wildlife, plants and habitats.

As part of the process of identifying suitable sites, it has been agreed by conservation organisations and outdoor activity providers that there should be some areas that are not used by organised groups in order to preserve wild places where people are able to walk, kayak, climb and fish without disturbance from commercial groups which can be loud and intrusive at times. This part of the project involves adapting techniques used by previous researchers for mapping wilderness and tranquillity (Carver et al, 2002 and Macfarlane et al, 2006) to a local area that is primarily coastal. (The term '*wildness*' has been used in this project as opposed to '*wilderness*' in recognition that there is no true wilderness within this study area.)

The final aim is to evaluate the usefulness of GIS techniques within this process. There is likely to be some value in being able to map some of the factors pertaining to wildness and tranquillity and it is possible to produce map layers showing conservation interests and protected areas.

There are many problems with this process including confidentiality of data (particularly bird nest sites and seal breeding locations) and the complexity created by seasonal and other temporal factors. Conservation bodies are hoping to digitally map all the conservation interests in the area in order to be able to provide advice about future developments of activities and land use. The scale and level of detail of this work is worthy of investigation.



**Figure 1.15: Caerbwdi Bay: Ideal coastering environment (deep water inlets, short cliffs, ledge systems and regular access to safe ground).**

## **2. Literature Review**

### **2.1 History/background**

Outdoor Recreation has been known to have an impact on the natural environment for many years and records of impacts go back at least as far as 1759 when effects of trampling of meadow grass on footpaths in the Malvern Hills was recorded by Stillingfleet (reported in Liddle, 1997). Apart from trampling and associated erosion, the effects of outdoor recreation include disturbance of wildlife due to human presence and modification of vegetation and landscapes in order to allow recreation to take place (ski tourism for example). Keller (1991) recorded increased predation on Eider Ducklings due to disturbance by human presence and Nunn (1988) reported on the effect of ‘gardening’ by rock climbers on cliffs in the Lake District. National Park Authorities and other conservation bodies have been working with outdoor recreation groups such as the British Mountaineering Council (BMC) for many years in attempting to minimise these negative impacts with varying degrees of success.

### **2.2 Recreation and Conservation Management issues**

The potential problems facing land use managers are well summarised by Itami and Gimblett in their study which used GIS to model the interactions of different users of the environment:

*“As visitor numbers increase, there is a simultaneous increase in environmental impacts, crowding, and conflicts between different recreational types and users. These circumstances make recreation management a complex problem. Managers of natural areas must accommodate increasing visitor use while at the same time, maintaining environmental quality and ensuring visitors have the high quality experience they anticipate.”*

(Itami and Gimblett, 2001)

This is particularly relevant to the management of outdoor recreation in Pembrokeshire where conflicts have been identified and outdoor activity providers have recognised the threat to client satisfaction resulting from overcrowding.

Pressure from visitors taking increasingly more active breaks in National Parks and other sensitive landscapes is being taken seriously by organisations involved in management and conservation of these areas, particularly in view of government-led policies to further increase these numbers. Within Wales, the Welsh Assembly Government's (WAG) document, "*A Progressive Agenda for Wales*" includes the following aim:

*"... encouraging people from all backgrounds to enjoy the natural environment, especially those from socially excluded groups".*

(Welsh Assembly Government, 2009)

In 2002, Adventure Tourism accounted for "*at least 1.25 million visits to Wales, and £180 million of direct visitor spending*" (Welsh Tourism Board, 2002). These are figures that WAG is keen to increase through strategies such as 'Time for Action' and 'As Wild As You Want It' (a marketing campaign to promote adventurous activities in south west Wales).

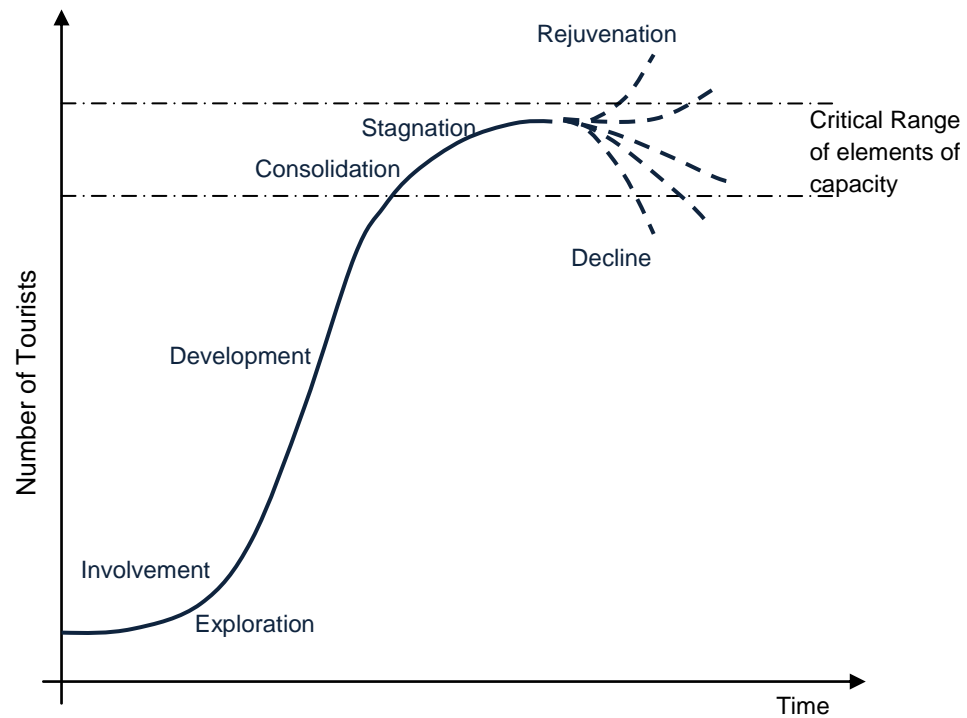
In Pembrokeshire, this is seen as a growth market and an important sector in the local economy:

*"Increasing demand for adventure tourism and wildlife cruises has led to increased activity in these sectors in Pembrokeshire in recent years. Indications are that these sectors have potential for significant further growth, as they are currently under-developed locally."*

(Pembrokeshire Coastal Forum, 2003)

These policies, which are mirrored in many other parts of the UK and Europe, are driven by health-related benefits, economic benefits and an increasingly important need for the population to get 'in touch' with a vulnerable environment. It does, however, pose certain threats to the environment that provides these opportunities for enjoyable, sustainable recreation.

Penz (1975) attempted to define carrying capacity for recreation areas with US National Parks. Factors such as public facilities, car parking and effects on flora and fauna were considered but many complicating factors were also identified that would be difficult to model such as visitor behaviours. The idea of carrying capacity and a semi-predictable life cycle of tourist destinations were further developed by Butler (1980) with his model of exploration, development, consolidation, stagnation and decline or rejuvenation as illustrated below in figure 2.1.



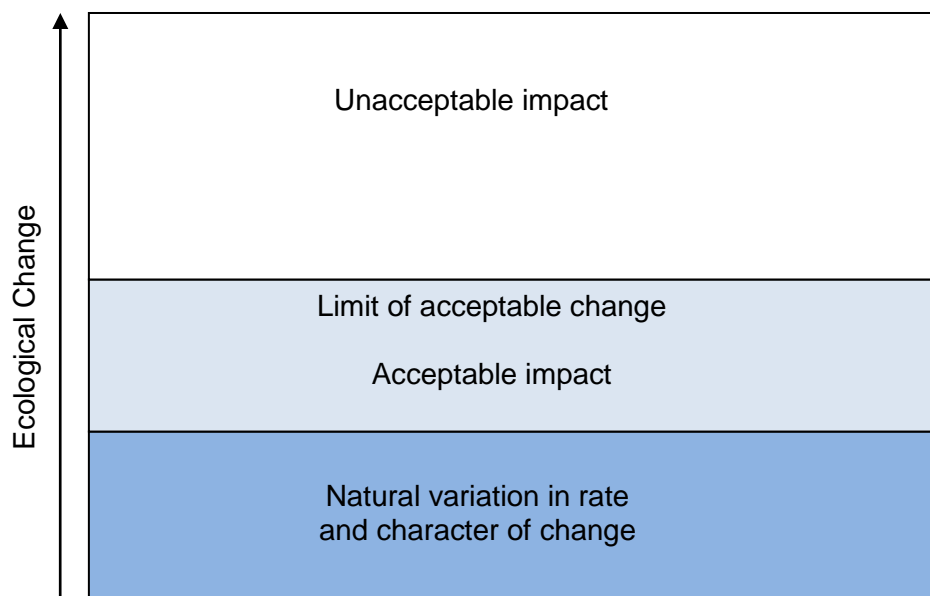
**Figure 2.1: Hypothetical evolution of a tourist area** (After Butler, 1980)

It could be said that several ‘honeypot’ sites within the study area are at, or close to, the top of this curve and require a form of management intervention to prevent decline in the industry.

Attempts to quantify carrying capacity for recreation include the development of a ‘Recreational Use Intensity’ (RUI) measurement (Minnesota Environmental Quality Board, 1993) that assigns a value to the amount of recreational use that an area can sustain over a given time period. However, the complex relationships between recreation type, user type, habitat characteristics, species behaviours and seasonal changes has created problems for land managers when attempting to define carrying capacity and management strategies in relation to outdoor recreation (Cole

and Stankey, 1997). One approach developed in the US Forestry Service is the 'Limits of Acceptable Change' (LAC) framework (Stankey et al 1985) illustrated in figure 2.2 below. This bypasses the carrying capacity concept and assumes that some impact will result from any recreation. The key point is limiting that impact to an acceptable level so that habitats and landscapes are not excessively harmed and visitor experience is maintained.

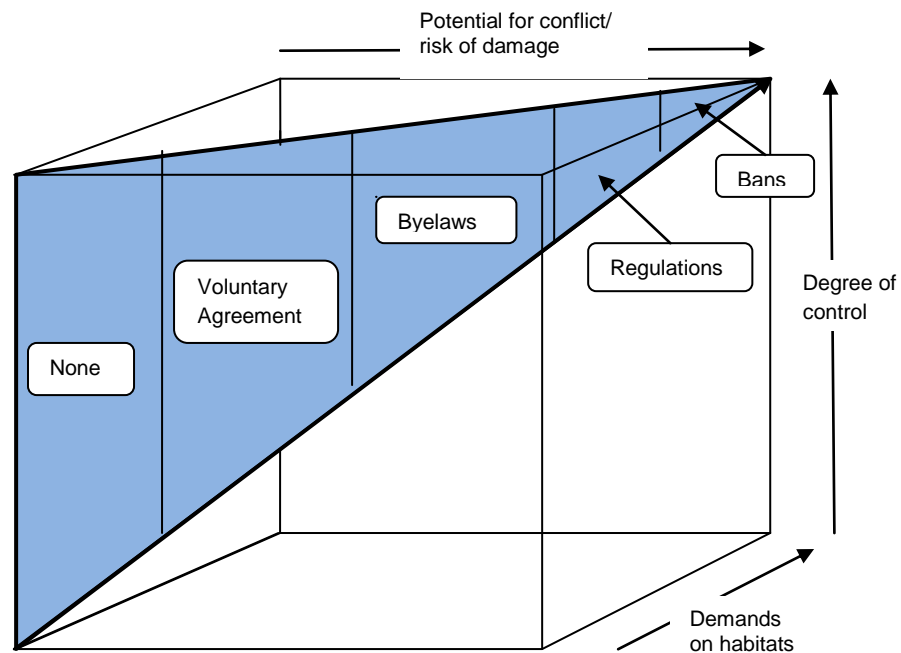
Associated with the LAC framework is the concept of zoning where areas are zoned according to wilderness status. Some areas may be already modified by human presence while others could be pristine wilderness. These differing zones may then be managed in differing ways including designation of so-called 'honeypot' sites where people may be encouraged to go in order that more remote/wild sites are protected and used much less regularly.



**Figure 2.2: Limits of Acceptable Change framework** (Hammit, 1990)

The concepts of acceptable change, wilderness areas and zoning are particularly relevant to the present study. Identification of wild areas and areas where recreation is to be encouraged or discouraged will form an important part of this dissertation as these are also priorities for land managers such as the National Trust and National Park Authorities.

There is therefore, widespread understanding that growth of outdoor recreation can lead to problems as a ‘carrying capacity’ is reached or impacts exceed what is considered acceptable. The quantification of these points presents a thorny problem but management intervention is likely to be necessary to preserve ecosystems and visitor experience quality as pressure grows. This may include a range of actions from education, through zoning to closure of areas. The range of approaches is illustrated by Hugget (1995) as shown below in figure 2.3.



**Figure 2.3: A Hierarchical approach to activity control in a variable environment (after Hugget, 1995)**

Greater control in the form of bans and regulations has been used in some areas of the USA and Europe where powerful conservation bodies or land owners have used environmental legislation to prevent recreationists disturbing wildlife or damaging important natural and cultural heritage sites. Examples include Berdorf in Luxembourg where it is illegal to climb without a permit and sections of Hueco

Tanks in Texas, USA where areas are closed to recreation in order to preserve geological features and native rock art.

The use of legislation in the form of regulations and bans can be an expensive method of protecting conservation interests and particularly difficult to enforce. In the UK, voluntary agreements are generally considered to work well in reducing impact on climbing sites and legislation is currently under review in terms of access to coasts and inland waterways for canoeing. Voluntary agreements are currently being negotiated for coasteering at one site within this study area (Abereddy, see section 1.4.2) and this type of arrangement may be extended to other sites in the future, particularly on National Trust properties where a policy of licensing commercial outdoor activities is being considered.



**Figure 2.4: National Trust signpost (left) and cliff-top voluntary climbing restriction marker (right) at Trevalen in South Pembrokeshire.**



### **2.3 Legislation and Conservation**

The legal framework within which conservation organisations work in the UK is the Environment Act (1995). This sets out the purposes of National Parks as follows:

*“(a) of conserving and enhancing the natural beauty, wildlife and cultural heritage of the areas specified ...; and*

*(b) of promoting opportunities for the understanding and enjoyment of the special qualities of those areas by the public.”*

(Environment Act, 1995)

This legislation also sets out the following priorities for management of conflicts:

*“If it appears that there is a conflict between those purposes, (The National Park Authority) shall attach greater weight to the purpose of conserving and enhancing the natural beauty, wildlife and cultural heritage of the area comprised in the National Park.*

(Environment Act, 1995)

Within UK law, conservation always takes precedence over recreation and enjoyment for the obvious reason that environmental damage is often irreversible and may have unforeseen long term consequences. This approach is echoed in the EU Habitats Directive (1992) for Special Areas of Conservation (SACs):

*“Member States shall take appropriate steps to avoid, in the special areas of conservation, the deterioration of natural habitats and the habitats of species as well as disturbance of the species for which the areas have been designated, in so far as such disturbance could be significant in relation to the objectives of this Directive”*

(Council Directive 92/43/EEC,1992),

In addition to the legislation listed above, the Wildlife and Countryside Act (1981) part one provides specific protection for birds by creating the following offence:

*“... to disturb any wild bird listed on ‘Schedule 1’ while it is nest building, or at a nest containing eggs or young, or disturb the dependent young of such a bird”*

Plants are also protected by the same legislation under section 13 which prohibits *“the unauthorised intentional uprooting of any wild plant species and forbids any picking, uprooting or destruction of plants listed on Schedule 8”*.

This legislation has been strengthened by the introduction of the Countryside and Rights of Way Act (2000). While this increases the so-called ‘right to roam’ it also created the offence of *‘reckless disturbance of wildlife’*.

There is, therefore, a strong legislative system in place in the UK that provides the potential for a high level of protection of vulnerable habitats. The organisations that enforce the legislation (English Heritage, Scottish Natural Heritage, CCW, the National Trust and National Park Authorities) also have a role in promoting recreation in the countryside which has led to a less authoritarian approach to protection compared to some countries in Europe and parts of the USA.

#### **2.4 National Governing Bodies and Representative Bodies for Outdoor Recreation**

Outdoor Recreation organisations such as the BMC, Ramblers Association (RA), and the Royal Yachting Association (RYA) have developed environmental/conservation information in an attempt to minimise impacts from their members and to protect access to cliffs, mountains, rivers and the sea for recreation. The RYA have developed a project called ‘the Green Blue’ (RYA, 2009) which encourages sustainable watersports by informing sailors about conservation issues and good practise. The BMC produce conservation advice for members such as ‘Green Guides’ to highlight conservation issues and good practise in specific areas (Quinton, 2010). They have also developed a guide for crag and habitat management with the aim of helping climbers to keep cliffs in good

condition for climbing without reducing their habitat value. This highlights the importance of crag management:

*“Achieving a sustainable balance between recreation and conservation can seem a daunting task. Cliffs often provide safe havens for wildlife and support many rare species, and the conservation value of crags should never be underestimated.”*

(BMC, 2008)

There is no National Governing Body for the sport of coasteering but a Best Practice Guide has recently been developed by the National Water Safety Forum (2010) which includes some guidance relating to environmental protection.

In south west Wales, the Pembrokeshire Outdoor Charter Group (POCG) was established in the early 1990s to act as a link between recreation providers and conservation organisations in order to minimise the impact of activities on the environment and to expand the environmental education that is included in outdoor recreation provision. This group is currently involved in negotiating access for outdoor activity sites and contributes towards the National Park Recreation Management Plan on behalf of the local outdoor activity centres.

Representatives of outdoor recreation providers and participants are therefore beginning to work with conservation bodies to address the issues of increasing pressure on the environment and to coordinate efforts to promote sustainable recreation in vulnerable locations. Within this framework, GIS is increasingly forming a part of the information gathering, and decision making process.

## **2.5 GIS approaches to managing conflict between recreation & conservation**

### **General overview**

Use of GIS in outdoor recreation management is a relatively recent development but is now standard practise among organisations such as CCW, Natural England, Scottish National Heritage (Bates and James, 2002) and National Park Authorities in the UK. Further afield, GIS is used by the US Forestry Service (Baerenklau et al, 2009) and ‘Parks Victoria’ in Australia (Itami et al 1999) amongst others as part of systems to manage recreation and tourism impacts.

GIS has been used in several ways including the following examples:

- Mapping of recreation activities and conservation areas
- Measuring Landscape value
- Development of Spatial Decision Support Systems (SDSS)
- Simulating effects of management strategies
- Modelling changes in recreation pressure

Bates and James (2002) used GIS to map human use of Scottish Marine SACs and to link these patterns to conservation value. A similar approach was taken by Burton and Scrase (2002) in their study of recreation activities in the Solent area.

Baerenklau et al. (2009) used GIS as a tool for measuring landscape value in the forests of southern California based largely on visitor numbers and willingness to pay for access to landscapes. Crawford (1994) used a different approach to measure landscape beauty by combining remote sensing data (satellite images) with Digital Elevation Models (DEMs) and a similar method using DEMs was used by Chhetri (2008) in Victoria, Australia model landscape quality based on topography. Carver et al (2002) formulated a method for assigning wilderness value to UK landscapes based on remoteness from population and transport, ‘naturalness’ and altitude. The Campaign for the Protection of Rural England (CPRE) has constructed tranquillity maps of England using GIS techniques that combined researched factors associated with tranquillity with spatial datasets to create maps showing tranquillity scores for the whole of England. The positive and negative factors affecting tranquillity are shown in table 2.1 below:

<b>Positive Factors</b>	<b>Weight</b>
Openness of the landscape	24%
Perceived naturalness of the landscape	30%
Rivers in the landscape	21%
Areas of low noise	20%
Visibility of the sea	6%
Total of positive factors	100%
<b>Positive scores as a percentage of the overall scores</b>	<b>44%</b>

<b>Negative Factors</b>	<b>Weight</b>
Presence of other people	60%
Visibility of roads	12%
General signs of overt human impact	10%
Visibility of urban development	8%
Road, Train and urban area noise	7%
Night time light pollution	3%
Aircraft noise	1.5%
Military Training noise	< 1%
Total of negative factors	100%
<b>Negative scores as a percentage of the overall scores</b>	<b>56%</b>

**Table 2.1: Factors affecting tranquillity according to MacFarlane et al (2006)**

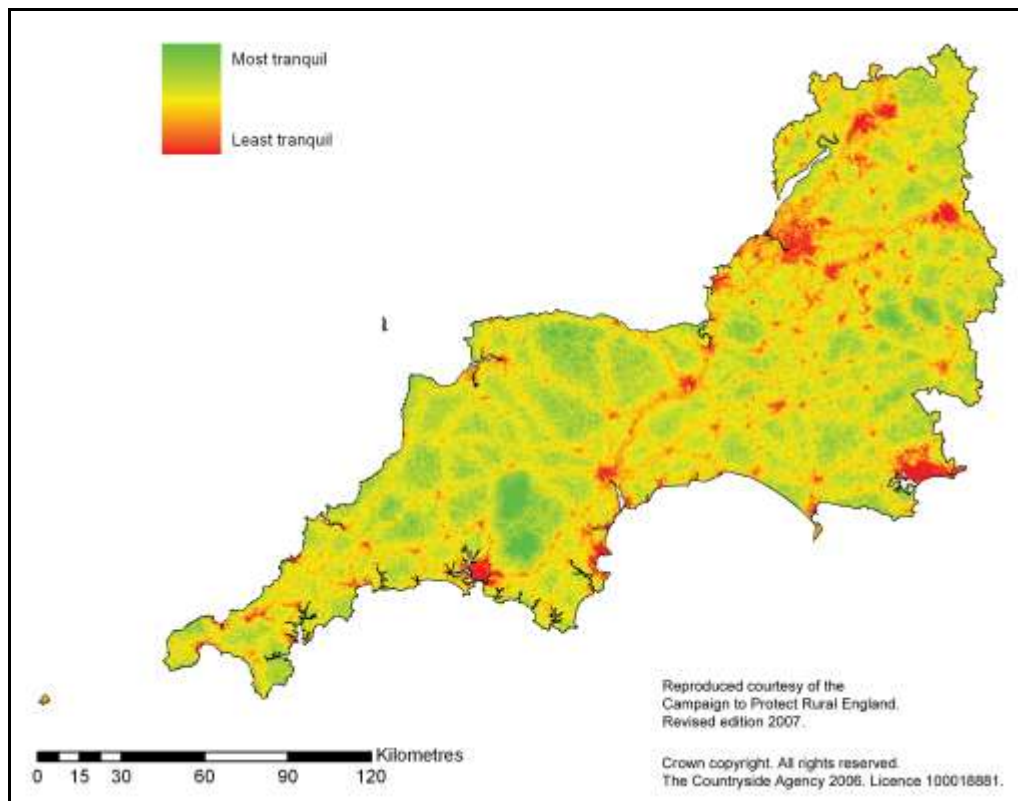
The importance of tranquillity is summarised by MacFarlane et al, 2006 as follows:

*A recent review of over 100 studies found convincing evidence of the importance of the natural environment in facilitating recovery from stress. It highlighted that the primary reasons for visiting natural environments included escape from the stress of urban areas and the attainment of tranquillity and solitude. Furthermore, Government sponsored research points out that the benefits of viewing green- space or other nature goes beyond aesthetic enjoyment to include enhanced emotional well-being, reduced stress, and, in certain situations, improved health.*

(Macfarlane et al, 2006)

Maintaining areas where tranquillity is available for people is therefore considered a justifiable aim for organisations such as National Park Authorities. Loss of tranquil areas by inappropriate development of commercial activities should be avoided, particularly considering that by far the most significant negative factor listed above is the ‘presence of other people’.

A sample Tranquillity Map is shown below in figure 2.5.



**Figure 2.5: Tranquillity Map of SW England, (MacFarlane et al, 2006)**

There exists, therefore, a range of techniques within the literature for measuring landscape quality/wilderness and tranquillity using GIS combined with surveys, remote sensing and various datasets describing physical and human features of the landscape. These offer the potential for developing a SDSS to aid land managers in taking decisions on recreation areas in areas such as the Pembrokeshire Coast National Park.

Itami et al (2001 and 2003) simulated the effects of various management strategies on outdoor recreation areas such as the Grand Canyon and Port Campbell National Park, Australia by combining GIS with intelligent agents. This model predicts the numbers of visitors at various sites as well as pressures on car parking and visitor interactions with the aim of preserving the quality of visitor experience in increasingly busy locations. Modelling of visitor behaviour and visitor satisfaction has been tested by Bishop and Gimblett (2000) who used GIS techniques to simulate the impacts of various management strategies on where visitors are likely to go, how this affects congestion and the resultant erosion.

Modelling of recreation pressure is another application of GIS proposed by De Vries and Goosen (2002) amongst others. This study predicted the number of visits expected based on recreational value and various management actions such as providing more car parking or visitor centres. GIS techniques allowed the researchers to map predicted visitor density and interactions between visitors in Forest areas in Holland. GIS analysis of recreation pressure using satellite images has been trialled by Landré (2009) who tracked flows of yachts and developed a model to simulate the effects of various management strategies and how these would affect movements of yachts in sensitive parts of Biesbosch National Park in The Netherlands.

The use of Multi-Criteria Evaluation (MCE) techniques within GIS has been trialled in Mauritius by Beedasy and Whyatt (1999) where a SDSS was developed to guide tourism development in an area with limited space and high levels of tourism pressure. This system uses spatial data such as accessibility, population/settlement location, nature parks and agricultural land to help identify areas that are appropriate (or not) for tourism development.

Within Wales, GIS has been used as a monitoring tool in order to map recreational use of parts of the Pembrokeshire Coastline (Jones, 2009). The main purpose of GIS within this project is to establish baseline data and produce information on activities for recreation, tourism and conservation management. GIS have also been used in identifying vulnerable intertidal habitats in relation to 'Coasteering' (sea level traversing and cliff-jumping) activity sites in Pembrokeshire (Tyler-Walters, 2005). This study, undertaken by 'MarLIN' and commissioned by CCW was instigated in order to provide information on the potential for disturbance and trampling caused by frequent large groups of 'coasteerers' on rocky intertidal communities within the Pembrokeshire Marine SAC. The methodology included use of buffering within a GIS to identify sensitive species within 0.5km of known Coasteering sites and production of a sensitivity map layer to aid CCW in evaluation of potential impacts of coasteering. The desk study above has been further developed by Luddington (2008) to include observed levels of activity and visible impacts of outdoor recreation on one section of the Pembrokeshire Coast. This included the production of GIS layers recording activity levels and conservation designations.

GIS is also part of the methodology being used by the University of Brighton's 'Strategic Plan for Water Related Recreation in Wales' (Church et al, 2008). In this case, the role of GIS is in mapping the available resource and the accessibility of the resource for the population. Bateman et al (1999) developed a GIS-based model for predicting visitor numbers to woodlands for recreation using travel times calculated through network analysis of a digital road network. This was used to estimate potential annual value of recreational visits to the Welsh economy should new sites for woodland recreation be developed. Similar techniques could be used when evaluating the impact of developing new recreation sites within the Pembrokeshire Coast National Park.

In summary, there is a wealth of research history in the field of conservation management and the application of GIS to these issues. Within the following sections, the work of Carver and Macfarlane, in particular will be applied to mapping 'wildness' in Pembrokeshire and previous research on the study area by Luddington, Jones and Tyler-Walters will provide useful location-specific data that will enhance the process of identifying suitable sites.



### 3. Methodology

The following methodology is intended as a first stage in developing a management tool to help achieve the objectives listed within the Draft Recreation plan for Pembrokeshire Coast National Park.

- *Continue to manage the National Park and surrounding area as a recreation destination while maintaining environmental and cultural integrity and contributing to the economy of the area.*
- *Limit activity development and manage recreation impact in the most environmentally sensitive areas on a spatial and/or temporal basis.*

(PCNPA, 2010)

There are several complicating factors which must be considered when attempting to map suitability for recreational use including seasonal differences, tidal differences and factors of scale. There are also very subjective factors such as the concept of wilderness and tranquillity. To what extent can these factors be mapped and how can they be used to define suitable and unsuitable areas for coasteering sites? The aim is to produce maps that can be used as a first stage in decision-making on where coasteering could be developed and where it should not. The general approach is one of narrowing down the area by eliminating sites that would not be suitable so that detailed study can be targeted at the most likely sections of coastline.

Initially, the St. David's Peninsula was used to test systems and identify some potential areas. This area was chosen for several reasons including the availability of detailed data (such as bird nesting sites, seal pupping sites and 'escape routes') that allowed more detailed analysis in some respects. The study was then extended to the whole of the Pembrokeshire Coast to cover a wider range of environments and produce results that could then be further investigated as more data is accessed.

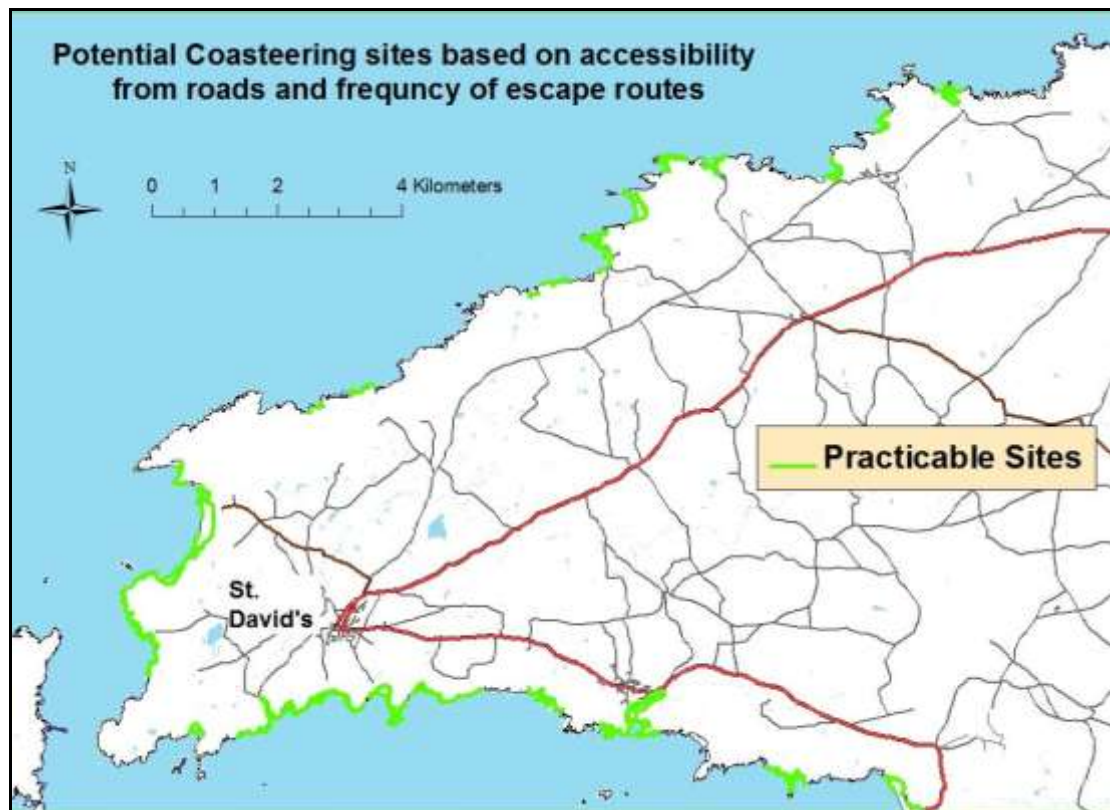
### **3.1 Study Area 1 (St. David's Peninsula) Methodology**

Several stages were used in the process of identifying potential sites for development:

Firstly, areas that were considered impractical due to accessibility were removed. This was achieved by applying a 1km buffer to all roads. This was then used to eliminate sections of the coast that are greater than 1 km from road access. This is based on the assumption that commercial operators will generally need to get their clients to locations quickly and walking over 1 km in wet coasteering kit would normally be considered excessive.

Secondly, escape routes were marked using the editor tools in ArcMap. Escape routes form an important element in risk assessments for coasteering where hazards are multiplied by accessibility issues and changing sea conditions may necessitate a quick exit to the safety of the coastal path. Identifying these escape routes is problematic as it is only local knowledge or detailed field surveys that would be able to assess the accessibility from coastal path to sea level where the coastline consists of cliffs. For the purposes of this study, suitable escape routes have been marked on the map as a layer, based on personal knowledge of the author combined with cliff photos acquired as part of work on a rock climbing guidebook. Escape routes are defined as places where it is possible for a coasteering leader to guide a group of beginners from sea level up to the coast path or safe ground without the use of rock climbing equipment. National Guidelines for coasteering do not set maximum distances between escape routes but state that there should be a 'regular escape points' for inexperienced groups (National Water Safety Forum, 2010). The frequency depends on the ease of movement along the shore. If groups can move easily along sections of shingle, beach or flat ledges, it may be appropriate to have distances of several hundred metres between escape routes. Sections of high cliffs with difficult climbing or swimming sections will require a greater frequency of escape routes. A maximum distance between escape routes of 400m (based on existing coasteering sites) has been used for this study so that sections of coast that are more than 200m from the nearest escape route have been eliminated. This has been achieved using a 200m buffer around all sections marked as escape routes and 'clipping' the tidal boundaries using this buffer.

The accessibility map and availability of escape routes map has been combined to produce a map of practicable sites on the St. David's Peninsula and this is shown below in figure 3.1.



**Figure 3.1: Practicable sites for coasteering on the St. David's Peninsula**

Map created by S. Quinton, Dec. 2010 for MSc in GIS

Ordnance Survey © Crown Copyright and database right 2010

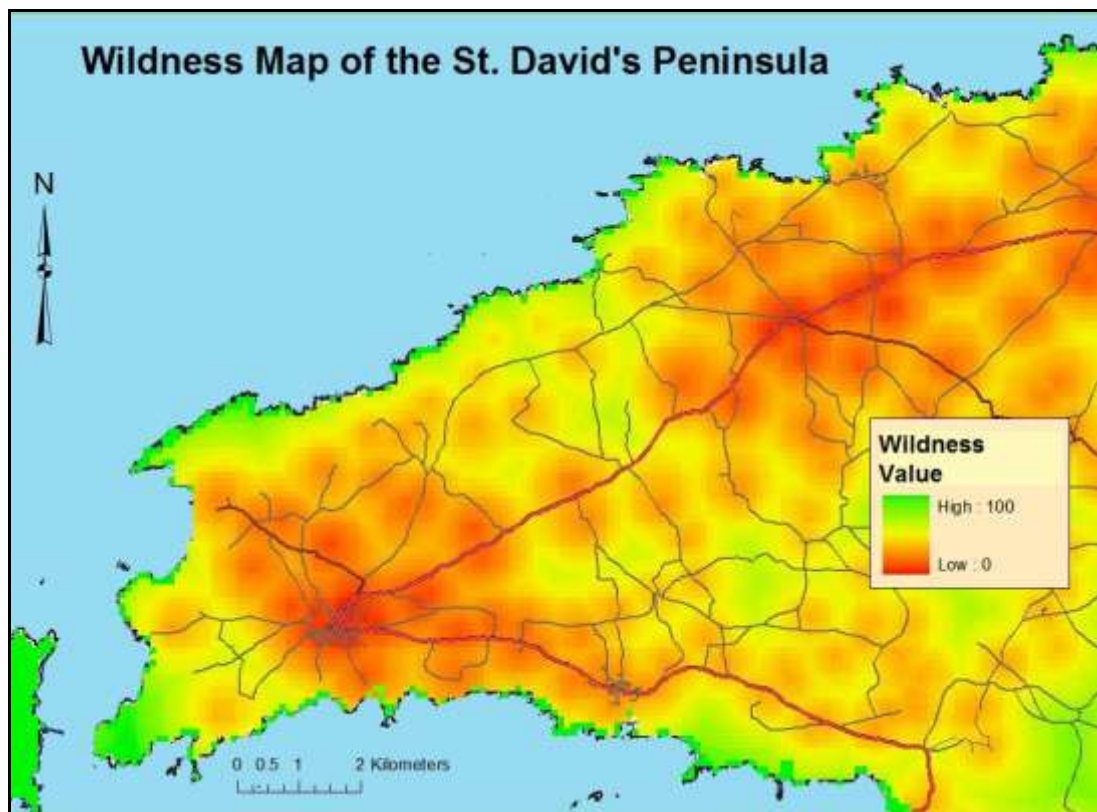
The next stage was mapping wild places in order to 'designate' sections of coast that could be protected from intrusion of commercial activities. A simple approach using just three factors was used for study area 1 (a more sophisticated approach was used for study area 2):

1. Distance from buildings
2. Weighted distance from roads
3. Landscape Quality

Three stages were used in the process of creating the wildness map:

1. A raster layer was created using Spatial Analyst tools based on distance from buildings as mapped on the Ordnance Survey OpenData map. This was then standardised using a scale of 0.0 – 4.0.
2. Raster layers were also created for distance from A roads, B roads and minor roads. These were then added using weightings of 3, 2 and 1 respectively to produce a weighted distance raster that was also standardised as above.
3. Landscape Quality values were acquired from CCW LANDMAP data. This classifies ‘aspect areas’ in terms of visual and sensory value as either outstanding, high, moderate or low (see section 3.2.2 and appendix 2 for further details). The landscape values were reclassified from 1 – 4.

All three rasters were combined using the raster calculator tool, using equal weightings to produce a wildness raster as shown below in figure 3.2 .

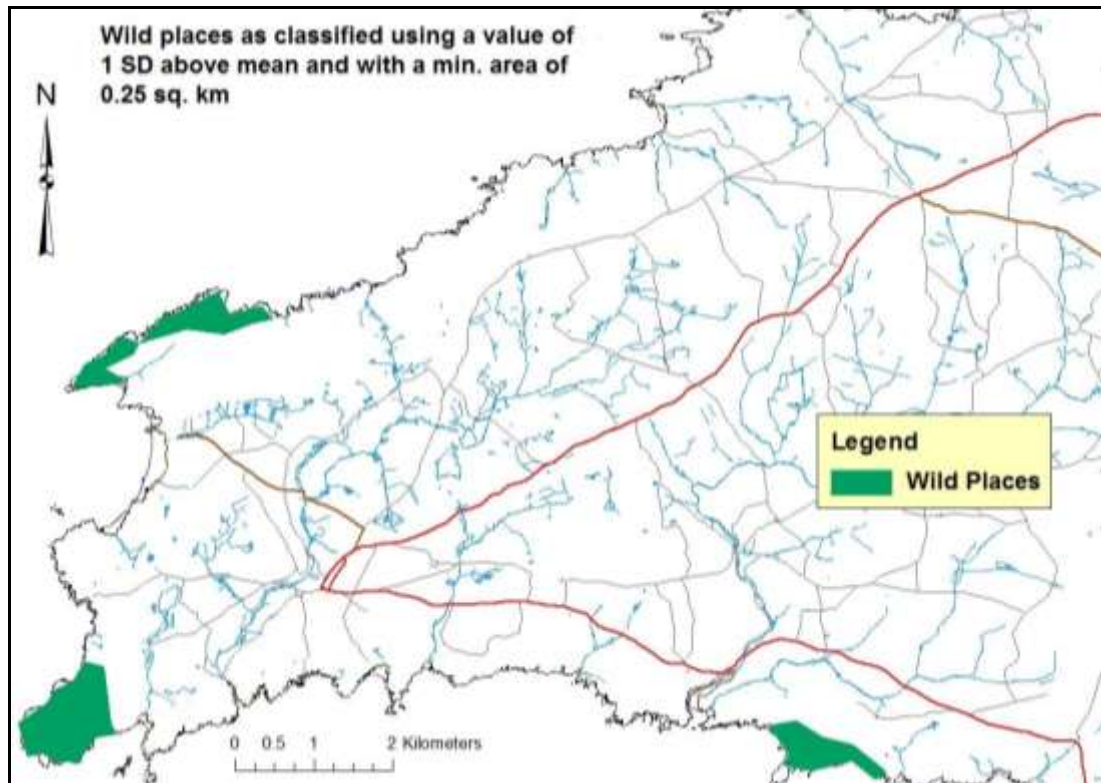


**Figure 3.2: Wildness raster for St. David’s Peninsula based on distance from buildings, weighted distance from roads and landscape quality**

Maps created by S. Quinton, Aug. 2010 for MSc in GIS

Ordnance Survey © Crown Copyright and database right 2010

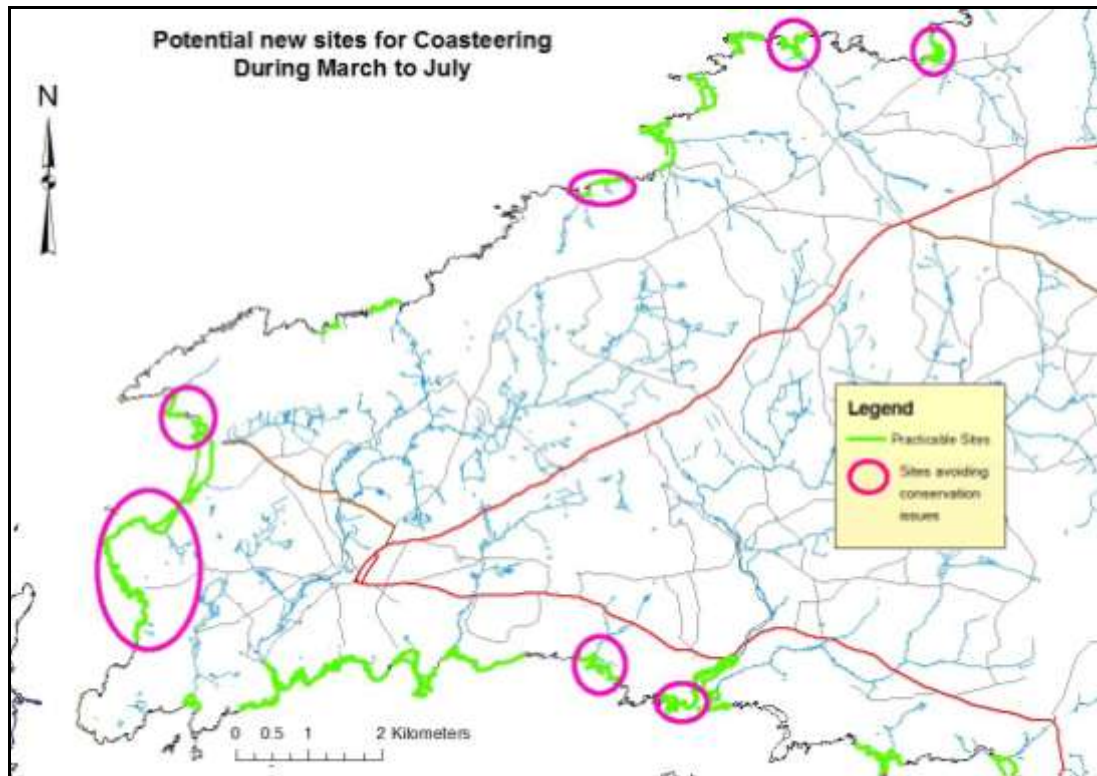
In order to identify ‘wild’ places that might be protected, a threshold value was set (using trial and error) of mean + 1SD (standard deviation). This resulted in a map showing several areas that could be considered as wild including some very small sections of the coastal strip. A minimum area of 0.25 km<sup>2</sup> was used to eliminate these and the resulting map is shown below in figure 3.3 .



**Figure 3.3: Wild places on the St. David's Peninsula.**

Maps created by S. Quinton, Aug. 2010 for MSc in GIS  
Ordnance Survey © Crown Copyright and database right 2010

Key conservation features were also mapped using data provided by CCW. This data is confidential and cannot, therefore, be published here but using known locations of ‘schedule 1’ bird nest sites, it was possible to create a map that shows potential areas for development that are (i) practicable, (ii) would not impact on nesting sites for key species, and (iii) also avoid encroaching on the wilder parts of the study area. This map is shown in figure 3.4 below.



**Figure 3.4 Potential new coasteering locations on the St. David's Peninsula based on practicability, avoiding wild places and avoiding disturbance of nesting birds (as well as ignoring locations that are already used).**

Map created by S. Quinton, Aug. 2010 for MSc in GIS  
 Ordnance Survey © Crown Copyright and database right 2010

The process described above for study area 1 has been used to experiment with techniques and to identify some potential sites in this area. The second stage in the project will refine these techniques and add further criteria to make the process more applicable to current issues.



### **3.2 Study Area 2 (Pembrokeshire Coast) Methodology**

The broader area of Pembrokeshire as a whole includes more diverse landscapes and coastlines. Techniques used in the first study area have therefore been modified and improved to suit this larger area.

A four stage process is proposed:

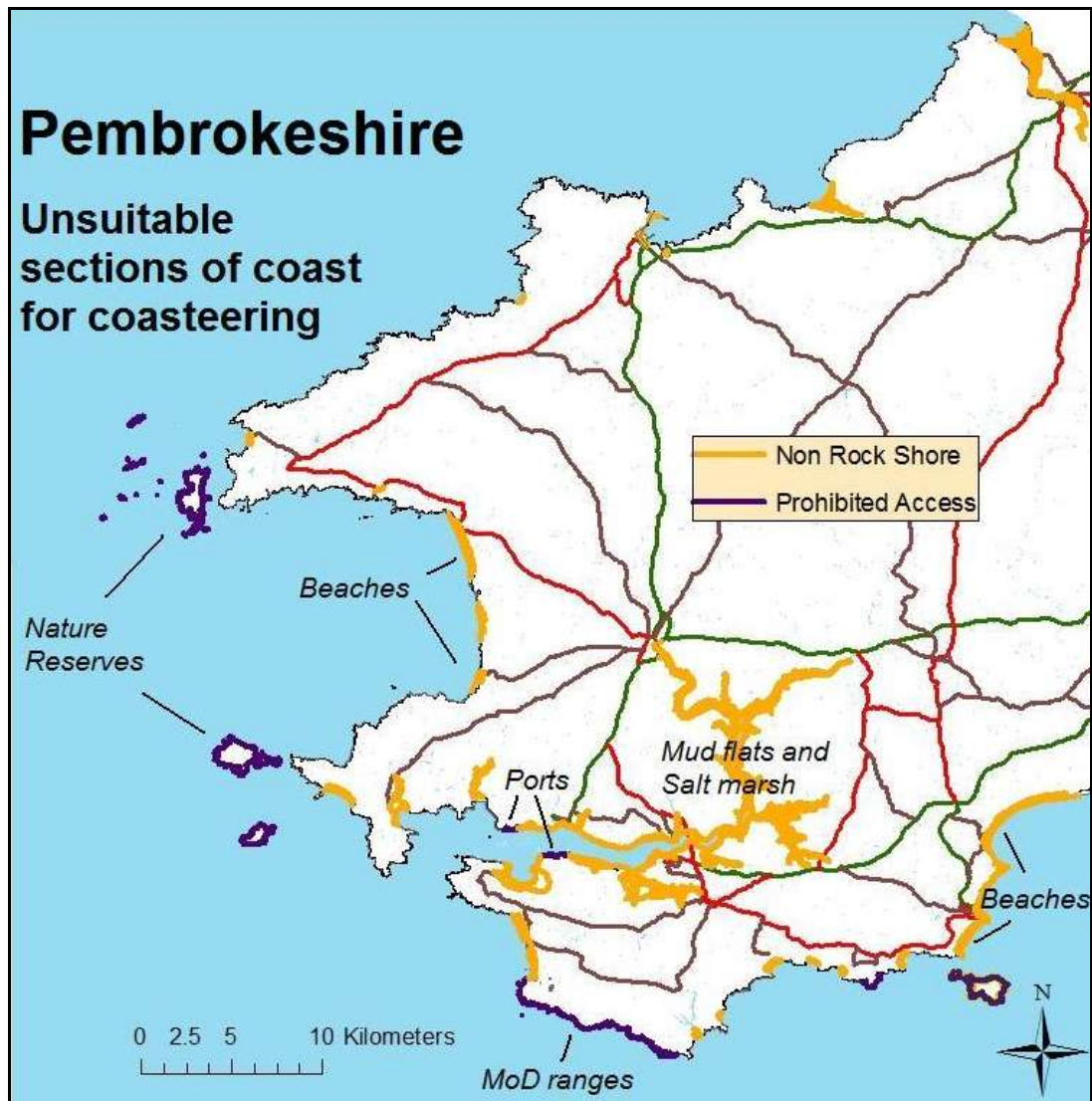
1. Eliminate sections of coast by identifying practical impediments such as accessibility and shoreline type.
2. Assess 'Wildness' value to protect wild places from commercial activities
3. Identify potential sites for detailed study based on outcomes of 1 & 2
4. Identify and map conservation interests that would affect access for coasteering

#### **3.2.1 Practical and safety issues**

Firstly, some sections of the coast can be eliminated due to the nature of the foreshore and public access. For locations to be attractive for coasteering operators, there needs to be a rocky shore with cliffs and reasonably deep water (2-3 metres or more) below. Sections of coast that consist of beaches, mud flats and salt marsh can therefore be eliminated. Areas that are used as ports such as the ferry port at Fishguard Harbour and tanker ports within Milford Haven would also be unsuitable due to security and safety issues.

The coastline that lies within the Castlemartin firing ranges in South Pembrokeshire would be impractical due to public access restrictions and the islands of Ramsey, Skomer, Skokholm and Caldey are also out of bounds due to conservation issues and/or private ownership.

These sections of coast have been mapped as separate layers by drawing polygons around the areas and 'selecting by graphics', then creating a new layer to include the coastlines that are not suitable for these reasons:



**Figure 3.5: Sections of the Pembrokeshire coast that are unsuitable for commercial coasteering due to shoreline type and public access issues.**

Map created by S. Quinton, Dec. 2010 for MSc in GIS

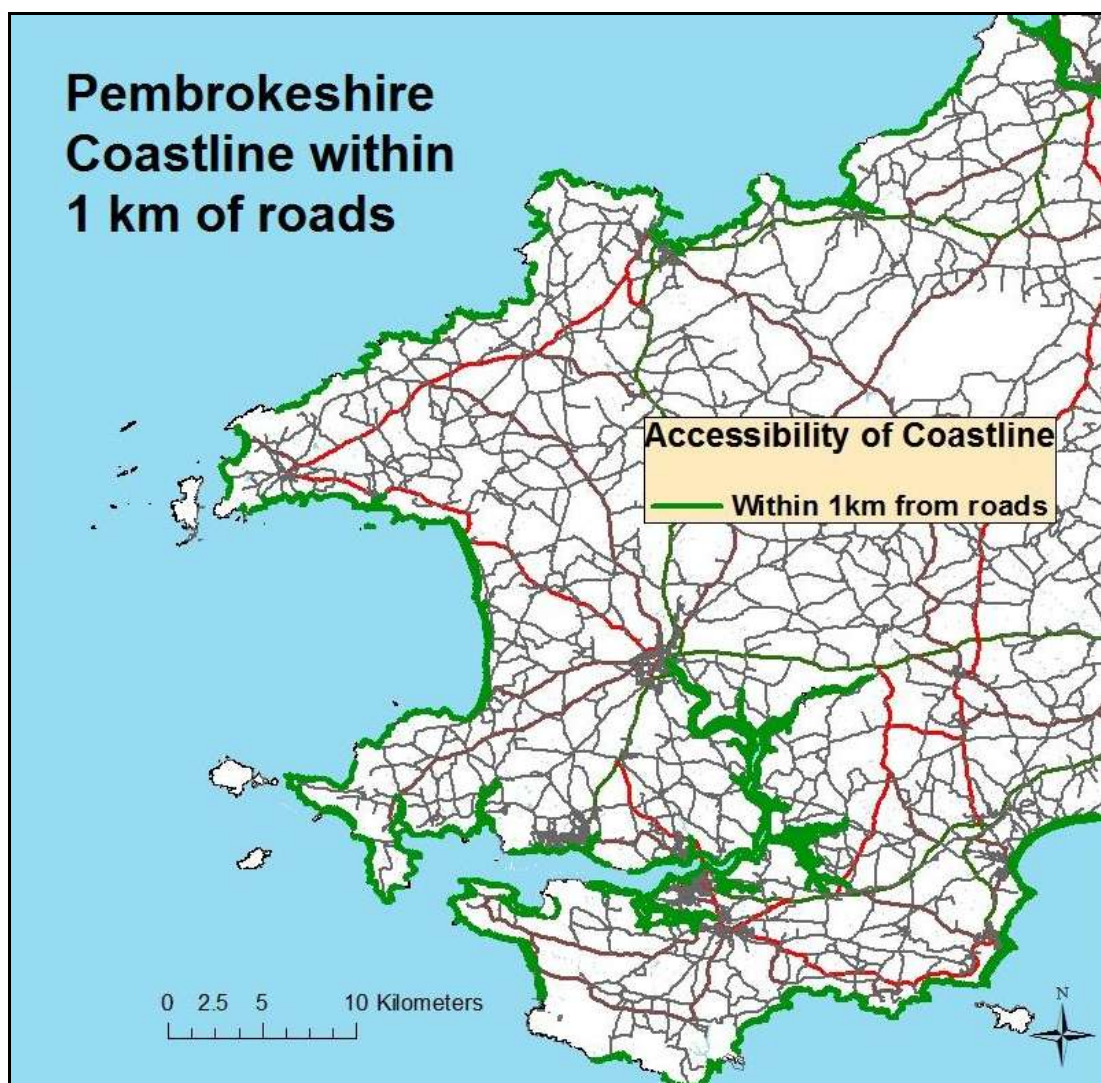
Ordnance Survey © Crown Copyright and database right 2010

Secondly, it should be possible to eliminate some sections of coast based on practicalities and safety. Commercial operators need to be able to transport clients to the locations in a reasonable time, without lengthy walk-ins from parking places. It should be noted that the use of powerboats to access coasteering sites and to provide rescue cover makes road access and escape routes irrelevant but for most operators, this is an unlikely scenario. An approximation of sections that are too remote can be achieved by applying a 1 km buffer to the roads layer as in study area



1. This is illustrated below in figure 3.6. This does not necessarily take into account the feasibility of parking a minibus but it is possible that parking may be negotiated with landowners if there is not an existing public car park.

There is also a need for a reasonable frequency of escape routes (simple access, up or down the cliff) in case of emergency. For an area the size of Pembrokeshire with over 300km of coastline, it would be a huge task to identify every possible escape route so this is something that would have to be investigated on a local scale once potential sites have been identified by other means.

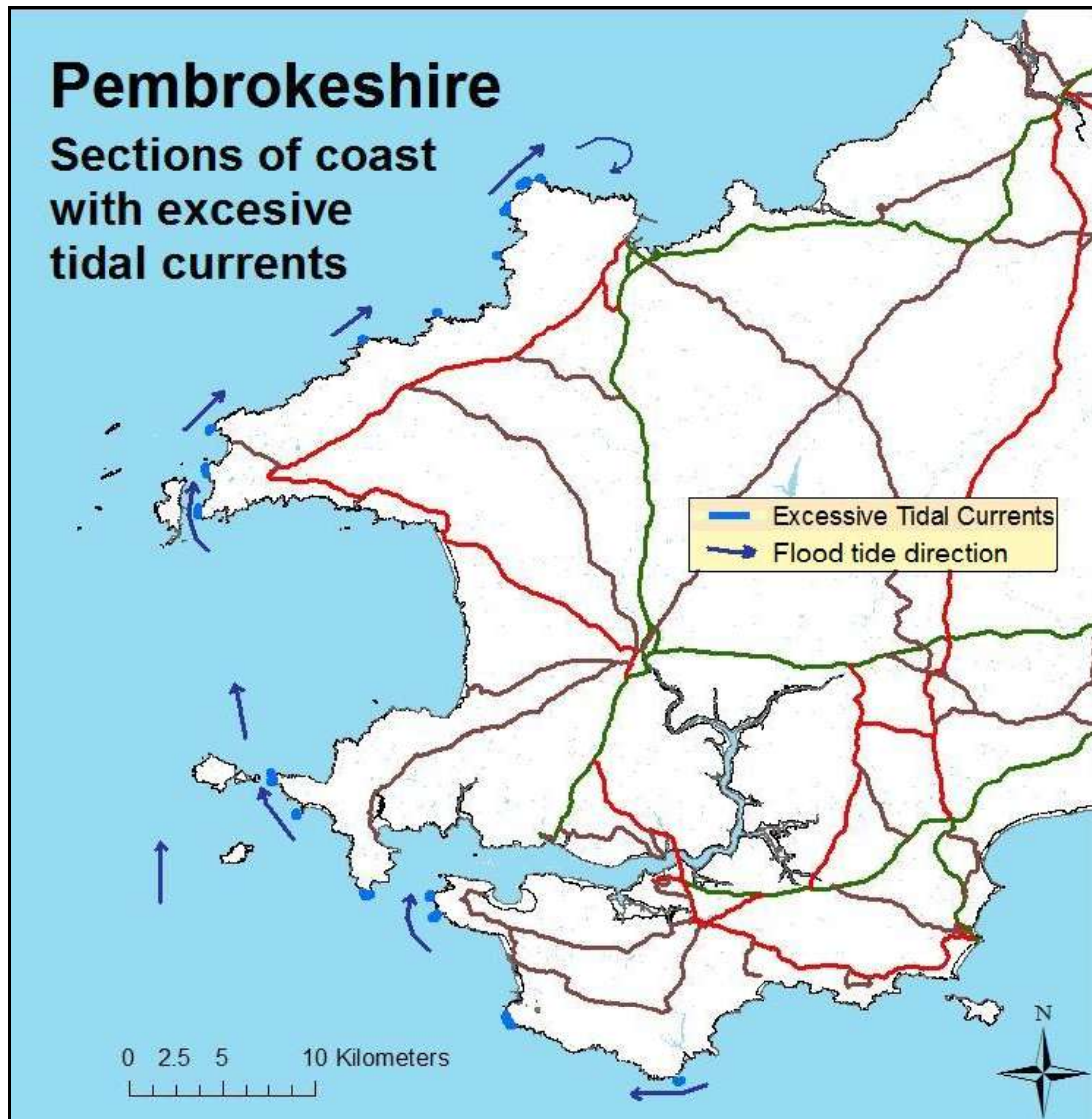


**Figure 3.6: Sections of coast that could be accessible for coastering groups based on proximity to roads.**

Map created by S. Quinton, Dec. 2010 for MSc in GIS

Ordnance Survey © Crown Copyright and database right 2010

Other safety factors that could lead to sections being unfeasible include exposure to swell and proximity of strong tidal currents. These can be mapped but are complex factors as both alter with changing state of tide, wind and swell directions and for type of group. An attempt has been made to map sections that are likely to be unsuitable for commercial coasteering due to dangerous tidal currents in figure 3.7 below. Figure 3.8 shows the sections of coast that are likely to be compromised by regular occurrence of dangerous waves. Both of these layers have been mapped using personal experience and should not be considered as anything more than approximations. The criteria for exclusion due to waves, is areas that have a similar, or greater degree of exposure to waves as that experienced at St. Non's Bay (see case study 1 p ...). This is due to the requirements of the local outdoor activity sector (POCG 2010) which is in need of new locations that can be used when sites such as St. Non's Bay are un-useable due to wave conditions.

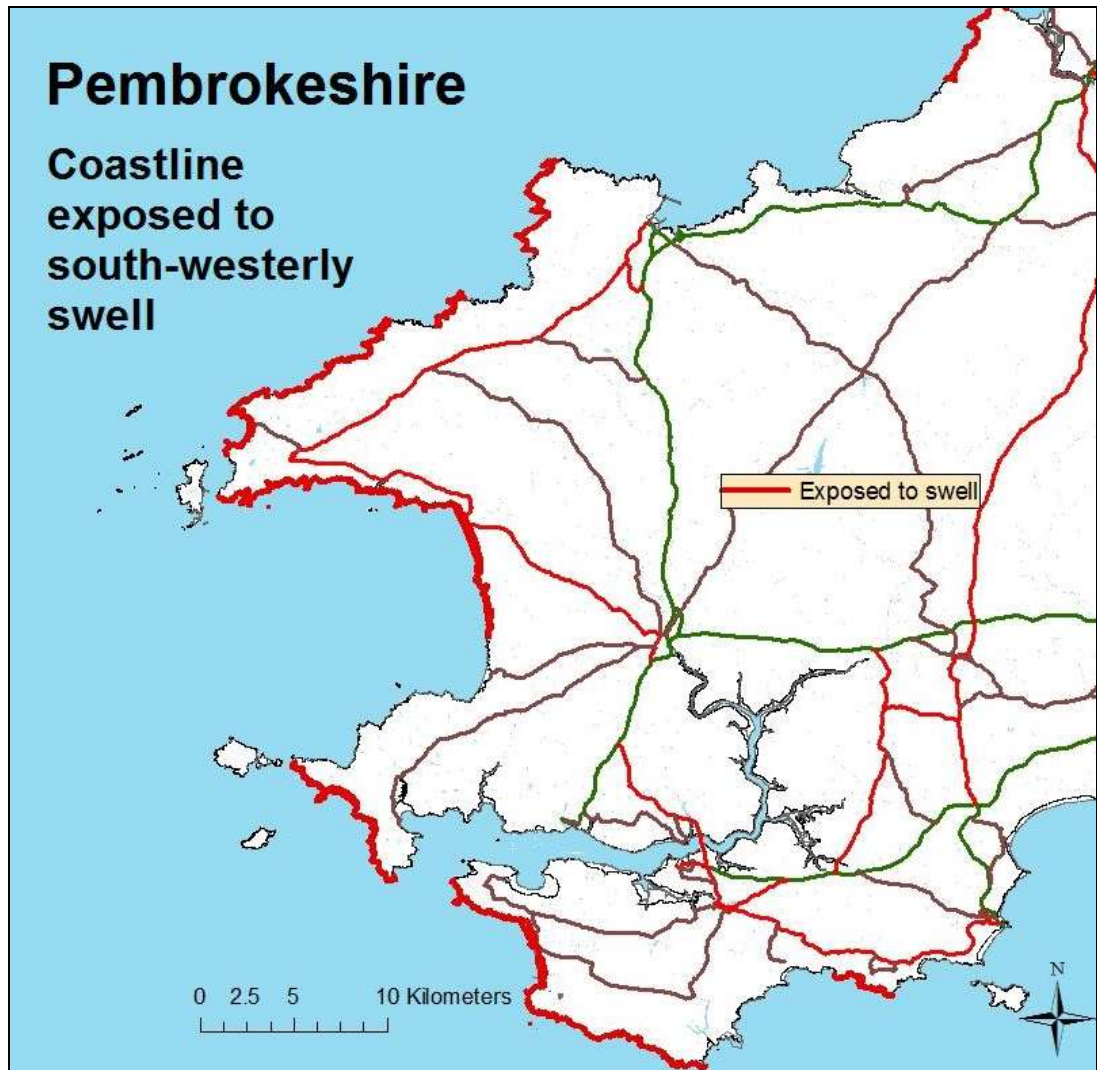


**Figure 3.7: Sections of mainland coast that are likely to be unfeasible due to tidal currents of 3 knots or greater adjacent to cliffs.**

Map created by S. Quinton, Dec. 2010 for MSc in GIS

Ordnance Survey © Crown Copyright and database right 2010

It should be noted here that tidal currents vary in strength and direction throughout the tidal cycle so the areas marked in blue above could be useable at certain times but they have been eliminated from at this stage as the risk levels are likely to deter most operators from using these locations.

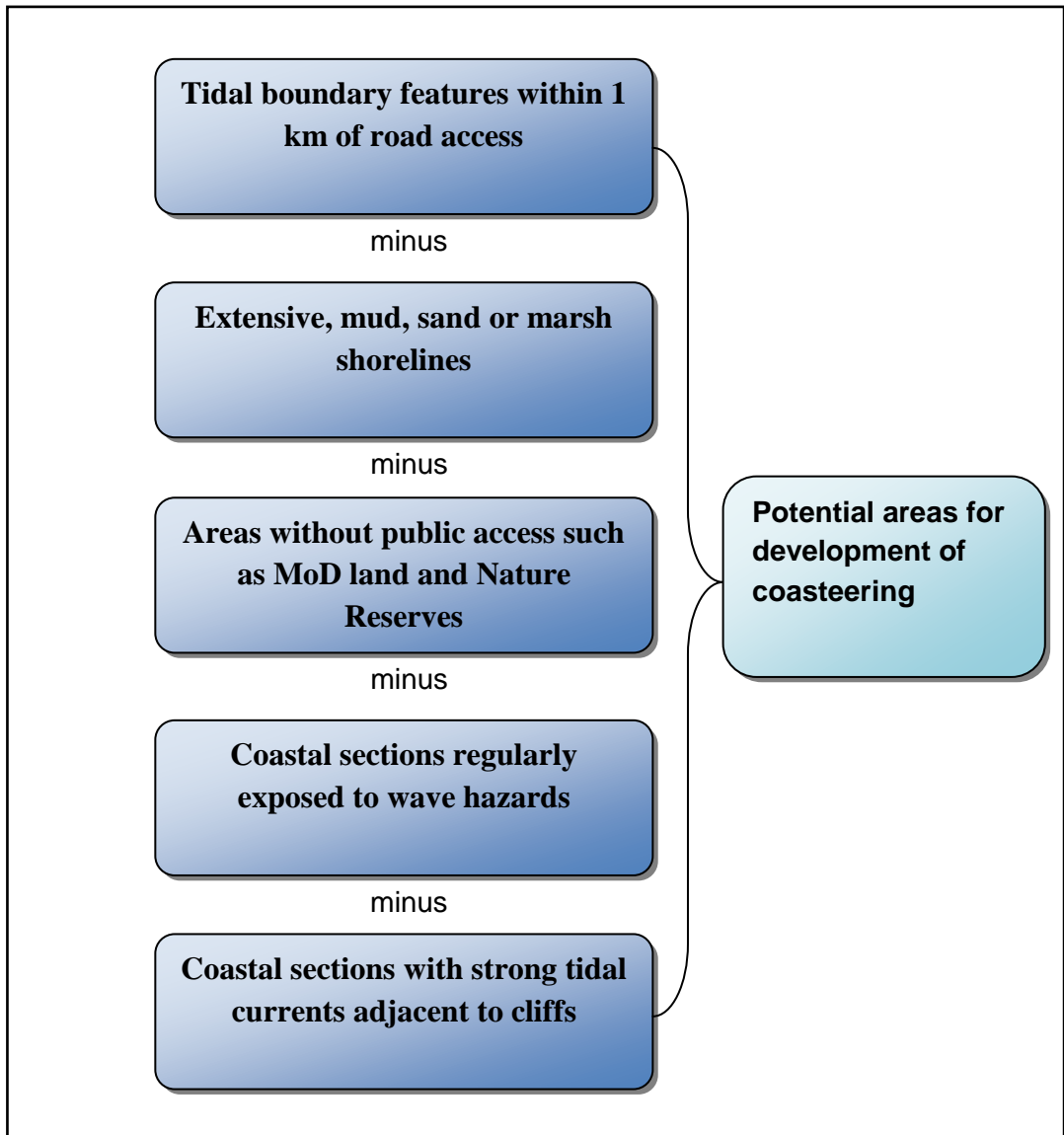


**Figure 3.8 Sections of mainland coast that are most exposed to south-westerly swell and therefore likely to be less useful as new coastering sites for commercial operators.**

Map created by S. Quinton, Dec. 2010 for MSc in GIS

Ordnance Survey © Crown Copyright and database right 2010





**Figure 3.9: Diagram to illustrate the process of eliminating unsuitable sites**

### **3.2.2 Preserving wild places**

The next stage in eliminating sections of coast for new coasteering development involves a study of 'wildness', using data available from the Ordnance Survey and CCW to produce a map of wildness value. This is intended as an aid in preserving areas of the coast that can be relied upon for quiet enjoyment: Places where walkers, climbers and kayakers can expect to see few people, enjoy the landscapes, seascapes and wildlife without encountering commercial activity and organised groups. This factor has been identified as an important consideration by commercial outdoor activity providers as well as conservation organisations active in the area. Areas with the highest level of 'wildness' should be considered as potentially worth avoiding by centres providing outdoor activities for the reasons above.

Classification systems used for identifying wildness could have hundreds of permutations. The works of Macfarlane et al (2006) on tranquillity mapping and Carver et al (2002) on wilderness mapping provide useful starting points for defining wildness. The positive and negative factors identified by Macfarlane are, in many cases, duplicated by Carver's six factors and some of the remaining factors are not considered relevant for coasteering venues (e.g. visibility of the sea and night time light pollution). It was therefore decided to adapt the methods used by Carver to fit the available data and nature of the study area.

Carver et al (2002) used 6 factors; remoteness from local population, remoteness from national population centres, remoteness from mechanised access, apparent naturalness, biophysical naturalness and altitude (as shown in table 3.1 below).

<b>Factor</b>	<b>Source</b>	<b>Interpretation</b>
Remoteness from local population	UK 1991 Census	Population-linear distance weighted surface using 25 km radius from target cell. Provides a measure of accessibility to local population.
Remoteness from national population centers	UK 1991 Census and CEH Countryside Information System	Population-road distance weighted surface for whole of Britain. Provides a measure of accessibility to the whole of the British population based on real travel distance weighted by population.
Remoteness from mechanized access	CEH Countryside Information System	Distance from nearest road weighted by road class. Larger roads with an implied greater traffic volume are weighted higher than smaller roads.
Apparent naturalness	CEH Countryside Information System	Distance from nearest human artifact weighted by number of features.
Biophysical naturalness	CEH Countryside Information System	Reclassification of the CEH Land Classification map showing degree of naturalness of land cover based on intensity of human use.
Altitude	CEH Countryside Information System	Height above sea level based on digital elevation model.

**Table 3.1 Factors affecting wilderness value, from Carver et al (2002)**

As the study area and application is coastal and of relatively local scale, a modified system is required for this study. The following methodology has been used to generate a map representing ‘wildness’ in Pembrokeshire.

**(a) Remoteness from local population**

This has been calculated by creating a layer based on distance from settlements where the population density is greater than or equal to 100 persons per square kilometre and areas with population density of greater than or equal to 1000 persons per square kilometre. The latter areas are given a weighting of 3 to reflect the relative significance of proximity to census output areas where there is a density of population equating to urban areas.

The data was accessed via ‘CASWEB’ (Census Area Statistics on the WEB) using 2001 Census data at the level of ‘census output areas’. These vary in size from 0.0016 km<sup>2</sup> to 39 km<sup>2</sup> and have populations from 0 to nearly 500. Population density was calculated using the field calculator tool and the thresholds of 100 persons per km<sup>2</sup> and 1000 persons per km<sup>2</sup> were chosen after experimentation to define settlements of significance. This method is far from perfect as the identification of significant settlements is affected by the choice of boundaries of output areas. However, it is felt that when using the two values, this method provides a reasonable approximation of remoteness.

The raster layer showing distance from settlements has been standardised on a scale from 0-256, in common with the other four factors, to facilitate integration to form the wildness layer.

**(b) Remoteness from mechanised access**

Four feature layers showing roads have been created using Ordnance Survey OpenData. The data includes several classifications of roads from local and minor roads to A roads and Primary roads. These have been reclassified to produce a layer for each of Primary roads, A roads, B roads and minor roads. (The latter includes all roads smaller than B roads.)

The remoteness from mechanised access layer uses weighted distance from roads using the following weighting system:

Primary roads x 4

A Roads x 3

B roads x 2

Minor roads x1

I.e. distance from primary roads is four times as significant as distance from minor roads.

**(c) Apparent naturalness**

This factor is based on distance from buildings as shown in Ordnance Survey OpenData maps. No weighting factor has been used. This layer is indicative of parts of the county where it is less easy to see man-made structures although at this stage, no account has been taken of actual visibility affected by topography. A 'viewshed' layer could be considered as an additional element in this factor that might be worthy of inclusion in future studies.

**(d) Biophysical naturalness**

Biophysical naturalness is represented by the CCW LANDMAP data (CCW, 2010). This is based mainly on the classification of the land at four hierarchial levels:



Level 1	Level 2	Level 3	Level 4
Broad landform and land cover	Landform	Land cover	Detail - location / scale / exposure / settlement

**Table 3.2: Hierarchical levels of scale used in LANDMAP visual/sensory classification (from CCW LANDMAP Methodology 2008)**

The levels shown in table 3.2 above are used to identify ‘Aspect Areas’ which are then assessed to give values for 28 different qualities including texture, light pollution, aesthetic qualities, unity and scenic quality value. For the purposes of this study, only the scenic quality value is used, as defined in table 3.3 below.

<b>Evaluation Criteria</b>	<b>Outstanding</b>	<b>High</b>	<b>Moderate</b>	<b>Low</b>
Scenic Quality	A landscape offering many scenes of a picturesque quality throughout the area, which are aesthetically pleasing in composition. The area is iconic for these nationally and internationally.	A landscape with some scenes of a picturesque quality, which are aesthetically pleasing in composition. The area is notable for these regionally.	Landscapes with a few scenes of a picturesque quality, which are aesthetically pleasing in composition. These areas are notable locally for these	Landscapes with very limited aesthetically pleasing scenes.

**Table 3.3 Evaluation criteria for visual and sensory value (From CCW LANDMAP Methodology) CCW, 2008**

The LANDMAP data is obviously subjective as it relies on the interpretation of the assessor to some extent but this is the best data available in Wales that maps the quality of landscape and views. It is an important component of the wild characteristics of the area and is likely to impact on the perceptions of people using the coast path when responding to the presence of outdoor activity groups. Further details of LANDMAP methodology are provided in appendix 2.

The Landscape value has been reclassified using the scale of 0-256 in common with the other factors. Actual values used are based on the mid-points of 4 categories that range from 0-256. These are shown in table 3.4 below:

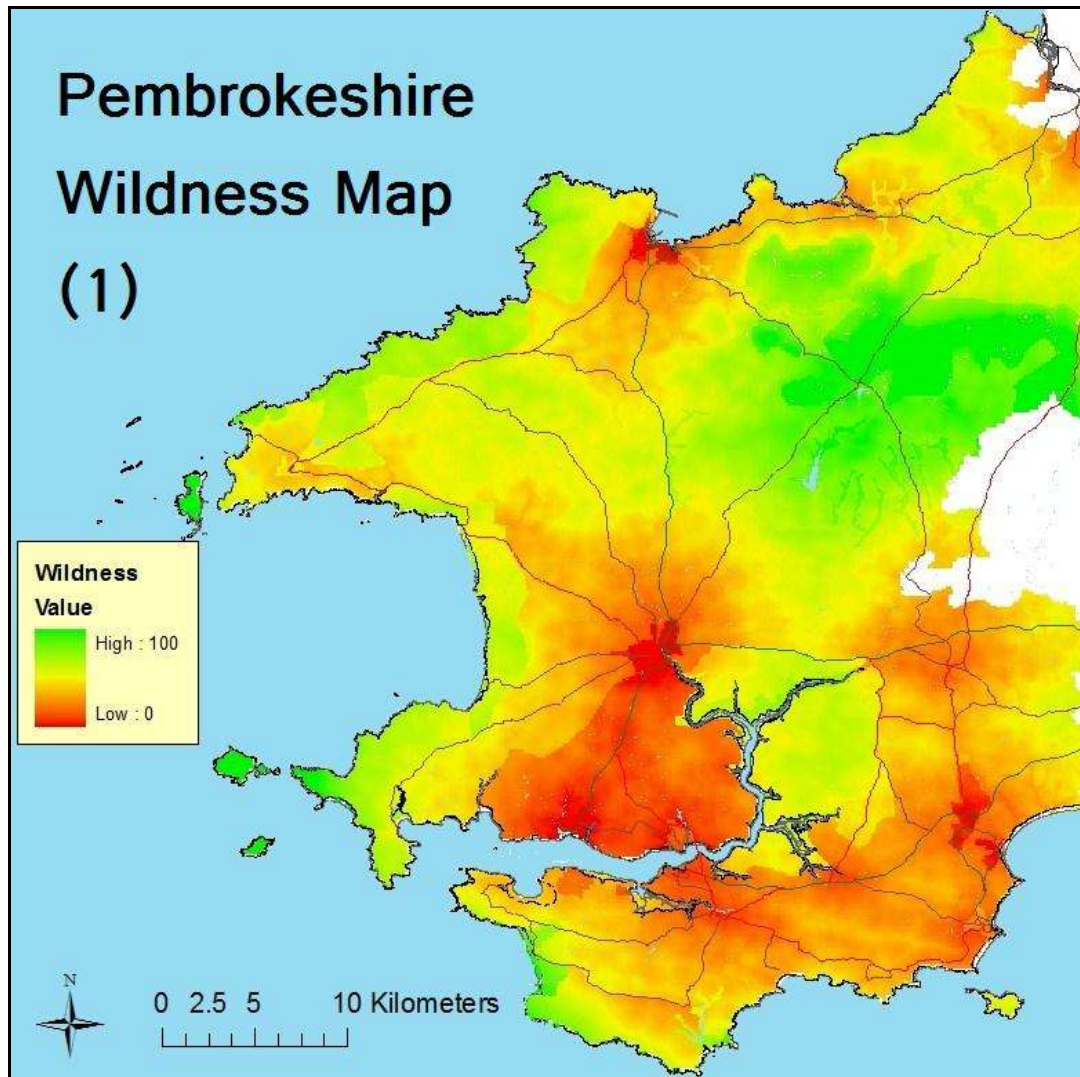
LANDMAP VS value	Outstanding	High	Moderate	Low
Standardised value for use in calculating 'wildness'	<b>224</b> (193-256)	<b>160</b> (129-192)	<b>96</b> (65-128)	<b>32</b> (0-64)

**Table 3.4 Standardised values of Visual and Sensory Landscape Quality (derived from CCW LANDMAP data)**

**(e) Altitude**

A Digital Terrain Model was obtained from the Ordnance Survey 'Digimap' service. This has been used to create a raster layer with values from 0 – 535 metres above sea level which has been standardised to values from 0-256. Although the area is coastal and the principle application of this work is concerned with activities close to the sea, altitude does affect vegetation, landscape quality and land use so it is considered relevant when assigning values for wildness.

(It was felt that 'remoteness from natural population centres' (as used by Carver et al, 2002) is considered to be of little relevance, there being no significant difference at the scale of the study area).



**Figure 3.10: Wildness Map of Pembrokeshire (based on weighted distance from settlements, weighted distance from roads, distance from buildings, visual/sensory landscape value and altitude.**

Map created by S. Quinton, Dec. 2010 for MSc in GIS

Ordnance Survey © Crown Copyright and database right 2010

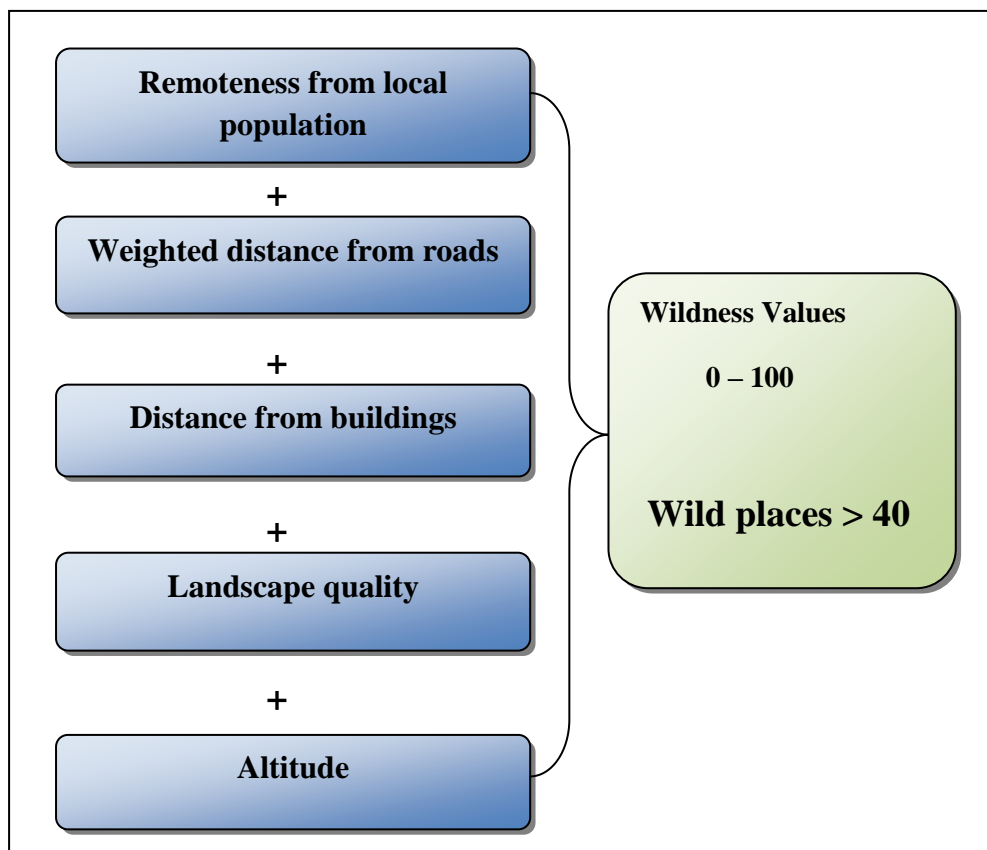
In order to identify wild places from the data in figure 3.10, a threshold value has been applied which equates to the mean value + 1 std deviation. This gives a number of areas as shown in figure 3.11 below.



**Figure 3.11: The wildest parts of Pembrokeshire as defined by a threshold value of  $> 40$  on a scale of 0-100 and with equal weighting of all 5 factors.**

Map created by S. Quinton, Dec. 2010 for MSc in GIS

Ordnance Survey © Crown Copyright and database right 2010



**Figure 3.12: Summary diagram illustrating the definition of wild places.**

Having eliminated sections of coastline that are likely to be unsuitable for the reasons stated above, the map layers were then overlaid to produce a map showing locations that could be considered for further investigation on a local, and more detailed, level. This is shown in the results section.

In order to remove coastal sections that are in areas classified as wild places (using the protocol described above), the raster layer showing wildness values was reclassified then converted to polygons using the conversion tools. Sections of coast that were within 200m of wild places were eliminated from the list of practicable sites using the ‘selection by location’ tool. (A 200m buffer was used to compensate for the loss of accuracy resulting from converting the raster layer to a feature.)

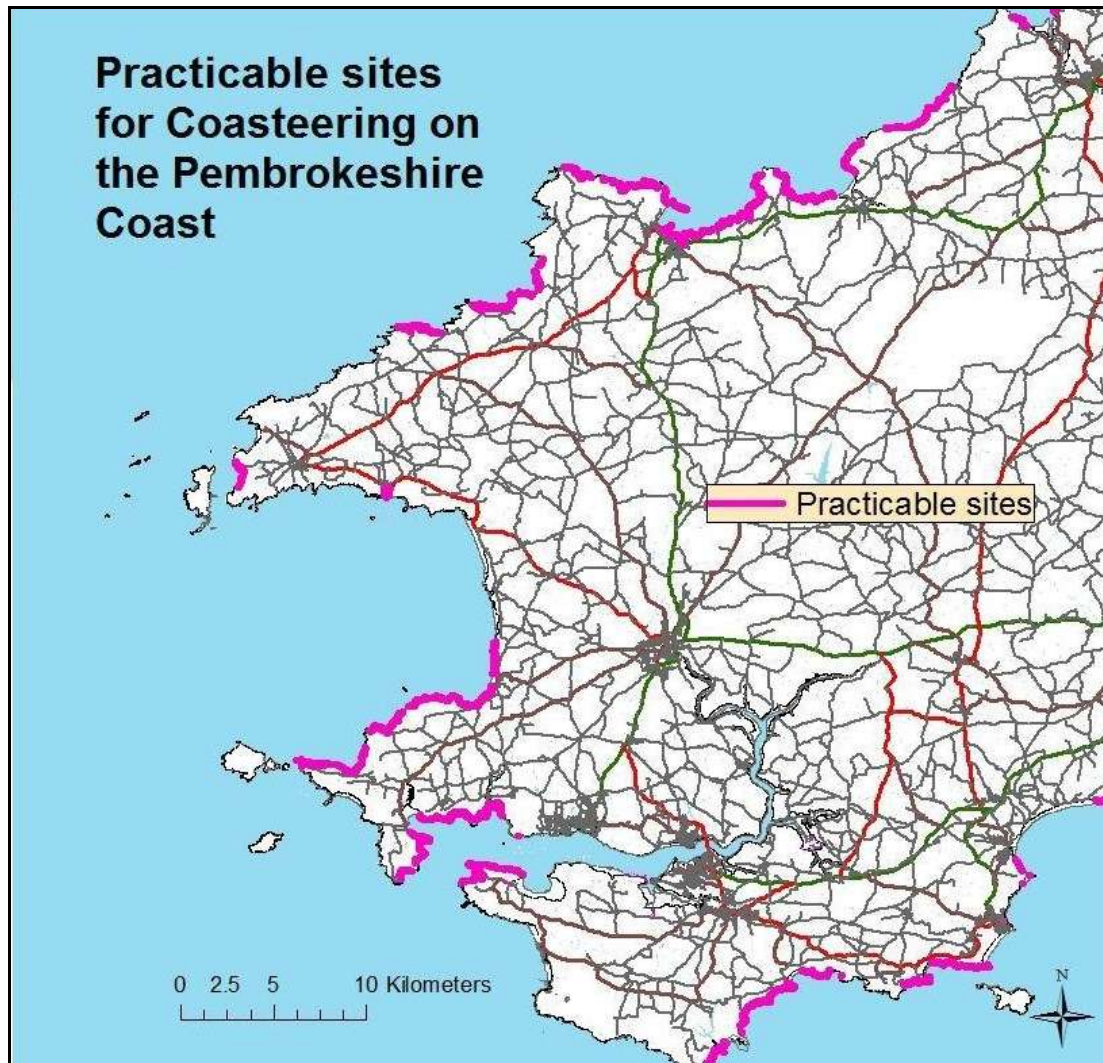
Once the methods described above had been applied to the data in order to identify some potential new locations, one of these areas was further studied using a combination of photography from the sea and mapping some of the relevant conservation features by fieldwork. This involved a short survey of the area to identify potential impacts of coasteering groups and was supplemented by questioning of experts from the National Park, National Trust and CCW.



## 4. Results

The following section includes the key map outputs and main findings of the study.

### 4.1 Pembrokeshire Sites



**Figure 4.1: Potential areas for coasteering development based on accessibility and avoiding sections that are likely to be affected by excessive waves or tidal currents.**

Map created by S. Quinton, Dec. 2010 for MSc in GIS

Ordnance Survey © Crown Copyright and database right 2010



**Figure 4.2: Potential locations for new coasteering development based on practical issues and preservation of wild places. The main areas with potential are labelled 1,2 and 3 on the map.**

Map created by S. Quinton, Dec. 2010 for MSc in GIS

Ordnance Survey © Crown Copyright and database right 2010

The coastal sections shown above in blue represent sections that are worthy of further study to investigate the additional factors that are relevant in establishing suitability for coasteering. Areas marked 1,2 and 3 in particular have significant sections of coastline that consist predominantly of sea cliffs, with reasonable access and some degree of shelter from prevailing waves and tidal currents. None of the areas include significant wild places so should not impinge excessively on people's enjoyment of wild/tranquil environments.



The following issues should now be studied for each of the areas identified:

1. Presence of sensitive flora and fauna on cliffs, foreshore and in the sea
2. Identification of other conservation issues such as geological and archaeological features.
3. Detailed access issues (parking and footpaths)
4. Availability of escape routes and other localised safety issues

#### **4.2 Detailed analysis at Pen Anglas Point**

As an example of the next stage in the process, a section of coast within area 1 (see figure 4.2 ) has been studied in more detail. This area which is 2km to the north of Goodwick in North Pembrokeshire fulfils the key requirements for use by outdoor activity centres and is not part of an SAC, SPA or SSSI. It is owned by the National Trust and has some impressive and well-known geological features but is not part of the Fishguard Geological Conservation Review (GCR) area.

Potential conservation issues have been identified by field work and added to the map in order to contribute towards an Environmental Impact Assessment (EIA) prior to more detailed study by the stakeholders involved (Outdoor Activity companies, PCNPA, NT and CCW).

The resulting maps are shown below in figures 4.4 and 4.5.

The findings under points 1-4 (above) are as follows:

1. The coastal slopes which would be crossed by groups accessing the shoreline are being managed by the National Trust through grazing. Soils are generally thin and vulnerable to localised erosion. There are diverse lichen communities on the upper part of the rocky shore. There are few signs of birdlife other than oystercatchers. The cliff morphology is not conducive to requirements for chough, peregrine or auk nests. There is evidence of a wealth of wildlife in the intertidal zone that would be crossed by coasteering groups (except at high tide). This includes beadlet anemones, red encrusting algae, thongweed, limpets, barnacles, periwinkles, various types of wrack and sponges. There are no records of seals using the site for pupping. Harbour porpoise and bottlenose dolphin feed in the bay to the east of the site but their activity is unlikely to be affected by people on the shore.
2. This area consists of igneous rocks of the Fishguard Volcanic Series, a combination of pillow lavas and rhyolitic layers of Lower Llanvirn age reaching thickness of up to 750m ( Thomas and Thomas, 1956). The site has some of the most important exposures of volcanic geology in Pembrokeshire. There are also exposures of quaternary glacial remnants including sediments and a possible relic wave cut platform. There is no evidence of archaeological remains on the headland but there are three iron age burial chambers ('cromlechs') adjacent to the car park in Goodwick which would be passed on the likely approach route.
3. The nearest public car park is at Harbour Village, Goodwick which is 1.6km from the furthest point of the coasteering section (via the coastal park). This car park is behind a row of houses and there is potential for conflict with local residents if large numbers of groups used the site. There is road and track access to points that are closer so it is possible that another parking location could be negotiated with land owners.

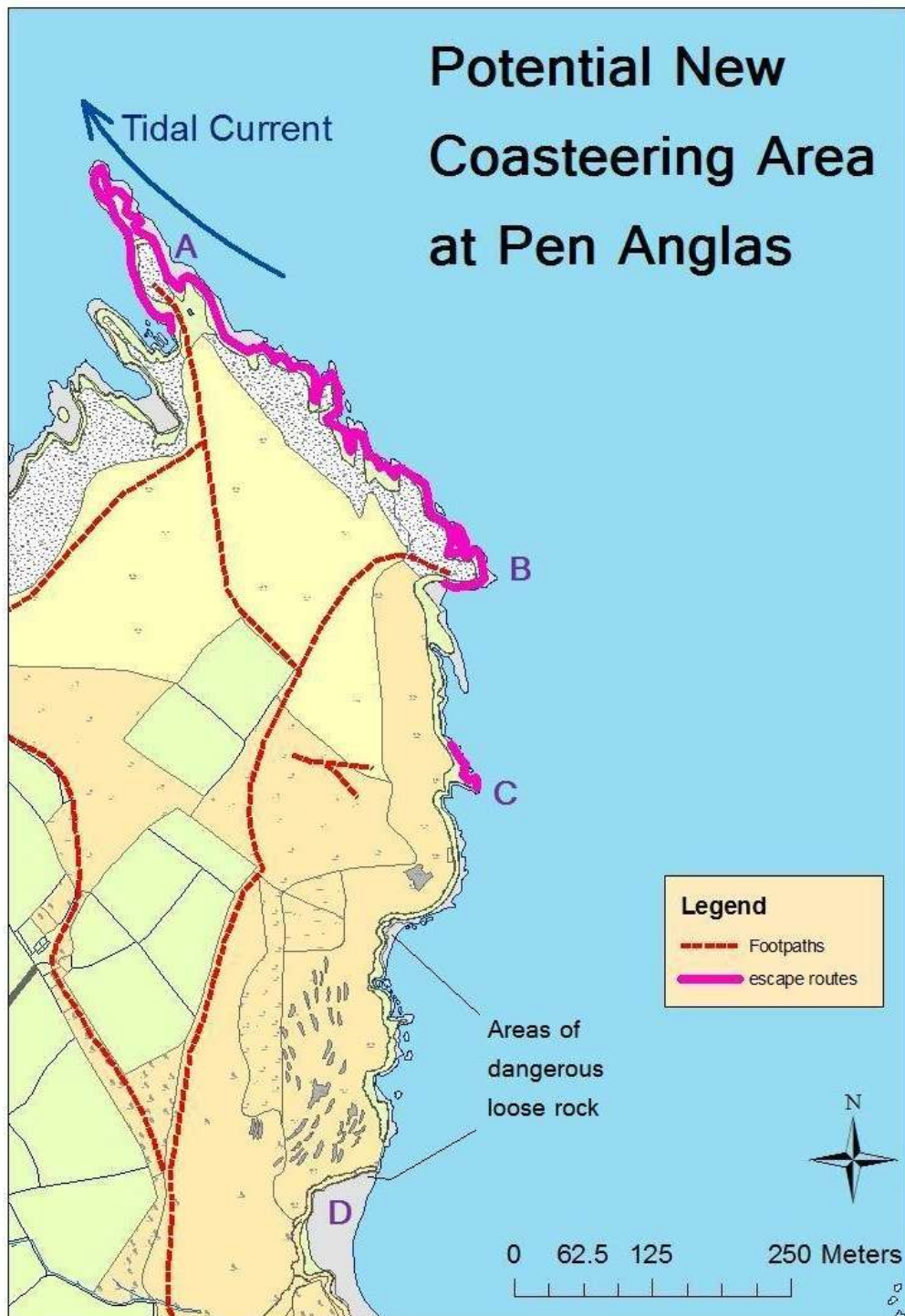
4. The majority of the northern part of the area is easily escapable by scrambling up short easy angled rock sections to reach coastal slopes. The southern section of coast, near Pwll Hir is topped by steep and poorly consolidated slopes consisting largely of glacial deposits. Other hazards include a significant off-shore tidal current at Pen Anglas Point and exposure to swell from a northerly direction.

Based on the information above and in figures 4.4, it is likely that the northern part of this coastline is preferable due to the ease of escape and generally solid rock. The area leading towards Pwll Hir further south has few escape routes and several areas of dangerously loose rock.



**Figure 4.3 Location of the Pen Anglas area**

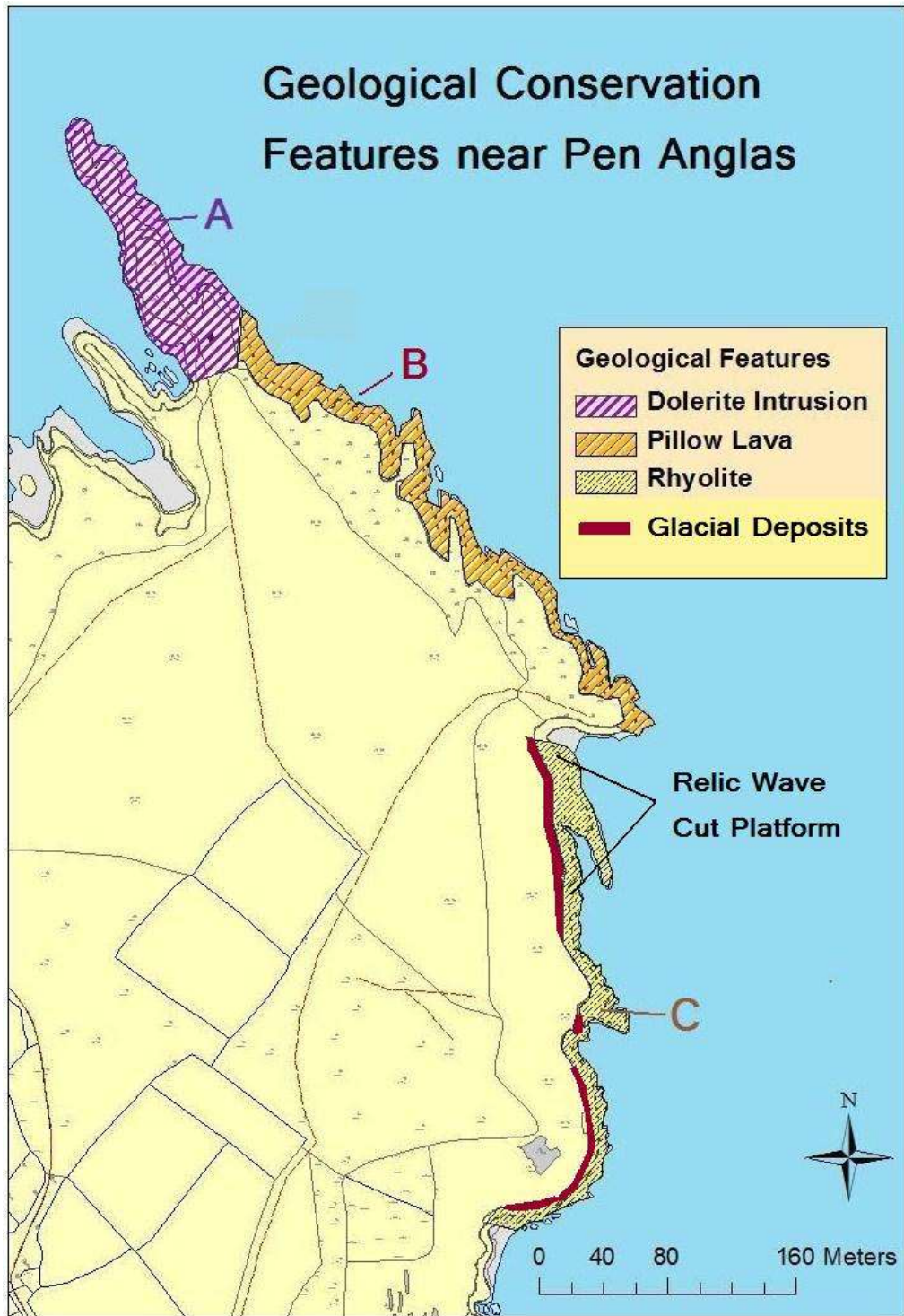
Map created by S. Quinton, Jan. 2011 for MSc in GIS  
Ordnance Survey © Crown Copyright and database right 2010



**Figure 4.4: Pen Anglas and a potential new area for commercial coasteering development with key safety issues marked. A is the likely start location at Pen Anglas Point, B is Crincoed Point, C is the likely egress point and D is Pwll Hir.**

Map created by S. Quinton, Jan. 2011 for MSc in GIS

Ordnance Survey © Crown Copyright and database right 2010

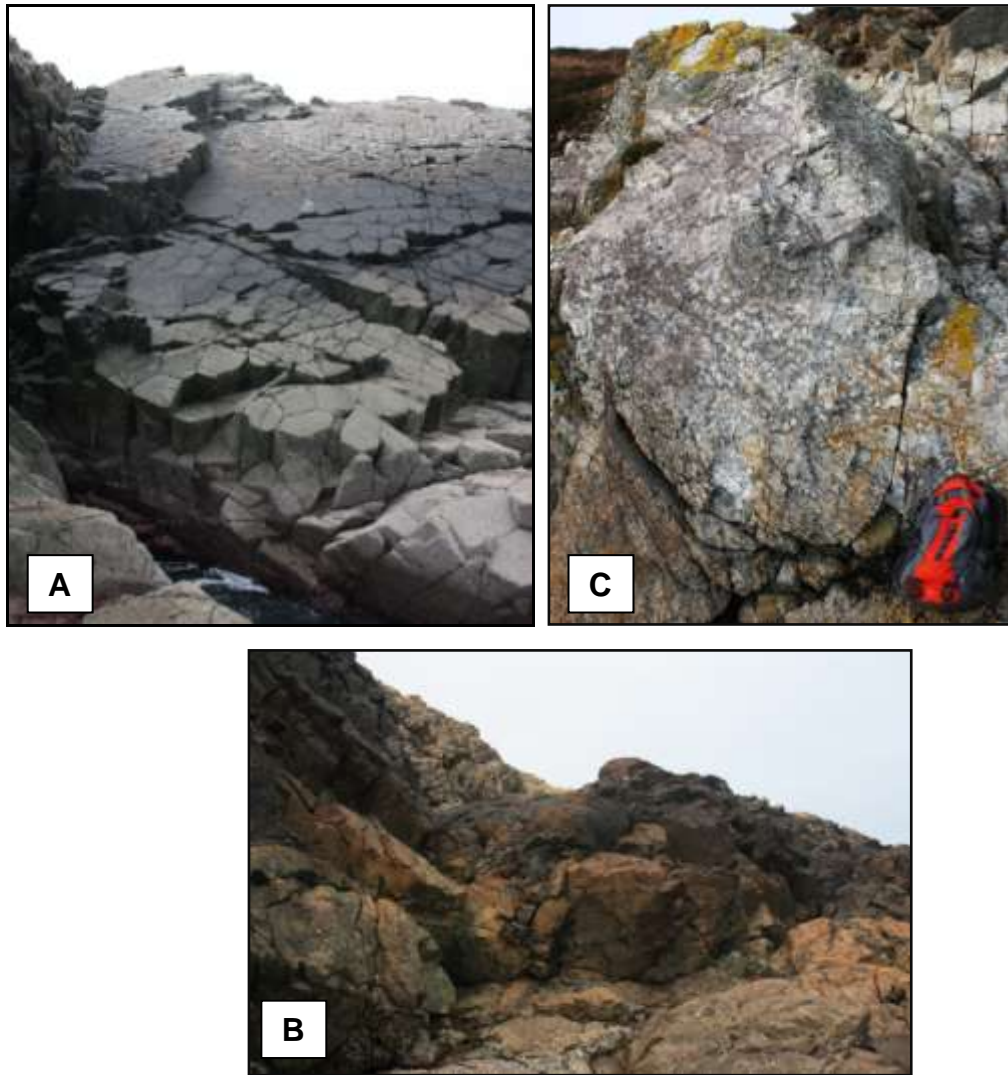


**Figure 4.5: Geological features near Pen Anglas Point. A, B and C correspond to photographs in figure 4.6 below.**

Map created by S. Quinton, Dec. 2010 for MSc in GIS

Ordnance Survey © Crown Copyright and database right 2010





**Figure 4.6: Geological Features near Pen Anglas; (A) columnar jointed dolerite at Pen Anglas Point, (B) Pillow Lava south of Pen Anglas and (C) Rhyolitic agglomerate south of Crincoed Point.**



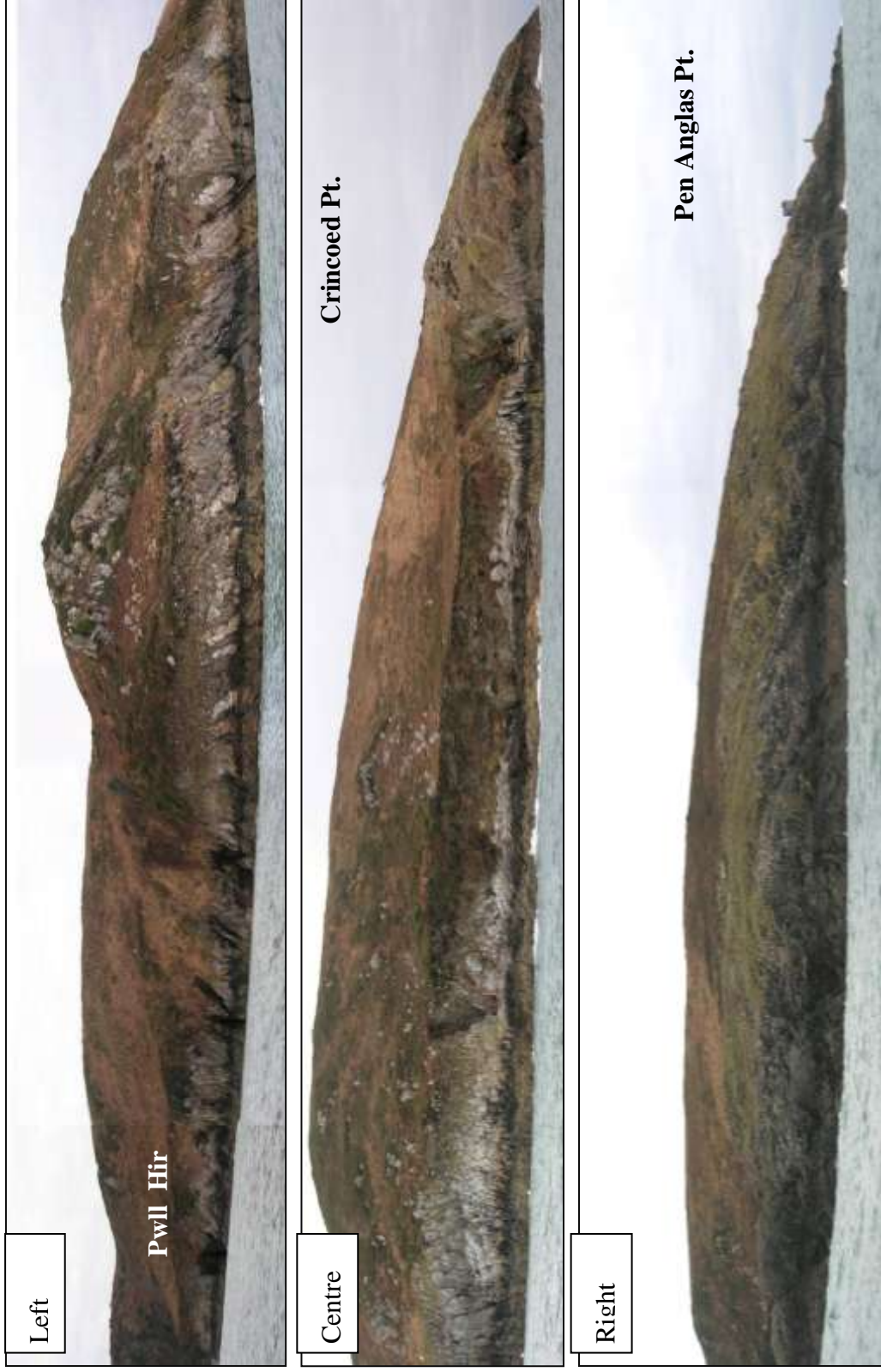
**Figure 4.7: Examples of hazards for coasteering groups at Pen Anglas; loose glacial deposits above cliffs (left) and tidal currents of 1-3 knots at Pen Anglas Pt.**

Photographs showing some examples of the conservation features are included below in figures 4.9, 4.10 and 4.11.

Other users of the area include geologists and students studying the rocks at Pen Anglas Point. Walkers regularly use this section, particularly for exercising dogs (this is a popular section for residents of Goodwick) and sea anglers use the ledges at Crincoed Point and Pen Anglas Point which provide excellent mackerel fishing. Use of the area by coasteering groups could create conflicts with some of these users who might consider the activity intrusive.

The photographs shown below in figure 4.8 illustrate the nature of the cliffs and coastal slopes.

**It should be noted that the inclusion of this site here does not imply that it is suitable, safe or an approved location in any way for coasteering. A full EIA has not yet been completed and there may be features on this section that would preclude coasteering activity.**



**Figure 4.8: Pwll Hir to Pen Anglas Point.**





**Figure 4.9: Glacial/periglacial deposits overlying a possible relic wave cut platform 200m south of Crincoed Point.**



**Figure 4.10: Lichen community above Crincoed Point.**



**Figure 4.11: Rocky shore community north of Crincoed Point**

## **5. Discussion**

It is clear that conservation management is an increasingly important issue given the pressure of rising population, scarcity of outdoor space, climate change and the resultant stress on ecosystems. Within the Pembrokeshire Coast National Park there are specific issues relating to congestion and the potential decline of recreational value that threatens the success of an important sector of the tourism industry. Establishing an effective means of selecting suitable sites for development is therefore a worthwhile topic of study.

The three main aims of this study were to develop a method to classify sections of coast, to adapt wilderness mapping to local cases and to investigate the role of GIS within the task of identifying sites for outdoor activity (specifically coasteering) development. The following sections include an analysis of these topics and evaluate the methods that have been used to date.

### **5.1 Methodology for identifying suitable sites for coasteering development**

With over 300km of varied coastline including internationally important conservation value, it is important for land managers to have a valid system of supporting or opposing development of new locations for commercial outdoor activity sites.

The approaches adopted here were based on a combination of practical and conservation issues with a staged method that eliminated unsuitable areas before investigating potential sites in more detail. The reasoning behind this is the level of detail required when assessing the conservation aspects of sites. Although it may be desirable to map all features worthy of protection within a GIS for the whole of the coastline, this would involve extremely detailed research for large numbers of specialists and would necessitate huge outlay in terms of time and resources.

A comprehensive map of the conservation features relevant to decision making for coasteering sites might include the following information:

<b>Type of feature</b>	<b>Example Species or features</b>	<b>Approximate Scale</b>	<b>Potential Impacts and issues</b>
Mammals	Greater and Lesser Horseshoe Bats	Sea caves (metres)	Disturbance from hibernation, difficult to map due to cave location (seasonal – winter)
	Atlantic grey seals	Caves and coves (metres to tens of metres)	Interruption of feeding of pups (seasonal - autumn)
	Otters	Coves (tens of metres to hundreds of metres)	Disturbance while feeding and breeding? (very little known about otter behaviour on the coast)
Rocky shore communities	Sponges, anemones, sea urchins and star fish	Rock pools and caves (centimetres to metres)	Trampling and trauma from contact with people scrambling over rocks (low tide only)
	Algae e.g. kelp, fucoids, brown algal mats, coralline algal turf	Ledges, rock pools, bays (centimetres to tens of metres)	Trampling (low tide only)
	Barnacles, limpets, whelks etc.	Rock pools, cliff sections (metres to tens of metres)	Trampling can create bare patches (low to mid tide, quick recovery)
Plants	Thrift, sea campion, rock samphire and sea lavender	Upper cliff ledges and fissures (centimetres)	Trampling and removal by climbers and coasteering groups on approach or escape

(Continued on next page)

Type of feature	Example Species or features	Approximate Scale	Potential Impacts and issues
Birds	Chough	Cliff ledges, fissures and caves (centimetres to metres)	Disturbance to feeding, and breeding (seasonal – spring)
	Peregrine Falcon and Cormorants	Cliff ledges (centimetres to metres)	Disturbance to feeding, and breeding (seasonal – spring)
	Auks (guillemots and razorbills)	Cliff ledges (metres to tens of metres)	Disturbance to breeding, specifically egg incubation, and disturbance of resting in ‘rafts’ (seasonal - spring)
	Oystercatcher	Coves, beaches, rock ledges (metres to tens of metres)	Disturbance of breeding (seasonal – spring)
Lichens	Ramalina siliquosa (grey zone)	Rock outcrops and upper cliffs (metres)	Trampling, particularly in wet weather (relatively slow recovery)
	Xanthoria Parietina and Caloplaca (yellow zone)	Mid-lower cliffs (metres)	Trampling (relatively slow recovery)
Archaeological remains	Promontory Forts and associated embankments	Promontories (tens of metres)	Erosion on approach routes and exits
Geological and Geomorphologic features	Solid Rock features e.g. dolomitic limestone, columnar jointed dolerite, folds and faults	All scales up to kilometres	Erosion of delicate features, possible vandalism (scratching names on rock surface etc.)
	Fossils (e.g. trilobites and graptolites)	centimetres	Possible theft of fossils (sites may be otherwise unknown to public)
	Raised beaches, periglacial deposits, ‘fossil forests’ and boulder clay	Bays and cliff sections (tens of metres)	Erosion of material and interruption of palaeo-structures

**Table 5.1: Summary of conservation features that could be mapped as part of a SDSS for development of new coastering sites.**

Table 5.1 above illustrates the complexity of a mapping project for a whole coastline on a scale of hundreds of kilometres which includes features on the scale of centimetres that may be relevant at certain states of the tide but not at others or wildlife that is present in spring but not in the autumn (and vice-versa). One could add human users of the coast and invertebrates to this list, both of which could be relevant. The process of narrowing down the choices by other means is therefore an important consideration.

Practical considerations have been mapped using local knowledge of the area and without this, it would be difficult to identify some of the impediments to outdoor activities along coastal sections. Exposure to waves and tidal currents can be approximated from marine charts and wave models but these are often lacking in detail at the required scale when studying conditions on rocky shores where small changes in coastal alignment can have a large effect on wave power and tidal stream strength. If this approach was to be repeated in another area, it would be essential to involve personnel with detailed knowledge of the local sea conditions. Locations of escape routes were used at an early stage in the analysis of locations on the St. David's Peninsula because it was possible to identify these from personal knowledge but for wider areas such as the whole of the National Park coastline, these would have to be mapped by field study during the latter stages in the process.

The nature of the shoreline can be estimated from maps and satellite imagery so this could be used as a first step to eliminating areas where the coastline does not consist of cliffs. Accessibility information is also available from OS maps combined with Countryside Access maps provided by CCW and EN.

Assessing wildness and protecting wild places was considered important due to concerns expressed by the National Park Authority, the National Trust and members of the Pembrokeshire Outdoor Charter Group. It was felt that there should be protection for the wilder parts of the coast so that individuals and small groups could explore the more remote parts of the National Park without seeing large numbers of organised groups taking part in commercially organised activities. A farmer who owns part of the Abereiddy site, described on page [...](#), has stated that he did not want to see the natural coast turn into a "theme park" (POCG, 2010). This is one of

the reasons why restrictions on the use of natural sites are being introduced as it is felt that the environment is changing beyond what is acceptable at certain times of the year. (Sites could be said to have crossed the threshold, as defined by Hammitt (1990) in the ‘Limits of Acceptable Change’ model.) The methodology of assessing ‘wildness’ is discussed in the next section.

Once the possible locations had been narrowed down using the methods described above, a more detailed study of individual sites would be necessary. This has only been carried out for one small section as part of this study although it is hoped that further work will be done on more sites in the near future.

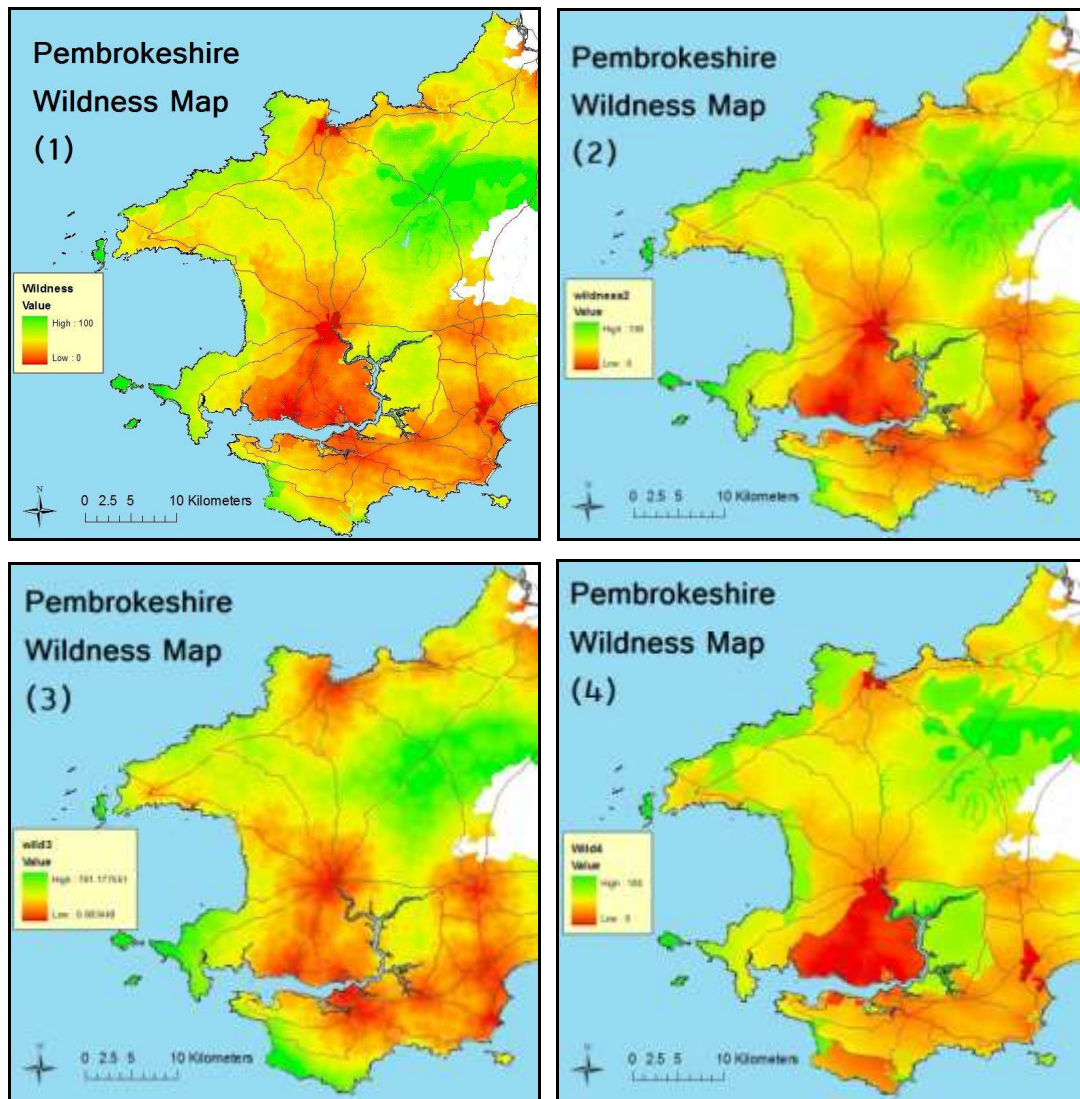
This final stage involves mapping of specific conservation features and using these to indicate whether areas are likely to be suitable for development, suitable with specific management controls, or unsuitable for coasteering development. This will be further discussed below in the final part of the discussion (5.3).

## 5.2 Adapting Wilderness mapping

Initially, a very basic system was used for the St. David’s Peninsula which was then adapted to a method similar to that used by Carver et al (2002) for classifying the whole county. The factors chosen were those that matched Carver’s factors as far as possible, with consideration of the available data. Each of the five factors was given equal weighting which produced a map that gave a good approximation of the wilder parts of the county. Three other combinations are shown below using different weighting methods as described in table 5.2.

Factors	Weightings			
	Map 1	Map 2	Map 3	Map 4
Remoteness from local population	1	2	1	1
Remoteness from mechanised access	1	2	1	1
Apparent naturalness	1	1	1	0
Biophysical Naturalness	1	2	0	3
Altitude	1	1	0	1

**Table 5.2: Factor weightings used in 4 versions of the wildness value mapping.**



**Figure 5.1: Wildness Maps using different factor weightings as described in table 5.2 above. (1) equal weighting, (2) emphasis on population and road access, (3) emphasis on proximity to people and man-made structures, (4) emphasis on landscape quality.**

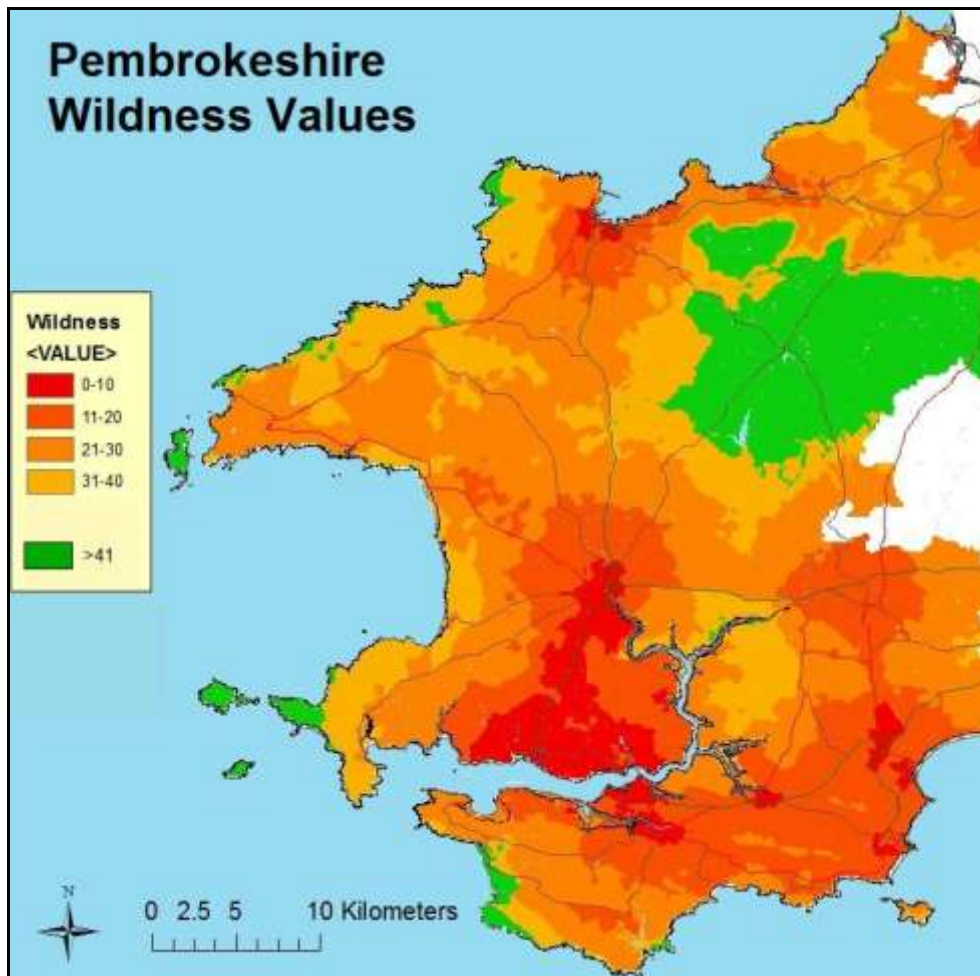
Maps created by S. Quinton, Dec. 2010 for MSc in GIS

Ordnance Survey © Crown Copyright and database right 2010

The 4 versions of wildness maps were shown to colleagues for comments and it was felt that the first version with equal weighting represented actual wildness more closely than other variations.

The threshold 'wildness value' was set at the mean value + 1Std deviation (or >40% of the maximum value) in order to identify 'wild places'.





**Figure 5.2: Wildness values displayed as a classified layer with 10% increments up to a threshold of 40% of maximum (equal weighting of factors).**

Map created by S. Quinton, Jan. 2011 for MSc in GIS

Ordnance Survey © Crown Copyright and database right 2010

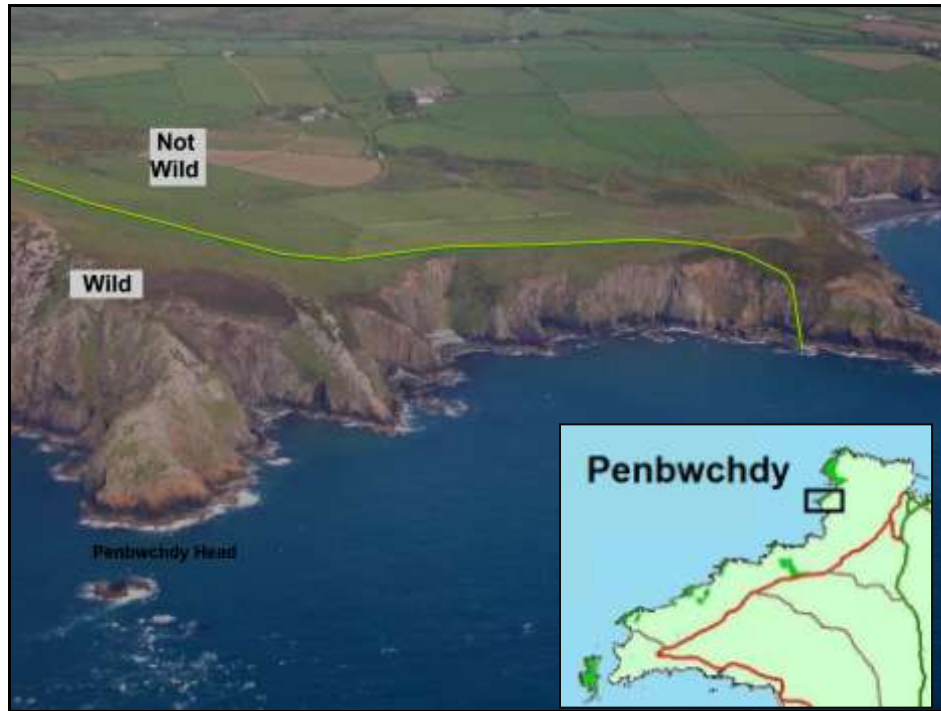
Setting a threshold value for ‘wildness’ is very subjective. In reality there will be a transitional zone between wild areas and less wild areas but if wild places are to be protected there needs to be some means of definition. As Nash (1982) states, wilderness is ‘*one extreme on a continuum from the paved to the primeval*’. Towns and villages are clearly not wild, cultivated land in close proximity to roads is not wild, areas of coastal heath and cliff faces with no houses or man-made features visible could be termed as wild. Between the latter two cases, there will be semi-improved land with some visible influences of human activity. Miller (1995)



provides the following definition of Australian wilderness: “... *substantially undisturbed by colonial and modern technological society; and remote at its core from points of mechanized access and other evidence of colonial and modern technological society.*” This definition, although based on a very different environment can be applied to the current study in that wild places are those that are substantially undisturbed by modern society and remote (to an extent) from road access. A wild place can be considered as one where a walker (or other user) can feel a sense of being away from modern life, within a natural environment and have little contact with other people. Presence of others was considered the most important negative factor in Macfarlane’s study of tranquillity (2006) but it is a difficult factor to measure and to map. In order to achieve this for the current study, it would be necessary to record numbers of people visible, for a large number of points on the coast path, over a range of times during the year and map these figures. This would be a lengthy and resource-intensive task but could provide an alternative measure of wildness that might be equally valid to the methodology used here.

The following aerial photographs can be used to compare the nature of wild places as mapped (using the 5 factor GIS methodology described) to the local landscape appearance. This raises some interesting points and it might be worthwhile using a combination of GIS techniques and aerial photographs to produce a more valid classification of wilderness or wild places.

Figure 5.3 below shows the area around Penbwdy Head. The coastal heath here is classified as wild using the criteria described above. The intersection with the coast path on the right of the photograph corresponds to a point that is 1.5km from the nearest road access point (via footpaths) and this boundary could be said to provide a reasonable classification of an area where few people would be seen. There are also very few man-made structures other than field boundaries visible. In this case, the methodology is reasonable effective.



**Figure 5.3: Penbwochdy Head showing the line of the threshold wildness value. (Inset shows the location. The camera is pointing towards the south east.)**



**Figure 5.4: Aberdeiddy Bay showing coastal areas that are classified as ‘wild’. (Inset shows the location. The camera is pointing towards the south east.)**

The classification of wild places around Aberdeiddy Bay could be said to be less effective than the example of Penbwochdy Head. Firstly, the headland to the left of centre includes the busiest coasteering venue in the county and a popular attraction for locals and tourists alike. This is within a 5 minute walk from a car park and

easily accessible. There is also a small area of ‘wild’ coast just to the south of the beach which appears to be no more ‘wild’ than the coastline immediately to the west. At the right edge of the photograph, there is a stretch of coastline that is more remote and out of sight of man-made structures where the classification is more realistic.

The third example, near Whitesands Beach (figure 5.5), shows coastal strips and an extensive area of coastal heath that includes a hill where igneous rocks protrude from Cambrian sedimentary country rocks. The area in the distance appears to broadly fit the concept of wildness with a natural appearance, reasonably remote from roads and with views dominated by hills and open water. The narrow coastal strip in the foreground however, gains its high wildness value from the outstanding views and distance from settlements and is, in fact, an easily accessible section of coast. It is very close to two large caravan sites (visible in the photographs) and would not be considered as a wild place by most users.



**Figure 5.5: Whitesands Bay showing areas classified as wild on the coastal strip and on heathland at St. David’s Head and Carn Llidi. (Inset shows the location. The camera is pointing towards the north.)**

Figure 5. 6 below shows the map section corresponding to the photograph above. The polygons shown are those that have been created by converting the raster wildness layer to a feature layer using a threshold of 40% of maximum value to define wild places. This process have led to a loss of precision in the conversion and is another weakness in the methodology. The sections that have been circled purple could be removed from the original classification based on information from photographs.



**Figure 5.6: Wild places near Whitesands Bay and sections that could be reclassified based on photographic data**

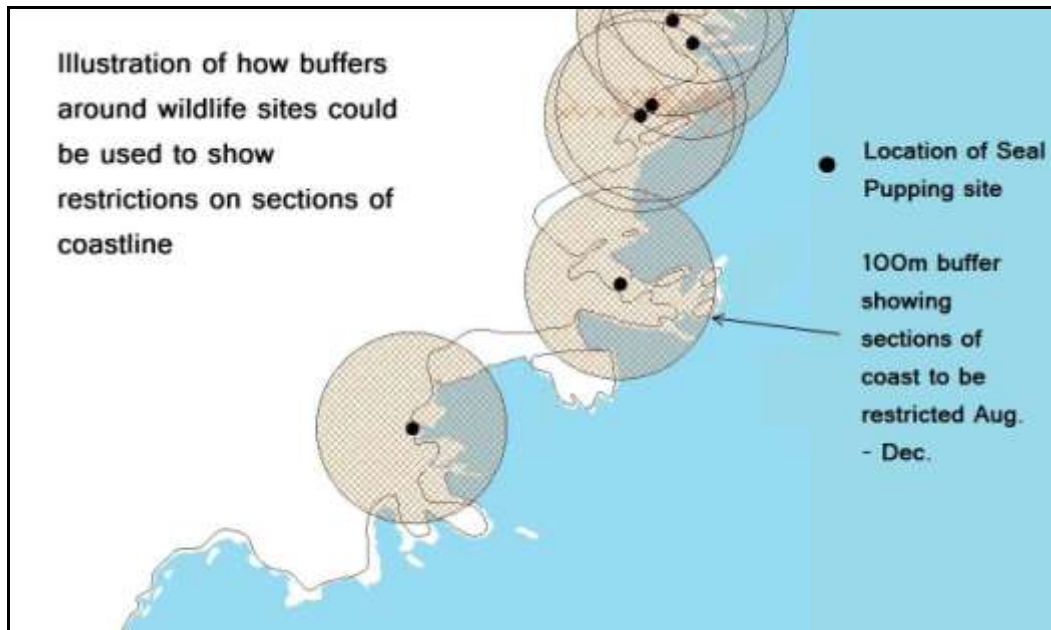
The process of classifying places as wild, using GIS techniques alone, is in need of refinement. This could be achieved by using a combination of photographs and fieldwork together with eliminating some of the very narrow or very small sections as in the methodology for study area 1 described on page ... .

### **5.3 The Role of GIS within assessing suitability of sites for coasteering**

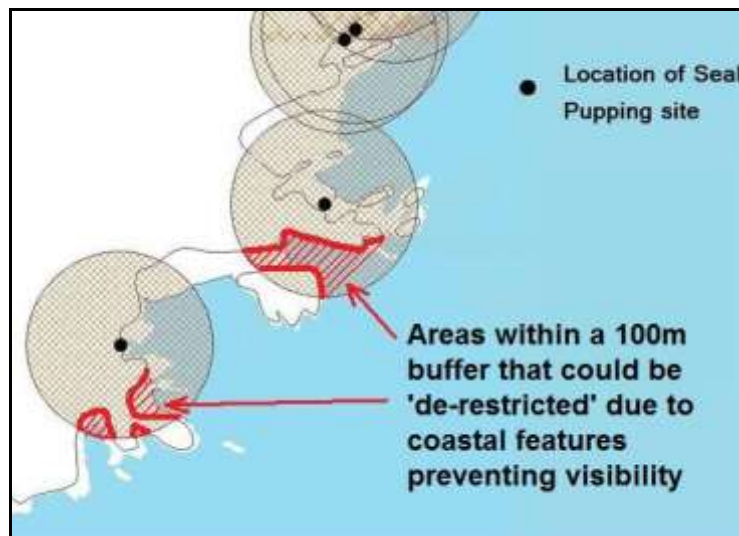
GIS techniques are already being used by CCW as a means of recording locations of species and analysing breeding success rates, also by PCNPA in mapping activities and developing interactive maps to provide information about activities and conservation (Jones, 2009). The study presented here attempts to link conservation interests and outdoor activity sector requirements to facilitate good decision-making and sustainable development.

Once possible sites have been identified, a detailed environmental impact assessment is required before organisations such as the National Trust can support the development of commercial activities. This process requires knowledge of precise locations of vulnerable features and GIS has the potential to fulfil useful roles within this. Firstly, by storing and displaying data on these locations as map layers, secondly by processing this data in order to support decision making. This can be achieved using buffers around sites such as seal pupping coves or bird nests. Although buffering can be used to give a broad representation of areas that might need to be avoided, it would be necessary to modify restricted zones due to detailed topography of the coast. In the case of seal pupping and bird nests, it may be possible for groups to be relatively close to sites without causing disturbance if these are within coves that restrict visibility. This situation is illustrated below in figures 5.7 and 5.8. An effective method of producing maps of restrictions would need to combine GIS techniques with fieldwork and input from experts in animal behaviour in order to ensure that decisions are valid and credible.

In view of the comments in sections 5.1 and 5.2 above, it is likely that the main roles of GIS could be at the stages of eliminating sites on the grounds of practical issues and preservation of wild places as well as providing an approximation of potential restrictions at a local EIA stage. The details of actual restrictions and management controls on commercial outdoor activities require focused study on the ground and decision-making based purely on GIS analysis would very likely be flawed.



**Figure 5.7: Illustration of the use of 100m buffers around sites to protect seal habitat during the autumn pupping season. At this time of year, only the extreme south west of the mapped area would be available for coasteering groups if this system was used.**



**Figure 5.8: Illustration of the over-simplification of buffering in relation to protecting seal sites.**

(Maps are for illustration purposes only and do not show genuine pupping sites due to confidentiality of CCW data.)



Using the example of Pen Anglas area as discussed in section 4.2, it would be possible to create a code of practise for group leaders that would help them to minimise the impact of their activities on the site. A draft site card has been constructed below:

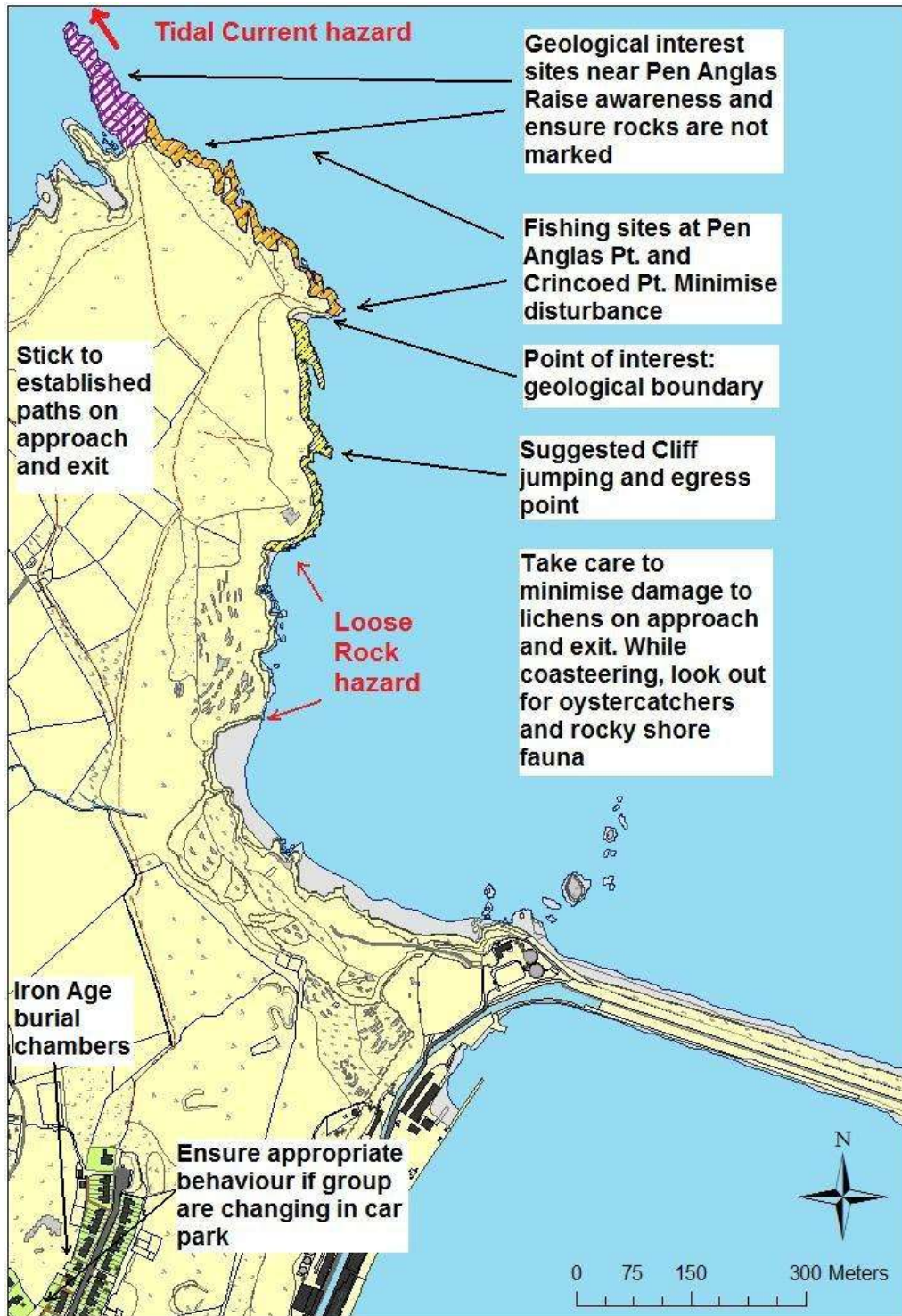


Figure 5.9: Draft site card based on preliminary field survey for Pen Anglas area.

The next stage in the process would be a detailed EIA with outdoor activity providers, experts from CCW and the National Trust. This would be used to evaluate the potential impacts in more detail and to finalise a site card, or, if important features were found that would be seriously affected by coasteering groups, the site could be rejected.

Other sites could be assessed using a similar system following a list of prioritised locations based on degree of shelter from waves, accessibility for activity providers and predicted quality of coasteering value.



## 6. Conclusion

As discussed above, although GIS has been applied to the problem of locating suitable sites for new coasteering development, there are many problems with the use of these techniques without combining them with field work and consultation with local experts. Vulnerability of natural features to disturbance is a highly complex subject and an effective system of map layers would need to include information on precise locations as well as an indication of the specific range of potential disturbance. This is affected by species behaviour, detailed local topography and temporal factors such as season and the tidal cycle.

Wilderness/wildness mapping can be achieved using readily available data from sources such as OS OpenData and OS Mastermap. However, in order to ensure that the assessment of wild places is realistic, it is important to combine initial outputs with other sources of information such as photographs, remote-sensing images and local expertise. This additional information could be used to eliminate very small sections of the coast and areas that are well-used and accessible but still fall into the 'wild' category based on the five-factor methodology described in section 3.2.2.

The PCNPA Recreational Plan (PCNPA, 2010) asks a number of questions about management of coasteering. An attempt to answer some these has been made below:

- ***Should we be seeking voluntary agreements to ensure that commercial coasteering does not develop in some of the wilder parts of the park?***

Yes, there are wild places that show many of the attributes of true wilderness. These can be mapped and should be avoided by organised groups to preserve opportunities for quiet enjoyment by those seeking out tranquillity and adventure within the National Park.

- ***Should we be looking for agreed voluntary seasonal restrictions to be agreed as with climbing for some areas? – These might be to protect cliff nesting birds, cliff face habitats or seal pupping /moulting sites.***

Yes, there are vulnerable species on the coastline that would very likely experience reduced breeding success if disturbed during the nesting/breeding season by coasteering groups. It is possible to map these locations and introduce similar restrictions to those negotiated with climbers.

- ***Do we need to develop an agreed coasteering specific code of practice and resources for the growing numbers of coasteering leaders and assistants to help reconcile coasteering with conservation as has been done with gorge walking in North Wales?***

This has been completed in draft form as part of the Best Practise Safety Guidance for Coasteering Providers (National Water Safety Forum, 2010)

- ***Should some of the most popular areas be subject to an agreed time zoning /booking system with agreed limitation on numbers to prevent overcrowding and if so how would this work?***

This is on-going at Abereddy and will lead to reduced capacity for that site and hence, increased demand for alternative venues, particularly in rough sea conditions.

- ***How do we influence groups coming to Pembrokeshire from away who are not with locally trained guides / members of the POC?***

This is being investigated by Pembrokeshire Outdoor Charter Group – new websites are being developed and leaflets produced explaining conservation issues and restrictions on coasteering groups.

- ***Is there a danger that public bodies find an attraction in new activities like coasteering and by supporting the activity with promotion, help to create the problems of overuse without contributing to the management and sustainable development of activities?***

Materials produced by organisations such as the National Park Authority and Welsh Tourist Board promote the use of the coastline for Adventure Activities. They therefore have a degree of responsibility in supporting the

sustainable development of these activities and helping providers to minimise impacts on the natural environment. These organisations (and others) fulfil this responsibility by supporting bodies like POCC and should continue to increase the level of support as far as possible, as pressures on the environment continue to increase.

Further study that could develop the methodology for classification of areas would include the following:

- Improving the methods of identifying exposure to prevailing waves and tidal currents
- Surveying interested parties in order to help establish a more robust system of weighting factors and defining a threshold value in classifying wild areas.
- Further testing of mapping conservation features on a local scale

Further work to refine techniques and possibly modify the selection of possible sites would lead to a list of prioritised sites that are *likely* to be suitable and could be investigated in more detail. Site cards could then be developed for group leaders using data that has been mapped within the GIS as shown in figure 5.9 above.

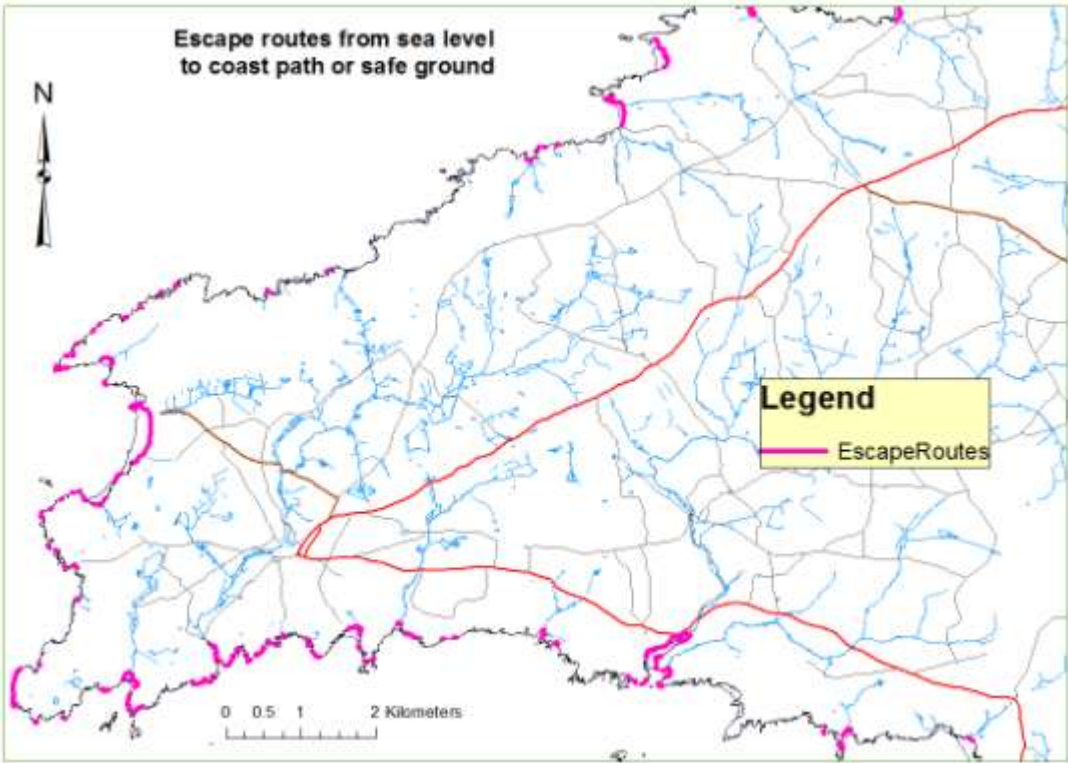
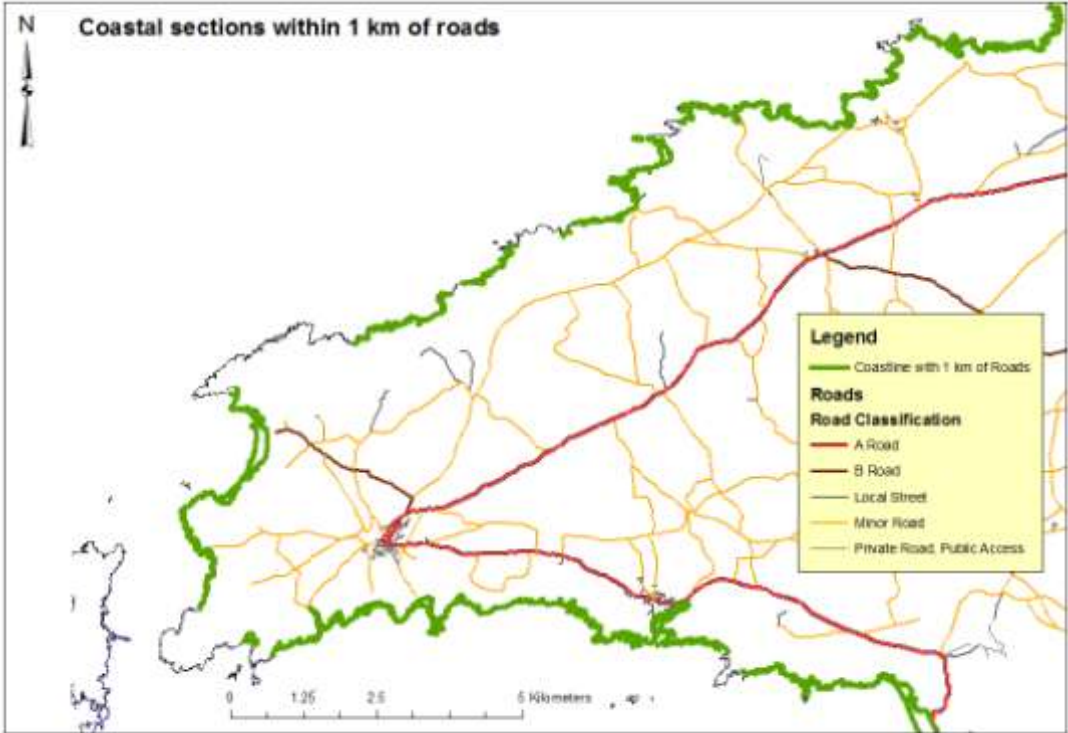
As stated by Cordell and Tarrant (2002) there is a “... *general increase in recreation-based conflict due to general rising demand and increase in technology-driven activities. For managers, early detection of user conflicts and effective conflict resolution depend on understanding where and how conflicts arise. Resolving conflict at its initial stages can help avoid costly political and legal actions.*”

It is hoped that this study would be useful to the outdoor activity industry as an aid in finding new locations and to organisations such as the National Trust who need to be able to make valid judgements on the suitability of sites for new activities and hence minimise the potential for recreation/conservation conflict.

# **Appendices**

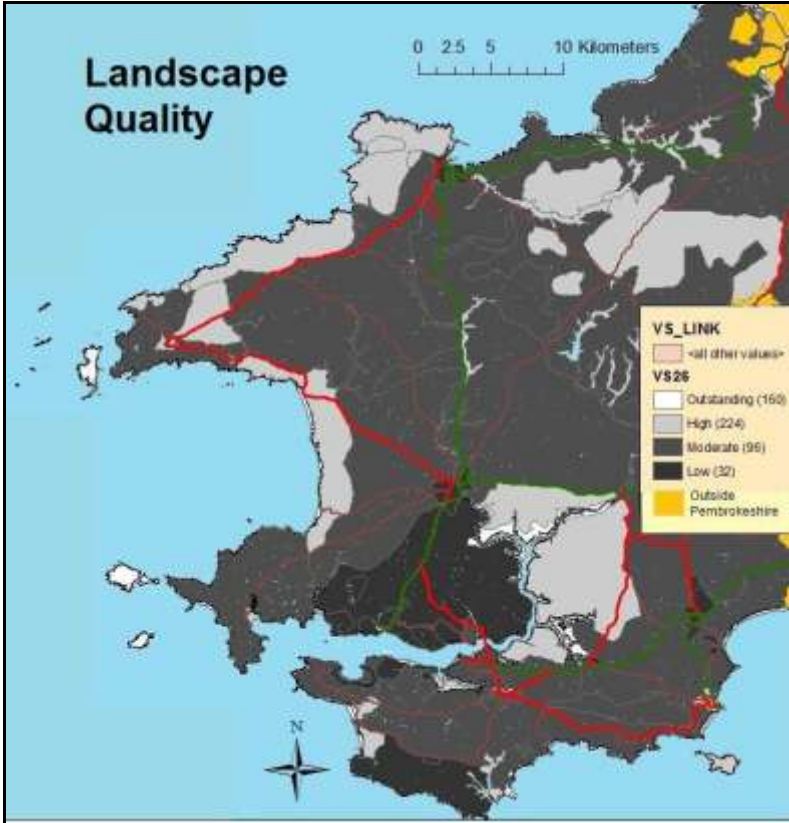
# Appendix 1 Additional map sections used in analysis

## (a) Study Area 1: The St. David's Peninsula

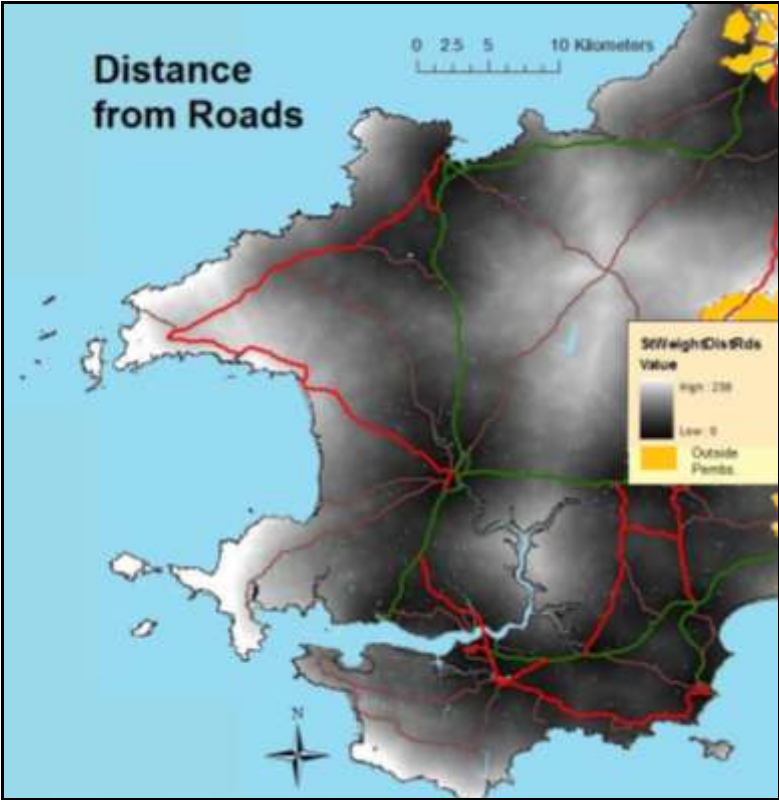


Maps created by S. Quinton, Aug. 2010 for MSc in GIS  
Ordnance Survey © Crown Copyright and database right 2010

(b) Component layers used in creating wildness raster for Study Area 2











Maps created by S. Quinton, Dec. 2010 for MSc in GIS

Ordnance Survey © Crown Copyright and database right 2010

## Appendix 2: LANDMAP Procedure

### Visual and Sensory Landscape Mapping Methodology (Extracts from CCW, 2008)

#### 1.2 Overview of procedure

The process for carrying out the Visual and Sensory aspect is similar to the other evaluated aspects. Initially the study area is classified into different landscape types. These are mapped and Collector forms filled out for each. As with all landscape assessments, this is likely to be an iterative process. Desk study derived Aspect Areas will be refined by field assessment which will form the basis for data recording. When the assessment is completed, a technical report is prepared to explain judgements and any deviations from the method. A Quality Assurance procedure is then carried out on the assessment to ensure consistency and quality control.

The compilation of the LANDMAP Visual & Sensory Aspect therefore involves *four* main processes:

**Step 1:** Classifying and mapping Visual & Sensory Aspect Areas

**Step 2:** Aspect Areas data capture (Collector Surveys)

**Step 3:** Compilation of a Technical Report

**Step 4:** Quality Assurance

Visual & Sensory Aspect Specialists are responsible for Steps 1-3 in this process. However, to achieve nationally consistent standards, each LANDMAP data-set is reviewed by CCW's Quality Assurance Panel before it can be approved as verified LANDMAP Information. The QAP is therefore responsible for Step 4 in the process but can also provide guidance on the undertaking of Steps 1-3.

The Visual & Sensory Aspect is organised according to a hierarchical classification system. This typology aims to classify the landscape into areas of distinct Visual & Sensory character, and is based on a hierarchy of four levels. The levels are broadly based on the following criteria:

Level 1	Level 2	Level 3	Level 4
Broad landform and land cover	Landform	Land cover	Detail - location / scale / exposure / settlement

The classification will initially be carried out as a desk study exercise. It will be related to mapping of the study area and allocating a classification to each Aspect Area. Each Aspect Area will be mutually exclusive and jointly exhaustive. The classification will be refined by site appraisal. LANDMAP Aspect Areas must be identified to at least Level 3 with Level 4 Aspect Areas being desirable. Because the Aspect Specialist's reasoning in reaching classification decisions, and the evidence leading to those decisions, may be required to be submitted to, or challenged at, a Public Inquiry, careful collation and storage by Aspect Specialists of all research information is required.

There follows a list of classes for the Visual & Sensory Aspect based on this typology.

#### Visual & Sensory hierarchical classification

The classification system below should be adhered to, but local landscape differences may necessitate that the actual classes selected may be different in each Local LANDMAP Area. Any required deviations or problems should be resolved in discussion with the CCW and reported as part of the standard contents of the Technical Report.

## References

- Baerenklau, K.A., Gonzalez-Caban, A., Paez, C. and Chavez, E.** (2009), Spatial allocation of forest recreation value. *Journal of Forest Economics* 10.1016/j.jfe.2009.09.002
- Bateman, I. J., A. A. Lovett and J. S. Brainard** (1999), 'Developing a Methodology for Benefit Transfers Using Geographical Information Systems: Modelling Demand for Woodland Recreation', *Regional Studies* Vol. 33 (3), pp191–205.
- Bates, R. and James, B.** (2002) Marine GIS for Management of Scottish Marine Special Areas of Conservation, in *Marine Geography; GIS for the Oceans and Seas*, Breman, J. (Ed.) California, ESRI
- Beedasy, J. and Whyatt, D.** (1999) Diverting the tourists: a spatial decision-support system for tourism planning on a developing island, *International Journal of Applied Earth Observation and Geoscience* Vol 1, Issues 3-4 1999, pp163-174
- BMC** (2008) Crag and Habitat Management (Accessed on-line at [www.thebmc.co.uk/](http://www.thebmc.co.uk/) 21/11/09)
- Burton, R. and Scrase, A.** (2009) Solent Forum recreation study group: Recreation Audit (Accessed on-line at <http://www.solentforum.org/> 20/11/09)
- Butler, R.W.** (1980) The Concept of a Tourist Area Cycle of Evolution: Implications for Management of Resources, *Canadian Geographer* Vol.24 (1) pp 5-12
- Carver, S., Evans, A. and Fritz, S.** (2002) Wilderness attribute mapping in the United Kingdom. in *International Journal of Wilderness*. 8(1), pp 24-29.
- CCW** (2008) LANDMAP Methodology: Guidance for Wales: Visual and Sensory (accessed on-line at <http://www.ccw.gov.uk/landscape--wildlife/protecting-our-landscape/landmap/> 11/09/10)
- CCW** (2010) Countryside Council for Wales LANDMAP data (accessed on line at: <http://test.landmap.ccw.gov.uk/> 09/08/10)
- Chhetri, P. and Arrowsmith, C.** (2008) 'GIS-based Modelling of Recreational Potential of Nature-Based Tourist Destinations', *Tourism Geographies*, Vol. 10: 2, pp233 - 257
- Church, A., Hughes, G. And Taylor, R.** (2008) A Strategic Plan for Water Related Recreation in Wales. (accessed on-line at [http://www.brighton.ac.uk/waterrecreation/plan\\_wales.htm](http://www.brighton.ac.uk/waterrecreation/plan_wales.htm) , 20/12/09)

**Cole, D. N. and Stankey, G. H.** (1997) *Historical Development of Limits of Acceptable Change*. Proceedings, Limits of Acceptable Change and Related Planning Processes workshop, Lubrecht Experimental Forest, Montana, USA, May 20–22, 1997

**Cordell, H. K. and Tarrant, M. A.** (2002) Southern Forest Resource Assessment Draft Report: *Forest-based outdoor recreation*. (Accessed on line at <http://www.srs.fs.usda.gov/sustain/draft/socio6/socio6.pdf> 25/12/10)

**Council Directive 92/43/EEC** (1992), *European Habitats Directive*, Article 6.2 (Accessed on line at <http://eur-lex.europa.eu/LexUriServ/> 22/11/09)

**Crawford, D.** (1994) Using remotely sensed data in landscape visual quality assessment. *Landscape and Urban Planning* Vol. 30 pp7 1-8 1

**De Vries, S. and Goossen, M.** (2002) Modelling recreational visits to forests and nature areas, *Urban Forestry & urban greening*, Vol 1 Issue 1 pp 5-14

**Great Britain.** Countryside and Rights of Way Act (2000) c.37 London, HMSO

**Great Britain.** Environment Act (1995) c.25 London, HMSO

**Great Britain.** Wildlife and Countryside Act (1981) London, HMSO

**Hammitt, J.K.** (1990) *Probability is All We Have: Uncertainties, Delays, and Environmental Policy Making*, Garland Publishing, Inc., New York and London, 1990

**Hugget, D. J.** (1995) A Review of Coastal Byelaw Making Powers: A Response to DoE's Review of Byelaw Making Powers in the Coastal Zone. ....

**Hurford, C. and Evans, S.** (2006) Monitoring Coastal Heathlands in St. David's, in C. Hurford and M. Scheidner eds. *Monitoring Nature Conservation in Cultural Habitats: A Practical Guide and Case Studies*, Netherlands, Springer

**Itami, R.M., Gimblett, R, Raulings, R, Zanon, D. , Maclaren, G., Hirst, K. and Durnota, B.** (1999) RBSim: *Using GIS-Agent simulations of recreation behaviour to evaluate management scenarios*, Aurisa '99, Conference of the Spatial Information Association, Blue Mountains, New South Wales, 22-26 November 1999

**Itami, R.M. and Gimblett, H.R.** (2001) Intelligent recreation agents in a virtual GIS world, *Complexity International Journal*, Vol. 08

**Itami, R.M., Gimblett, R, Raulings, R, Zanon, D. , Maclaren, G. and Chladek, P.** (2003) RBSim 2: simulating the complex interactions between human movement and the outdoor recreation environment. *Journal of Nature Conservation*. Vol. 11, pp278–286

**JNCC** (2009) North West Pembrokeshire Commons, Site Details, (Accessed on-line at <http://www.jncc.gov.uk/ProtectedSites/SACselection/sac/> 12/01/10)

**Jones, D.** (2009) *South West Wales Recreation Audit, Interim Report* (Accessed on-line at <http://www.pembrokeshireoutdoors.org.uk/documents> 20/11/09)

**Keller, V.E.** (1991) Effects of Human Disturbance on Eider Ducklings *Somateria mollissima* in an Estuarine Habitat In Scotland, *Biological Conservation* 58 (1991) pp213-228

**King, J.** (2010) Coastal Destinations Rated: Top Rated, *National Geographic*, National Geographic Society (accessed on line at <http://travel.nationalgeographic.com/travel/> 1/12/10)

**Landré, M.** (2009) Analyzing yachting patterns in the Biesbosch National Park using GIS technology , *Technovation*, Vol. 29 Issue 9 pp 602-610

**Liddle, M.** (1997) *Recreation Ecology: The Ecological Impact of Outdoor Recreation and Eco-Tourism* London, Chapman and Hall.

**Luddington, L.** (2008) Pilot study to develop a method to monitor recreational activities on the South St David's coast (Accessed on-line at <http://pembrokeshireoutdoors.org.uk/documents/FinalRecReport08.pdf> 09/11/09)

**Lyles, G.** (2009) *Otter Activity on the Open Coast within the Pembrokeshire marine Special Area of Conservation*. Report to the Pembrokeshire Marine SAC Relevant Authorities Group. MHPA, Milford Haven

**MacFarlane, R., Haggett, C. and Fuller, D.** (2006) Tranquillity map: South West (Accessed on-line at <http://www.cpre.org.uk/campaigns/landscape/tranquillity/national-and-regional-tranquillity-maps/south-west> 06/01/10)

**Miller, J.** (1995) Australian Approaches To Wilderness. *International Journal of Wilderness* . Vol. 1, No.2. pp38 – 40 .

**Minnesota Environment Quality Board** (1993) *Recreational and Aesthetic Resources*, Prepared by Jaakko P'oyry Consulting, Inc. Minnesota. (Quoted in Chhetri, P. and Arrowsmith, C. (2008) 'GIS-based Modelling of Recreational Potential of Nature-Based Tourist Destinations', *Tourism Geographies*, Vol. 10: 2, pp233 – 257.

**Nash, R.** (1982) *Wilderness and the American Mind. 3rd edition*. New Haven, Conn. Yale University Press.

**National Water Safety Forum** (2010) *Best Practise Safety Guidance for Coasteering Providers, Final Draft October 2010*. (Personal Communication)

**NERC** (2010) Geological Map Data Downloaded accessed (on line at <http://digimap.edina.ac.uk/> 16/2/2010)

**Nunn, P.** (1988) *Effects of "gardening" on different crags in the Lake District throughout the 60's and 70's*. Conference report: The Adventure and Environmental Awareness Group, Rock climbing and environmental awareness, Ambleside, 1988 (Accessed on-line at <http://www.aea-uk.org/reports00.html> 22/10/09)

**PCNPA** (2010) *Enjoying the Pembrokeshire Coast National Park: A Plan to Provide and Manage Opportunities for Sustainable Recreation in the National Park*, NPA Draft 22/10/10 (Accessed on-line at <http://www.pembrokeshirecoast.org.uk/default.asp?pid=435&LangID=1> 12/11/10)

**Pembrokeshire Coastal Forum** (2003) *Tourism, Recreation And Access Topic Paper*, (Accessed on-line at <http://www.pembrokeshirecoastalforum.org.uk/index.php/resources> 08/01/10)

**Pembrokeshire Marine Code** (2004) *Code of Conduct* (Accessed on-line at <http://www.pembrokeshiremarinecode.org.uk/> 11/11/09)

**Pembrokeshire Outdoor Charter Group** (2005) *Coasteering* (Accessed on-line at <http://www.pembrokeshireoutdoors.org.uk/coasteering.htm> 12/02/10)

**Penz, A. J.** (1975) Outdoor Recreation Areas: Capacity and the Formulation of Land Use Policy. *Management Science*, Vol. 22 Issue 2 pp139-147

**POCG** (2010) Abereiddy Meeting Minutes from 6/12/10, Pembrokeshire Outdoor Charter Group (received as personal communication, December 2010)

**Ponsford, S.** (2007) The effect of coasteering on barnacle density at St Nons Bay. Unpublished ecology project, University of Cumbria

**Quinton, S.** (2010) *Pembrokeshire Green Climbing Guide* (accessed on-line at : <http://www.pembrokeshireoutdoors.org.uk/documents/PembsGreenGuide.pdf> 21/10/10)

**Rogers, A.** (2010) *Scoping Study into the Potential Impacts of Coasteering in Pembrokeshire*, Interim Report July 2010 (Part of report commissioned for The National Trust, received as personal communication, October 2010)

**RSPB** (2008) Ramsey Island RSPB Nature Reserve (Accessed on-line at <http://www.stdavids.co.uk/nonprofit/ramsey/> 14/01/10)

**RYA** (2009) *The Green Blue* [On-line] (Updated 19<sup>th</sup> May 2009) Accessed on-line at <http://www.rya.org.uk/infoadvice/planningenvironment/> 22/11/09)

**Stankey, G.H. et al** (1985) *The Limits of Acceptable Change (LAC) system for wilderness planning*. U.S. Department of Agriculture, Forest Service Gen. Tech. Report INT-176.

**Strong, P.** (2010) Atlantic Grey Seals in Quinton, S. Ed. *Pembrokeshire Green Climbing Guide* (accessed on-line at : <http://www.pembrokeshireoutdoors.org.uk/documents/PembsGreenGuide.pdf> 21/10/10)

**Strong, P. and Morris, S. R.** (2010) Grey seal (*Halichoerus grypus*) disturbance, ecotourism and the Pembrokeshire Marine Code around Ramsey Island, *Journal of Ecotourism* 9: 2, 117 — 132. (Accessed on-line at: [http://pdfserve.informaworld.com/16993\\_758064766\\_922295349.pdf](http://pdfserve.informaworld.com/16993_758064766_922295349.pdf) 06/06/10)

**Thomas, D.** (2007) The impact of coasteering on *Fucus vesiculosus* at St Nons Bay. Unpublished BSc. Honours project, Pembrokeshire College.

**Thomas, G. E. and Thomas, T. M.** (1956) The volcanic rocks of the area between Fishguard and Strumble Head, Pembrokeshire, *Quarterly Journal of the Geological Society*; 1956; v. 112; issue.1-4; p. 291-314 The Geological Society, London, Legacy

**Tyler-Walters, H.** (2005) *Assessment of the Potential Impacts of Coasteering on Rocky Intertidal Habitats in Wales*, MarLIN (The Marine Life Information Network for Britain and Ireland) (Accessed online at <http://pembrokeshireoutdoors.org.uk/documents/CoasteeringimpactsnonrockyshoresMARLIN.pdf> 23/11/09)

**Welsh Assembly Government** (2008) Coastal Tourism Strategy. Visit Wales (Accessed on line at <http://wales.gov.uk/docs/drah/publications/Tourism/090612coastaleng.pdf> 19/08/10)

**Welsh Assembly Government** (2009) One Wales: A Progressive Agenda for Wales, (accessed on-line at <http://wales.gov.uk/docs/desh/publications/> 15/11/09)

**Welsh Tourist Board** (2002) ‘Time for Action’ – an adventure tourism strategy for Wales (2002-8), accessed on-line at <http://wales.gov.uk/docs/drah/publications/Tourism/090331adventureeng.pdf> 18/11/09