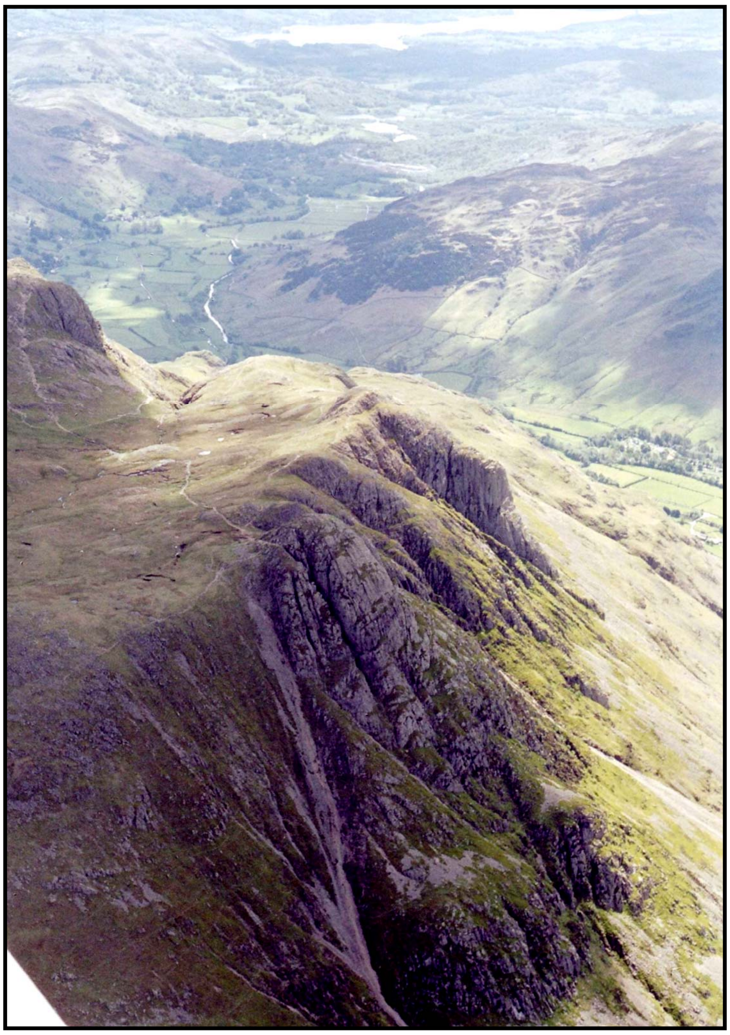


UPLAND PEATS - MANAGERIAL ASSESSMENT

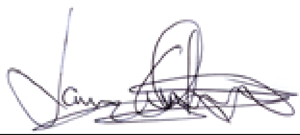
Final Report - Volume 1

Oxford Archaeology North

June 2009

English Heritage

Issue No: 2008-9/850
OAN Job No: L9200

Title	UPLAND PEATS, MANAGERIAL ASSESSMENT
Authors	Elizabeth Huckerby, Jo Cook, Jamie Quartermaine, Paul Gajos
Derivation	MAIN
Origination date	June 2009
Reviser	
Date of this, latest, version	30th June 2009
Version	1.0
Status	Final
Summary of changes	
Circulation	English Heritage: Helen Keeley, Kath Buxton
Required action	
File name/location	uppeats_final_30_6_09.doc
Approval:	
Jamie Quartermaine (Project Manager)	
Rachel Newman (Project Executive)	
On behalf of English Heritage	

Oxford Archaeology North
Mill 3
Moor Lane Mills
Lancaster
LA1 1GF
t: (0044) 01524 848666
f: (0044) 01524 848606

Janus House
Osney Mead
Oxford
OX2 0EA
t: (0044) 01865 263800
f: (0044) 01865 793496

w: www.oxfordarch.co.uk
e: info@oxfordarch.co.uk

CONTENTS

VOLUME 1

TABLES FOR VOLUME 1

VOLUME 2

TABLES FOR VOLUME 2

VOLUME 3

FIGURES

PLATES

ACKNOWLEDGEMENTS

OA North would like to acknowledge the help and support of many people in the development, execution and reporting of this complex project. Most importantly, we would like to thank English Heritage for commissioning and funding the project, and special thanks are given to Dr Adrian Olivier, who was inspirational in advising and encouraging OA North to submit the project proposal, and without whose support the project would not have been commissioned. Many English Heritage staff have supported and guided the project, and special thanks are given to Tony Wilmott and latterly Mark Bowden, who monitored the project. The geophysics programme has benefited from the expertise of Andrew David and other members of the Geophysics team based at Fort Cumberland, and the advice and encouragement given by both Dr Alex Bayliss and Dr Peter Marshall (formerly of English Heritage) on the scientific dating programme, together with that from Dr David Robinson, Dr Sue Stallibrass and Jacqui Huntley on environmental issues, was invaluable. Andrew Davison (Inspector of Ancient Monuments for the North West) and Neil Redfern (Inspector of Ancient Monuments for the Yorkshire and Humberside Region) both took part in discussions with the project team.

OA North would like to acknowledge the considerable help that was given by the county archaeologists of Lancashire - John Darlington (formerly) and Peter Iles, and also the county archaeologist of Greater Manchester, Norman Redhead. We would also like to thank the archaeologists from the National Parks, who gave freely of their time: John Hodgson (Lake District), Ken Smith (Peak District), Graham Lee (North York Moors) Rob White (Yorkshire Dales), and Paul Frodsham (then of Northumberland). We would also like to thank Jamie Lund, National Trust Archaeologist for the North West Region.

The extent and present condition of the peats both locally and regionally was discussed with many people, including Peter Jepson (Lancashire County Council) and staff of English Nature (now Natural England): Jean Johnston, Jon Hickling, Alistair Crowle and Valerie Hack. The latter also gave advice on other aspects of the project.

One important element of the project was to consider the many and varied threats to the fragile environment that is described here as ‘upland peats’, and we would have been unable to assess these without the patient support of both individuals and organisations; the report could not have been written without their enthusiasm and help. Many discussions took place about the major threat of fire, particularly with Steve Heath and Steve Yearsley (Greater Manchester Fire Service), Amanda Clarke (Lancashire Fire Service), Penny Webb (The National Trust in Cumbria), Rachel Pickering and Graham Lee (both from the North York Moors National Park).

OA North would like to acknowledge and thank the many people who advised and discussed the present and continuing threats of farming in areas of upland peat and changes in land management. They include Dr Bob Evans (Anglia Ruskin University), Dr Marianne McHugh (Durham University), James Archer (The National Trust), John Metcalfe (The National Trust), Peter Jepson (Lancashire County Council), Ian Harper (United Utilities) and Liz Chalk (Environment Agency). The staff from Natural England (formerly DEFRA and English Nature) are warmly thanked for their participation in discussions, particularly Bob Middleton, Peter McCrone, Ian Condliffe, Valerie Hack (formerly English Nature Moorland Restoration Officer), Mervyn Edwards, Colin Newlands, Ian Harper, and staff at the Peterborough, Kendal, Bakewell and, particularly, the Leyburn offices. Finally, we would like to thank Alan Hume and Paul Wilkinson, both rangers with the Yorkshire Dales

National Park, for their invaluable local knowledge of farming around Sedbergh and the Howgill Fells.

Until recently, areas of upland peat have been extensively used for forest plantation, thus causing damage to both the archaeology and the fragile environment. The impact of this forestry and future land management was discussed with many people, and we would like to thank particularly Nigel Williams, Dave Lowe, Tim Yarnell, Gareth Browning and Bill Burlton of the Forestry Commission, and Philip Wilson of Natural England, for their invaluable help.

The GIS programme would not have been so successful without the advice and support that Tom Evans, formerly of Oxford Archaeology, gave to Joanne Cook. Data from the counties and National Parks were also made freely available, in particular from The Lake District National Park (Eleanor Kingston) and from the Peak District National Park. The compilation of the GIS was also assisted by both the fire services of Greater Manchester and Lancashire. We would like to thank the Lake District National Park Authority and Lancashire County Council, which supplied us with Ordnance Survey and British Geological maps, aerial photographs, and other data.

OA North would like to thank Rod Banks (Abbeystead Estate), SEB Clowes (Bleasdale Estate), Caroline Holden (Bowland Estate), and all the farmers within the Forest of Bowland study area for facilitating our access to the land in the Forest of Bowland that is in their care. We would also like to thank United Utilities for allowing access to Anglezarke Moor, the National Trust for permitting the Langdale Fells survey and also Muncaster Estates for permission to undertake the survey of the South-West Fells.

OA North would like to thank all those involved in the Upland Peats Seminar, held at Lancaster University. In particular, we would like to thank Elizabeth Huckerby and Sandra Bonsall, who undertook most of the set-up, and also Mark Bowden, of English Heritage, for the financial assistance and general support. Speakers who have not otherwise contributed elements to this report include Steve Yearsley and Steve Heath of Greater Manchester Fire Service, Rachel Pickering, North York Moors National Park Authority, Bob Middleton, Natural England, and Simon Stainer, Natural England.

OA North would like to thank the following people, with whom more general topics were discussed. Kate Snow supplied information about the policies of United Utilities towards land management, bracken control and controlled burning in moorland areas. Dr Aletta Bonn and her colleagues at the ‘Moors for the Future’ project spoke about the problems of moorland in the Peak District National Park and restoration projects there. Dr Ciara Clarke (AOC Archaeology Group), Sally Bassham, Dr Ivor Brown and many others discussed a wide range of subjects from peat cutting for both domestic use and the smelting industry, and investigation techniques. We would also like to acknowledge the support and academic advice given to us by Professor Bryony Coles, Professor Robert van de Noort, Dr Chris Caseldine, and Dr Richard Jones, all of the University of Exeter.

Paul Gajos (formerly of OA North) and Denise Druce were instrumental in the smooth running of the archaeological and environmental fieldwork and the analysis of the data collected. Paul was helped in the field by Pip Haworth, Christina Robinson and Karl Taylor. Paul also wrote the first draft of the archaeological case studies.

Denise valiantly and uncomplainingly coped with the logistics of participating in a large palaeoenvironmental survey of an upland landscape, with help from Pip Haworth and Sandra Bonsall, and Frances Claxton and Jess Opie (both formerly of OA North). Denise also carried out all aspects of the post-survey environmental programme and wrote the environmental case studies. She and Peter Marshall designed the radiocarbon dating programme and wrote the relevant report section. We would like to thank Dr Gordon Cook and his staff at the Scottish Universities Environmental Research Centre, who dated the peat samples by AMS techniques, and also Dr Philip Barker and Dr Lydia King, of Lancaster University, who kindly looked at diatoms in some samples from the South-West Fells study area. Jim Innes (Durham University) has been an invaluable consultant on all environmental aspects of the project, and we are greatly indebted to the quiet and thoughtful guidance that he gave so willingly to Denise and Elizabeth. Pete Schofield and Jamie Quartermaine recorded the position of the cores with GPS. In addition, we would like to thank Helen Quirk and the Biology Department at Lancaster University for use of its laboratory facilities.

Professor Valerie A Hall of Queen's University, Belfast examined cores from the Forest of Bowland and identified a tephra horizon in them. Erica Utsi, of Utzi Electronics, and Karl Taylor (OA North) undertook the geophysical survey in the South-West Fells and contributed to this report. The threats to the upland peats were identified and assessed by Vivienne Metcalf (farming, tourism and forestry), Jeff Warburton of Durham University (drainage and climate), and Elizabeth Huckerby of OA North (fire, former threats and a general overview), and all three contributed to this report.

Joanne Cook has been a key player throughout the project, co-ordinating and manipulating the data to build up the GIS database, and analyse this so that judgements could be made of where archaeology might be present, and the level of threats to the resource. Joanne co-ordinated the mapping and the collation of aerial photographs; she also patiently sorted out general computing problems, and has contributed sections to this report.

The various strands of the project have been brought together by Jamie Quartermaine, who managed the project, identified the key management issues, made recommendations for the future management of the upland peats, and is a major author of this report. He also undertook aerial photography across the study areas. Anne Stewardson, with Joanne, and Dane Campbell, produced the illustrations. The report has been edited by Mark Brennand (formerly of OA North) and Rachel Newman (OA North). Rachel has quietly guided the project since Adrian Olivier first sowed the seeds of the idea.

The project team wish to thank all the many others, both within Oxford Archaeology and in the wider community, who have spared their time to answer queries and discuss the project.

SUMMARY

Oxford Archaeology North (OA North) was commissioned by English Heritage to conduct a study to investigate archaeology within areas of upland peat. The project was set up in response to the recognition that the most extensive peatlands in the UK are within the uplands, that they protect a significant archaeological resource, and that this resource is under threat, particularly at the peat edges. This study was intended to assess the impact of the threats upon the resource and to investigate methodologies that can address the major issue of site visibility within peatland landscapes. The over-arching aim of the project was to develop an effective and efficient management strategy that can be applied to upland peat landscapes throughout England, and, indeed, in similar environments elsewhere.

The study relied on the creation of a GIS and concentrated, for practical reasons, on four study areas within north-west England, given the wide variety of conditions within the region. These were deemed to be representative of peat character and the threats to such environments throughout the uplands of England. The study areas chosen were the South-West Fells, in West Cumbria, because they had a well-documented archaeological resource; the Langdale Fells, in the Central Lake District, because they had an artefactual resource, and generally have considerable visitor pressure; the Forest of Bowland, in North Lancashire, because it was perceived that it had deep undisturbed peats and could serve as a control; and finally, Anglezarke Moor, in South Lancashire, because it was an area of upland peats with a long history of erosion and decay, reflecting its proximity to urban centres.

The project entailed an investigation of all threats that have the potential to impact upon the vast resource of upland peats. This involved the investigation of secondary sources, discussions with researchers and land managers, and site investigations within the study areas, to assess the state of the upland peats, their rate of deterioration, and which of the threats have the greatest impact on both the peats and any underlying archaeology.

The assessment of threats concluded that a principal area of concern to the upland peats was from the dessication of the peats, which reflected in part climate change, and the continuing impact of drainage schemes from the latter half of the twentieth century. However, perhaps the greatest and most dramatic perceived threat was from wild fires, which have caused massive devastation to whole moorlands and have the potential to have a severe impact on the survival of both the archaeological and peatland resource.

Both archaeological remote sensing and ground-based methods were used and assessed to establish their potential for discovering archaeological remains beneath the peat. These included fieldwalking and the examination of peat scars, probing to discover stone features and hollows beneath the peat, test pitting and evaluation trenching, resistivity survey, Ground Penetrating Radar survey, and palaeoenvironmental coring and assessment. Some techniques, such as the fieldwalking and palaeoenvironmental coring, were applied to all study areas, but the detailed probing, test-pitting and geophysical surveys were only undertaken on the South-West Fells, where there was a documented resource on which to undertake trials on the techniques, so their success or otherwise could be measured.

The survey data from the wider area and the study areas were compiled into the GIS and were used to model the areas of greatest threat and the potential for buried archaeology. The latter model was established solely for the South-West Fells, where there was

relatively good site visibility to test the technique, and there it was concluded that there was a good correlation between the predicted and actual resource.

The methodological trials established that the most efficient and effective means of discovering underlying archaeological sites was by fieldwalking and the examination of peat scars, in conjunction with probing to search for structural remains. Palaeoenvironmental techniques were effective in determining peat inception and producing evidence for truncation, which allowed an assessment of which moorland areas had the greatest potential for a buried archaeological resource. The technique was, however, not necessarily a particularly efficient means of assessing the archaeological potential of an area.

A seminar was organised in 2007 to provide an opportunity for all the different agencies involved in upland management to discuss the potential for conservation of the archaeological and peatland resource. The seminar was very successful in providing the much-needed opportunity for inter-agency dialogue and recognised that there were considerable amounts of common ground between the views and approaches of the contributors, and that there was significant potential for cooperation between the agencies in the conservation of upland peat.

In conjunction with the Upland Peats project, OA North has been working with ADAS to develop strategies for conservation of archaeological monuments within the highland zone on behalf of Natural England. The common threads of the two projects had a beneficial outcome in being able to provide an over-arching view on the conservation issues pertinent to the upland peats.

The study has demonstrated that the fate of the underlying archaeology was closely entwined with that of the overlying peats, and therefore the prime recommendation is that a partnership should be established between all environmental and archaeological agencies so as to afford the protection of the peatlands. Despite this, it was recognised that there was a need to provide preferential management to those areas of greatest archaeological potential, and that there was a need for a scheme comparable to the one successfully tested in Dartmoor (Premier Archaeological Landscapes (PALs). This would entail selecting areas of archaeological importance on the basis of their observed resource and their potential for buried remains, and by working with partners, particularly Natural England, to put forward such areas for Higher Level Stewardship (HLS) schemes. This approach was perceived as a first stage in addressing the long-term issues that have potential to impact on the archaeology preserved within the upland peats.

1. INTRODUCTION

1.1 CONTRACTUAL BACKGROUND TO THE UPLAND PEAT PROJECT

1.1.1 Oxford Archaeology North (OA North) was commissioned by English Heritage to conduct a study to investigate the archaeology of upland peatlands, which was defined as land above 100m AOD (OA North 2003a). The project was set up in response to the recognition that the most extensive peatlands in the UK are within the uplands, that they protect a significant archaeological resource, and that this resource is under threat, particularly at peat margins. This study is intended to assess the impact of threats upon this archaeological resource and to investigate methodologies that can address the major issue of site visibility within peatland landscapes. The over-arching aim of the project is to develop an effective and efficient management strategy that can be applied to upland peat landscapes anywhere in England, and, indeed, elsewhere. The Upland Peat Project was as defined within a project design submitted by OA North, and approved by English Heritage (*ibid*). This established that the investigations would concentrate on north-west England, where there is a vast abundance of peatlands, and provide the opportunity to examine very different types of peatland, in various conditions.

1.1.2 ***Partners:*** the project has been undertaken in conjunction with local and national partners who have been crucial to the successful implementation of the study. In particular, there has been considerable support from the local archaeological curators (Cumbria County Council, Lancashire County Council, Greater Manchester Archaeological Unit (GMAU), the Lake District National Park Authority, the National Trust). The project has also received considerable encouragement from the English Heritage Regional Scientific Advisors for the North West and North East respectively. Lancashire County Council provided a full suite of digital datasets that have been of immense value, comprising the Historic Environment Record (HER), aerial photography, historical mapping, contour datasets, Historic Landscape Characterisation (HLC), and the loan of digital mapping data. The Lake District National Park Authority provided digital HER data, digital mapping of earlier surveys, aerial photography, and the loan of digital mapping data.

1.1.3 ***National Agencies:*** in addition to the direct partners, the project has forged links with those national agencies that are involved in the management of the environment. These include the Department for Environment, Food and Rural Affairs (DEFRA), the former English Nature, the former Countryside Agency (both now Natural England), The Environment Agency, other National Park Authorities (particularly the Peak District National Park), and The Archaic Peat Deposits Project (funded by English Nature and English Heritage). The establishment of links with these organisations has enabled the cross-feeding of research data, intended to enable the facilitation of management prescriptions at a national level, for the preservation of the peatland resource. In particular, considerable help and advice have been afforded by Bob Middleton and Peter McCrone of DEFRA. During the project, there was a major fire on Fylingdales Moor in North Yorkshire, exposing a remarkable archaeological resource. The data from the subsequent surveys and consolidation works were of immense value to the present study, and were provided, alongside considerable advice, by English Heritage, and the North York Moors National Park Authority.

1.2 THE UPLAND PEATLAND RESOURCE

1.2.1 ***The Peatland Resource:*** peatlands are one of the most valuable contexts for the recovery of archaeological and environmental data, arising from the enhanced preservation of organic structures and deposits within the peat, and early archaeological sites sealed beneath the organic deposits. Preservation within wetland sites, such as bog-bodies (Turner 1986), wooden trackways (Coles and Coles 1986), and waterlogged settlement sites, such as the Neolithic settlement at Ehenside Tarn in West Cumbria (Darbishire 1873), demonstrate the considerable potential of peatlands for providing an important insight into the culture and character of prehistoric populations.

1.2.2 ***Lowland / Upland disparity:*** such sites have all been found in the lowlands, reflecting the fact that, until recently, emphasis has been placed on the recording and management of lowland peats. This was in part due to the well-publicised threat from a number of activities, principally the expansion of settlement, agricultural improvement, drainage, landfill, and the continuing commercial harvesting of peat for horticultural uses. In response to these threats, a series of wide-ranging surveys was undertaken, including the Somerset Levels Project, the Fenland Survey, the North West Wetlands Survey (NWWS), and the Humber Wetlands Project, all funded by English Heritage (Cowell and Innes 1994; Middleton *et al* 1995; Hall *et al* 1995; Leah *et al* 1997; Leah *et al* 1998; Hodgkinson *et al 2000*; Middleton *et al* forthcoming; Van de Noort 2004; Hall and Coles 1994). These have highlighted the considerable archaeological and environmental resources of the lowland wetlands throughout England. By contrast, there has been no comparable study undertaken in the uplands, although limited surveys have been carried out, often following catastrophic erosion episodes. Examples include work in the Pennines at Anglezarke (Howard-Davis 1996), and the Peak District (Anderson 1986; Anderson and Tallis 1981; Anderson *et al* 1998).

1.2.3 The peatland resource within an upland context is both sizeable and significant. For example, northern England contains some 36,689ha of lowland peat (Burton and Hodgson 1987), but there are *c* 216,000ha of upland peats, at depths of greater than 0.5m (Valerie Hack (English Nature) *pers comm*). It is clear that this represents an enormous resource in comparison with that in the lowlands.

1.2.4 ***Upland Archaeological Resource:*** the dramatic organic finds in lowland mires, such as Lindow Man (Stead *et al* 1996) and the Sweet Track (Coles and Coles 1986; Coles *et al* 1973), have been of considerable interest to the general public, who are fascinated by gruesome finds such as the body of a garrotted man. By contrast, the upland finds associated with peatlands, such as lithic scatters, clearance cairns, and field boundaries, have not usually had the same appeal in the press, although the recently recorded rock art from Fylingdales Moor enjoyed some coverage (*Yorkshire Post,* Dec 2004). This situation has led to a perceived lack of importance of upland archaeology.

1.2.5 Despite this, exceptionally rich archaeological remains, particularly of prehistoric date, are preserved by upland mires and organic silts which are unparalleled within the lowland context. These include the internationally important Neolithic axe-production sites of, in places preserved beneath the peats of Langdale Coombe (Claris and Quartermaine 1989), and extensive settlement remains of the Bronze Age, which are often afforded a better preservation than their lowland counterparts, including funerary and religious sites, often situated so as to have a wide vista that will encompass the associated lowland settlements (Quartermaine and Leech forthcoming). The archaeological value of this upland resource is most effectively epitomised by the remains revealed on Fylingdales Moor, following the devastating fire in 2003, which removed the organic silts and heather (Vyner 2005), exposing cairnfields, settlements, funerary and ritual sites, and the remains of industrial activity and nineteenth- and twentieth-century military training exercises. Although much attention was concentrated on one distinctive piece of rock art (*Yorkshire Post*, Dec 2004), the opportunity also allowed the reconstruction of a complex landscape that had developed over the last 5000 years, and provided an insight into the complex process of exploitation and reclamation of these marginal lands.

1.2.6 ***Character of the resource:*** the anthropogenic evidence derived from wetlands of all kinds falls neatly into three elements:

1) archaeological structures, sites and deposits pre-dating the development of peat, which have been protected and preserved by it;

2) archaeological monuments and deposits lying within or on top of the peat (often with a well-preserved organic element having potential for radiocarbon dating);

3) evidence for human activity and its context extrapolated from palaeoenvironmental evidence preserved within the peat, which also bears excellent potential for radiocarbon dating.

Where evidence has been forthcoming from upland peats in the North West, sites identified have spanned a wide chronological range, from the early Mesolithic period (Simmons and Innes 1987) to at least the medieval period, and many peat sequences have been truncated by medieval and later turf cutting (Hodgkinson *et al* 2000, appendix 5).

1.2.7 In the Central Pennine area, the Mesolithic period is perhaps the best represented, with known monuments ranging from small hunting camps to the large and long-lived gathering places that have been reused time and time again, of the type characterised by Warcock Hill South in West Yorkshire (Radley and Mellars 1964). On the western slopes of the Lake District, extensive prehistoric stone-built settlements and field systems are often partially covered by blanket peats. These are traditionally dated to the Bronze Age, but little absolute dating is available for them, and they could potentially extend into the Iron Age (Quartermaine and Leech forthcoming). Complex enclosed settlements, traditionally dated to the Roman period, are occasionally wholly or partly preserved beneath peat, and even such monuments as the Roman road on High Street (*ibid*) and the Roman fort at Hardknott (Bidwell *et al* 1999) are partially covered by peat.

1.2.8 Evidence has emerged in recent years for post-Roman/early medieval exploitation of an already peat-covered landscape, for instance at Shoulthwaite, where palaeoenvironmental investigation of peats within a hillfort ditch revealed that it was cut (or possibly recut) in the late sixth or early seventh century AD (LUAU 1999). Additionally, palaeoenvironmental analysis at Littlewater basin mire, near Haweswater, has revealed considerable agricultural activity through the second half of the first millennium AD (LUAU 2000). A fence or hedgeline at Seathwaite (Cumbria), preserved beneath peat, has also been dated to the medieval period, cal AD 1301-1442 (535±45 BP, OxA-7751; Wild *et al* 2001, 55).

1.2.9 ***Upland Palaeoecological Resource:*** in contrast to the archaeological remains, the palaeoecology of both lowlands and uplands in north-west England has been extensively studied. Although this research has been geographically more evenly spread across the lowlands, it has been more focused in the uplands: for example, on the upland tarns of the Lake District (Pennington 1964; 1973; 1975; 1991), the Derbyshire Peak District (Tallis and Switzur 1973; 1990), the North York Moors (Simmons *et al* 1989) and Dartmoor (Caseldine and Hatton 1993), although large areas of moorland remain unstudied. In contrast, most lowland raised mires have received some level of palaeoecological study. Although some of this work is not dated, and in many cases the resolution of the work is poor, it does provide a regional picture of vegetational change. The emphasis of this earlier work tended to be centred on studies of vegetation history, climate change, and, in the lowlands, sea-level change, although there has always been considerable interest in changes to vegetation thought to be associated with anthropogenic activity. For example, from the 1940s and 1950s onwards, Winifred Pennington, Donald Walker and Frank Oldfield, amongst others, have interpreted fluctuations in the pollen and sedimentary records as linking with anthropogenic activity, perhaps most notably by associating the decline in the quantities of elm pollen with the arrival of Neolithic culture and the introduction of cereal cultivation (*eg* Pennington 1970; Walker 1965a).

1.2.10 Studies of direct relevance to archaeology are more limited, however, and were often included as short appendices to archaeological reports (*eg* Pennington 1965a; 1973, 235-6; Walker 1949; 1965b; 2001). The growing awareness by both archaeologists and palaeoenvironmentalists of the value of environmental data to enhance the archaeological record has, more recently, led to an increase in the use of biological indicators to inform that record both in the lowlands and the uplands.

1.3 THREATS TO THE UPLAND PEATS

1.3.1 This project was largely prompted by the evident threats to the upland peats, highlighted by the study *Monuments at Risk in England's Wetlands* (MAREW) (van de Noort *et al* 2001). The present threats to the uplands are less well documented and less dramatic than those affecting the lowland mires, where there is widespread and severe destruction of the resource by commercial peat cutting, the creation of landfill sites, road building, and housing schemes. The threats affecting the upland peats are more insidious, but over an extended period are just as detrimental. The interaction of a whole suite of diverse upland threats can often lead to extensive damage, subsequent peat loss, and results in the degradation of archaeological remains, before there is an awareness that they exist. The pressures on upland landscapes have resulted in damaging changes to the wetland environment, and the long-term effect has been highlighted by the

Monuments at Risk Survey (MARS) (Darvill and Fulton 1998), where, in an upland study of Cornwall, 16-20% of the upland landscapes had been lost between 1949 and 1980. The *Monuments at Risk in England's Wetlands* (MAREW) survey suggests that as much as 20% of the upland peats have been subject to severe damage by erosion over the last 50 years (van de Noort *et al* 2001, *Section 6.1*). The situation has reached such a level that there is now an urgent need to redress the decline, before the survival of upland wetlands is damaged to the extent currently experienced in the lowlands.

1.3.2 The uplands have come under pressure from a wide range of environmental and man-made impacts, which include artificial drainage, climate changes, pollution, farming, forestry, recreation, wild fires, peat cutting, and mast and wind farm construction. The individual effects of these threats combine to create a much more significant impact, but the mechanisms of how they interact is both complex and varied; at the outset of the present study, it was not evident as to which had the greatest impact and what was their combined effect. It was recognised that if any management strategy was to be able to redress the decline in the upland peats and the buried archaeological resource, there needed to be an effective understanding of how the threats combine to affect the upland landscapes.

1.4 AIMS OF THE STUDY

1.4.1 The aims and objectives were outlined in a project design (OA North 2003a) and are in accord with the English Heritage *Strategy for Wetlands* (2002), which places considerable emphasis on the management of the wetlands, in conjunction with other wetland management agencies (Natural England and the Environment Agency). The strategy also highlights the need for outreach to raise awareness of the threats, and the value of the wetlands to a wider institutional and public audience. In addition, the strategy recognised the need for further research to quantify the archaeological resource, and identify the '*range of direct and indirect threats*' to the archaeological resource beneath the peat. As a response, this project defined as a priority the need for research into the upland peatlands. The separate aims were as follows:

i) Development of Appropriate Methodologies:

- to develop a suite of field and analytical methodologies by means of a series of studies centred on four areas of upland peatlands, selected to provide a range of contrasting physical, archaeological, and palaeoecological landscapes on which to develop and test methodologies;
- to establish the possibility of creating a predictive model that can be used as a management tool for the nationwide resource.

ii) Threat to Peatland Landscapes:

- to determine the physical extent and survival of upland peats in the selected study areas;
- to establish the extent and likely causes of erosion in these areas;
- to assess the rate of loss and decline of the peatlands in these areas;

- to extend the assessment of peat loss and erosion, by means of a broader desk-based study;
- to identify and quantify the threats impacting on the peatlands within the study areas, and to establish a model that identifies the conditions governing peat loss and decline.

iii) Evaluation of the Archaeological and Palaeoecological Resource:

- to determine the nature, extent, quality, survival and date-range of associated archaeological and palaeoenvironmental evidence within four contrasting study areas;
- to determine the impact of peat-loss on the resource in these areas;
- to gain an understanding of the archaeological process and any human activity in the peat-covered elements of the study areas, with a view to gaining ultimately a broader understanding of human interaction with the physical landscape in the uplands of England at all periods;
- to contribute towards an understanding of the archaeology of upland peats.

iv) Management:

- to develop an academically sustainable suite of predictive models which will facilitate the development of a schedule of economical, efficient, flexible and proactive management.

v) Academic:

- to contribute to an understanding of the development of the upland peats and to an understanding of the anthropogenic activity in the uplands.

vi) Dissemination:

- to publish a review of the project, to inform and enable discussion within the archaeological profession;
- to publish guidance documentation to inform other landscape and environmental management professionals;
- to extend the outreach of the project and disseminate its aims and results to a wider audience.

1.5 OBJECTIVES

1.5.1 ***Development of Methodologies (Aims I and III):*** the principal management aim of this study was to develop a baseline survey and management tool that will be applicable for all upland peat regions in England. The objectives towards this aim were:

- to implement a programme of experimentation in identification and recording techniques of the archaeological resource, and a corresponding experimental approach to palaeoecological field methodologies;

- to assess the potential of a range of palaeoenvironmental strategies to optimise data recovery in disparate and varying terrain and, where desirable, the refinement of old and the development of new approaches to the closer integration of palaeoenvironmental and archaeological data;
- to develop an effective, well-designed, and flexible GIS which will provide an easily accessible presentation of a range of datasets;
- to effect the economic and efficient collection and utilisation of extant written and photographic records to provide an appropriate, reliable, and swiftly assimilated information base for a GIS, intended to provide the potential for predictive modelling;
- to provide systematic absolute dating of significant peat horizons and peat inception in close association with selected monuments, transects, and/or other significant palaeoenvironmental deposits;
- to achieve the integration of the project, where possible and appropriate, with other regional environmental and economic initiatives.

1.5.2 ***Management Objectives (Aims II and IV):*** the detailed management objectives were:

- to assess the nature of the threats to the peatlands, to quantify the impact of the threats on the resource, and to examine what topographical contexts are most threatened;
- to develop an effective, well-designed, and flexible GIS which can provide an easily accessible presentation of a range of datasets. This will facilitate the development of predictive models, intended to inform management decision-making;
- to achieve the integration of the project where possible and appropriate, with other regional environmental and economic initiatives, in order to maximise the added value of the project as a proactive tool in the management and preservation of upland peat;
- to inform the formulation of countryside stewardship schemes within upland contexts, and thereby allow the management of the resource;
- to ensure, wherever realistically achievable, easy compatibility between the proposed GIS and the datasets of agreed curatorial bodies within the region;
- to liaise with national agencies involved in the management and conservation of upland peats.

1.5.3 ***Academic Objectives (Aim V):*** while the academic objectives were not the prime drivers for the project, they represented an underlying premise behind the proposed project, and were:

- to contribute towards an increased understanding of anthropogenic activity at all periods within the uplands;
- to gain an increased understanding and more reliable dating of the inception and development of 'Bronze Age' settlements and field systems

in the uplands of the North West, and to establish if this activity extended back into the Neolithic period;

- to contribute to the study of the Iron Age and early medieval periods in the North West, and to establish if the apparent dearth of activity in the uplands in these periods is perceived or actual;
- to contribute to an understanding of the physical and topographical constraints on human activity throughout prehistory and history in an attempt to determine whether the factors of altitude, aspect, and slope have more than an incidental bearing on the distribution of sites.

1.5.4 ***Publication and Presentation Objectives (Aim VI):*** the objectives of dissemination were fundamental to the project, and are defined as follows:

- ***Academic Publication:*** to provide for the academic dissemination of the results.
- ***Specialist Publication:*** to provide for the dissemination of elements of the project significant to the understanding of particular periods, where possible, via an appropriate national journal. Likewise, significant contributions to the understanding and interpretation of the palaeoenvironmental record will be disseminated, where possible, through the appropriate national journal.
- ***Conference / Seminar:*** to organise a conference or seminar that would present those results and would invite input from specialists working in similar fields throughout the country.
- ***Outreach:*** to provide for targeted public presentation, serving essentially as a management tool, using data and information accrued during the project. To provide a series of lectures to local groups and societies, particularly within each study area, to broaden the outreach of the project.
- ***Digital Outreach:*** to provide some internet dissemination of the GIS or its datasets via the Archaeological Data Service.

1.6 STUDY AREAS

1.6.1 The North West was chosen for this study because it contains the largest amount of upland peat in England, which is of a varied character, and reflects, in one relatively localised area, the range found elsewhere in the country. Four study areas within the North West were selected as being representative of distinct types of upland peat landscapes, on the basis of their topography, land-use, condition and archaeological potential. These comprised the South-West Fells of Cumbria, the Langdale Fells (Cumbria), and the western slopes of the Forest of Bowland, and Anglezarke Moor, both within Lancashire (Fig 1). Three of the areas (South-West Fells, the Langdale Fells and Anglezarke Moor) had previously been subject to detailed survey (*Sections 5.2, 5.3 and 5.5*), involving the mapping of the eroding peat scars in the vicinity of archaeological sites, and as such provided comparative data for assessing the changing condition of the peatlands.

1.6.2 ***South-West Fells, Cumbria***: the study area constituted a transect across the South-West Fells of the Lake District in West Cumbria (Fig 2). It was selected because it is an area with proven archaeology (Quartermaine 1989; Leech 1983), but where peat cover is generally thin and patchy. The general absence of peat has resulted in exceptional site visibility and, allowing for differences in topography, would enable an assessment of archaeological potential of other upland areas of similar aspect where site visibility was restricted by peat cover. By virtue of the limited areas of peat, however, the archaeological resource is vulnerable to external disturbance and environmental change.

1.6.3 The western part of the proposed study area had already been surveyed as part of the English Heritage-funded Lake District National Park Survey (Fig 3), which had revealed an extremely rich archaeological resource (Quartermaine and Leech forthcoming). The archaeological remains represent potentially Bronze Age and multi-period settlement sites and agricultural landscapes (Plate 1) over an area of as much as $40km^2$ in extent. This existing extensive dataset provided a valuable resource on which to base the GIS analysis of archaeological landscapes.

1.6.4 As there was a well-documented archaeological resource, the area provided an ideal location for testing different methodologies for identifying buried archaeological remains. Areas of the study area with a high probability for buried remains were examined using a variety of techniques, to establish which was the most effective and efficient at identifying remains beneath the peat (*Section 4*).

1.6.5 A transect was defined between SD 116 962 and SD 200 936 (Fig 3), which took in significant variations in terrain and altitude, and included areas of known archaeological interest, in particular the large cairnfield and settlement of Barnscar (Plate 1). Although blanket peat coverage was generally thin, the presence of a large number of small basin mires provided the opportunity for detailed examination and comparison between local environmental conditions through time. It also allowed an assessment of how peat loss can affect preservation, by laying monuments open to other forms of damage (*Section 5.2*).

1.6.6 ***Langdale Fells, Cumbria:*** the Langdale Fells study area (Figs 2 and 4) was selected specifically to enable the opportunity to review the impact of visitor pressure upon a peatland resource. The area is subject to considerable numbers of visitors, being in the centre of the Lake District and one of the mountainous areas most easily accessible to the public. The plateau behind the summits of Harrison Stickle and Pike of Stickle has a substantial peatland resource, which overlies extensive Neolithic axe-production workings (Bradley and Edmonds 1993; Edmonds 2004) exploiting the outcropping fine-grained tuff (Group VI). The area was important for the present study because earlier surveys, dating back to 1984 (Claris and Quartermaine 1989), have provided detailed recording of the axe-production workings and the associated peat deposits, including precise mapping and fixed point photographs for all axe-production working sites. Investigation of the area as part of the present study has provided a direct comparison between the condition of the peatlands in 1985 and 2004, and the discovery of new working sites can be shown to be all from areas of recent erosion. The area has also been subject to intense grazing pressure (Quartermaine 1994). It has thus provided a comparator for other areas of peatland which have high levels of similar pressures.

1.6.7 A transect was defined (Fig 4) extending north from the Langdale Pikes (NY 276 073), the principal source of Group VI tuff, to north of High Raise (NY 278 104). The study area extended across an expanse of peatlands which covered a number of axe workings that were remote from the principal areas of geological outcrop and has linked them into a study of the development of the peats across this area.

1.6.8 ***Forest of Bowland, north Lancashire***: the Forest of Bowland is designated as an Area of Outstanding Natural Beauty (AONB), and was selected as it was perceived to have extensive tracts of largely undisturbed peat. Within the area (Figs 1 and 5), the peatlands are actively managed for the preservation of the vegetation cover in pursuance of the needs of other industries, such as water catchment, moorland management, and game shooting. Within this project, it was considered that there was a need to have an area of 'control', which was seemingly not eroded or subject to immediate threat, that could provide an appropriate comparator to other study areas where the threats to the reserve were well documented. In the event, it was discovered that the area had been subject to repeated episodes of fire, which had resulted in substantial peat loss on the western slopes, within the study area designated for this project (*Section 5.4.2)*.

1.6.9 An archaeological survey had previously been undertaken of the United Utilities holdings in Bowland (Fig 5), which extended across the southern and eastern parts of the AONB (LUAU 1997). This did not directly overlap with the study area, but provided comparative information for the general locale. The study area had benefited from a recent palaeoecological examination at Fairsnape Fell, on the western slopes of the Forest, which had demonstrated vegetation change in later prehistory and in the historical period (Mackay and Tallis 1994).

1.6.10 A transect was defined from the eastern edge of the North West Wetlands Survey (NWWS) study area (Middleton *et al* 1995), at the Lancaster Canal near Cabus (SD 485 485), via Nicky Nook, to White Moss (Grizedale Fell; SD 575 505), at the western edge of the survey area for the United Utilities survey (LUAU 1997). It examined the archaeological resource within the area and the development of the peats.

1.6.11 ***Anglezarke Moor, south Lancashire***: the extensive Anglezarke Moor was chosen as a study area (Figs 1 and 6) as it encompasses both an area of actively eroding peat, with a moderately to relatively well-known archaeological resource, and has seen relatively recent palaeoecological research on the modern vegetational cover (Howard-Davis 1996). Anglezarke Moor (Fig 6) is a relatively low-lying and gently-sloping moorland (maximum altitude 390m AOD). Extensive survey in the 1980s (*ibid*) has established the potential for the discovery of significant archaeological monuments preserved beneath the peat, as well as demonstrating a significant amount of activity post-dating peat onset, in the form of stone structures within and upon the peat. The survey established a rich archaeological record from as far back as the early Mesolithic period, with evidence for Neolithic ceremonial monuments, Bronze Age landscapes, and a considerable amount of built evidence for post-medieval farming practice and industrial extraction (*ibid*).

1.6.12 The area has suffered from a number of natural and man-made episodes of erosion in the last quarter-century. Particular events include widespread peat fires, heavy recreational use as a direct result of its proximity to the major urban conurbations of Bolton and Manchester, and the likelihood of arrested peat development as a result of atmospheric pollution. The principal reason for selecting this area was to provide a direct comparator between this and less disturbed moorlands (such as the Forest of Bowland), and those parts of Anglezarke Moor that have less erosion. As this is an area of seemingly ongoing severe peat erosion, the detailed survey in the 1980s (Howard-Davis 1996) allowed an assessment of the impact of peat erosion upon the resource over the last 20 years, by comparing the present-day condition with the records of the earlier survey. At the same time, palaeoecological investigations have been able to establish the degree and extent of truncation, by comparing cores across the moor. A combination of these techniques has allowed an assessment of the level of threat posed to the peat-covered archaeological resource.

1.6.13 A transect was defined from the western edge of Stronstrey Bank, which marks the western edge of Anglezarke Moor (SD 619185) via Round Loaf and Black Hill to the Belmont Road and Reservoir (SD 666185). It examined the archaeological resource within the area and the development of the peats.

1.7 STRUCTURE OF THE REPORT

1.7.1 This report presents the results of the study into the upland peats in north-west England, but its results can be applied to all upland peats in the country. A principal concern of the study was to establish to what extent the peatland landscapes are under threat, and by what agencies. A major study of the threats was undertaken, and the results serve as the starting point for the rest of the investigation. The results of the assessment of the threats are therefore presented in *Section 2*.

1.7.2 *Section 3* assesses the datasets available for the upland peats of north-west England and how useful these sources were to define their extent, to provide an assessment of their erosion, and to define the archaeological resource. In addition, the existing palaeobotanical datasets were examined, which are key to gaining an understanding of the development and condition of the peats.

1.7.3 A major element of the study was to explore different techniques that may be used to identify archaeology underlying the peat. A broad range of approaches, from simple fieldwalking to ground probing and geophysical surveys, was explored. The techniques were assessed for their effectiveness and efficiency, and the results are presented in *Section 4*.

1.7.4 A key element of the project was a programme of intensive fieldwork within the four study areas, to assess the archaeology and the palaeoenvironmental character of the peatlands. The results of this are presented in a series of appendices (*Volume 2*), as they provide a valuable resource in their own right, but a summary of the case studies is presented in *Section 5* within this volume.

1.7.5 *Section 6* examines the condition of the peats within the four study areas, including evidence for truncation. It examines the range of dates for peat inception, and also the relationship between the identified archaeological resource and the peatlands.

1.7.6 *Section 7* examines the overall results of the programme and highlights the archaeological potential contained beneath within the peats of the uplands.

1.7.7 The results of the fieldwork and documentary study have been incorporated into a GIS, and a programme of analysis has been undertaken to examine the efficacy of using this technique to predict the extent of peat, peat depths, the areas of greatest potential for the existence of archaeology, and the areas of predicted ongoing threat. The results of this analysis are presented in *Section 8*.

1.7.8 The ultimate result of the programme is a series of recommendations for the ongoing management of the peatlands and the underlying archaeological resource. These highlight the need for inter-agency cooperation, particularly between DEFRA and Natural England, to ensure that policies on land management, sensitive to the needs of the peatlands, are introduced. These recommendations are presented in *Section 9*.

2. PEAT LOSS AND THREATS

2.1 INTRODUCTION

2.1.1 The ultimate aim of the project is to establish a mechanism for the control and reduction of the threats that are acting upon the upland archaeological resource preserved by the peatlands. Given that the peat both obscures and protects archaeology, the fate of this archaeology and the peat are intimately linked, and any threat to the peat will ultimately affect the archaeology. It is therefore essential to establish the extent and nature of the present-day threats to the peat, so that appropriate, efficient and targeted management regimes can be established, to minimise the effects of the erosion and so enable the recovery of the protective peats. The results of an assessment of all the perceived threats to the upland peats has examined historical impacts, alongside the present-day impact, and has investigated the extent to which the various erosive factors combine to cause damage to the peat.

2.2 EXTENT OF PEAT LOSS FROM UPLAND ENVIRONMENTS

2.2.1 ***Introduction:*** a key factor in determining management solutions to the perceived threat to the upland peat is the establishment of the scale of the problem. This can be approached at the level of erosion in the uplands in general, but specifically by examining the erosion of upland peats. The problem of erosion was examined at a general level by the *Monuments at Risk Survey* (MARS), which highlighted numerous threats to the upland landscapes in the period between 1949 and 1980 (Darvill and Fulton 1998). This suggested that upland grasslands had diminished from 10% of the land surface of the country to 7.4%, with the presumption that between 1980 and the beginning of the twenty-first century it has been further reduced. Looking specifically at the threat to the peat, the extent of peat erosion can be derived from several sources:

- direct measurements of particular erosion processes at specific sites (*eg* Francis 1990);
- morphological surveys of landforms assuming an initial surface or form, or even a dated horizon (McHugh *et al* 2002);
- measurements of catchment sediment yields at gauging sites on rivers (Evans and Warburton 2005);
- the reconstruction of erosion rates from sediment storage sites, typically involving lake or reservoir stores (Yeloff *et al* 2005).

2.2.2 What is often lacking in these approaches is an attempt to provide a national picture of peat loss. Tallis *et al* (1997) tried to produce a countrywide synthesis of research into peatland degradation, and although much site-specific information on factors controlling erosion and measured local rates of degradation were documented, no reliable overall estimate of the extent of degradation of blanket mires was given. The authors did, however, suggest that there is evidence to indicate that this degradation was most severe in Ireland. Foss and O'Connell (1996) estimate that in Ireland only 18% of the peat resource is of 'conservation value', 46% has been cut-over, 27% has been afforested, and 14% is over-grazed. In Scotland, approximately 60% of the resource exists in an 'active' state, but there is considerable variation in the degree of degradation across the country. In Wales, only about 27% of the intact blanket mire peatland remains (Tallis *et al* 1997). Estimates of degradation of blanket mires in England, until recently, were not made in a systematic fashion. Results from the *Peak District Moorland Erosion Study* suggest that some 8% of the total peat-covered landscape is now bare, and that peat is being eroded locally at up to 30mm per year. Gully erosion is widespread, and affecting 74% of the peat blanket (Phillips *et al* 1981).

2.2.3 Estimating the total amount of peat loss from the UK uplands is hard to define for four main reasons:

- the timescale over which erosion has taken place is difficult to establish with certainty (Tallis 1997a);
- a representative baseline survey of erosion does not exist, and only fragmentary small-scale catchment studies have been reported (Warburton *et al* 2003a; Evans and Warburton 2005);
- the extent of peat, and hence the extent of loss, are subject to debate (Tallis *et al* 1997);
- rates of peat erosion are spatially and temporally highly variable (Labadz *et al* 1991; Butcher *et al* 1993).

2.2.4 More recently, Harrod *et al* (2000) and McHugh *et al* (2002) have reported on a MAFF-sponsored research project, on the 'quantification and causes of upland erosion', which attempted to quantify upland erosion in England and Wales. This arose out of recommendations from the Royal Commission on Environmental Pollution (1996), which reported on the sustainable use of soil, and identified upland soils, and peat in particular, as susceptible to accelerated soil erosion. The aim of the MAFF survey was to provide a robust and objective assessment of erosion from 399 upland sites in England and Wales. The survey suggested that 24,566ha were affected by erosion (0.284km^3 erosion volume) in upland England and Wales, the vast majority of which (73%), was thought to result from water erosion. Short-term erosion measurements between 1997 and 1999 indicated an expansion of the area of erosion by 518ha. Within the survey, peat soils were most severely affected by erosion (Fig 7) but the response varied nationally, with some areas of upland peat continuing to erode, whilst other regions were revegetating. It was concluded that erosion was most extensive on peat soils, in comparison to dry, wet mineral, or wet peaty mineral soils, and the higher incidence of erosion at high altitudes, and at low slope angles, reinforced the relationship between erosion and peat areas (McHugh *et al* 2002). The significance of peat soils as the most sensitive soil type to erosion is emphasised in the erosion classification survey undertaken by Grieve *et al* (1995) in upland Scotland. In this survey, 12% of the upland area sampled (20% of the Scottish uplands) was subject to some form of erosion. Half of this erosion was attributed to the degradation of peat soils.

2.2.5 The paper by McHugh *et al* (2002) on the extent of soil erosion in upland England and Wales appears to represent an important contribution to the debate. It provided a comprehensive field survey of upland soil degradation, and complements the work in Scotland (Grieve *et al* 1995). Under close scrutiny, however, the paper has several important limitations, which should be considered when evaluating the significance of the results contained in the research. The main limitations focus on an inadequate definition of the field survey methods, a lack of appreciation of the geomorphological context of the survey plots within the larger sediment system, and no linking of erosion loss to timescale. Such extensive surveys must stand up to detailed scrutiny, because they are often attractive to policy makers. If the assumptions of the methods are not rigorously justified, the outcomes are dangerous and often very costly, because inappropriate erosion management strategies may be implemented. Warburton *et al* (2003a) have criticised the methodology used in the McHugh *et al* (2002) study, and suggested that the values quoted may not represent a true picture of erosion nationwide.

2.2.6 What does appear to be evident is that peat erosion varies considerably over time. There appear to have been several discernible periods of peat erosion in the past, often associated with gullying and the transition to drier, drained moorland conditions. Tallis (1997a) identifies the period between AD 1050 and AD 1200, as a time when there was considerable blanket mire degradation in the southern Pennines. This was accompanied by periods of gully erosion in the Medieval Warm Period (and more recently, 200-250 years ago). Elsewhere, similar estimates for the onset of peat erosion have been documented. Stevenson *et al* (1990), working in Galloway in south-west Scotland, showed that peat erosion was initiated between AD 1500 and AD 1700, well before the recent episodes of acid deposition on the blanket peatlands. A range of possible explanations for the onset of this erosion has been proposed, including wetter/drier climate, atmospheric pollution, over-grazing, and fire.

2.2.7 There is also considerable qualitative evidence indicating that peat erosion at many UK upland sites is not as severe at present as it was a few decades ago. Evans and Warburton (2005) demonstrate this quantitatively for a small catchment in the northern Pennines. There, they compared contemporary measurements with previous estimates of erosion (Crisp 1966), and demonstrated a three-fold reduction in sediment loss from the catchment. Similar patterns can be found in the Cheviot Hills (Wishart and Warburton 2001), and parts of the Peak District (Clement 2005). Yeloff *et al* (2005) present an interesting temporal record of upland peat erosion from March Haigh reservoir in the south Pennines. The results, based on reservoir sedimentation of organic sediment from peat erosion, suggest low catchment erosion rates between 1838 and 1963, with blanket peat erosion increasing significantly after 1963, and peaking between 1976 and 1984. Although the overall peat delivery to the reservoir is generally low by south Pennine standards (Labadz *et al* 1991), the pattern of sedimentation is in accord with general patterns of peat erosion in the area (Tallis *et al* 1997).

2.2.8 The *Monuments at Risk in England's Wetlands Project* (MAREW) interrogated the Sites and Monuments Records (SMR) for three upland areas on Dartmoor, the northern Pennines, and the south Pennines, utilising an additional unpublished survey by Daryl Garton (van de Noort *et al* 2002). The study also looked at the extent of the erosion recorded on aerial photographs between 1953 and 1988. This showed that, between 1953 and 1968, 30% of the peat resource in the study area had actively eroded, although this slowed down in the period to 1988, and thus accords with the other findings (*Sections 2.2.4-7*). The MAREW report put forward no explanation for the high level of erosion, or for the slow down. The active erosion before 1968 might, however, be correlated with a general increase in the number of fires recorded in the UK between 1954 and 1976, which Maltby *et al* (1990) noted. Conversely, the slowdown may have been related both to a reduction in the number of fires, and in reduced industrial activity, and a move towards cleaner domestic fuels. Both of these would have led to a reduction in the level of pollution and perhaps some recovery in the growth of *Sphagnum* spp (bog mosses). Central heating also began to be more commonplace in the 1970s and 1980s, and perhaps small-scale peat cutting for domestic consumption was less prevalent. The late 1960s and early 1970s were also the period when ecological conservation began to have an impact on the population in general, and so perhaps alerted the public to the fragility of the upland peat resource. The MAREW report also calculated that, over the last 50 years, peat erosion in the uplands caused the loss of 360 monuments. This figure was based on a 20% erosion of 150,000ha of upland peat, but must be treated with caution, as these figures are based on the assessment of only three areas, and large areas remained unstudied.

2.2.9 ***Conclusion:*** estimates of the total value of peat loss from the UK uplands is of limited value in assessing threats to the peat, unless the timeframe for this loss, the significance of this in terms of the overall peat store, and the ability of the peat to regenerate are known. Rates of peat loss vary considerably. For example, a rapidly eroding gully incising an intact blanket peat may be juxtaposed with an area of boggy moorland, which has a net accumulation of organic material. Making the link between gullying and the larger-scale stability of the blanket peat is an important consideration in terms of what are the key processes that destabilise blanket peat as a whole. The only way of adequately understanding this question is by placing known or measured erosion rates in the context of the upland ecosystem as a whole. Despite the difficulties in determining the accurate assessment of peat loss from the uplands, it is clear that peat erosion is a dynamic process which responds extremely rapidly to changing environmental conditions. The pattern of erosion varies regionally across the UK, so cannot be easily characterised by a fixed rate through time. A better understanding of the erosional dynamics of individual regional peatland systems, defined by their topography, hydrology and vegetation make-up, is required.

2.3 HISTORICAL PEAT LOSS

2.3.1 No single agency is responsible for peat loss, and it is evident that there are several agencies which are currently affecting modern loss (*Sections 2.4-12*). An exact figure for the extent of past loss, though, is impossible to measure, as documentary records are in general patchy, and often unavailable. The results of a recent England-wide survey of 400 areas of upland sites, however, found that 43% of them were eroded, and of these, 85% (156 sites) were actively eroding (Simmons 2003, 226). Upland peat accounted for 60% of the eroded areas, and 6% were stagnopodzols, which can have a high moisture and organic content. Although there are few actual measurements of how much has, and is, being eroded, in areas of peaty moorland in the southern Pennines, the organic fraction of erosion has been measured in the run-off, and over the two years where this was studied, the yield was 55 t km^{-2} yr^{-1} (Labadz *et al* 1991). The percentage of eroded blanket mire varies in different parts of the British Isles, with 87% of the

Peak District blanket mire being eroded, whereas in the Cheviot Hills, only 37% has been recorded as such (Wishart and Warburton 2001).

2.3.2 Simmons (2003, 226) considers that the initial cause of all erosion in the uplands is anthropogenic land-use and management, although periods of past climatic change, such as the climatic deterioration of the Little Ice Age (*c* AD 1500-1850) should not be overlooked (*op cit*, 232). Tallis *et al* (1997) suggest that there is a lack of evidence to indicate that gullying occurs if the surface vegetation remains intact. There is evidence of increased erosion in the sedimentary sequences of small lakes in Scotland between AD 1530 and AD 1690, which suggests that climatic change was an important factor (Stevenson *et al* 1990), although it should be noted that charcoal levels in blanket mire peat have also increased in the last 500-700 years (Tallis and Livett 1994). Alternatively, Tallis (1999) suggests that the Medieval Warm Period (*c* AD 1050-1200) may have brought about the desiccation of the blanket peat, which was the trigger for the initial gully formation (Tallis 1999; Wishart and Warburton 2001).

2.3.3 Simmons (*op cit*) considers that vegetation has often developed in areas of earlier erosion, which Tallis (1987) thinks have often been active for at least four or five centuries. At Holme Moss, in the southern Pennines, clearance in the eleventh century brought about the formation of the main drainage gullies (Tallis *op cit*; Simmons *op cit*), and other gullies probably originated after a severe fire in the late eighteenth century.

2.3.4 Perhaps one of the agencies that has brought about the most extensive loss in the past is peat cutting (see *Section 2.11*). This ranged from small cuttings for domestic fuel, to the large-scale removal of peat for fuel for industrial purposes, such as the smelting of lead, iron and copper, in the North, at any rate. As a consequence, there are likely to be very few areas in the uplands where the peat has remained intact (J Huntley *pers comm*).

2.3.5 Earlier periods of peat instability in the uplands have also been recorded in the palaeoenvironmental records, most notably at Featherbed Moss, in the southern Pennines (Fig 8). There, it is thought that, 1000-1200 years ago, a series of slides from the margins of the mire may have initiated drainage channels (Tallis 1985a; *Section 2.4*).

2.3.6 Several documentary records relate to catastrophic events in the lowlands of the British Isles, associated with severe climatic episodes during the centuries within the 'Little Ice Age' (*eg* Hodgkinson *et al* 2000, 121). A number of these came from the north-west of England, the earliest being the eruption of Chat Moss, in Greater Manchester, reported by Leland in 1533 (Crofton 1902, 142-4; Hall *et al* 1995, 23, 125). Earl Cowper, from Derbyshire, describes a further example in Greater Manchester from 1633, when White Moss erupted after bad storms (*ibid*). This type of event was not confined solely to Greater Manchester, and examples are recorded in 1771 at Solway Moss, Cumbria (Pennant 1774; McEwan and Wither 1989; Hodgkinson *et al* 2000, 121), and in 1744/5 at Pilling Moss, Lancashire (Sobee 1953, 153).

2.3.7 The uplands have not escaped from such events, although in this context they are described as peat slides rather than eruptions. On Holme Moss, in the southern Pennines, Tallis (1987) has identified areas of peat slides which are probably associated with a reported cloud burst in 1777 (*Section 2.10.4*). Again, in 1834, two gamekeepers witnessed a severe storm at Glossop in Derbyshire, and described how peat was thrown up into the air for some distance (Anderson *et al* 1998, 41; Simmons 2003, 232-3). In the Pennines at Meldon Hill, North Yorkshire, a peat slide was recorded in 1870 (Crisp *et al* 1964), and in 1963 this was the site of two further slides, together with one nearby, on Stainmore Common (near Iron Band), following a period of heavy rain.

2.3.8 Peat instability, as manifested by peat slides, has also been recorded beyond the North West. Wishart and Warburton (2001) state that although there are no specific studies of peat erosion prior to the one undertaken by them, there are frequent references to it in the general literature about the Cheviot Hills. The authors cite references by Dixon (1903), Clough (1888), and Muschamp-Perry (1893) of peat slides in the late nineteenth century near Bloodybush Edge, and by Clough (1888) at Caplestone Fell. Peat slides, like the eruptions of the lowland mires, although causing severe localised peat loss, are generally relatively infrequent.

2.4 DRAINAGE

2.4.1 ***Natural versus artificial drainage of upland peat:*** upland peatlands are dissected by complex patterns of drainage. These include a continuum of drainage forms, from natural dissection patterns, found in pristine peatlands, to artificial drainage networks deliberately cut into the peat. This dissection is often associated with differing erosion processes and degrees of degradation of the peat. Research concerning this issue has been carried out in many upland areas of the UK (*eg* Bower 1960a; Tomlinson 1981; Francis 1990; Stevenson *et al* 1990; Birnie 1993; Grieve *et al* 1995; Tallis 1997a; 1998), and, in 1997, the British Ecological Society organised a conference specifically to examine the 'causes, consequences and challenges' associated with blanket mire degradation (Tallis *et al* 1997). Detailed studies of peat erosion processes in the UK are, however, still relatively sparse, and with a few exceptions (*eg* Mosley 1972; Tallis 1985a) much of the geomorphic analysis relies on descriptive frameworks established in the 1960s (Bower 1959; 1960a; 1960b; 1961; 1962). Peat erosion creates a range of features characteristic of the degradation of blanket mires, and classification of such features has formed the basis of the most influential contributions to the discussion (Bower 1960a). Working in the Pennines, Bower identified five main types of erosion system (1959; 1960a; 1960b) on the basis of morphology and pattern, which were considered to result from the operation of the two main processes of water erosion and mass movements. Water erosion produces dissection systems, which developed onto and into the peat mass. This can lead to sheet erosion on the peat surface as vegetation breaks up, and erosion along marginal faces at the edge of the peat mass, where, once thinned at a break of slope, peat erodes back to form a steeply inclined peat face. On steeper slopes, mass movements may result, and, under very wet conditions, bog bursts and peat slides can occur. Also, in peat overlying drift-covered limestone, sinkholes often develop, producing erosion.

2.4.2 Dissection of the peat by drainage was considered by Bower (1960a) to be the most important erosive process, both spatially and in terms of volume of peat removed. Bower defined two types of dissection system associated with water erosion, which differ in the pattern of gullying produced, classified as Type 1 and Type 2 (Fig 8). Both these processes form from one of three mechanisms:

- within the peat mass, originating along horizontal or vertical lines of seepage;
- as runnels on the surface, encouraged by the destruction of vegetation;
- or by headward erosion of gullies from the margin of the peat.

2.4.3 Type 1 dissection occurs in peat of 1.5–2m depth on slopes of less than 5°. Gullies advance headward, and expand laterally, and rapidly incise to the peat base. Gully frequency is high, and these tend to branch and intersect; ultimately, the peat mass is reduced to a large number of peat islands. Where lateral erosion continues, but vertical erosion ceases, expanses of bare peat are produced. Type 2 dissection occurs on slopes exceeding 5°. The pattern is more extensive than that resultant from Type 1, but the gullies are more open, individual gullies rarely branch, and the pattern varies with the angle of slope. Steep slopes have linear gullies, whereas shallower slopes tend to have more meandering gullies, and the frequency is highest on the most exposed summits. These processes have operated with varying intensity since peat first formed, but evidence suggests that they have intensified in recent millennia (Aaby 1976; Tallis and Switzur 1973; Tallis 1985b; Higgitt *et al* 2001).

2.4.4 Bower's (1960a) classification scheme has been widely employed in the literature of blanket mire degradation. Tallis (1985b) remarked that peat erosion in the southern Pennines, studied during the 1981 *Peak District Moorland Erosion Study*, conformed well to Bowers scheme (1960a; 1960b). Others, however, have criticised this and suggested modifications to the scheme (Radley 1962; Barnes 1963; Mosley 1972; Wishart and Warburton 2001). Mosley (1972) stresses that there is an overlap between Type 1 and Type 2 dissection systems. Tomlinson (1981) drew attention to two other types of water erosion systems, anastomosing channels and parallel/sub-parallel gullies. Tomlinson (*ibid*) further added that gullies might owe their origin to the collapse of pipes within the peat.

2.4.5 Upland peat will always be subjected to dissection by fluvial processes, but more especially such processes can be detrimental to the long-term stability of the peatland if:

1) human action enhances the efficiency of fluvial processes by accelerating run-off through changes to mire vegetation and/or over-grazing by stock (Fig 9; Anderson and Tallis 1981);

2) artificial drainage is created, thus substantially altering the typology of the upland drainage network and related hydrological connectivity and hydraulic conditions.

2.4.6 ***Exploring the myth – upland peat drainage:*** understanding the drainage of upland peat is arguably the key to understanding peat loss, and requires an appreciation of peat hydrology. Peat is the partially decayed organic remains of plants accumulated under saturated conditions, and occurs where there is a surplus water balance. In its natural state, it can contain 88-97% water by volume, 2-10% dry matter, and 1-7% gas (Ivanov 1981; Hobbs 1986). Peat is therefore very sensitive to the hydrological balance, and alteration in the water table can have an important bearing on its stability. According to Clymo (1992), drainage ditches have three main effects on peatlands:

- they change the hydraulic behaviour of the peat;
- they increase the depth of the acrotelm, which increases the depth of aerobic decay;
- they alter the chemistry of run-off.

2.4.7 In addition, drainage dissection is the dominant process determining rates of erosion and sediment delivery in upland peatlands (Evans and Warburton 2005). For example, in the Rough Sike peat catchment in the north Pennines (*ibid*), fluvial-borne sediment, under contemporary conditions, is controlled to a large degree by channel processes (Fig 10). Although gully erosion rates are high in the context of British upland environments, poor connectivity between the slopes and the channels minimises the role of hillslope processes in generating sediment build-up. Notably bare areas of flat peats, which are conventionally thought to be the areas most susceptible to erosion, contribute little to the overall sediment deposition (Fig 10). Comparison with historical field data (Crisp 1966) suggests that current sediment transport rates of 44 t km^{-2} a^{-1} represent a 60% reduction in fluvial-suspended sediment yield from Rough Sike over the last 40 years. This correlates with photographic evidence of significant revegetation on the Moor House Reserve over this period (Plate 2). Together with the indication from the sediment budget that there is little connectivity between the slopes and the channels (Fig 10), the observed revegetation suggests a mechanism for the reduction in overall sediment deposition. Changes in the sediment budget over several decades have been associated with modifications in run-off and the connectivity of different landscape units (Heathwaite 1993) through changes in sediment delivery. Extensive revegetation of the gully floors has led to a greatly reduced sediment supply, and strongly suggests that the reduced sediment yields are a function of increased sediment storage at the slope-channel interface, associated with revegetation (Fig 9). Although this is a 'natural' drainage network, the sediment dynamics will be similar to artificial drainage networks.

2.4.8 Although the practice had been established as early as the mid-eighteenth century, the excavation of artificial drainage schemes increased in the 1940s, and most of the upland drainage of blanket peat in the UK occurred in the 1960s and 1970s, as a result of agricultural expansion (Holden *et al* 2004). The purpose was to lower the water table, removing surface water, and thus improve moorland for grazing and game. This practice generally involved the excavation of steep-sided open ditches (known as grips in northern England). The ditches are often arranged in a herring-bone or parallel strip pattern, and are cut at intervals of 10-30m, to a depth of 0.4-0.5m (Fig 11). This method was used to drain approximately 1.5 million hectares of blanket peat in upland Britain (Stewart and Lance 1991). For example, in the Yorkshire Dales National Park, approximately 60% of peat moorland has been subjected to machine-cut ditching (Backshall *et al* 2001). The effectiveness of such schemes, however, has never been properly assessed, and hydrological studies of these drainage networks have yielded conflicting results (Holden *et al* 2004). It is now evident that the effectiveness of upland drainage depends on the design of the ditch network, its position in the larger catchment, and the particular properties of peat at a particular site.

2.4.9 In addition to drainage ditches, many upland peat areas have also been cut-over for peat extraction, and several natural drainage networks have been modified by peat cutting activities (Ardron 1999a). Such features channel water run-off, and may in themselves develop into larger gully features, thus accelerating erosion.

2.4.10 ***Secondary impacts of artificial drainage of upland peat:*** drainage of upland peat can be deliberate through the cutting of drainage channels (*eg* grips), but can also result from other actions, associated with peat extraction, changing land-use and surface engineering. Drainage will locally lower the water table because of the very low hydraulic conductivity of catotelm peat (which is below the water table, where oxygen levels are low, there is little decomposition, and where the peat accumulates slowly). This will be most pronounced in summer, but the impact is highly localised, only affecting 1m or so on either side of the drainage ditch. The influence can become greater, however, as the hydrological impact extends laterally (Ingram 1992). In addition to the direct impact of cutting, there can be considerable peat loss due to changes in run-off and the water chemistry downstream.

2.4.11 Drainage also affects the surface chemistry of peat, which can impact on the composition of local species and the water quality of the run-off. Lowering the water table will tend to aerate the peat, which affects microbial decomposition rates. Aerobic decomposition occurs at a rate which is approximately two orders of magnitude faster than anaerobic decomposition (Clymo 1992), and is often associated with enhanced mineralisation of nutrients and therefore a greater release. These changes impact on the water chemistry, resulting in short-term changes to the solute concentrations. The chemical changes are closely coupled with the physical changes in the grip system, hence the run-off is altered, not only in terms of its magnitude and timing, but also of its water chemistry and sediment loading.

2.4.12 ***Irreversible impacts of the drainage of upland peat:*** the drying out of catotelm peat often results in irreversible changes in the physical character of the soil, through shrinkage. Drier circumstances lead to aerobic conditions and accelerated decomposition, which results in greater compaction of the peat and a decline in permeability (Heathwaite 1993). Compression, shrinkage, wastage and subsidence further add to the degradation of the surface.

2.4.13 If left unchecked, accelerated upland erosion, through fluvial dissection and sub-aerial processes, may result in the complete removal of the peat blanket. Relatively small, 0.5m wide, ditches have been observed to widen for up to several metres (Mayfield and Pearson 1972). Once such widening has occurred, and the hydrological integrity of the peatland is destroyed, it is impossible to re-establish the peat blanket naturally under contemporary conditions (Lindsay and Immirzi 1996). Interestingly, where drainage networks have not been maintained, natural processes, such as bank failures and local sedimentation, often result in natural revegetation of drainage ditches (Fisher *et al* 1996). The impeding of the drainage at key points in the network is sufficient to impact on large areas of drainage. In the right circumstances, a deliberate lack of maintenance can result in the stabilisation of upland peatlands if climate conditions permit.

2.4.14 ***Reversible changes:*** more recently, conservation and restoration measures have been proposed to reverse the detrimental effects of upland drainage. The key to such measures is re-establishing the water table, and encouraging the regrowth of *Sphagnum* and other important peat–forming species (Bragg 1995; Holden *et al* 2004). This can be achieved through a water management strategy, normally directed at blocking previously cut drainage ditches. The objectives of grip blocking are predominantly to restore natural drainage, promote revegetation of the mire surface, and to reduce erosion and minimise effects downstream (Backshall *et al* 2001).

2.4.15 These objectives are achieved through the blocking of eroded and actively eroding grips, and allowing grips to infill and block naturally. There is an array of methods suitable for this purpose, including the insertion of a peat plug with the surface vegetation intact, insertion of heather bales, and blockage with other materials (*eg* boards, piles and fabrics (Brooks and Stoneman 1997)). Where grips have become heavily eroded into gullies, larger reinforced dams may need to be built. The frequency of dams is determined by the slope and drainage condition, although average spacing is often 10-20m.

2.4.16 ***Importance within the overall upland peat system:*** in the closing chapter of their book on *Peatlands*, Moore and Bellamy (1974, 207) highlight the main threats to peatlands in the UK as 'drainage for agriculture and forestry, and eutrophication. These activities, together with peat extraction for fuel and horticulture, are bringing about rapid destruction of peatland sites'. Thirty years later, we now have a greater appreciation of the impact of these activities, and much has been done to alleviate their effects. It should not be forgotten, however, that the fundamental control governing the status of a particular peatland is the hydrological balance, and that drainage impacts on this balance directly (Charman 2002).

2.5 CLIMATE

2.5.1 ***Brief context – peat in equilibrium (peat formation):*** for upland peat to form, the climatic conditions must be cool and wet. Goode and Ratcliffe (1977) suggest that a minimum of 160 days with 1mm or more of precipitation, and the correct topographical and evaporation conditions, are the key to the formation of an ombrotrophic (rain-fed) mire (Lindsay 1995). Moore and Bellamy (1974) describe this as a simple hydrological template:

INFLOW = OUTFLOW + RETENTION.

2.5.2 Peat is the medium governing the 'retention'. If there is any change in the composition of the peat this is altered, disrupting the water balance, and as a consequence something in the overall peatland system must readjust. In response to a shift in climate to greater oceanicity, the accumulation of peat in the uplands began in Britain in the period 5500-3000 BC, and may also have been initiated at other dates in response to more localised woodland clearance and prehistoric land disturbance (Simmons 2004). Long-term estimates of the rate of peat accumulation vary from 0.1mm to 1.2mm yr^{-1} dependent on local conditions (Tallis 1995). At the present time, active peat development is therefore confined to the wettest parts of Britain, and elsewhere peat is not in equilibrium with current conditions, and is in a fragile and sensitive state, which may not recover when disturbed (Bragg and Tallis 2001; Ellis and Tallis 2001).

2.5.3 The stability of areas of upland peat depends on the balance between accumulation and erosion, as both processes are primarily climatically (hydrologically) driven. In a survey of upland soil erosion in England and Wales, McHugh *et al* (2002) attempted to quantify the extent of erosion and the main causes. Their research suggested that, of the 400 sample sites visited, 43% were eroded, and of these eroded sites, 60% were on peat soils (Harrod *et al* 2000). Although the methodology of this survey has been criticised (Warburton *et al* 2003a), the general results are not surprising, as the susceptibility of peat soils to erosion has been established previously (Labadz *et al* 1991). The susceptibility of peat soils to erosion is wholly predictable from their physical characteristics, and the nature of upland peatland systems. In particular, the unconsolidated nature of peat, and its high water content, makes it vulnerable to disaggregation as a result of rainfall, frost and direct run-off. Once disaggregated, peat sediment may become desiccated, and be removed by wind erosion. This is accentuated by the low density of the material, which results in highly efficient transport in wind and water, with little chance of redeposition. Furthermore, peat is very sensitive to direct mechanical breakdown by livestock, humans or vehicular traffic, often resulting in erosion scars that cannot be repaired. Peatland degradation is often characterised by:

- a reduction in species diversity;
- a reduction in the cover of *Sphagnum* species compared to the past;
- an increase in the area of discontinuous plant cover;
- a reduction in the rate of peat accumulation (Simmons 2004).

Historical changes can clearly be seen, for instance, in the Burnt Hill gully system at the Moor House National Nature Reserve in the north Pennines, between 1958 and 1998 (Plate 2). This indicates regeneration of much of the previously eroded peat blanket, and raises important questions about the balance between agents of erosion (*eg* grazing pressures), and natural environmental change. It is partly in this context that the debate over the impact of sheep on upland environments has been hampered (*Section 2.7.7*), through a shortage of quantitative information on the effects of grazing regarding the initiation and acceleration of erosion (Shimwell 1974; Shaw *et al* 1996).

2.5.4 In terms of erosion, site sediment yields are typically low where the vegetation cover is intact (regardless of type) as the sediment cannot easily be entrained and is therefore resistant to water erosion (Fig 10). Changing vegetation type has an important influence on the scale of run-off, and the routing of the surface run-off into concentrated flow paths will inevitably result in local erosion, causing incision and gully development. Where the surface cover is disturbed directly by the impact of rain, often in conjunction with wind, there can be high sediment yields resulting (Labadz *et al* 1991).

2.5.5 ***Erosion of upland peat - the key processes:*** the processes by which the erosion of peat in the uplands takes place can be characterised into two main groups:

1) catastrophic erosion, often associated with severe storm events, resulting in the massive extension of gullies, large mass movements on hillslopes, and channel incision and trimming of the peat blanket;

2) sub-aerial regional processes operating in a pseudo-continuous fashion, for instance the dispersal of peats from run-off events and as a result of wind erosion.

2.5.6 The focus for erosion activity is in and around stream channels incising the peat blanket, or on exposed bare peat flats. Vegetated areas of peat have very low erosion rates, unless they are trimmed laterally by migrating channels or gullies (Evans and Warburton 2005).

2.5.7 In assessing such erosion, it is essential that land management practices are also taken into account, as these greatly affect the impacts of the various climatic elements. In terms of upland peat, two activities are particularly relevant. Over-grazing has been identified as a significant factor in the degradation of many areas of upland peat (Backshall *et al* 2001), and active management of upland grazing will be a key element in preserving upland peat environments in the future. English Nature (2004) suggests year-round stocking rates of 0.037 to 0.075 livestock units per hectare to maintain moorland mire habitats, and a level of 0.015 livestock units per hectare to encourage recovery of damaged areas. Many upland peat areas are also managed as grouse moors, which require a rotational burning scheme to ensure heather regeneration. Where this is mismanaged, or burning is uncontrolled, all surface vegetation can be removed, exposing the underlying peat to erosion (Radley 1965; Mallik *et al* 1984; Rhodes and Stevenson 1997). The impact of burning closely relates to both drainage and climate. The level of the water table and depth of peat at the time of burning (drainage conditions) are crucial in determining the impact on the vegetation and peat. Where the water table is deeper than 50mm, the peat itself may ignite (Watson and Miller 1976; Maltby *et al* 1990).

2.5.8 ***Impacts of climate on erosion:*** the main factors promoting peat erosion are generally recognised as water, frost and wind (Phillips *et al* 1981). Climate change will mitigate these processes and produce a range of erosion consequences. Scenarios of future climate change cannot be determined with absolute certainty (UK Climate Change Impacts Programme 2005), but a general response to broader directions of change can be hypothesised. It is generally assumed that there will be an average rise in temperature of 0.8–2.0°C by 2050, likely to manifest itself in warmer and drier conditions in the late summer and early autumn (Simmons 2004). This will be coupled with more intensive summer and winter precipitation events. These changes may eventually lead to changes in the distribution of upland habitat, but will also make the landscape more vulnerable to fires.

2.5.9 ***A) Increased summer drought:*** summer drought has the potential to bring about large and to some extent irreversible changes to the peatlands (Burt and Gardiner 1984; Burt *et al* 1990; Evans *et al* 1999). Extreme drought will result in desiccation of the surface peat, which in turn leads to cracking and disaggregation of the crust into small peds (soil particles bound together into larger units) which are vulnerable to wind erosion and mechanical breakdown by trampling. Once desiccated, peat is very hard to rewet, and thus becomes detached from the peat blanket, and is more vulnerable to erosion. Gully systems are particularly at risk to erosion/ desiccation processes, because exposed faces dry quickly and, under the influence of gravity and wind, particles are rapidly removed to the gully bases, and then wash away. Dried peat, because of its low density (0.1-0.2 g cc-1), is particularly vulnerable to wind erosion. A major factor governing peat loss and degradation during drought is the increased incidence of fire. The effects of fire on peatland systems are well documented (Imeson 1971; Mallik *et al* 1984; Maltby *et al* 1990), and can lead to greatly increased erosion through enhanced run-off and dissection of the peat blanket by drainage systems. The recovery times following such events are prolonged, and in some cases the peat is permanently damaged.

2.5.10 ***B) Increased summer and winter storms:*** there are predictions of an increased frequency of winter storms, which can have severe short-term erosion impacts in the uplands. Upland peat landscapes are, by their nature, areas of high run-off, and streams draining the peat blanket are often steep and subject to flash floods. The impact of these storms is therefore focused predominantly on streams and gully systems. This can result in lateral stripping of the peat blanket, resulting in erosion at the margins of flood plains and in gully systems, often yielding large masses of peat blocks. These peat blocks are significant in terms of the sedimentation from upstream floodplains, and result in a substantial level of organic matter within the streams. The other, potentially more damaging, effect of winter storms is the widespread failure of the hillslopes adjacent to channels. Peat slides or bog bursts are a well-documented phenomenon of upland peatlands, and their frequency appears to be increasing (*Section 2.3.6*; Warburton *et al* 2004). These are major landscape-changing processes, resulting in the complete removal of peat from vast tracks of hillslope (Plate 3). They deliver vast quantities of peat into upland stream systems, resulting in channel modification and considerable ecological damage for several kilometres downstream. The remaining hillslopes are often left bare, and can be susceptible to secondary erosion processes and gullying of the mineral substrate. There seems to be a rapidly increasing frequency of landslides recorded in British peatland environments (Fig 12), and an associated frequency of triggering events. For example, one severe storm may trigger multiple failures in a particular area (Carling 1986; Warburton *et al* 2003b; 2004). Peat failures are important because of their short-term severe impact on the ecology of nearby streams, and the permanent long-term degradation of the peats. Although shallow failures in mineral soils are often quick to recover, peat failures represent a permanent loss. Bog bursts represent some 80% of the total global record of landslides in peat. This rapid rise in the frequency of peat failures (Fig 12) is associated with few significant clusters of landslides, occurring in a small area from a single triggering event (usually a storm). This suggests that, although the frequency of individual triggering events is increasing slowly (linearly?), the impacts of such events on the landscape may be proportionately greater, resulting in greater economic loss.

2.5.11 ***C) Changes in the growing season and vegetation:*** as climate changes, the vegetation will respond in several ways. Of greatest significance for peatland erosion is probably the extension of the growing season, leading to changes in the moisture balance of the peat soils, and changes in the composition of the vegetation species. Rising temperatures will generally result in an extension of the growing season, and a reduction of the frequency of frosts (Holden 2001; Holden and Adamson 2002). It is well known that vegetated peat is far less susceptible to erosion than unvegetated peat (*Section 2.2*), so an extended growing season allows vegetation to develop for longer, and a lack of frosts means seedling survival is increased. The net effect is the progressive revegetation of bare peat soils, although this can only be achieved alongside grazing management (Wheeler and Shaw 1995). During the Foot and Mouth epidemic of 2001, vegetation recolonisation of the bare peat surface at Moor House National Nature Reserve in the north Pennines was significant, as grazing by sheep was not taking place (Holden and Adamson 2002).

2.5.12 ***Overall response of the peatland system:*** upland peatlands have formed because of a unique set of conditions, caused by the retention of water. Climate change will alter this balance. Upland peat is unlikely to be affected by the warmer and wetter conditions, however, if the blanket mire is intact, and supports a healthy *Sphagnum* population. If the mire is degraded and the peat is exposed, erosion may increase due to aeolian processes and erosion by extreme events. This in turn may be linked to ecological degradation triggered by an increase in the frequency of fires. The significance of these changes will have important implications for peat loss from the uplands and, indeed, for the overall carbon balance (Worrall *et al* 2003).

Climatic change	**Hydrological change**	**Erosional impact**
Increased summer and autumn drought	Lower water tables (greater acrotelm depth)	Peat shrinkage and desiccation Aeolian (dry blow) erosion
Increased summer and winter storminess	Increased storm run-off	Accelerated erosion of bare peat areas (rain splash and wash) and increased channel erosion and gullying
Extended growing season	Greater evapotranspiration (minor)	Reduced erosion due to revegetation of bare peat areas and more mature vegetation blanket
Reduced frequency of frosts	Reduced impact of snowmelt events	Less frost heave disturbance Less disruption to newly established vegetation

Table 1: Hydrological and erosional consequences of climate change on upland peat in Britain

2.6 POLLUTION

2.6.1 Following the onset of the industrial revolution in the mid-eighteenth century, pollution is thought to have been a major factor in the condition of both upland and lowland peat. This has been of particular importance in the uplands of Derbyshire, Yorkshire and Lancashire. Industry was widespread in Northern England, from the early nineteenth century through the greater part of the twentieth century, until its decline from the 1970s onwards. Many of the industrial centres were located near to the coalfields and on the fringes of the Pennine uplands. The high emissions of sulphur dioxide (SO_2) into the atmosphere, from the burning of fossil fuels, has contributed to acidity in rain, and this is thought to have had an impact on vulnerable plants such as mosses and lichens (Caporn 1998). Past pollution may have changed the species composition of the blanket mires within the Forest of Bowland, and in particular *Sphagnum papillosum* may have been replaced by *S recurvum*, which is more tolerant of pollutants (Mackay and Tallis 1996). Mackay and Tallis (*ibid*) recorded a shift between these two species in peat profiles from Fairsnape Fell, dating from the beginning of the twentieth century, which could be linked to increasing levels of pollution. Today, such emissions have been reduced, but nitrogen oxide (NO), volatile organic compounds (VOC), and ammonia (NH_3) are steadily rising due to the increasing use of motor vehicles (NO and VOC), and probably agriculture (NH_3). This still leads to low pH in rainwater (greater acidity), and in central Wales this has resulted in a decline of lichens (Simmons 2003, 186). Lee *et al* (1987) have shown experimentally, that levels of combined nitrogen from the atmosphere in the southern Pennines are supra-optimal for the growth of *Sphagnum* mosses, with concentrations of 10µ and 100µ of either ammonium or nitrate reducing the growth of *Spagnum cuspidatum* (Caporn 1998, 33).

2.6.2 These pollutants, including (SO_2), have a profound effect on the vegetation in an upland environment today, and are likely to have done so in the past. The high rainfall and prolonged cloud cover mean that plants are exposed for long periods to high concentrations of pollutants, and consequently to increasing acidity (Grace and Unsworth 1988; Lee *et al* 1988; Caporn 1998, 29). Caporn notes that plants growing at altitude are subjected to extreme climatic stress (1998), and a modified, polluted climate causes major changes to the soil, and subsequent damage to plant roots. He concludes that, in the Dark Peak, plant communities are still subjected to chronic or acute injury from air pollutants.

2.6.3 In the Dark Peak area of the Peak District, *Sphagna* spp are relatively rare, with only *S recurvum* described as being widespread (Tallis 1964). At Fairsnape Fell, in the Forest of Bowland, the death of *Sphagna* recorded at some sites is not likely to have been caused by pollution, as it has not declined at all sites (Mackay and Tallis 1994). Mackay and Tallis concluded that, on Fairsnape Fell, pollution may have helped to prevent the recolonisation of the bare peat areas, damaged by other factors such as fire, which then accelerated the erosion processes.

2.7 FARMING

2.7.1 A primarily desk-based study was undertaken to provide an assessment of the impact of agricultural and land-management practices on upland peats. Information was obtained from a number of national and regional agencies, including DEFRA, English Nature, The Countryside Agency (both now Natural England), the Environment Agency, the National Trust, the Lake District and the Yorkshire Dales National Park Authorities, United Utilities and Lancashire County Council. Consultation was also undertaken with rangers and land managers within the North West and Yorkshire.

2.7.2 Anglezarke Moor and the Langdale Fells were selected as the two study areas for the initial impact assessment, because of the amount of previous archaeological survey work undertaken in these areas, and because they differ in their land-use. Data-gathering was therefore concentrated on, but not confined to, these areas. Changes in management techniques over the past quarter century were taken into consideration, including drainage, improvement of pasture, over-stocking, the drive to diversify, agri-environment schemes, changes in land tenure and in agricultural employment, and the impact of the outbreak of the Foot and Mouth epidemic in 2001.

2.7.3 ***Causal agents of degradation and erosion of upland peat:*** while the various causes of erosion are discussed separately below, none of the agents should be considered in isolation. Most erosion problems are complex - one factor may open an area to erosion, but other factors will exacerbate the situation.

2.7.4 ***Agricultural Drainage:*** agricultural drainage has taken place on the uplands, certainly since medieval times and, notably on Anglezarke Moor, has increased from the Victorian period into the 1960s, as the water catchment was developed (P Jepson *pers comm*). From the late 1940s until the late 1980s, drainage grants were given with the intention of improving upland pasture, and thereby increasing sheep production. Such drainage tended to be on the higher, flatter land, and took the form of indiscriminate straight-line ditches, or grips, over wide areas, in herring-bone or dendritic patterns (see Fig 11). It has been suggested that, on the flat upland plateaux, the grips do little primary damage, the volume of run-off after heavy rain being more of a problem (I Condliffe, M McHugh and I Hartley *pers comms*). Conversely, however, there is also a school of thought that believes that the grips contribute to the drying-out of the peat, and therefore encourage conditions that lead to erosion (V Hack, P Jepson *pers comms*). All opinions agree that grips on a slope can initiate gullying, and that the steeper the slope, the more severe the erosion.

2.7.5 Drainage works were also undertaken on grouse moors, but these tended to be targeted on the very wet areas in order to improve conditions for the heather and the adult grouse. However, grouse chicks feed on insects, and the insects require plants that survive in wetter, mineral-rich conditions. Sometimes, therefore, some areas of drainage on grouse moors were intended to enhance conditions for the insects that supported the young grouse, and thereby made small areas wetter by diverting water, rather than making the ground drier (V Hack *pers comm*).

2.7.6 In the last 15 or 20 years, the problems caused to upland peats by artificial drainage have been recognised, and attempts have been made to reverse the situation. Grips and gullies have been blocked with heather or straw bales, and in many instances the peat and its vegetation cover are gradually regenerating - provided that other agents of erosion are also controlled (*Section 2.4.5*).

2.7.7 ***Stocking Levels:*** farming in the uplands concentrates almost without exception on animal husbandry, mainly sheep, but sometimes cattle, which in some cases graze the uplands all year round. Stocking levels have increased throughout the eighteenth and nineteenth centuries, and have soared since the Second World War, due to the emphasis on increased production, supported by Government subsidy schemes (introduced by the 1947 Agricultural Act) and latterly the Common Agricultural Policy payments. To date, these have been based on stock number (headage payments). High stock levels, particularly of sheep, have led to a number of pressures on the delicate upland peats:

- over-stocking leads to over-grazing, particularly of the finer, sweeter grasses that sheep prefer. Other coarser, and less palatable species, for example mat-grass (*Nardus stricta*), are not usually touched, and increase as other species decline;
- over-stocking is detrimental to the regeneration of vegetation, and leads to, for example, over-grazing of new growth after burning. This problem is exacerbated by modern methods of farming, where the sheep receive only limited shepherding, and are often left to roam uncontrolled;
- over-stocking pushes sheep to the higher levels, and they are forced to eat species that they otherwise would not touch, and graze others to

extinction, such as heather and bilberry. This can create bare patches, and corresponding scars;

- trampling and poaching by sheep and cattle, particularly around feeders and nutrient licks in the wet winter months, destroys the vegetation cover and opens areas to erosion;
- sheep 'scars' (rubbing and shelter points) and 'trods' (pathways), though not as great a problem on peat plateaux as on mineral soils and slopes, break through the sward and allow erosion to begin. Sheep take advantage of slopes, tussocks and disused peat cuttings to create scars.

2.7.8 Ideal stocking levels are in the region of two sheep per hectare on heather moorland, and less than half a sheep per hectare on blanket mire and other peat areas (Hulme and Birnie 1997). Cattle are grazed on some uplands, and can be complementary to sheep in that they graze different plant species, and can cope with coarser vegetation - *eg* mat-grass (*Nardus stricta*). They are generally less discriminating grazers, however, and their different feeding methods can pull up vegetation by the roots. Being heavier, and having larger hooves, any poaching problems can be more severe, particularly at gateways and around feeders and troughs. Overall, cattle tend to cause greater damage to peat than sheep (I Condliffe *pers comm*).

2.7.9 ***Common Agricultural Policy Reform:*** the impact of the reform of the Common Agricultural Policy (CAP) could not be accurately foreseen at the time of the study (2003). It is possible that some smaller farmers may give up their hill flocks as not being economically viable, particularly given the relatively small commercial value of hill sheep. The effect of this might be to leave large areas of fell under-grazed, or not grazed at all. Stopping grazing at the highest altitudes, for instance on the Langdale Fells, might not have any effect on the natural vegetation, except to aid the regeneration of the present species community. It is unlikely that bracken or shrub species would colonise at this altitude, but at lower elevations the species community might change in response to the lack of grazing.

2.7.10 ***Bracken Control:*** bracken growth is limited by altitude, and as the plant prefers drier ground, its presence is less of a problem on deeper peats (C Newlands *pers comm*). Controlling bracken has, however, led to erosion problems in the past, particularly the control of thicker stands, with deep surface litter, where other vegetation is non-existent (I Condliffe *pers comm*). Where the killing of thick stands of bracken has taken place, the soils that are exposed as a result have been poisoned by the chemicals produced by the bracken itself, reducing the chance of regeneration of other species, and increasing the likelihood of erosion. High grazing pressure may encourage the invasion of bracken but, conversely, in some areas too little grazing, or grazing by inappropriate types of stock, can cause more of an invasion problem. It has been shown that cattle trampling is more effective in reducing the spread of bracken than trampling by sheep (Backshall 1999).

2.7.11 ***Shooting:*** land management for game shooting is a major factor on some areas of upland peat. This is primarily for grouse shooting, although it can also be for red deer in some areas. Burning of the vegetation cover (*Section 2.10.2*) is usually well-controlled, though fires do sometimes get out of control, and similarly, drainage is usually limited and well-targeted (*Section 2.4*). Any problems tend to be associated with the construction of badly-placed access tracks, and possible compaction caused by driving across the open moor. Positive benefits include a regular presence by gamekeepers on the moorland, which inhibits arson.

2.7.12 ***Langdale Fells:*** the Langdale Fells study area is managed by the National Trust, and discussions with their management team of John Metcalfe (Farm and Countryside Officer), and James Archer (Langdale Property Management Team), provided an insight into the agricultural issues relating to this upland peat landscape.

2.7.13 ***Drainage:*** drainage by gripping under the post-Second World War grant schemes was not undertaken on the Great Langdale plateau. Run-off drainage, causing gullying, can be a problem at the extreme edges of the upland because of the steepness of the slopes, but is not generally a problem over most of the area. There is heavy run-off on the front face of the Langdale Fells, where the sward is thin and easily damaged.

2.7.14 ***Stocking Levels:*** headage payments resulted in over-stocking and subsequent over-grazing in the Langdale Fells area. This coincided with the decline in intensive farm labour, and so sheep are no longer closely shepherded. Over-stocking has pushed sheep up to higher elevations and areas, and to graze on species that they would not normally choose, as well as over-grazing on the more palatable grasses and other species. This observation echoes closely the work undertaken by Robert Evans for the *Langdale Erosion Research Programme* (Quartermaine 1994). In October 1992, Evans noted 'severe' grazing of bilberry; heather 'always chronically over-grazed'; and that mat-grass (*Nardus stricta*), 'generally considered unpalatable to sheep', was 'frequently grazed' (*op cit*, 28). Evans' work often refers to the mineral soil slopes of the Langdale Pikes, rather than the specific study area under consideration here, but the results are comparable.

2.7.15 The National Trust has encouraged its tenant farmers to participate in Environmentally Sensitive Area (ESA) and other agri-environment schemes. Two comparable areas of National Trust land give an interesting insight into the results of participation. Loughrigg Fell is used by only two graziers, who entered the ESA scheme at the same time. Stocking levels have been reduced overall, and from casual observation (no formal study has been undertaken), it would appear that there has been good species regeneration, with bluebells, primroses and even the occasional rowan sapling being observed. This regeneration is, however, more likely to be taking place on the mineral soils, as neither bluebells nor primroses are mire species, although they do grow in wet grassland (Stace 1991). In contrast, Langdale Fell is used by more graziers, who entered the ESA scheme later, and in a piecemeal fashion. Some de-stocking has resulted, but because of a lack of control on the sheep movement by the farmers, the larger flocks have pushed into the reduced flock areas, and consequently grazing remains at a high level. It is likely that, on Langdale, ESAs have made little difference to overall stocking levels. Consequently, there is little visible regeneration, although it is possible that the plateau 'tops' are stabilising rather than continuing to degrade.

2.7.16 The 'hefting' system for Lake District sheep depends largely on pressure from other flocks to keep sheep hefted in their own areas. Any decline in stocking levels in one area allows flocks from adjacent areas to move in. Because of the high elevation, it is not usual to over-winter sheep on the Great Langdale plateau, so there is no need for winter feeding points, and there is little or no use of quad bikes in the wetter months.

2.7.17 ***Impact of the Foot and Mouth epidemic:*** while there was some immediate regeneration of plant species in areas where there was no grazing, subsequent stocking levels are the same as previously in some areas, and lower in others, and overall there appears to be little overall difference in the Langdale Fells.

2.7.18 While the overall effect of the foot and mouth epidemic and the ESAs has been relatively minimal on the regeneration of the vegetation, in localised areas there has been a marked recovery. In particular, the exposed, craggy high-altitude pasture is land that sheep only use when other, lower land is over-grazed. So a slight reduction in grazing pressure across the whole area will result in a marked reduction in the exposed areas. The archaeological sites on the craggy face of Pike of Stickle have become vegetated within the last eight years, which is a reflection of reduced grazing pressure in these locations.

2.7.19 ***Anglezarke Moor:*** information specific to Anglezarke Moor was gained from a number of sources in Lancashire County Council and at United Utilities. In particular, Peter Jepson of Lancashire County Council, and Ian Harper, the United Utilities' Wildlife Warden for the area, were able to provide information on current practices on the Moor.

2.7.20 ***Agricultural Drainage:*** the slopes on Anglezarke Moor are particularly steep, and many of the feeder drainage ditches are on the fairly level area north of Round Loaf (Fig 6). Ian Harper believes that most of the erosion has been associated with periods of heavy rainfall and flash floods, and that much of the erosion has scoured out the stream, but not necessarily moved large volumes of peat. One particular erosion concern on Anglezarke is the large drainage channels feeding Black Brook (Plate 4), some of which are extensive in size, and which were created up to the 1960s, to promote 'water catchment'. This was a policy which, with hindsight, has had the opposite and more costly effect of causing run-off of organic material, and has compromised water quality.

2.7.21 ***Stocking levels:*** over-grazing should be looked at as a localised issue, due to the trends in farm management brought about by economic factors. Over-stocking is often quoted as an issue when, in fact, it is modern farming techniques and a lack of shepherding of stock that is at fault. Feeding techniques using big bale and ring feeders create feeding zones, and in many areas limited vehicle access can lead to the same site being used throughout the winter period. This leads to vehicle erosion, localised erosion due to trampling around the feeder, and localised over-grazing around the feeder, as stock wait to be fed. Sheep 'trods' in themselves have little impact, but their subsequent use as footpaths by ramblers and mountain bikes causes rutting and compaction, and consequential development as a water run, which leads to erosion. Although cattle are viewed as complementary grazers to sheep, water-quality issues related to poaching are concerning United Utilities, and as a consequence tenants are being encouraged to reduce cattle numbers.

2.7.22 Agri-environment schemes have mainly brought about positive rewards due to the over-wintering of stock in alternative areas, reducing mechanised erosion and localised over-grazing. CAP reforms will probably not have a big impact on Anglezarke Moor, as the tenant is already operating at lower than prescribed stocking densities, and has a Countryside Stewardship Agreement.

2.7.23 ***Shooting:*** game shooting brings positive benefits to the Anglezarke area, through a regular, controlled programme of burning. There is little or no erosion that is directly attributable to management for game shooting.

2.7.24 ***Discussion:*** the sources consulted in putting together this report divide into two broad categories - academics, scientists and field workers concerned with hydrology, soil science and environmental issues, and those individuals directly concerned with land-management issues, including the staff of the National Trust, United Utilities, English Nature and the National Parks. While there is consensus across the groups about the main causes of the erosion of upland peat generally, there is some disagreement about which of the causal agents of erosion have the greatest effect, particularly at a local scale.

2.7.25 In April 1997, the British Ecological Society Mires Research Group held a conference at Manchester University entitled *Blanket Mire Degradation: Causes Consequences and Challenges* (Tallis *et al* 1997). At the end of the conference, a questionnaire was circulated concerning the various issues that had been discussed (Tallis 1997a, 210), and the summarised results were:

	A	**B**	**C**
Over-grazing	51	42	7
Accidental burning	33	35	32
Controlled burning	20	37	43
Ditching and drainage	17	32	51

The percentage of replies is shown in each of three categories: **A** = of major importance, **B** = of moderate importance, **C** = of low importance. The first three reflect the general opinions across all sources consulted for this report. Ditching and drainage were not considered to be a great problem by any authority, particularly as drainage has now almost entirely ceased, and measures are being taken to remedy earlier problems by blocking existing drains and grips to stop run-off.

2.7.26 ***Stocking levels:*** over-stocking was considered to be the main cause of erosion on the Langdale Fells by National Trust personnel (John Metcalfe and James Archer), but was not considered to be a problem on Anglezarke Moor by Ian Harper of United Utilities. It is interesting to note that both these sources considered that modern farming methods, with limited control of stock by shepherding, was almost as much a cause of the erosion problems associated with grazing animals as the stocking level itself.

2.7.27 Some immediate regeneration of plant species was noted during the Foot and Mouth epidemic outbreak of 2001, in those areas where the uplands were only lightly grazed, if at all. Stocking levels have in general recovered, although the limited shepherding of modern farming methods means that lower-stocked areas are under pressure from the flocks on higher stocked areas (the Langdale Fells). From the information given, Anglezarke Moor is not over-stocked, and the present mixed species grazing, with stock removed during the winter months, seems to be more beneficial to the upland peat than sheep-grazing only. John Metcalfe (National Trust) considers that stopping grazing altogether at the highest altitudes on the Langdale Fells would have the primary effect of aiding the regeneration of the existing plant community, and that this would help to slow down and even stop the erosion process, thereby safeguarding any archaeological remains.

2.7.28 Under-grazing at lower altitudes would result in vegetation succession, through tall grasses, bracken, scrub, small trees etc, all the way to (eventually) full forest cover, all of which would protect the peat and keep it *in situ* (M McHugh *pers comm*). Under-grazing on heather moorland results in the high rate of growth of the heather, which then makes the moorland vulnerable to catastrophic wild fires. While fires are not uncommon on moorland, they do not typically get out of control unless the conditions are very dry, and there is a thick growth of surface vegetation to fuel the fire. Moorlands which have suffered severe fires have typically been under-grazed (*Section 2.13.10*). No managerial authorities have advocated a total cessation of grazing, and most accept that the correct levels of stocking on upland peat landscapes do no harm, and in fact may be beneficial. Ian Harper (*pers comm*) of United Utilities is of the opinion that the well-controlled mixed species (sheep and hardy cattle) grazing on Rivington Moor helps limit the risk from accidental burning, by creating a reduced sward height and a reduction in heather cover.

2.7.29 ***Ditching and Drainage:*** drainage appears to be more an historical than a current problem of land management, in that drainage grants are no longer paid, and the trend is now to block grip systems to prevent run-off. This is largely for reasons of habitat regeneration, flood prevention, and water quality, rather than agricultural productivity. Water loss over previous decades, however, may well have caused damage to archaeological deposits preserved in once-waterlogged environments, a problem for the historic environment that does not seem to have been considered by any of the sources consulted for this report. Wet peat, in good condition, is better able to resist external factors that cause erosion (P Jepson *pers comm*), and many of the erosion problems suffered by peat can be attributed to a lowering of the water table. On Anglezarke Moor, most of the erosion problems are as a result of heavy rainfall and flash floods expanding the drains.

2.7.30 ***Conclusion:*** in the area of the Langdale Fells, over-stocking, with its related problems (*Section 2.7.14*), together with a lack of shepherding, is generally considered to have the greatest effect with regard to the degradation of the vegetative cover and consequent erosion of the peat. The uptake of agri-environment schemes in the Langdale Fells has been relatively piecemeal, and overall, stocking levels do not appear to have reduced as a consequence (*Section 2.7.14*). On Anglezarke Moor, stocking levels are considered to be at an acceptable or even low level, but lack of shepherding management of the stock hinders regeneration and contributes to erosion problems. On Anglezarke and Rivington Moors, fewer tenant farmers and a good uptake of agri-environment schemes have resulted in lower stocking levels.

2.7.31 ***Future Changes*****:** in 2005, the Common Agricultural Policy was reformed, and the Environmentally Sensitive Area (ESA) and Countryside Stewardship Schemes were transferred into a single farm payment agri-environment scheme, known as the Environmental Stewardship Scheme. Under the new system, farmers are rewarded for environmentally sensitive farming practices and management of historic assets, rather than acreage of crops or numbers of stock. Agreements under the new scheme combine grazing management and the management of burning, with a view to reducing both the intensity and frequency of burning on the upland peats, as well as controlling stocking levels. It also has the advantage over past schemes of enabling whole farm plans, which in particular may make it more attractive for upland farmers.

2.7.32 The historic environment has been given equal consideration with the natural environment in the new scheme. One positive impact on the preservation of archaeological sites within upland peatlands is the inclusion in the Higher Level Stewardship scheme of points/payments for the active management of archaeological sites – for instance by scrub clearance and grip blocking. The scheme has been in place only a short time and the long-term ramifications for upland farming and the peatlands have yet to be discerned. Some smaller farmers have given up their hill flocks altogether (J Metcalfe *pers comm*), and others have increased their stocking levels to compensate for small area payments. In places there has been a reduction of hardy upland cattle, which are likely to become uneconomic, in favour of increased hill-sheep flocks. The hardy breeds of cattle could also be replaced by heavier cross-bred cattle or lowland breeds, which are more commercially viable but are more selective grazers than the hardy breeds, and can do irreversible damage to the upland sward, both by 'pulling' fragile species and by poaching (V Hack *pers comm*). Other problems for the uplands may result on common land, where the area payments may have to be divided between all right-holders, and on those large estates with only a single landowner, where the area-based payments may not benefit tenant farmers.

2.7.33 Payments are available for grip blocking and for shepherding, and all of these factors should help control and reduce the erosion of upland peats (B Rooley *pers comm*); however, some methods of grip blocking have resulted in damage to the very peats that they have attempted to protect (ADAS and OA North 2008). The benefits for the upland peats will depend very much on the take-up of the new scheme by individual farmers. The Higher Level scheme includes payments to encourage cattle grazing (J Metcalfe, I Condliffe *pers comms*), which may in part obviate the less-beneficial effects of the CAP reforms on upland cattle farmers.

2.7.34 Those upland peats which are part of water-catchment areas may well be affected by the European Union *Water Framework Directive* (European Union 2000), which is now in force. This sets new water-quality standards, including stricter regulations on water colour and acidity, both of which can be problems in water from peat catchments. Peat dried out by drainage accumulates acid from oxidisation; re-saturation allows these acids to be flushed out, and rainfall can cause a massive flood of acidity. Meeting the new standards may lead to a change in management practices, with the Water Companies discouraging the blocking of grips and ditches in an effort to keep the acid-levels and colour of the water from the catchment area as acceptable as possible (V Hack *pers comm*). This could adversely affect the recovery of waterlogged deposits.

2.8 FORESTRY

2.8.1 An assessment of the impact of forestry practices on upland peatlands was undertaken, which was primarily a desk-based study, but included a field visit to the Hollow Moor woodland, west of Gosforth in Cumbria (NY 100 055; Fig 13), to inspect existing woodland, felled areas and re-stocked plantations.

2.8.2 ***Background:*** the management and planting of forests and woodlands have been part of the landscape history of the British Isles since at least Norman times, and forests have been the subject of legislation since 1184 (James 1981). Timber and wood were valuable raw materials, widely used for many and varied purposes, and forests and woodlands were managed, conserved and renewed as a valuable resource into early modern times (James 1981; Rackham 1990). Changes in the use of timber during the eighteenth and nineteenth centuries (the decline in its use for building, ship-building, and fuel, but a rise in its use for tanning and paper production) led to changes in forestry methods and in the species planted, with new species being introduced from abroad. By the 1880s, the modern approach to forestry management, including education and training, was developing, partly through the influence of French and German practices (James 1981).

2.8.3 The impact of the First World War led to the realisation that timber was essential for the economic survival of the country, and that Britain lacked sufficient woodland to produce timber for home requirements. This led to the establishment of the Forestry Commission in 1919. Its purpose was to promote afforestation and timber production in the UK, both on its own lands (including the former Crown Forests and other land acquired by purchase), and by advising, managing and making grants or loans available for woodlands in private ownership. The intention was to make the UK self-sufficient in timber. The Forestry Commission was also intended to establish and operate woodland industries, undertake training and carry out research (James 1981). Government policy continues to require the expansion of the total area of woodland. The Forestry Commission's brief has changed somewhat over the decades since its establishment, and its work now includes the aim of providing 'the best public benefit' (B Burlton *pers comm*), and has emphasis on public access and environmental and archaeological conservation.

2.8.4 The promotion of afforestation throughout the twentieth century deliberately avoided productive farmland, in favour of marginal and otherwise unproductive land. This included planting large areas of upland peats, both shallow (less than 0.45m) and deep peat, with conifer forests, with sitka spruce and lodgepole pine being the most common species.

2.8.5 ***Forestry Techniques and their Impact on Archaeological Remains:*** on wet upland sites, such as those with peat soils, ploughing to provide a raised turf was widespread from the 1930s up to the 1970s and 1980s. Most trees are unable to grow in soils that are permanently waterlogged, and ploughing produces a ridge of soil with mixed horizons, giving increased drainage and aeration, both of which benefit root formation. The ridge also provides a raised weed-free planting position, while the furrow acts as a drain. Ploughing for forestry creates a deep and wide furrow, involving substantial ground disturbance, and has the potential to cause damage to any archaeological remains buried near the surface. The use of heavy machinery can also compact and compress the underlying soils. Such deep ploughing is less common today, and is discouraged by the Forestry Commission, particularly in water-catchment areas, many of which include upland peats (Patterson and Anderson 2000).

2.8.6 Other site preparation techniques, used particularly for re-stocking, include the use of scarifiers and mounders. Scarifiers are generally used on free-draining sites, where the surface of the soil is scraped into heaps, turned in patches, or harrowed to leave a line of loose soil for planting. Mounders are preferred for poorly-drained soils such as peat. The mounder produces a planting mound, a minimum of 300mm high, by excavating soil from the adjacent area. While this process can be done by excavating single mounds, a continuously acting mounder cuts and upturns large square turves, approximately 500 x 500mm, to produce a continuous planting mound of the required height. Mounding techniques, while marginally less damaging to shallow-buried material than deep ploughing, still have the potential to disturb, damage or destroy any archaeological remains encountered, including any that might have survived the initial ploughing.

2.8.7 In 1993, the then Lancaster University Archaeological Unit (LUAU) undertook a survey and watching brief at Blengdale Forest (LUAU 1994), West Cumbria, on an area lying adjacent to the Hollow Moor Forest visited for this study (*Section 2.8.21*), in advance of then new forestry planting by the mounding method, which involves creating a mound for planting each individual tree. The area had previously been surveyed as part of the Lake District National Park Survey (LDNPS; Quartermaine 1990) (Fig 13). The planting scheme for this area had carefully avoided a number of visible cairns, although the subsequent watching brief recorded 16 possible cairns which were not visible on the surface, and which had been effectively destroyed by the planting (*ibid*). The conclusion in this case was that the clearance cairns were only the surface remains of the prehistoric agricultural landscape, much of which was buried and invisible, and that the planting of forestry away from the visible cairns may disturb settlement evidence that is of considerable archaeological importance (LUAU 1994).

2.8.8 ***Planting (primary and re-stocking):*** forestry planting can be mechanised, but is still predominantly a manual task, involving minor soil disturbance (Crow 2004). Direct sowing of seed is not common, as most young trees are from nursery stock, and have been prepared to remove the taproots and stimulate more lateral growth (Aldhous and Mason 1994). Crow (2004) suggests that deliberate planting may therefore be less detrimental than natural regeneration, on sites with deeper archaeological deposits.

2.8.9 The establishment of trees on poor soils may require the application of fertiliser, particularly for upland plantations of Sitka spruce and lodgepole pine on peat, and plantations are also treated with herbicide, to suppress weeds while the young trees are becoming established. Both fertilisers and herbicides have the potential to alter soil chemistry and therefore adversely affect buried archaeological remains, particularly organic deposits. Neither fertilisers nor herbicides, however, are applied in high concentrations in forestry, and the effects on buried archaeology, though difficult to quantify, are likely to be minimal (Crow 2002; 2004).

2.8.10 ***Drainage and Hydrology:*** tree cover affects the amount of rain water able to reach the ground (throughfall), as well as increasing groundwater use by the trees themselves. The increase in water use by coniferous forest, compared to grassland, was found to be 15-20% in the North West uplands (Dobson and Moffat 1993). Additionally, tree roots need oxygen to support healthy growth, and will not thrive on waterlogged soils, where the trees tend to produce long, shallow roots, hence the need for drainage. The recommended distance between forest drains on fairly level deep peat is 20m (Crowther *et al* 1991). Some of these drains can be more than 1m deep and 1m wide, and have a considerable potential for damaging buried archaeological remains. A research project at Rumster Forest, Caithness, where forest was planted on blanket peat, showed that a combination of drainage and transpiration by the trees themselves produced measurable subsidence due to dehydration. This subsidence was up to 20m from the forest edge within 20 years of planting, and rose to 40m from the forest edge within 30 years. In addition, subsidence of up to 1m was measured under the forest itself. Peat coring showed measurable drying, decreasing with depth, to 0.9m (Townend *et al* 1997); such drying out of the peat can be irreversible. In *Forestry Practice* (Hibberd 1991), it is stated that: 'Once establishment is achieved, tree roots are an effective way of drawing moisture out of impervious peats and clays, and this can result in a drying and cracking process which is not reversed even in winter' (Crowther *et al* 1991, 34). The cracking forms a secondary, below-ground, drainage system, which continues to function even if the plough furrows and forestry drains are blocked (Anderson 2001). Such drying also leads to shrinkage, with a consequent loss of depth in the peat. Any action which reduces either the water table or burial depth would increase the risks of loss to any archaeological evidence present, especially organic-based evidence (Crow 2004).

2.8.11 ***Managing, Harvesting, Processing and Extracting the Crop:*** the management of an established plantation, through to full site clearance, involves a number of processes. Historically, much of the work would have been done manually, but as the twentieth century progressed, tasks became increasingly mechanised, until at the present time manual work is the exception rather than the rule. Tree thinning, felling, processing, and extraction are all mechanised processes carried out on site.

2.8.12 Thinning is carried out by foresters to manipulate the development of the stand and achieve the best quantity and quality of the final crop. The removal of trees allows more light into the forest and reduces competition for the remaining individual trees, thus enhancing development. The stem is usually cut close to ground level, and the stump left in the ground, leaving the remaining trees with space and therefore greater freedom of movement. This can, however, result in wind throw, where trees are uprooted by the wind, causing damage to the timber and great disturbance to the soil, and any potentially underlying archaeology. In some extremely windy areas, where the risk of wind throw is great, no thinning is carried out. Forests can be thinned *selectively*, a labour-intensive process where individual trees, possibly damaged, weak or dead, are removed, but this is not the preferred option. The most common practice is systematic thinning, where predetermined areas, such as entire rows of trees, are removed, as part of a fully mechanised process (Crow 2004).

2.8.13 When a commercial plantation has reached maturity, harvesting usually follows. This can be sub-divided into three stages (Crow 2004):

- *Felling* is the action by which a tree is removed from its standing position, while the stumps are usually left in the ground;
- *Processing* cuts the tree into desired, manageable sizes and removes unwanted brash;
- *Extraction* is the process of physically removing the cut material from the point of felling.

2.8.14 All of the above processes can be carried out manually, including the extraction of the timber by horses on particularly vulnerable or inaccessible sites. Usually, however, the processes are fully mechanised, either individually or in combination. The process normally uses a harvester, also known as a feller-limber-bucker, which fells and de-limbs the tree and cuts the timber to the required length in one operation. Some of these machines are necessarily very heavy, though attempts have been made to mitigate compaction effects by the use of brash mats and balloon tyres. Though these machines are capable of great precision when cutting trees on sites known to be sensitive, the danger of damage to unrecorded or unmarked archaeological sites, or small sites obscured by the use of brash mats, must be considerable during mechanised harvesting operations. Damage can occur through physical disturbance or destruction by the machines themselves, through rutting, or through compaction. Typically, processed trees are dragged by winch along the ground to the nearest forest road. This can cause considerable scarring and damage to the ground, and therefore the underlying archaeology, and is probably the most damaging of the harvesting processes.

2.8.15 ***Forest Roads:*** the function of forest roads is to provide access for machines used in management and harvesting, and for the transport of timber to the market. Road construction is greatly affected by the topography and ground conditions. *Forestry Practice* (Hibberd 1991) considers the construction of such roads on both shallow and deep peat. 'Where the peat is shallow it is usually excavated, and the sub-grade thus exposed is shaped accordingly. Where deep peat is concerned the established method is to construct a road embankment on top of the peat using suitable, locally won, materials' (McMahon 1991, 132). The author goes on to describe the required drainage, allowance for bridges and culverts, compaction of the embankment, and the bringing in and spreading of pavement materials (locally derived if possible) by tipper lorries and a small angle bulldozer (*op cit*). The road structure should then be compacted by roller. It has not been possible to discover whether the survival of archaeological remains during forest road construction on upland peats has ever been investigated. The assumption must be that such remains directly affected by the engineering works will be destroyed.

2.8.16 ***Other Impacts of Forest Cover on Archaeological Sites:*** the impact of trees on archaeological sites has been discussed in detail by Peter Crow of Forest Research (Crow 2004, ch 3). The issues he discusses include the effects of tree roots on soil structure and stability; the physical and chemical effects of roots on buried remains; the influence of trees on atmospheric deposition and soil solution chemistry; the effect of trees on soil hydrology, and the effect of tree growth on soil biota. There is little in his discussion, however, that refers specifically to conifers on upland peats, which reflects a lack of published work on this subject. The fact that both the methods of sapling preparation and the high water content of the peat soils prevent deep root penetration probably mitigates in favour of the protection of archaeological deposits against all of the above, with the notable exception of soil hydrology (*Section 2.4.6*).

2.8.17 ***Provision for the Protection and Conservation of Archaeological Remains on Forestry Sites:*** historically, little attention was paid to any archaeological remains located on an area selected for afforestation. Even as late as 1991, though increasing thought was being given to nature conservation, ancient monuments were only mentioned twice in official guidance (Hibberd 1991). It was thought that ancient monuments were 'relatively straightforward to locate', that there was 'no reason why subsequent forest operations should affect them' (Hughes and Roebuck 1991, 119-20), and that they were appropriate sites for leaving within open spaces during re-stocking (*op cit*, 218). It is evident that only Scheduled Monuments, or other obvious features, were being referred to, and that there was no consideration of buried archaeological remains, or even an historic landscape.

2.8.18 By the mid-1990s, however, changes in Forestry Commission policy were evident. The document *Forestry and Archaeology Guidelines* (Forestry Commission 1995) sets out advice on managing archaeological sites in relation to new planting, and in existing woodland, and includes a list of sources of information and advice about archaeology. The document states that 'the phase of major upland afforestation when environmental safeguards were not of current standards resulted in damage to an unquantified part of our archaeological resource. Improved liaison arrangements between the Forestry Commission and archaeological authorities have transformed the situation and resulted in the standards of practice outlined in these guidelines' (*op cit, 28*).

2.8.19 These guidelines state that best practice for new plantings, either Forestry Commission or private, and in some cases for felling and extraction of existing plantations, should begin with an Environmental Impact Assessment. This should include field survey, and an assessment of the impact of the operation on any archaeological remains (*op cit*). No new planting should occur in areas identified for archaeological conservation, and the unplanted area should extend for a minimum of 20m beyond the identified site(s). The area should not be ploughed, ripped or scarified, and the movement of machinery across the site should be avoided at any time. Drains and fencelines should avoid the protected area, as should roads, although continued access to the archaeological feature(s) for management purposes should be secured. Any archaeological features or objects found during operations should be left undisturbed, and reported to the relevant Regional or County Archaeologist (*op cit*).

2.8.20 The *Forests and Archaeology Guidelines* also state that, by observing the code, woodland managers 'will be making a positive contribution to archaeological conservation. But remember; it [the code] deals with sites that have already been identified. There are others which are as yet unrecognised or unclassified. This is especially true of those upland areas where there has been little archaeological fieldwork. Previously unrecorded features can also be found in many woods and forests where conditions for survey are sometimes difficult' (*op cit, 6*).

2.8.21 ***Hollow Moor Forest, Cumbria - some observations in the field:*** the Forestry Commission woodland at Hollow Moor, Cumbria (NY 100 055), was visited as an example of a new plantation in an area of upland peats which has considerable archaeological potential. It is situated on the Cumbrian fells, north-west of Gosforth and south of Stockdale Moor, and most of the planting is above the 200m contour. Tree planting had been undertaken in stages over a considerable period of time, and the site contained standing trees varying in height, from 2-3m (about four years old) south of the bridleway (Losca; NY 099 052) to approximately 7m (ten years old) in the plantation north of the bridleway (NY 100 058; Fig 13). Further east, where the trees were planted as much as 55 years ago, the area was completely felled over a three year period ending in 2001, and some re-stocking has taken place (NY 105 060). This re-stocking appeared to be mainly broad-leaved species at the edges of the felled area. Much of the area adjacent to the Hollow Moor forest (Whin Garth and Nether Wasdale Common) was surveyed by the then Lancaster University Archaeological Unit (LUAU) in 1989, as part of the Lake District National Park Survey (LDNPS; Quartermaine and Leech forthcoming). Extensive settlement from the prehistoric and medieval periods was identified throughout the area, including cairnfields and multi-period field systems, and an enclosed settlement was identified to the south of the planting (Bolton Wood; NY104 054). There is no reason to suggest that similar remains did not exist on the area now under forest.

2.8.22 Although there was potential for the survival of archaeological remains, the high levels of vegetation between the trees made access difficult, and obscured the forest floor. This is borne out by a survey undertaken of a mature forest plantation (planted in the 1950s) at Sutton Bank, North Yorkshire, which was situated on the perimeter of an Iron Age hillfort (OA North 2003b). The trees were planted close together, typically *c* 2m apart, and the plough cut for each row was sufficiently wide that there was only a small strip (*c* 0.25m) of undisturbed ground between each furrow. Coupled with the ground vegetation, and the considerable disturbance to the ground caused by the deep ploughing prior to planting, it was determined that any archaeology that had survived the plough would be obscured by the vegetation, and survey was unfeasible. This situation would become even worse following felling, as the ground would then be covered with brash, the separated branches from the trees, which would further obscure the ground surface.

2.8.23 By contrast, useful survey work has been undertaken within a forest context at Ennerdale (OA North 2003c), and has produced abundant evidence of medieval settlement remains. In this instance the trees were hand-planted, so there was no severe plough damage, and the trees were set further apart. At the time of the survey, the trees were mature, and the canopy discouraged vegetation growth on the forest floor, hence it was possible to identify and record the archaeological remains.

2.8.24 ***Potential for Damage to Monuments during Forestry Operations:*** during the early part of the twentieth century, when many forestry tasks were still carried out manually, damage to archaeological sites could probably have been avoided if their presence had been known. As mechanisation has increased, so too has the likelihood of damage to remains, given the increasing size and weight of the machines themselves. Although mounding is wholly preferable to the deep plough, it will cause damage to any archaeological remains that are not marked for avoidance. The use of brash to cover trackways during felling operations may help to protect archaeological remains, but can also obscure them, leading to accidental damage. It is inevitable that forestry activities, from first planting to harvesting, and including re-stocking, will inevitably cause serious damage to archaeological remains, despite the best efforts to protect them.

2.8.25 ***Future Forestry threats to Upland Peats:*** it is now generally accepted that peatland habitats, particularly upland blanket mires, are of international importance, and require conservation. Since 1990, little new forestry planting has taken place on these landscapes, and the presumption now, at least in England, is against further forestry expansion on:

- active raised mire, and degraded raised mire capable of restoration to active status;

- extensive areas (exceeding 25ha) of active blanket mire averaging 1m or more in depth, or any associated peatland where afforestation could alter the hydrology of such areas.

2.8.26 Forest Enterprise planting proposals will exclude such sites, and the Forestry Commission will not approve grant applications containing proposals for new planting or new natural regeneration in these situations. Under revisions concerning the production of Environmental Impact Assessments for forestry projects, the Forestry Commission can also prevent forestry development which could damage these habitats, even if no grant aid is requested by the developer. These policies should help to ensure the preservation of the archaeological resource on some previously untouched upland peats. Sensitive proposals for the creation of new woodland on other peatland sites, however, including shallow peat (<1m depth) and degraded blanket mire on deep peats, will be allowed (Patterson and Anderson 2000).

2.8.27 ***Mire Restoration:*** the conservation and restoration of mires in existing forests will be encouraged where appropriate; in the Kielder Forest, for example, approximately 30% of the land will not be re-stocked, but will be retained as mire, both at stream sides and as open mire. Mire restoration primarily depends on raising the water table, to provide the correct conditions for the regeneration of the plant species characteristic of an active mire. The system of deep-level cracks caused by dehydration of the peat is impossible to reverse, however, since peat cannot be fully rehydrated. On flat sites, at least, the drainage effect of the cracks can be eliminated by simply blocking the system of forest drains (Anderson 2001). Raising the water table to produce waterlogged anaerobic conditions would halt any further destruction of buried archaeological remains, but would not reverse any losses that had already occurred. This subject appears not to have been addressed in Forestry Commission research (*ibid*).

2.8.28 To date, several thousand hectares of mire have already been restored (B Burlton *pers comm*). In general, because Government policy is to maintain and expand woodland cover, mire restoration projects which exceed the normal open ground provision within woodlands will only be approved by the Forestry Commission where there are potentially considerable environmental benefits from permanent tree removal. Those instances when archaeological benefits justify felling without replanting in peatland areas are only occasional, and typically when they are combined with ecological benefits (Patterson and Anderson 2000).

2.8.29 An opportunity for mire restoration can arise when the mature forest is harvested, but rewetting the ground at this stage may not be feasible. The few examples of mire restoration already undertaken have shown that costs can be high, varying from hundreds to thousands of pounds per hectare, depending on physical site factors, such as slope, and how close the trees are to their normal harvesting age (Anderson 2001). It was noticed during the field visit to Hollow Moor, in Cumbria, that several plant species characteristic of active mire, for instance, *Sphagnum*, were present among the immature trees, suggesting that restoration would still be possible in this location. As trees reach maturity, the lack of light, and the drying out of the peat, kills mire vegetation, making restoration more difficult. In general, mire restoration is usually only a management option on those previously forested sites that are inherently unsuitable for producing trees, and where the crop is poor and uneconomic, and the site is therefore not worth re-stocking.

2.8.30 ***Conclusions:*** in the early period of commercial forestry, successful but labour-intensive methods were developed for forest planting on mires. These entailed manual planting, and were not overly destructive to the archaeological resource. By the late 1950s, mechanised techniques had been developed which enabled the large-scale planting of upland peats. The planting was principally achieved using a deep plough, which was highly damaging to the archaeological resource. Many sites would probably not have been recognised by the untrained workforce, and would have been destroyed without recording.

2.8.31 It is highly probable that extensive archaeological remains have been damaged or destroyed by forestry operations. The Lake District National Park Survey (Quartermaine and Leech forthcoming) has demonstrated that much of the Lake District's uplands have a significant archaeological resource, dating from the Neolithic period onwards. The areas of surviving cairnfield are often adjacent to plantations, and there are several examples where the plantation boundary extends through the middle of cairnfields, such as the Intake, Stainton Fell (SD 137 945), and at Mecklin Park (NY 123 021). In both these instances, it proved impossible to check the extent of the cairnfield within the areas of plantation, due to the density of tree coverage, plough disturbance, and ground vegetation cover. While it is now Forestry Commission policy that sites of archaeological importance should be conserved, 'the damage to the archaeology of the upland peats since the Forestry Commission was established remains unquantified and may well be unquantifiable' (Forestry Commission 1995, 7).

2.8.32 In addition to the direct impact of deep ploughing and other ground disturbance, there is also damage caused by the widespread drying of the peat by both deliberate drainage and by transpiration. The problems related to drainage and soil hydrology in forestry plantations occurred as soon as forestry planting began (*Section 2.8.10*) and have undoubtedly caused great destruction to organic archaeological remains within the peat. Forestry has undoubtedly caused great damage to the archaeological archive of the peatlands in the past, and will continue to do so unless appropriate mitigation strategies can be devised and implemented.

2.8.33 ***Mitigation:*** the planting of forest on upland mire continued until the 1980s, but by the 1990s the value of undisturbed peats as a wildlife habitat began to be appreciated, and little new planting has been undertaken since then on active mires. The present presumption against new planting on areas of active peat will undoubtedly conserve a considerable and hitherto undisturbed archaeological resource. In addition, the Forestry Commission now recommends Environmental Impact Assessments and archaeological surveys ahead of new planting, and, sometimes of felling. Mitigation strategies during forestry works are also recommended, but these apply mainly to known and easily recognisable sites. Mitigation strategies for small sites and surface scatters would be almost impossible to implement, given the difficulty of identifying these sites in standing plantations of any age, and also the difficulty of marking them in such a way that they could be avoided during the highly mechanised management and harvesting processes. On those areas that may be brought into forestry (*eg* shallow or degraded peat) or in areas where re-stocking will take place, damage will still occur (*Section 2.8.11*).

2.9 RECREATION

2.9.1 ***Introduction:*** two areas, Anglezarke Moor, in South Lancashire, and the Langdale Fells, in Cumbria, were proposed for the initial assessment of the impact of recreational and leisure use on upland peats. These two areas were chosen because they both have recognised high visitor levels, and would therefore serve as test cases for the present study. The Langdale Fells have the higher level of visitor activity, which is very much targeted on accessing specific peaks and routes, while Anglezarke Moor has more casual visitor pressure, reflecting the easy access to the moor from the nearby conurbation of Bolton/Manchester.

2.9.2 The assessment of the impact of recreational and leisure use on upland peats was primarily a desk-based study, information being obtained from a number of national and regional agencies, including DEFRA, English Nature, The Countryside Agency (both now Natural England), the Environment Agency, the National Trust, the Lake District and the Yorkshire Dales National Park Authorities, United Utilities and Lancashire County Council. Rangers and others working directly in the field as land managers were contacted for first-hand views on present and/or changing conditions affecting upland peats.

2.9.3 ***Recreation and Leisure uses of Open Moorland and their Contribution to the Erosion of Upland Peat:*** while the various causes of erosion associated with recreation and leisure use are discussed separately below, none of the agents should be considered in isolation. Most erosion problems are complex - one factor may open an area to erosion, but other factors will exacerbate the situation. An area of landscape can be considered to have a 'recreational carrying capacity', which has been defined as ‘the level of use an area can sustain without an unacceptable degree of deterioration of the character and quality of the resource or of the recreation experience’ (Countryside Commission 1970, 32). If this carrying capacity is exceeded, damage results, and erosion will occur.

2.9.4 The level of use of open countryside rose through the second half of the twentieth century, as more people were able to access areas (*eg* the National Parks), through increased car ownership and increased leisure time. For example, survey work in the Peak District National Park resulted in the estimate that visitor numbers increased from 16 million in 1972-3 to 18.5 million in 1986-7 (Anderson *et al* 1998, 2.3.2). Figures for 1986 showed that 20% of the visitors were hikers, who visited all year round (2.1 million visitors over the summer and 1.6 million over the winter). Visitor numbers are lower in bad weather, but the moorlands remain popular in all conditions (Yalden and Yalden 1988). As visitor numbers have risen, types of recreational use have changed and expanded over the same period. Present-day recreational activities include:

- informal and sight-seeing visits, caravanning and camping, which tend to focus on specific areas not too far from roads and car parks, and can include camp-fires and picnicking;

- active pursuits, including walking, running, orienteering, horse-riding and pony-trekking, mountain biking, and motor sports involving off-road all-terrain vehicles and trail bikes;
- minority activities including climbing, caving, gully scrambling, hang-gliding, model aircraft flying, winter sports, and shooting.

2.9.5 The increase in the leisure use of moorlands affects degradation and erosion directly, through the activities themselves, and the problems associated with increased public access in general. These effects are not necessarily widespread, but tend to be concentrated on specific areas and routes, for instance around car parks and beauty spots, along popular routes and footpaths, and at gateways and water crossings. The effects include trampling, destruction of surfaces, and fire, whether set deliberately or accidentally (the aspect of erosion resulting from fire is dealt with in more detail in *Section 2.10*).

2.9.6 ***Trampling:*** the main initiator of erosion caused directly by leisure activities is trampling, which can be caused by a number of agents but particularly results from booted feet, and the hooves of horses. The areas worst affected are much-used paths, the most common being to peaks, view-points which are accessed via gateways, and at water-crossings (Plate 5). Other areas of particularly heavy use include 'green lanes', favoured by vehicle users, and bridleways favoured by horse-riders and particularly pony-trekking centres (Ratcliffe and Oswald 1988).

2.9.7 Trampling at first causes damage to the soil structure, and is the critical period in which erosion is initiated (Agate 1983). The first visual evidence is often a change in vegetation from taller plants to shorter grasses, while excessive trampling, or trampling in extreme conditions, causes the mat of vegetation and roots to break up, and exposes the soil. If the vegetation is not allowed to recover, such as through temporarily removing the visitor pressure, water run-off, combined with wind and frost, begins to create gullies. Further trampling exacerbates the problem and widens the gullies, and as the path becomes muddy and/or waterlogged, users seek firmer or drier ground and the path becomes widened (Dartmoor NPA 2003). Path wear increases with ground wetness, and thus peaty ground tends to have the most worn and widest paths (Bayfield and McGowan 1986). The most extreme historical form of such erosion can be seen in the hollow-ways caused by drove routes, and in these instances the gullies creating the hollow-ways can be up to 2-3m deep. Trampling affects all types of environment, but, 'as a general principle ... the greatest effect of recreation pressure is likely to be manifest as sward degeneration and erosion on blanket peat of vegetation dominated by cotton-grass and crowberry and on the well-drained mineral soils that support *Deschampsia flexuosa* grassland' (Shimwell 1981, 161).

2.9.8 Survey work on the Pennine Way in the Peak District National Park (Anderson 1998, 2.3.5-8; Tallis 1997a) showed the damage that can indeed be done by trampling. In 1989, the southern section of the Pennine Way was described as a 'man-made quagmire in wet conditions, and rapidly deteriorating to the detriment of the landscape, wildlife, walkers, and those who seek to earn a living from the land which the Pennine Way traverses' (Porter 1989, 41). Comparative surveys of the mean width of trampled ground along two stretches of the Pennine Way in the southern Pennines produced dramatic results demonstrating considerable increases in erosion damage over a 16-year period.

Path Section	Erosion width in 1971 (m)	Erosion width in 1987-8 (m)
Mill Hill to Snake Summit	3.54	14.28
South-west approaches to Black Hill	1.8	21.7

Table 2: Changes in Erosion Damage to the Pennine Way over a 16-year period (after Porter 1990)

2.9.9 Heavy trampling also occurs in specific areas, for instance around car parks, at particular access points where it is possible for walkers to join a major footpath, and at popular destinations (‘honey-pot’ sites) such as Malham Tarn or Ingleborough, in the Yorkshire Dales National Park (YDNPC 1993). The British Trust for Conservation Volunteers' handbook on footpaths notes that ‘in the past, serious damage has been caused by mass walks, particularly on upland areas of peat mire. The effects can be particularly long-lasting if a sponsored walk, training exercise or other event coincides with a period of wet weather. The damage caused by a single event may be seen for many years’ (Agate 1983, 17).

2.9.10 Trampling in itself has the potential to cause great damage to archaeological remains, particularly those lying close to the surface, by actual physical destruction or dislocation of evidence, as well as from the ensuing erosion. The hollows through the peat can channel drainage and contribute to the dessiccation of the surrounding peat. As paths deteriorate and widen, so the area susceptible to damage increases. On occasions, stone has been deliberately removed by walkers from nearby walls or other features (*eg* cairns), in an attempt to provide firmer footing though particularly wet or boggy areas.

2.9.11 Other damage associated with high visitor numbers at ‘honey-pot’ sites includes the removal of stones from archaeological features, such as cairns, in order to add a personal marker to a ‘summit cairn’. In other cases, visitors have been known to dismantle archaeological stone features in order to build temporary shelters or wind-breaks, for instance when resting and picnicking in an exposed place. Both these activities have occurred at Ingleborough in the Yorkshire Dales (A Hume *pers comm*).

2.9.12 ***Recreational Vehicles:*** over the last few decades, the use of vehicles, both for work and recreation, on areas of open moorland has increased significantly. Mountain bikes, trail motorbikes (two- and four-wheeled) and four-wheel-drive all-terrain vehicles are now widely used for off-road recreation. Some of this use is legal, such as on paths categorised as ‘by-ways open to all traffic’, or by farmers and others with legitimate access to the land. Illegal use is also frequent, however, and difficult to police. Undoubtedly, some of the evident damage is caused by farmers and other land managers, rather than by recreational users, but it is not in a farmer’s best interest to damage the land that stock grazes, and they will therefore often maintain/repair the tracks. In contrast, some users are undoubtably irresponsible and seem to have no care or comprehension of the damage that results from their activities. These users can create conflict with other legitimate users of an area, such as walkers or horse-riders, and can give the whole of the leisure vehicle fraternity a bad reputation.

2.9.13 Much of the damage from the use of vehicles on areas of upland peat is caused by rutting, where the wheels cut deeply into the soft ground and rapid erosion follows. The narrow tyres of mountain bikes can cut deep ruts, and motorised vehicles of all types can similarly cause great damage if driven too fast for the conditions, when impact and wheel-spin can cause deep and wide ruts and holes which lead swiftly to erosion. Where this happens on footpaths and bridleways, other vehicles, as well as users on foot or on horseback, will avoid the wet and damaged sections as much as possible, widening the path and causing trampling over a wider area. Some off-road organisations claim that the severe rutting (occasionally more than 500mm deep) cannot be caused by their vehicles, which only have a maximum ground clearance of 250mm, and more usually 150mm. This does not take into account the fact that the initial damage caused by their vehicles can lead to further and swift erosion.

2.9.14 Possible damage to underlying archaeological remains includes physical destruction and/or disturbance, often to a deeper level than that caused by foot traffic, as well as the potential damage caused by the ensuing erosion. Other damage can occur during attempts to free stuck vehicles, for instance by removing stones from nearby features in an attempt to give purchase to wheels. Attempts have been made to free vehicles with winches by anchoring the cables to gateposts or standing stones, which have in some cases been uprooted or broken.

2.9.15 ***Fire:*** one of the most damaging impacts of visitor pressure is uncontrolled burning, known as 'wild fires', started accidentally or as an act of vandalism. It is such a major threat to upland peat landscapes that it is considered in a separate section (*Section 2.10*).

2.9.16 ***Mitigation Strategies and Management Practices:*** damage and erosion caused by visitor pressure is of great concern to landowners and managers in the areas of highest visitor numbers (typically National Park Authorities, Local Government Authorities, Utilities and the National Trust). Visitor pressure not only causes damage to archaeology and ecology, but also affects the livelihood of the hill farmers involved, and by causing bare ground, scarring and quagmires, can reduce the amenity value of an area. Excluding visitors and grazing animals from affected areas greatly helps regeneration, but is not always possible. Over the last decades of the twentieth century, several studies have been undertaken (notably in the Peak District National Park and the Three Peaks Project in the Yorkshire Dales National Park) which have examined the problem in detail, formulated management strategies, and undertaken trials on various methods for repairing and/or mitigating the effects of recreational pressure.

2.9.17 Several approaches to repairing and/or managing areas damaged by recreational use have been developed. These include ecological methods to facilitate regeneration and/or strengthening of vegetation, engineering solutions of reinforcing and/or constructing paths, and providing information and education to land-users. It is worth noting that the effects of both erosion and mitigation strategies on archaeological remains receive minimal attention in the published sources, in comparison to ecology, landscape value, and visitor experience of the area(s) in question.

2.9.18 ***Information and education:*** the education of user groups is necessary, since this will explain the causes and effects of over-use and erosion of an area, and get the users 'on board' in co-operating with and implementing mitigation strategies.

Various methods can be used to disseminate this information, including published media, outreach to the local communities and user groups, and signage at car parks, visitor centres, and directly on site. Conversely, the siting of such signs, which usually includes the digging of postholes, could affect archaeological remains during erection, and as the signs themselves become the focus of heavy wear and trampling by people as they are read. The experience of the lengthsmen on the Hadrian's Wall National Trail has demonstrated that signs need to be located very carefully so as to prevent damage to the underlying deposits (A Gledson *pers comm*).

2.9.19 ***Ecological methods:*** reinforcing and strengthening of vegetation can be done in a variety of ways, which were experimented with during the lifetime of the Three Peaks Project (YDNPC 1993). These include the application of mineral fertilisers in an attempt to make the vegetation more resistant to trampling; however, this has the risk of changing the ecosystem and is of particular concern within SSSIs. The results of these trials were interpreted as inconclusive, although some regeneration of vegetation was noted. No mention is made within the reports as to whether the application of minerals, including lime, might alter the soil chemistry to such a degree as to have a damaging effect on any buried archaeological remains.

2.9.20 The Three Peaks Project (*op cit*) also undertook trials of physical methods of reinforcing swards on peat soils, using a variety of synthetic 'fabrics'. These were laid directly onto the turf, using fertiliser and seeding to encourage vegetation growth upon and through the synthetic material, and allowing trampling and grazing immediately. Some success was noted, but the general conclusion was that the idea needed more development work to be completely satisfactory on upland peat soils. The disadvantages include the weight of the fabric rolls, which are difficult to transport to site, and to handle once there. Vehicles have been used for access, and may cause ground disturbance, with potentially damaging effects on buried archaeological remains. A modern-day alternative is to use helicopters to disperse the seed, but this is expensive.

2.9.21 Various methods of restoring severely damaged peat soils were tested, including reseeding with native seed mixtures, and the relocation of native turves, although neither of these proved successful. A longer-term approach involved reseeding with perennial rye grasses, which would germinate and establish quickly. These in turn would provide a temporary sward in which native species could establish, but which would not themselves survive in the environment without careful management, and this approach appears to have been successful (*op cit*). The method used involved no ground preparation, or the use of specialised machines for hydraulic seeding. The only potential damage to buried archaeological remains might be the physical impact of the seeding vehicles themselves, and the possibility of changes to soil chemistry caused by the use of fertilisers.

2.9.22 ***Engineering Solutions:*** the engineering solutions tested by the Three Peaks Project include the chemical consolidation of peat soils, which was a technique potentially damaging to archaeology because of the alteration of the soil chemistry, but was also found to be of no use on upland peats. Other methods include mechanised path construction using subsoils as a base, aggregate path construction, stone-pitched paths, and temporary timber-based constructions, including boardwalks and decking systems. Many of these techniques, particularly the stone pitched paths, have been developed as part of *Repairing Upland Path Erosion: A Best Practice Guide*, by the National Trust in the Lake District (Davies and Loxham 1996). All of these methods involve some ground disturbance, which can be minimal for the decking system, through to total disturbance for those methods of path construction which require working from a solid base. Of these, aggregate paths with geotextiles or geogrids normally require a minimum of 200mm of excavation before the path is laid, and subsoil paths require excavation to the subsoil. Both types of path require the construction of culverts to a further depth of at least 1m, to take water below the path. The critical factor in path construction is often the load of the machinery required to build it, rather than the use it will later receive. It is evident that engineered methods of artificial path construction on upland peats have the potential to cause considerable damage to any underlying archaeological remains.

2.9.23 ***Langdale Fells Case Study:*** the Langdale Fells are a popular visitor destination in an area that receives a large number of visitors annually, and it is a registered Urban Common with Open Access under the Countryside and Rights of Way Act 2000 (CROW). Most of the visitors to the study area are serious walkers rather than casual visitors, as reaching the Harrison Pike summit (736m AOD) requires a certain level of commitment and fitness, as well as suitable clothing and footwear. Visitor numbers are greatest in the summer months, with less pressure on the landscape in the wetter, colder months over the winter. Certain spots within the study area are particularly popular, and these areas and their access paths suffer damage from trampling at certain times of the year, and in certain conditions. On the slopes, sheep trods tend to be used subsequently as paths by people, which can often compound erosion. The fact that visitor numbers drop in the winter months, and that grazing decreases during the same period, allows for a certain amount of natural regeneration of vegetation. Because of the steep gradients in the Central Lake District, off-road vehicles or quad bikes are rarely used away from the valley floor, even by farmers. The bridleways are rarely used by horse riders. Although mountain bike use does occur, to date this has not caused undue problems (J Archer and J Metcalfe *pers comms*).

2.9.24 Remedial work on footpaths is generally reactive rather than proactive, and entails the establishment of deep-founded, stone-pitched paths. Their construction can potentially cause localised damage to the Neolithic axe-production sites that are frequent within the area, and the quarrying of source stone and turves from the environs has the potential to damage further sites. Typically, the National Trust undertakes mitigative excavation on sites affected by the path repair work (*eg* OA North 2004a).

2.9.25 Visitor pressure appears to have stabilised within the area, and no increase is anticipated as a result of current Open Access legislation; indeed, if anything it might reduce the impact as recreational use extends away from the 'honey-pot' sites onto hitherto less visited fells. Public access does contribute to sheep movements in some areas: as visitor numbers peak at certain popular spots, so the sheep try to avoid the visitors, and therefore move to less accessible areas, which are possibly more vulnerable to over-grazing, trampling and erosion.

2.9.26 ***Anglezarke and Rivington Moors Case Study:*** in contrast to the Langdale Fells, Anglezarke and Rivington Moors are within easy access of major population centres, and receive a large number of 'casual', less focused recreational visits, which diminish but do not cease during the winter months. As a result there is a large network of eroded pathways. On Rivington Moor, problems can be related both to access by pedestrians and vehicle users, which have led to footpath widths of over 50m. Erosion control methods have been vandalised, there have been numerous deliberately set and accidental fires, and access by mountain bikes, motorbikes, and off-road four-wheeled vehicles has greatly contributed to problems of rutting and erosion. Shooting brings some positive benefits to the Anglezarke area, as a regular presence of gamekeepers, and a well-controlled programme of burning, keeps the vegetation down in selective areas, limiting the impact of wild fires (I Harper *pers comm*).

2.9.27 ***Conclusions:*** recreational and leisure use on upland peats cause a number of problems which can result in damage to and erosion of the peat, with adverse effects on archaeological remains. These effects include physical damage to archaeological sites by deliberate or accidental disturbance, and damage to buried archaeological remains by the dehydration and subsequent erosion of the surrounding peat layers. At a conference in 1997 on *Blanket Mire Degradation* (Tallis *et al* 1997), participants were circulated with a post-conference questionnaire asking, among other things, their opinions on what were the most important causal agents of degradation. Accidental burning, which was considered separately from recreational pressure, was considered to be the second most important agent after over-grazing (*Section 2.7.25*). Without the burning, recreational pressure was considered to be one of the least important causes of degradation. Its impact tends to be concentrated either on narrow linear areas such as footpaths, or at much-frequented 'honey-pot' sites, such as Ingleborough in the Yorkshire Dales, and wide areas of peat remain unaffected. Footpaths often pass close to or cross archaeological sites, however, and many of the 'honey-pot' sites contain significant archaeological remains (*eg* Ingleborough in the Yorkshire Dales, or the Langdale axe factories). Such remains can be damaged or destroyed as easily by remedial works or mitigation strategies as by the initial trampling and erosion problems caused by visitors.

2.9.28 With the extension of Open Access land through the implementation of the 'Right to Roam' (CROW 2000), adopted in 2005, legislation will increase recreational pressure on areas of upland peat in certain places; on the Langdale Fells, visitor numbers seem to have stabilised, and it is anticipated that the new legislation will have little or even a reduced impact (J Metcalfe *pers comm*). By contrast, on Anglezarke and Rivington Moors, in proximity to major population centres, there is likely to be a more detrimental effect through casual visitor usage, as a result of Open Access.

2.10 FIRE

2.10.1 ***Introduction:*** this project, both through the use of documentary sources and fieldwork, has demonstrated that fire is one of the most serious threats pertaining to upland peat. The threat originates not only from the initial loss during the fire, but from the subsequent effect of other agencies upon the exposed peat surface. In modern times, two types of burning can typically take place on upland peat: controlled burning in the legal burning season (October to April); and uncontrolled wild fires, which can result from natural causes, accidents, picnic fires, managed fires that have got out of control, and unfortunately, arson. Wild fires tend to occur during the summer months, and are more frequent in times of drought; it has been estimated that three-quarters of all recorded wild fires could be the result of human carelessness or arson (Tallis *et al* 1997).

2.10.2 Controlled burning, for example for improving grazing or game bird habitat, typically causes minimal damage, whereas the wild fires, unless spotted and reported early, can quickly become uncontrollable and can damage large areas. They tend to burn at a very high temperature, destroying surface vegetation and the root mat, and occasionally penetrating the underlying peat. Under drought conditions, the peat may be dry enough to catch fire. If it does so, it may burn to a considerable depth, or even burn away completely. Damp peat can smoulder for many days, even months, reducing the peat to ash, and fire may break out again if conditions are right. At the very least, the upper levels of the peat will become dry and desiccated, rendering them liable to erosion by both water and wind (Tallis 1981). Once erosion has been initiated by severe burning, it is extremely difficult to stop. Subsequent regeneration of the ground cover can be extremely difficult, as it is possible that an intense long-lasting burn may create conditions which are more or less permanently unfavourable for revegetation (*op cit,* 176). Open and desiccated peat is subject to wind erosion, as well as run-off during heavy rains. Wet weather after a severe burn can erode up to 1m of peat, as was the case on Burbage Moor, in the Peak District, in September 1976 (Anderson 1997). In such conditions, any archaeological remains that had survived the actual burn would be under extreme threat of eventual total destruction.

2.10.3 The potential impact of burning on archaeological remains preserved in the peat is two-fold:

i) the direct effect on buried and preserved archaeological remains, such as organic materials or pollen and other plant remains, of the desiccation of an anaerobic waterlogged environment;

ii) the damage caused by disturbance or dislocation of archaeological features such as walls, cairns, flint scatters etc, by the total erosion of the peat cover and their subsequent exposure to the elements.

2.10.4 ***Historical Fires:*** fire is by no means only a current or future threat, and its impact on upland peat mires was noted as early as the late eighteenth century (Farley 1815). A ban on fires under the pre-enclosure manorial system (Anderson 1997) indicates that the danger of damage was, even then, appreciated. Anderson (*op cit*) suggests that the ban may indicate that there were fewer fires in earlier times, although the fact that a ban was considered necessary may conversely suggest that fires were a frequent occurrence. These fires are also widely recorded in the stratigraphy of blanket peats, from their initiation through to the present day (Tallis 1987). For instance, bands of charcoal in peat cores from the drier eastern section of Holme Moss, in the southern Pennines, suggest that there was at least one major fire on the mire in the eighteenth century. Tallis (*op cit*) identified areas of redeposited peat on hillside terraces at Holme Moss, and he suggests that these may have occurred after an initial fire, which caused areas of erosion to form around the mire edges, which may have been subject to peat slides. He also notes that, on the basis of known bog bursts in England and Ireland, some exceptional stimulus is required to initiate mass movement of peat. He goes on to quote a report, from the weekly *Leeds Mercury* of 29th July 1777, of a four hour-long cloudburst on 23rd July 1777, which was probably centred on Holme Moss (S

Pickles *pers comm*), and suggests this may have been the causal agent of the peat slides. Pollen analysis of the peat from these terraces suggests that they started to accumulate after fires in the eighteenth or nineteenth century and, by analogy with more recent damage caused to the margins of blanket mires by fires, Tallis (1987) suggests that damage caused by the fire in the eighteenth century may have contributed to the peat slides.

2.10.5 Mackay and Tallis (1996) attribute the onset of erosion of peat on Fairsnape Fell, in the Forest of Bowland, to a catastrophic burning episode, *c* 1921. This fire was probably the result of a combination of factors, such as a period of below-average rainfall in the early 1900s, a subsequent lowering of the water table, and a decline in upland management due to a shortage of gamekeepers during and after the First World War. The resulting decline in the frequency of burning for management purposes, and the corresponding rampant growth of heather, probably increased the risk of wild fires and, together with the dry condition of the peat, resulted in a catastrophic fire which then acted as a catalyst for further erosional processes.

2.10.6 A survey of historical fires in Derbyshire by Radley (1965) demonstrated that before 1900 few major fires were recorded, and that natural fires (*ie* lightning strikes) in peatland were unproven (Hall *et al* 1995, 60), suggesting that the majority of fires in the uplands have been anthropogenically generated. The incidence of 'accidental' fires appears to be increasing, and in the Peak District National Park 300 were recorded in 1970-90 (Simmons 2003, 238). At the present time, there is a 10-15 year cycle of moorland fires (S Heath, Greater Manchester Fire Services *pers comm*), which appears to correlate with a number of factors, including vegetational cover, land management, climatic conditions, and visitor numbers. If there is little management of the land, leaf litter (grasses or heather) accumulates, and the heather becomes leggy (woody); if ignited, the moorland will burn more easily than a less mature, managed plant community. Additionally, burning heather is more likely to reach higher temperatures than grass, and if weather conditions are such that there is little wind to move the fire on, it will cause more damage to the underlying peat, and so lead to greater erosion in the aftermath of the fire. In contrast, extensively managed heather moorland is less likely to be accidentally burnt, because the heather is greener and less woody, and therefore less likely to burn.

2.10.7 There is probably a relationship between vegetation cover, fire and the subsequent erosion of the peat. Both Anglezarke Moor and the Forest of Bowland, the two study areas which displayed the worst erosion, had ground cover that predominantly comprised heather. It would appear that fires on moorland covered with grass burn out more quickly than those where heather predominates, as heather is more substantial and thus burns for longer, increasing the chances of the underlying peat catching light. Of the other significant factors in the incidence of accidental or deliberate fires, the two most important are climatic conditions and human behaviour, either through negligence or deliberate acts. The incidence of fires is directly related to climatic conditions; for example, large numbers of fires followed the exceptionally dry spring of 2003 (*Section 2.10.14*). The relationship of fire to human causes, whether accidental or deliberate acts of arson, is clearly shown in the Peak District by the occurrences of fires in and around the National Park in 1970-95. The data collected in the Rangers' fire logbook show that fires were not random, but were concentrated on moorland in areas where there is a high level of visitor pressure, such as on the Pennine Way (Anderson 1986;

Anderson *et al* 1998, 38-41). Thirty fires were recorded in 1990-5, and of these, five were started by camp fires, five by cigarette ends, 13 were thought to be the result of arson, and seven were 'controlled' fires that got out of hand.

2.10.8 ***Controlled Fires:*** controlled fires are set in the wetter months, either to burn off older heather cover to encourage grass and other vegetation to sprout for stock grazing (Tucker 2003, 30), or to encourage new growth for grazing and suitable cover for red grouse. In general, a controlled fire is small in area, fast-burning, and not too hot, so that it burns off the surface vegetation without killing the root mat. Temperatures should not exceed 400° C, so that the rootstock and seed bank are undamaged (*op cit*, 71), and the peat is not exposed, thereby increasing the risk of erosion. Controlled fires have the additional effect of preventing vegetation, especially heather, from becoming too woody, which can produce greater heat when burning does eventually occur (M McHugh *pers comm*). Conversely, although not scientifically substantiated, it has also been postulated that large-scale and repeated burning, for example on grouse moors, may result in slow but progressive degradation of the peat (V Hack *pers comm*; Anderson 1997).

2.10.9 Controlled burning has been practised for many centuries, and possibly for millennia, as a management tool on both the lowland and upland mires. The charcoal record preserved in peat mires and lake deposits suggests that as early as the Mesolithic period populations were using fire as a means of clearing areas of woodland to encourage animals to graze (Middleton *et al* 1995). It has also been proposed that the ground layer of herbs and plant litter was being burnt more regularly, rather than the trees (Simmons 2003, 40). The environmental record preserved in peat and lake deposits, both from the lowlands throughout the North West (*eg* Middleton *et al* 1995; Hall *et al* 1995; Leah *et al* 1997), and from the uplands of the Central Pennines (Tallis 1991) and Upper Teesdale (Simmons 2003, 32-3), provide evidence of changes in the vegetation which are related to the charcoal recorded in the deposits.

2.10.10 By 1610, a law was in place to control burning of peat fires and to help minimise the adverse effects of smoke (Evelyn 1661; Rackham 1986, 321; Diemont *et al* 2002). The following is a quotation from that legislation:

'Anno vii. Jacobi Regis: *an act against burning of Ling, Heath, and other Moor-burning in the Counties of York, Durham, Northumberland, Cumberland, Westmerland (sic), Lancaster, Darbie, Nottinham (sic) and Leicester, at unseasonable times of the year'.*

'Whereas many Inconveniences are observed to happen in divers Counties of this Realm, by Moore-burnings, and by raising of fires in Moorish grounds and Mountainous Counties, for the burning of Ling, Heath, Hather (sic), Furres, Gorsse, Turffe, Fearn, Whinnes, Broom and the like, in the Spring time and Summer-Times: for as much as thereby happeneth yearly a great destruction of the Brood of Wilde-fowle, and Moor-game, and by the multitude of grosse vapours, and Clouds arising from those great fires, the Aer is so distemper'd and such unseasonable and unnatural storms are ingendered, as that the Corn and the Fruites of the Earth are thereby in divers places blasted, and greatly hindered in their due course of ripening and reaping. As also, great fields of Corn growing, having been consumed, and Meadows spoyl'd, to the great hurt and damage of His Majesties (sic) Subjects: which Moor-burnings neverthelesse, may be used,

and practised at some other convenient times, without such eminent danger or prejudice' (Evelyn 1661, 26).

The law goes on to state that burning will be unlawful in the months of April, May, June, July, August and September, which is very similar to the MAFF (1994) code of burning. The offenders were to be committed to the local prison for a period of one month without Bail or Mainprise.

2.10.11 The controlled burning of moorland became more intensive in Northern England and Scotland from about 1800, when sheep numbers were increasing and grouse shooting was developing (Rackham 1986, 321). Today, controlled burning by the farmers and landowners is allowed between 1st October and 15th April (MAFF 1994), but burns tend to occur as late in the season as possible.

2.10.12 Different fire regimes are practised for different types and uses of the land. United Utilities, a major upland landowner in the North West, has produced guidelines for heather burning, after the spate of uncontrolled fires in the early spring of 2003. The code stresses that all heather and grass burning must comply with the *Heather and Grass Burning Code* (MAFF 1994), and alongside the more obvious restrictions of dates, time, and safety, the code requires permission from English Nature (now Natural England) for burning on SSSIs, and that English Heritage must be notified if Scheduled Monuments are on the site or in the vicinity. United Utilities has also instigated additional requirements when burning is practised by their tenants. These are stringent and are sensitive to many aspects of the upland environment, both physical and biological, with particular reference to slope, burning along contour lines to help minimise erosion, to avoid peat hags, blanket mire and bracken stands, as burning of the latter tends to encourage its competitive regeneration to the detriment of other plants. Finally, they require that the wildlife warden keep a detailed record of any burning.

2.10.13 ***Modern accidental or deliberate fires***: the potential for wild fires has increased in recent decades, both as a result of greater numbers of people visiting moorland areas, and of changes in land-management practices, such as the decreased frequency of deliberate moor-burning. This leads to a larger mass of dead flammable plant material which, in drought conditions, catches fire easily and burns at a high temperature. It has been estimated that 42 square kilometres of the southern Pennine moorlands has been burnt since 1970 (Tallis 1997b), although no comparanda could be found for other areas.

2.10.14 ***Lancashire:*** as part of this project, the threat of moorland fires in Lancashire was assessed, and statistical information was obtained from the Lancashire Fire Service about moorland fires from those Districts with areas of upland peat. This data comprised the dates, locations and probable causes of all grassland and moorland fires between January 2000 and March 2004, although the extent of individual fires was not included. These data indicate that moorland/grassland fires in Lancashire increased in 2002 and 2003 (Fig 14). The unusually high numbers of fire incidents in 2003 are related to an exceptionally dry winter and spring. These data illustrate clearly the increased risk of fire as a threat to the upland peat resource if climate change does bring about warmer and drier conditions (*Section 2.10.46*).

2.10.15 It is also apparent, from this small dataset, that the Lancashire Fire Service considered the major cause of the fires to be deliberate (Fig 14). No definition of deliberate or accidental was given, however, and it is unclear what criteria have been used to differentiate between the two.

2.10.16 It was thought by Hallam (nd) that burning off vegetation from the peat on the Pennine Moors in the last quarter of the nineteenth century, as a preparation to forming grouse moors, exposed extensive areas of mineral soil. These areas allowed the amateur Victorian geologists to search for glacial activity, and also allowed the discovery of 'Neolithic' flint tools and chippings. While fires may indeed have destroyed the peat, it is unlikely that it was deliberately done for grouse shooting, as today only the surface vegetation is burnt to encourage new growth of the heather. On the Anglezarke, Rivington and Horwich Moors, large erosion areas began to disappear in the mid-1960s, which Hallam (*op cit*) believes was coincident with a decline in pollution, following legislation controlling smoke production, thus allowing sensitive moorland vegetation to recover. The recovery and restoration of the severely burnt moorland is discussed further below (*Section 2.10.42*).

2.10.17 More recently, Anglezarke Moor has been repeatedly damaged by fire. In 1958, a moorland fire destroyed an area of Stronstrey Bank (Fig 6), and by 1961 a local archaeology society was finding flints within the exposed areas. This led to a limited excavation, which recovered a small assemblage of mainly Mesolithic flints (Hallam nd). The late 1970s and early 1980s, and in particular during the 1976 drought, saw major uncontrolled fires on Anglezarke Moor, which burned for up to a fortnight, and notably affected the western slopes between Pike Stones and the Black Coppice/Stronstrey Bank escarpment. Subsequent wind/rain action has stripped most of the peat in some areas, leaving extensive areas of bare mineral soil, and exposing and destroying some of the archaeological remains (Hallam nd; Howard-Davis 1996). As a result of these fires, survey work was undertaken in 1983 and 1985 by the then Cumbria and Lancashire Archaeological Unit (now OA North; Howard-Davis 1996; Fig 6). During these surveys, all archaeological features were mapped, and the modern vegetation recorded. Additionally, an earlier Mesolithic site on Rushy Brow was excavated, as was a cairn on Hurst Hill, alongside palynological analysis of two associated deposit profiles.

2.10.18 Unfortunately, these fires were not isolated events, and between 1st March 2000 and 1st March 2004, 13 fires were reported to the Lancashire Fire Service in the Anglezarke / Rivington Pike uplands. Of these 13 fires, five were recorded as having been started deliberately, one was accidental, and the causes of the remainder were logged as unknown.

2.10.19 In December 2003, during the course of the present project, extensive damage was still evident from a fire which took place in the previous April, which had burned for several days (I Miller *pers comm*). The above-ground heather and purple moor grass (*Molinia*) was burnt, and the surface peat had been destroyed in places, leaving clumps of purple moor grass as 'islands'. There were, however, relatively few areas where there had been complete destruction of the peat. By December 2003, it was obvious that water erosion in the fire-affected area had increased. At the same time, however, it was noted that the areas devastated by fire during the 1970s and 1980s were recovering and becoming revegetated (A Olivier *pers comm*). Similarly, it was noted that the Scheduled Monument of Pike Stones (SD 627 172), which had been fenced to exclude grazing animals, was becoming overgrown and obscured by the tall herbaceous vegetation, to the detriment of the monument. Following discussions with the Greater Manchester Fire Service, it is now evident that the vegetation constitutes a severe fire hazard, and the monument would be better protected by removing the fence to allow some grazing of the area and so remove the fuel that could result in the development of a wild fire.

2.10.20 It is notable that Rivington Moor has not suffered the same intensity of uncontrolled fires as Anglezarke Moor, which is probably due to a number of factors. The road access to transmission masts on the moor creates a firebreak, and because of the permanent staffing at the masts, any fires are reported quickly. The presence of the staff at the masts may also discourage arsonists. Overall, Rivington Moor probably has wetter ground conditions, and also a higher stocking density of both cattle and sheep, creating a reduced sward height and a reduction of heather cover, both of which reduce the risk of fire.

2.10.21 ***Greater Manchester:*** the threat of fire to the upland peat resource of Greater Manchester is extremely high, and in 2003, following an exceptionally dry winter and spring, there were 11,500 grassland/moorland fires reported to the Greater Manchester Fire Service (GMFS). In the Greater Manchester area, fires generally occur between April and September (S Yearsley *pers comm*), the timing being dependent on weather conditions and the state of the vegetation. Therefore, in April and May 2003, after a dry winter and spring, the number of such fires reported was high. The GMFS classify moorland/grassland fires as either a 'good' or 'bad' burn. A good burn will move rapidly, often accelerated by wind, and will only burn the surface vegetation. If the weather conditions prohibit the fire from spreading, however, it can become deep-seated within the peat, becoming increasingly difficult to bring under control. The fire service deals with these by digging holes down into the peat at the point that the smoke is venting, but this is inherently difficult and they often resort to getting the ground as wet as possible over a longer period of time. In 2003, around Saddleworth Moor, prolonged and deep-seated fires caused a civil emergency, because of smoke pollution and the risk to people's health.

2.10.22 There is usually a five to ten year cycle in the frequency of deliberate or accidental fires, probably related to the build-up of leaf litter etc, but Steve Yearsley and Steve Heath of the GMFS are anticipating more frequent fires if global warming continues as predicted. Therefore, as a response to the 11,500 grassland and moorland fires in 2003, GMFS has instigated the Fire Operations Group (FOG). FOG is a group of interested parties and stakeholders, including the fire services of Derbyshire, Greater Manchester, South Yorkshire, and Lancashire, and representatives from the National Trust, the Peak District National Park, Chatsworth Estates, United Utilities, and the Countryside Agency (now Natural England). As yet, English Heritage (EH) is not represented on FOG, and should perhaps be encouraged to become so.

2.10.23 Steve Yearsley (GMFS) is compiling a set of guidelines for firemen on how to tackle moorland fires, and the particular hazards associated with them, such as unexploded ordnance and the carcinogenic nature of bracken. It is also difficult for firemen to operate on moors in their protective clothing, which is designed for urban situations, and specific moorland equipment is needed. He is convinced that there needs to be greater co-operation between the various fire services and other agencies to help combat the threat of moorland fires. Already United Utilities help with costs of helicopters etc, because of the impact of fires on the water catchment and quality.

2.10.24 Ideally, the fire services like to get in front of a fire and prevent further spread. A short break is often the only thing needed to halt the spread of a fire, and therefore they encourage farmers/landowners to mow the vegetation around areas that need to be protected. This is perhaps the one simple method of protecting the known archaeological record in areas of upland peat from the threat of uncontrolled fires. The FOG is encouraging organisations to highlight areas of special interest, for instance SSSIs, biological heritage sites, buildings, and woodlands. The fire service can then mark these on the appropriate maps, which helps to target specific parts of the moors to protect designated areas. It would, therefore, be beneficial for Scheduled Monuments to be included on these maps.

2.10.25 ***Peak District:*** much research has been done on the subject of wild fires in the Peak District National Park, and the adjacent southern Pennine moorlands. The initial *Peak Park Moorland Erosion Study* was commissioned in 1979, and the work continued until 1995. Results from the Peak District National Park Rangers' Fire Log were summarised as follows in Anderson 1997:

- between 1970 and 1995, 324 fires were recorded with full information;
- 72% of these fires started within or adjacent to access areas, or by paths or roads;
- 12% of the fires started close to the Pennine Way, which is one of the most heavily used moorland routes across the blanket mires.

The largest concentration of fires was in the most popular areas, and the locations suggested that they were caused by recreational visitors, and by travellers on roads. Discarded cigarette ends were suggested as the most likely cause, although other possibilities include discarded glass bottles, lightning, and sparks from steam trains.

2.10.26 ***Cumbria:*** moorland fires in Cumbria are thought to be less of a threat to the upland peat resource than around the large conurbations in Lancashire, Greater Manchester and the Peak District. On the Langdale Fells, for example, fire has not so far caused problems, despite the considerable visitor pressure problems (J Archer and J Metcalfe *pers comms*). There is little heather left in the area, and no controlled burning takes place to benefit grazing or shooting. The intensity of grazing across the commons has kept the vegetation down, and minimised the impact of uncontrolled burns. There are occasional serious fires, however, and there were two notable moorland fires in the Lake District National Park around Easter 2003 (P Webb, National Trust *pers comm*). These again followed a period of prolonged drought, and are thought to have been started accidentally. The larger of the two fires was at Barrow Hill, west of Derwent Water (NY 227 218), and possibly started in the gorse at the roadside between Braithwaite village and Uzzicar Farm. The fire lasted for three to four days, reaching fairly high temperatures in places, and affected an area of *c* $2km^2$. Grassland, bracken and heath (peat) vegetation was burnt, but has since recovered well, and there has been little erosion as a result of the fire.

2.10.27 A second fire took place, at about the same time, on the southern shores of Ennerdale Water, near Red Beck Close (NY 109 142) (M Astley, National Trust *pers comm*). Again, the cause of the fire was thought to be accidental, possibly as the result of campers who were walking the Coast to Coast long-distance route. The fire burnt an area of approximately 20ha, but was fortunately contained from spreading more extensively by a wall. It reached high temperatures on the crags and destroyed all the vegetation. On the moorland, the fire burnt off the heather and destroyed the insect population, but young tree saplings survived. Grazing is prohibited in the area, as it has been designated for the natural regeneration of ancient woodland, and there was dense vegetation on the ground prior to the fire. Altogether, it demonstrated the importance of a co-ordinated approach in controlling the spread of moorland fires, since a well co-ordinated exercise was led by the Forestry Commission, for whom it was imperative to protect the extensive plantations around Ennerdale Water. It not only organised the operation, but made funds available to bring in a helicopter, and boats were also used to ferry in people and equipment, as other access was difficult. The National Park Authority, Forestry Commission, Fire Brigade, National Trust, Cockermouth Mountain Rescue Team and the National Trust volunteer rangers all joined forces to prevent a much more damaging fire.

2.10.28 As a result of these two fires, the National Trust is looking into ways of managing moorland fires in Cumbria. It has bought and distributed fire-fighting equipment, and organised teams, and has also looked into measures on the ground, such as the construction of fire-breaks, but as yet this is only at the level of discussion.

2.10.29 ***Controlled Burning in Cumbria:*** deliberate burning for the purposes of managing the vegetation has also taken place in northern Cumbria over the last few years, and an area of blanket peat on the lower slopes of Bleaberry Fell (NY 285 195) was deliberately burned by the landowner, following the advice of English Nature (now Natural England). Several years later, however, the vegetation has failed to recover, and Natural England has revised its policies on fire as a management tool (P Webb *pers comm*).

2.10.30 ***Studies in the aftermath of fires on the North York Moors and in the Peak District National Park***: the damage, both immediate and long term, caused by major fires is of enormous importance when assessing the threat that fire poses to the archaeological record. The severity of the fire, and thus the level of damage to the peat, has a bearing on the potential threat, and the potential reaction to counter each threat. Long-term study of the effects of a major moorland fire, where the complete spectrum of damage has taken place, has been undertaken on both the North York Moors (Maltby *et al* 1990) and the Peak District National Park (Anderson *et al* 1998).

2.10.31 ***North York Moors:*** between March and September 1976, 62 uncontrolled vegetation fires affected more than 11km^2 of heather-dominated moorland, near Rosedale Head, on Glaisdale Moor, and Wheeldale Moor. At Rosedale, 600ha of *Calluna*-dominated moorland was burnt (NGR NZ 693010), and a ten year (1976-86) programme of ecological research was initiated in the immediate aftermath (Maltby *et al* 1990). The state of the soils and the vegetation was surveyed, and then systematically monitored over the lifetime of the project. When the fire was deep-seated on the blanket mire, it largely destroyed areas of the thinner peat and the organic horizons on neighbouring mineral soils, reducing them to a layer of ash. On the somewhat deeper peats, however, where sufficient moisture was retained to prevent complete combustion, only the vegetation and litter layer was destroyed, leaving the underlying peat badly charred but often producing distinctive columnar patterns of the contracted peat structures. Areas of deep blanket peat, which were sufficiently deep and retained moisture even after a period of prolonged drought, were largely undamaged.

2.10.32 It was found that, after a fire, five major processes were responsible for the modification of the surface morphology of the blanket peat. In extreme cases, these could remove the peat, causing potential exposure, and even destruction, of buried archaeological remains. The processes comprise erosion and deposition by surface run-off, deflation, disturbance by frost action, surface consolidation, desiccation and hardening, and fragmentation and granulation (*op cit*).

- ***Erosion and deposition***: erosion and deposition caused by surface run-off needs no further discussion (*Section 2.4*), except to say that it was most damaging where only a thin layer of deposit remained. In September 1976, after the fires, heavy rain resulted in extensive run-off and erosion.
- ***Deflation:*** all fine, loose, mineral and organic particles were liable to movement by wind, especially after dry spells, resulting in hollows and the build-up of material against obstacles, such as walls and stones.
- ***Frost Action:*** frost action can produce needle ice (pipkrake) in ashed areas, causing vertical displacement and contributing to surface instability. These also formed on the relatively intact peat, at the interface of the fibrous sub-surface and the humified surface, which had lost its insulating vegetation and litter layer. In turn, this increased surface instability, and loosened the upper crust, and thus increased the risk of erosion. Pipkrake did not appear to form where the peat was extensively charred, and there freeze-thaw activity caused the disintegration and progressive comminution of the hard dessication granules.
- ***Surface Consolidation/Dessication:*** fire damage and exposure to the atmosphere can induce biological, physical and possibly chemical changes, which can cause surface consolidation, desiccation and hardening of the peat, and an increase in peat loss. A 'hard' crust often forms on the charred peat columns, where the peat is highly humified, and is resistant to re-wetting. Where the peat surface is relatively intact, a 'soft' crust forms, which detaches easily on an horizontal plane, resulting in increased peat loss. Wetting-drying and raindrop impact is the causal agent of the thin, fragile, mineral crust, which forms on exposed mineral soil. This crust is ephemeral, and easily broken.
- ***Fragmentation and Granulation:*** if the surface vegetation and the residual seed bank are destroyed by fire, there is a risk of fragmentation and granulation. Maltby *et al* (1990) found that non-fibrous, humified peat was most at risk from this, and cycles of wetting-drying, heating-cooling, and freezing-thawing were all contributing factors.

2.10.33 This study established that the regeneration of vegetation after the fires was more successful on the deeper, more intact peats and mineral soils. On areas where the surface was totally ashed, or severely charred, regeneration was poor, and the composition of species was restricted, often only to mosses. Maltby *et al* (1990) concluded that where either exposed mineral material or persistently bare peat remain, it would be advantageous to restrict grazing and to try to minimise wind damage.

2.10.34 ***Fylingdales Moor, Case Study:*** in the late summer of 2003, an area of some 250ha of moorland at Fylingdales, North Yorkshire (SE 955 998), was devastated by fire, revealing large numbers of archaeological monuments (Fig 15). This rich archaeological record encompassed all periods, from the internationally important prehistoric rock art and Bronze Age funerary monuments, to late twentieth-century geological boreholes, with the extracted cores lying alongside them. There was considerable evidence of military activity from the post-medieval period, including militia camps, Second World War dugouts, and spent ammunition, reflecting the fact that the area has been used as a military training ground for a considerable period (Vyner 2005). Some of the archaeological remains were more ephemeral, such as striations in the ground, which have been interpreted as the linear scars where the thin peat was removed for fuel (N Redfern *pers comm*). Similar features have been identified from aerial photographs in the Upper Derwent Valley (Ardron 1999a, 124).

2.10.35 The fire was caused when somebody set fire to rubbish in a lay-by, which subsequently set light to gorse at the roadside. The severity of the fire was exacerbated by a strong wind, causing it to spread rapidly over the moorland, burning stands of mature heather. Fylingdales Moor, unlike many North Yorkshire moors, had not been extensively managed for grouse shooting over the last ten years, and had been left ungrazed since the last war (R Pickering *pers comm*). This minimal management resulted in mature woody heather growth which, after a dry summer and early spring, was easily ignited. In the 1960s, the local rock art group noted that the heather was already approximately 18” high (0.45m) (P Brown and G Chappell *pers comms*).

2.10.36 Once alight, the fire burned for five days. Initially, it was fought by the local fire service, the National Park Authority, Forest Enterprise and the local community. It was gradually brought under control when helicopters were brought in on the third day, but some areas continued to smoulder 15 days later. The shallow peat was completely destroyed, leaving a layer of ash above the mineral substrate. Conversely, the wet valleys and areas of short heather remained unburnt, and in some parts of the moor there was a rapid regeneration of cottongrass only 13 days after the fire. This suggests that, although the wind exacerbated the fire, it also prevented it from becoming too intense in some areas.

2.10.37 Following the fire, dust and ash were blown off, and the charcoal substrate was either blown or washed off rapidly (R Pickering *pers comm*). Within the first month, heather bales were placed in the gullies to stabilise them, and to try and relieve the threat of erosion. In the spring of 2004, following a rapid archaeological survey (Vyner 2005), 60% of the most vulnerable burnt areas were reseeded with nurse grasses, *Agrostis* (bent grasses), and *Lolium perenne* (rye grass), although the latter was not successful. In some parts of the moor, where the vegetation was completely destroyed, a hard crust developed as a result of bitumenisation of the surface, and it is thought to have inhibited restoration work. Subsequently, heather brash has been used in these areas to help soften the hard crust by maintaining moisture, and thereby aided germination. The National Park Authority has been surprised at the speed of natural regeneration of the heather in the less burnt areas, although the seedlings have subsequently been killed by cold, frost, and summer drought.

2.10.38 Unfortunately, the northern slopes and valleys of the affected area are still actively eroding, but in the long term, the ecologists are cautiously optimistic about the restoration of most of Fylingdales Moor (R Pickering *pers comm*). The failure of sown or planted grass and heather to halt the erosion of the exposed stony regolith (periglacial material exposed when all the vegetation and soil have been destroyed) has been noted, however (Radley 1965; Maltby *et al* 1990), and it will be interesting to observe if this is the long-term result on Fylingdales Moor.

2.10.39 Although both the archaeologists and ecologists recognised that stabilising the landscape was the main priority following the fire, there were some factors where there was a conflict of interest. The need to record and map the archaeological record countered the need to stabilise the damaged landscape, since this would effectively obscure the archaeology. The close working relationship and co-operation between the two disciplines, however, has resulted in an impressive recovery of large areas of the moor, while allowing archaeological survey also. The experience from Fylingdales will help to inform the wider archaeological community about the necessary management plans needed in the event of fire damage in an upland landscape. Following a fire, the North York Moors National Park Authority and English Heritage recommend the following:

- a programme of aerial photography, both oblique and vertical, essential to record exposed archaeology;
- a rapid field survey to record and verify features shown on these aerial photographs.

At Fylingdales, the latter caused some concern to the ecologists, who could only put heather brash down between November 2003 and 31st January 2004. The archaeological survey was further constrained because seeding could only take place in April and May, and therefore all survey work needed to have been completed by then.

2.10.40 The aftermath of the fire has demonstrated that constant consultation of all stakeholders, including in this case members of a Court Leet, or elsewhere those holding common rights, is essential for damage limitation and the restoration of a moor. One simple example of this is the necessity for other agencies to recognise that machinery not only causes extensive damage to the exposed and fragile soil, but also to archaeological sites.

2.10.41 At Fylingdales, the various agencies have joined together in helping to stabilise and restore the moorland environment as quickly as possible, thus preventing further damage to the archaeological record and the environment. Rachel Pickering, of the North York Moors National Park Authority, stated that they were only able to carry out such an extensive programme of reseeding because of the generosity of English Heritage, who donated more than 50% of the total cost. As a direct result of the fire, the North York Moors National Park Authority has entered into a Wildlife Enhancement Scheme with Natural England for the whole area of Fylingdales Moor (2700ha), to initiate a programme of preventative measures to help reduce the likelihood of a further major fire on the moor. This includes the creation of fire breaks, where the vegetation along a 30m wide corridor will be kept cut, and the cutting of roadside verges. The National Park has bought a small fire tender to go on the back of a quad bike, which it is hoped in future will provide a rapid response to outbreaks of fire. The catastrophic fire on Fylingdales Moor has brought together the North Yorks Moor National Park Authority, English Heritage and Natural England, with a common purpose of restoring and protecting an area of moorland for future generations.

2.10.42 ***Restoration of Moorland Following Fires:*** natural regeneration of severely burnt moorland/upland peat is slow and patchy, and it is becoming increasingly recognised that attempts to stabilise the surfaces are crucial, to prevent further damage to the landscape, environment and archaeology. The Peak District National Park has been a leader in this field, setting up the *Moorland Erosion Study* in 1979 (Phillips *et al* 1981), which highlighted the impact that fire, and the resultant erosion, placed on the recovery of vegetation. This was followed by the *Moorland Restoration Project* (Tallis and Yalden 1983), which aimed to determine the extent of constraints imposed on the natural revegetation of the moorland and how they could be overcome, thereby reversing the causes of erosion. These projects have been drawn together in the *Moorland Management Project* (Anderson *et al* 1998), and have culminated in the *Moors to the Future Project*, which aims to restore 3km^2 of the worst affected areas of the Dark Peak. Anderson *et al* (1998) have summarised the experimental practical measures that were put into place in an attempt to restore the moorland habitats. For restoration following fire damage, the relative success or various schemes has been assessed:

- controlling of grazing only;
- application of heather seed only;
- controlled grazing with clarification and application of heather seed;
- removal of grazing and whole plant transplant;
- removal of grazing and whole plant transfers with lime and fertiliser;
- removal of grazing, reseeding with heather and non-native grasses, addition of lime and fertiliser;
- whole landscape projects.

2.10.43 There was an extensive fire on Burbage Moor in 1976 (NGR SK 27 83), near Hathersage in the Peak District, with the subsequent erosion causing the loss of 1-1.5 m of peat, down to the bedrock. By 1986, there had been little natural recovery, and experimental plots were established on which grazing was controlled with or without seeding, together with control plots, where there was no control of grazing. These plots were monitored to see to what extent the moorland vegetation could be restored (Walsh and Anderson 1998). On areas where heather seed was spread over the damaged surface, germination was good with or without the exclusion of grazing, but it was more rapid where the sheep were excluded. The terrain of Burbage Moor was such that a tractor could be used to spread the seed.

2.10.44 Similarly, the area of Ladycross (NGR SK 16 99) was severely burnt in 1959, and in 1989 there were still areas of bare peat and ash, with only occasional clumps of old heather. Because the site was exposed and unstable, it was decided to use heather turves to restore the blanket peat, rather than seeding. This proved to be an extremely effective, but expensive, means of restoration. The planting of heather turves may be the most appropriate method, however, for small areas of extreme erosion (Lees 1998).

2.10.45 At Kinder Low (NGR SK 07 87), a high-altitude, heavily polluted site, a series of complicated experiments has shown that excluding sheep from the unstable steep slopes brought about a dramatic improvement in revegetation. Additional treatments were required, however, on the deeper peats, and on the extensive bare areas on the tops and edges of Kinder Low. Of the experimental treatments, seeding with wavy-hair grass was the most effective method to revegetate the bare areas, for a period of up to four years. The exclusion of grazing in some of the areas reseeded showed that native moorland species failed to colonise bare areas of the moor at higher altitudes, even after these had been enclosed for 11 years (Anderson *et al* 1998).

2.10.46 ***Conclusions:*** extensive slow-burning fires are a major and serious threat to the upland peat resource. The frequency and severity of moorland fires is likely to increase, if global warming causes a shift towards warmer, drier conditions. This will also continue to be exacerbated by easier access to and greater interest in the countryside, as many fires seem to be initiated by accident, such as through a dropped cigarette end or a lack of care whilst camping. Where the vegetation and viable seed bank have been destroyed, subsequent regeneration is slow, with peat remaining bare for many years, resulting in further erosion and even the complete removal of areas of peat. This worst-case scenario would inevitably lead to the uncovering of any buried archaeological remains in the area, and in many cases their loss.

2.10.47 ***Prevention:*** because of the accidental nature of many of the fires, there is a need to make the public more aware of the dangers, both immediate and long-term, of such events on moorland. There is a need to expand existing public information programmes to warn them when moorlands are most vulnerable to fire. This will not deter arsonists, however, and therefore public awareness cannot be the sole means of managing moorland fire. There is also a need to manage the vegetation, to reduce the amount of fuel available for burning and thereby reduce the severity of any fires.

2.10.48 ***Fire Control:*** from discussions with the fire services, it is evident that there are many moorland fires, but only some of these become ecological disasters. The key factor is the extent to which the moorland is managed to prevent fire damage. Damage caused by fire can be minimised by appropriate management, to restrict the growth of the vegetation, either by controlled burning or by appropriate grazing. Control of fire can also be effected by the introduction of simple firebreaks, to help to stop the spread of the fire, providing these are maintained. Overall, a well co-ordinated fire-fighting policy should ideally be in place, as demonstrated in Ennerdale (*Section 2.10.27*), which would inform the fire service of areas of special interest, be they economic, human, archaeological or biological, so that the fire fighters can target them first, as is the case with the FOG (*Section 2.10.22*).

2.10.49 ***Repair:*** if these methods are unsuccessful in preventing extensive damage of the upland moorland/peat, it is important to put into place rapid mechanisms, such as blocking the gullies with heather bales and reseeding, that will reduce further damage to the landscape. Importantly, any exposed archaeology should be recorded prior to reseeding. This is the policy that has been used on Fylingdales

Moor, so far to good effect. In areas of less recent fires, such as in the Peak District, where large tracts of the Dark Peak remained without vegetation many years after the original fire, a restoration programme should be undertaken. The form this should take will depend on local factors, such as slope and altitude.

2.10.50 Perhaps the most important result of these recent catastrophes is that there is now a recognition that fire prevention and repair is the responsibility of all bodies with an interest in preserving the upland peat. It is now understood that the peatlands are a vital resource, and that the need for their preservation affects policies on water catchment, farming, the natural environment, and archaeology, as well as recreational uses.

2.11 PEAT CUTTING

2.11.1 Although a continuing threat in the lowlands, the cutting of peat for fuel is, for the most part, not a present issue in the uplands. Turbary rights do still exist, however, and individuals could exercise them if desired. The North West Wetlands Survey (*eg* Middleton *et al* 1995; Hodgkinson *et al* 2000) has demonstrated the historical importance of the removal of peat, both commercially and domestically, throughout north-west England, and its impact on landscape development, social history, and the archaeological record.

2.11.2 Peat cutting, both in the uplands and lowlands, has until recently largely been ignored as a factor in peat loss, and as late as the 1980s it was often dismissed as a cause of peat erosion (Ardron 1999b, 4-10). Although there are references to this activity in historical documents, these have largely been ignored in the academic literature, and even Phillips *et al* (1981), who looked extensively at the causes of erosion in the Peak District, have a lack of references to peat cutting (Ardron 1999a, 6). Pearsall and Pennington (1973, 129) have a single mention of peat cutting, stating that all raised mires have been modified to some extent by the removal of peat for fuel, but they make no specific reference to peat cutting in the Lake District. Rackham, however, does mention the dramatic effects and loss of peat caused by cutting on the Lizard in Cornwall, in the Norfolk Broads, and on the Somerset Levels (1986, 322-6, 359-60, 379, 387). In Cornwall, blanket mire has been completely removed and replaced by mixed or short heath, with only isolated patches of wet mire remaining. The remaining land which has not been taken in by crofters is covered with peat cutting striations. Rackham (*op cit*, 322-6) describes the landscape as having been significantly altered by peat cutting, rather than by cultivation, and that this has exposed earthworks and other archaeological monuments.

2.11.3 Perhaps the lack of recognition of the effect to peat by cutting is partially due to the nature of how peat develops over time. Peat is formed by the accumulation of organic matter, in particular types of ecosystems and under particular climatic conditions. If the peat is cut by hand for fuel, the mires have the potential to regenerate, and to continue to accumulate actively, and the truncation is therefore often not visible in the environmental and archaeological record. If mires have regenerated since cutting, for example in the Roman or medieval periods, it may be extremely difficult to distinguish by visual inspection where the peat has been removed. The top few millimetres of the peat may record recent vegetation history, and without closely spaced dating (*eg* radiocarbon or Lead 210), it is difficult to determine if an hiatus has occurred in the record. On Solway Moss, for example, the remains of a sheep were uncovered during commercial peat cutting operations, which were dated to the post-medieval period (Hodgkinson *et al* 2000, 130-5). The sheep was overlying peat dated to the Neolithic period, however, although there was little evidence of a break in the stratigraphy or the pollen record to explain this apparent anomaly.

2.11.4 In contrast, it is possible to identify clearly areas of previous peat cutting where surface evidence survives. Ardron (1999a, 23-6) identified areas of peat cutting in the Upper Derwent Valley, Derbyshire, by a combination of field survey and aerial photography, where cuttings were identified by abnormalities in the vegetation or by trackways leading to the cuttings. Many different styles of peat cutting were identified, and it was clear that extensive areas of the valley, both on the lower slopes and the tops, had been cut for peat, up to the late twentieth century (*op cit*, 117-30). In Yorkshire and the southern Pennines, peat cutting is still continuing today around Holmfirth and Huddersfield, particularly at Hades Green Peat Pits (SE 129 047), Peat Pit Moss (SE 129 048), and also Snittlegate (SE 151 042) (Brown 2002; S Bassham *pers comm*).

2.11.5 ***Turbary Rights:*** in Cumbria, turbary rights are known to have existed since the medieval period, and peat cutting for domestic fuel became widespread in the later medieval period, when woodland became a closely guarded resource (Winchester 1984; 1987, 90-1). A well-documented example of turbary rights is from the Graveship of Holme (around Holmfirth), West Yorkshire, which has had a constable, since 1250, to monitor peat cutting, an appointment still in existence today (Brown 2002). There is no formal planning permission required for peat cutting around Holme, as it is for 'own use', and not undertaken on a commercial basis. Tenants make bids in April for the turbary rights, and if these are awarded they are obliged to maintain the ditches, so that they do not direct water onto the roads, and to mend the turf gaites (peat tracks) (*op cit*; S Bassham *pers comm*). Each year, 40 initialled posts are placed in the peat workings, demonstrating that the rights have been claimed. Brown (*op cit*) notes that old peat cuttings are not obvious at Holme, but recent removal of peat and the use of roads to the peat cuttings are causes of considerable erosion.

2.11.6 Paradoxically, while peat cutting may have removed archaeological evidence, it has also left behind a rich archaeological legacy, for example, of hollow-ways radiating out from peat-cutting areas to the surrounding settlements (Ardron 1999b, 130-3), and boundary stones formally marking the edges of these areas (*op cit*, 141). Evidence of peat cutting can be seen on the Langdale Fells, with peat huts surviving on Loft Crag (NY 281 069) and at Scale Gill (NY 062 072), and tracks to Tarn Crag, Pike Howe, Troughton Beck and Scale Gill (National Trust 2002). The track up the eastern side of Scale Gill continues past the peat huts, to an area of peat cutting at 490m AOD (NY 299 075).

2.11.7 ***Reasons for the Peat Cutting:*** although the principal use of peat has been for domestic heating, there has also been an extensive industrial usage, which in localised areas has resulted in a considerable loss of the peatland resource. It was often used in northern England for iron, lead and copper smelting, and in Cumbria, the Mines Royal used peat as a fuel for smelting iron in the sixteenth century, especially in the Skiddaw area, and in the south of the Lake District at Lowwood, Wilson House and Leighton iron furnaces (Marshall and Davies-Shiel 1969, 39, 64). Peat was used for lead smelting at Old Gang Mine, Swaledale, in Yorkshire, which was stored in a peat house measuring 391 feet by 21 feet (119 x 6.4m). In the nineteenth century, it took 100 men, women and children, and two dozen carts, seven to eight days to cut enough to fill the house (Raistrick and Jennings 1989, 268). Industrial peat houses are also found elsewhere in Swaledale, where peat was also used to fuel lead smelting mills, for example at Blakethwaite (NY 938 027), where a peat house is shown on the first edition Ordnance Survey map (1857).

2.11.8 ***Conclusion:*** historical peat cutting is known to have depleted the upland peat resource extensively, but the extent of this loss cannot be accurately quantified. Although primarily an historical threat, turbary rights are still exploited in some areas, and if alternative fuel supplies were to be interrupted, some people may exercise their rights to cut peat for domestic use. Although historical peat cutting has caused considerable damage to the peatland resource, ironically the rich remains of this activity are now perceived as being of archaeological importance themselves. Peat cutting has played a major role in the shaping of the moorland landscapes that we know and value today, and its remains have become a component of the extant archaeological landscape. As such, the cause of so much damage to the peatlands and the underlying archaeological remains now needs to be preserved as part of that landscape.

2.12 MASTS AND WIND FARMS

2.12.1 A threat which is likely to become more problematic in the future is the construction of masts and wind farms within upland areas. Masts are likely to become more prevalent with our increasing reliance on modern communications, and the present governmental support for the generation of electricity from renewable sources is likely to result in increasing numbers of wind farms. The problems associated with the building and renewal of masts was first highlighted in 1983, when the BBC transmitting mast at Holme Moss (SE 096 040) in the Peak District was replaced (Anderson 1998). There, construction work caused considerable damage to a large area of moorland, and the then Peak Park Planning Board imposed a retrospective planning condition that required the developers to carry out a programme of restoration. This necessitated the hydraseeding of the damaged areas with water, seed, mulch fibre, lime and fertiliser, as required, to help restore the vegetation cover and stabilise the peat, thus preventing further erosion.

2.12.2 Similarly, as potential climatic change requires successive governments to consider the generation of electricity from renewable sources, it is likely that wind farms will become more widespread. By 1994, applications for the development of wind farms reached 200 *per annum* in England and Wales, with concentrations of development in North Wales and the north Pennines (Simmons 2003, 183-5). Upland sites are highly desirable because of their greater exposure to high winds, and their isolation from the more densely populated areas of the country. These installations are tending to be built on higher ground, but the terrain needs to be relatively flat, because of engineering constraints, and therefore they will potentially be constructed in situations where blanket peat is likely to be present.

2.12.3 As with masts, wind farms will initially damage the surface vegetation and the peat, or even remove it entirely, allowing natural erosional processes to become a major problem, and thereby cause potential damage to the archaeological record. The principal area of concern is not the siting of the turbines, but the extensive access tracks, which have the potential to damage and drain the adjacent peats. Even small areas of damage to the surface vegetation of a peat mire can allow erosional processes to become established; for example, a sheep track or little-used footpath quickly becomes a channel for water. A recent example is the wind farm on Scout Moor, near Rochdale (SD 833 179), which comprises 26 turbines across an extensive area of moorland, that is *c* 4km by 2.5km in extent (OA North 2007). While the footprint of the turbines is relatively small, the cutting of the linking tracks, through the extant peat down to the underlying bedrock, has severely disrupted the natural drainage of the moor. There was also extensive damage to the peatlands caused by vehicles undertaking geotechnical investigations.

2.12.4 Although wind farms and masts have the potential to cause extensive disturbance to the peat and the underlying archaeology, their proposal will usually warrant an Environmental Impact Assessment. As such, there is an opportunity to assess the environmental and archaeological impact of the development, and construction is likely to be accompanied by a programme of detailed archaeological and environmental investigation. Under these circumstances, there is no need to flag up the archaeological potential of individual sites in advance of such a development.

2.13 CONCLUSIONS

2.13.1 What this study has demonstrated is that there is no single reason for the erosion that is resulting in damage and loss to areas of upland peat. Indeed, it is normally a combination of erosive forces that cause the considerable damage that is often seen. Invariably, the initial episodes will be followed by ongoing natural water/drainage erosion, and a corresponding desiccation and wind blow, which can have a massive impact upon the landscape. Following the Fylingdales fire, for instance, the air was full of the dried out, but unburnt, particles of peat that were being dislodged by a strong wind, resulting in a significant loss of peat on the surface. The effect was most noticeable on the ring cairn where rock art was identified (Vyner 2005), where photographs taken shortly after the fire were compared with those taken six months later. This demonstrated that considerably more of the cairn was exposed in the later photographs, because desiccation and wind blow had removed the protective peat.

2.13.2 Although dessication and drainage can have a considerable impact on the landscape, the mat-grass or heather cover is typically sufficient to prevent the onset of this erosion. It is only after the loss of the protective vegetation cover that the peat deposits became susceptible to damage from erosive forces. Even the most minor erosion scars, from footpaths or off-road vehicles, can be amplified into massive erosion channels by water drainage.

2.13.3 ***Historical Erosion:*** it is evident that levels of erosion have fluctuated considerably in the past, and have occurred for at least the last 1000 years (Tallis 1997a). The present study has also established that there have been a number of erosional forces that have historically caused considerable impact on the upland peats, but which are no longer a major threat. It is therefore tempting to link these episodes of erosion with past threats. In Cumbria, peat cutting for domestic fuel became widespread in the later medieval period, when woodlands became a closely guarded resource, and then decreased in the later post-medieval period, as coal became more widely available (Winchester 1987). This would potentially have coincided with the period of intense erosion identified by Stevenson *et al* (1990) as occurring in south-west Scotland between AD 1500 and 1700. Certainly, peat cutting has resulted in the truncation or loss of huge swathes of peat, but while there are peat cutting scars across most areas of moorland, these are typically localised, and suggest that peat cutting had only a limited effect on the landscape. In contrast, survey of the area to the east of Stickle Tarn, Great Langdale (NY 292 076), revealed a complex infrastructure of peat tracks, peat scales, and even clapper bridges, but only a limited expanse of obvious peat cutting scars (OA North 2005). Either this infrastructure served only to extract a limited amount of peat, or more likely, the surface of the peat has recovered to the extent that the cutting scars are no longer evident. This is further implied at White Moss, in the Forest of Bowland (SD 5764 5085)) where the upper level of the peat was dated to 490-380 cal BC (2350±35 BP; SUERC-4504), which suggested considerable truncation (*Section 6.3.8*; *Section A4.5.6)*. Although there are no indications of peat cutting scars in this location, this is the most probable explanation for the truncation. Past peat extraction has played a major role in the shaping of the moorland landscapes that we know and value today, but it no longer represents a threat to the peatland resource, and indeed is now part of the extant archaeological landscape.

2.13.4 Similarly, the artificial drainage which resulted from the upland 'improvement' grants of the 1960s, 1970s, and early 1980s had a considerable impact upon the landscape, causing gully erosion and a lowering of the water table (*Section 2.4.8*). This coincided with a period of considerable erosion at the March Haigh reservoir (SE 013 129), in the south Pennines, which showed a significant increase of deposition in the reservoir (indicating higher erosion of the surrounding area) after 1963, and peaking between 1976 and 1984 (Yeloff *et al* 2005). With the loss of these grants for upland drainage, the level of erosion has declined, and although peat erosion is still severe, it is not as extreme as it was in the 1970s and 1980s. The legacy of this historical policy of upland 'improvement' can still be seen in the artificial grips, however, that continue to drain the moors. Any attempts to manage and preserve the peatlands must of necessity include blocking these grips to minimise their ongoing impact.

2.13.5 ***Pollution:*** although there are considerable present-day concerns about airborne pollution, in reality the air is considerably cleaner than it was earlier in the twentieth century, and certainly by comparison with the nineteenth century; in particular, there is a lower proportion of the SO_2 contaminant released from coal (*Section 2.6.1*). During the later twentieth century, there was a progressive reduction in the use of coal for domestic heating, and there has also been a significant reduction in the amount of power generated by coal-fired power stations, the emissions of which are now carefully filtered. The cleaning of the air was prompted by the infamous London smog of 1952, when up to 4000 people died of respiratory diseases over the winter months attributable to the airborne pollution (Ministry of Health 1954). This led to the Clean Air Act of 1956 (Ministry of Housing and Local Government 1956), intended to reduce domestic and industrial emissions respectively. The reduction of sulphurous acid rain contaminants has since allowed the recovery of vulnerable plant types, and improved the resilience of the vegetation mat. Although the impact of airborne pollution is difficult to quantify, the implications are that this is an historical threat, which has only a limited impact upon the present-day peatlands.

2.13.6 ***Farming:*** the upland peats are typically subject to uncontrolled grazing by sheep, and to a lesser extent, cattle. The impact of farming practice on the peatland landscape inevitably relates to the intensity of this grazing. Over-stocking results in the decline of the protective vegetation cover and thereafter the direct erosion of the peat, causing sheeptrods, and the expansion of natural peat hollows by sheep seeking shelter. In over-grazed areas, such as the Langdale Fells, much of the erosion has been attributed to a combination of drainage and over-grazing (*Section 2.7.14;* Quartermaine 1994), and only to a lesser extent to tourism, despite the fact that this is one of the most visited fells in the Lake District. On the lower fells, there is a greater tendency to raise cattle, which create considerable surface erosion, concentrated around feeding troughs in use during the winter months. Typically, these develop into massive scars, and the feed for the troughs is provided by wheeled vehicles, which create substantial scars.

2.13.7 While over-grazing is evidently detrimental to the landscape, conversely, under-grazing can also cause considerable damage, as the rampant growth of vegetation, such as heather or grass, becomes a fire risk. This can be demonstrated by the Fylingdales Moor fire, which was exacerbated by exceptionally dry conditions, a strong wind, and the knee-high growth of heather (*Section 2.10.35*). The moorland had not been grazed since the Second World War, and had not been subject to controlled burning for ten years, allowing the extensive growth of the heather.

2.13.8 ***Development Threats:*** forestry and wind farms can be grouped together when considering threats, as both reflect a major change in land-use of open upland areas. They are, however, subject to planning permission, and, because of their nature, to an Environmental Impact Assessment. While this does not necessarily prevent the implementation of such a development, it does mean that the specific environmental and archaeological implications of its enactment would be fully investigated.

2.13.9 ***Recreation and Fire:*** the present project has demonstrated that the most serious current threat to the upland peat resource is fire. Fire can remove the protective vegetation and burn the peat down to the mineral soil, sometimes over wide areas. There appears to be a direct link between the occurrence of fires and the use of the uplands for recreation, and the moors that have been affected the most are those within easy access from urban centres. Direct visitor erosion can have a severe localised impact, such as on the line of the Pennine Way, but for the most part, as demonstrated in the Langdale Fells, the effect on the peatlands is relatively minor (*Section A3.6.13*). The impact of a fire, however, whether accidentally or deliberately started, can be considerable. In Greater Manchester, there were 11,500 grassland/moorland fires in 2003 alone, and the Greater Manchester Fire Service has shown that the great majority of these fires were deliberately started (*Section 2.10.23*). Most of the fires were fast-burning, that is they just burnt the surface vegetation, but some were deep rooted and had set the underlying peat alight, thereby becoming much more difficult to put out.

2.13.10 Despite the considerable number of fires across the region, only limited numbers have got sufficiently out of control to cause extensive damage to the moor (*eg*

Anglezarke Moor, Ennerdale, and Fylingdales Moor, all in 2003 (*Sections 2.10.17, 2.10.28, 2.10.35).* The key factors that affect whether a fire will become out of control are the dryness of the ground conditions, wind speed, and the thickness and height of the vegetation. The key to the prevention of an uncontrolled wild fire would appear to be appropriate levels of management of the moor, either by controlled burning or by grazing, to ensure that the vegetation does not get to excessive levels, and also the rapid and sensible deployment of appropriate equipment, used by people who understand the environmental and archaeological importance and needs of the area.

3. UPLAND PEAT DATASETS

3.1 INTRODUCTION

3.1.1 The ultimate aim of the present investigative programme is to establish a means of identifying the level of threat to the peatlands, and likewise the potential threat to the archaeological resource. Given the scale of the upland peat areas (216,000ha across northern England alone), the assessment must necessarily be largely a documentary study, based on existing datasets. Additionally, the project has concentrated on selected study areas: the Cumbrian South-West Fells, the Langdale Fells, the Forest of Bowland and Anglezarke Moor (*Section 1.6*). It is therefore pertinent to review what datasets are available for the study areas, their accuracy, and the extent to which they can be applied to the aims of the present project.

3.2 GRAPHIC DATASETS

3.2.1 During the data-gathering phase of the project, several digital datasets were acquired and evaluated for use in the project GIS (which was created in ArcView 8.3). Undoubtedly, some of these datasets were of more use than others, and it was found that different datasets were useful for different aspects of the study, such as measuring the current extent of the peat, or identifying areas of erosion. It became clear at a very early stage that there was a diffuse spread of information throughout the various environmental organisations consulted, and that no single organisation could be considered as providing the primary data resource for any of the study areas. When the information was made available, it was not always available in a format that could be readily incorporated into the project GIS, and in some instances, notably with the Ordnance Survey mapping, this entailed time-consuming conversion processes.

3.2.2 Another major problem encountered during the data search was that there were different levels of coverage for the two primary regions (the Lake District and Lancashire). For example, usable vertical aerial photographic coverage of the two Lake District study areas was limited to 1950s RAF black and white images, whereas Lancashire had more recent colour images.

3.2.3 ***Modern Ordnance Survey Mapping:*** for the Lake District, Ordnance Survey vector mapping was supplied as ArcView shape files by the Lake District National Park Authority (LDNPA), and was directly incorporated into the GIS. For Lancashire (LCC), vector mapping in NTF format was supplied, and had to undergo an extensive conversion process before it was in a usable form. Raster mapping, in the form of modern 1:10,000 base maps, was also supplied for both regions.

3.2.4 The modern vector mapping was primarily useful for providing a solid base for georeferencing the other datasets. In the modelling phase, it was also useful for mapping the footpaths and drainage channels that were used in the creation of the buffer zones around areas of highest threat. Unfortunately, the vector datasets were in Landline format, which has since been superseded by Mastermap format. This meant that they were not fully up to date, and some features were not included. Landline data also have some conventions in their mapping procedure that mean some features are not mapped in themselves, but only as the boundary between other features. For example, footpaths that follow field boundaries are often not mapped, although the boundaries themselves are. This meant that it was often necessary to enhance the Landline mapping by digitising specific features manually from the raster base maps.

3.2.5 Contour data were supplied by the Lake District National Park Authority and Lancashire County Council in shape file format for each region, defined at 10m intervals. These were used to create digital elevation models for each study area, which led on to the creation of slope and aspect models for use in the modelling phase of the project (*Section 8.3*).

3.2.6 ***Geological / Soils Data:*** limited amounts of geological data were available for the project. For the Lake District National Park, the only information freely available was on Regionally Important Geological Sites, and this did not provide full geological coverage for the survey areas; further information had to be taken from paper versions of the solid and drift geological maps. For Lancashire, solid geological data were made available by Lancashire County Council, although only limited amounts of drift geological data were available, and these did not cover either of the study areas in Lancashire. Drift data for the Forest of Bowland were available from the British Geological Survey (BGS) in paper form, but no data were available for Anglezarke Moor.

3.2.7 ***Soils Data:*** no soils data were freely available for use in the project, as these are provided under strict licence from the National Soils Research Institute (NSRI) at Cranfield University. To evaluate the different data types available, a standard paper soil map for Lancashire, and digital soil data for the two Lake District study areas were consulted. The map for Lancashire was the Soil Survey of England and Wales (Lancashire) at 1:250,000 (Lawes Agricultural Trust 1970). The vector data purchased for the Lake District study areas were the National Soil Map (NatMap) 1000 and Soilscapes series. The NatMap 1000 series is a gridded (1km^2) vector rendition of the National Soil Map, containing the dominant soil series for each cell. Additionally, the hydrology data for the soil types were provided as an excel spreadsheet. The Soilscapes series is a simplified polygonised version of the National Soil Map, with the additional attributes of drainage, texture, fertility, land cover and habitat information. There were advantages and disadvantages to each type of soil data. The paper soil map was more detailed, but was limited by scale, and also referred to data that was 30 years old. The vector data were not so detailed, and were considerably more expensive, but were easier to use in the GIS. It was also possible to use vector data directly for spatial analysis, although the grid size meant that the resolution was coarse.

3.2.8 When the NatMap data were compared to the drift geological maps purchased from the BGS (*Section 3.2.6*), there were both similarities and differences in the datasets. The BGS data appeared to be the most detailed, showing smaller pockets of peat than were shown on the NatMap mapping, although for larger areas of soils the two datasets broadly agreed. The paper soil maps purchased for Lancashire tended to agree broadly with the BGS dataset, but were again less detailed. Overall, once the results of the field surveys had been overlain onto the soil and geological data, it was evident that no one dataset could be used to map the extent of the peat, and that a combination of the different datasets, aerial photographic sources and survey data was necessary.

3.2.9 ***Satellite Imagery:*** the process of verifying availability of satellite imagery proved to be time consuming, and eventually LandSat 7 satellite imagery was purchased for the North West. The data consist of eight bands, with a maximum resolution of 30m, which can be manipulated to highlight different aspects of the image. For example, the combination of bands 3, 2, and 1, in red, green and blue, gives a natural colour image, whereas the combination of bands 4, 5, and 3, in red, green and blue, gives an image suitable for the analysis of vegetation and land cover. The satellite data were provided in the form of geotiffs, which were internally georeferenced, and required no further processing to be utilised in the project GIS. These data were mainly used for background images and presentation, as they were of significantly lower resolution than the aerial photographs, and could not be magnified at a large enough scale for effective analysis.

3.2.10 ***Air photography:*** the intention had been to gather a range of different aerial photographs for both Cumbria and Lancashire, but as the coverage and availability varied considerably between these, this did not prove possible. For the Lake District study areas, only 1950s RAF vertical coverage was available, in black and white. The aerial photographs for the Lake District were supplied as hard copies, and had to be scanned at high-resolution, and georeferenced in the GIS. The level of accuracy achieved using this process depended on the nature of the terrain shown in the photograph, as sloping topography suffers considerable distortion when represented as a flat photographic image. In order to achieve the greatest level of accuracy in the study areas, these photographs were only 'rubber-sheeted' within the transects, and not at the outer edges, which gave an accuracy of between 5m and 20m, depending on the degree of slope of the terrain.

3.2.11 The photography was of a high resolution, but it proved difficult to differentiate changes in vegetation and peat extent on black and white images; however, this depended on the topography of the study areas. It proved easier to map peat extents within the South-West Fells study area than in the Langdale Fells, as these wetter areas showed up as veined, dark patches against a much lighter and more consistent background. In the Langdale Fells, the terrain was more rocky, and hence uneven in colour and texture, although features such as footpaths or streams showed up relatively clearly.

3.2.12 For the Lancashire study areas, modern colour vertical coverage was available, which was supplied georeferenced, in high-resolution MrSid format. Older individual verticals for selected areas of the study areas were provided from the National Monuments Record (NMR). The modern footage clearly showed areas of erosion, drainage and changes in vegetation cover, although care had to be taken in using vegetation change as an indicator of the presence of peat, as this is not always the case.

3.2.13 The oblique photographic coverage that was consulted was found generally to target specific monuments, and did not provide a general view of the peatlands, and subsequently new oblique photography was taken to provide these views. This oblique coverage proved to be the most effective indicator of peat erosion, and was considerably more effective than any of the vertical coverage (Plates 6 and 7). The oblique images could not be accurately rectified and georeferenced, however, so the mapping of visible features had to be undertaken in conjunction with the vertical coverage.

3.2.14 ***Other data:*** statutory information was made available for all the study areas, including boundaries of National Parks, Areas of Outstanding Natural Beauty (AONB), Districts and parishes, as well as Sites of Special Scientific Interest (SSSI), Historic Parks and Gardens, and Scheduled Monuments (SMs). This information was of limited objective use in creating the GIS models, but was of more use in the documentary stage of the project, and in assessing areas of peat under pressure from factors such as development and tourism. Historic Landscape Characterisation (HLC) data were provided by Lancashire County Council, but were not available for Cumbria. The study areas, by the very nature of this project, covered areas characterised as moorland, ancient enclosure, modern enclosure and woodland.

3.2.15 English Nature (now Natural England) datasets on blanket mires and heathlands are available from the internet. The datasets are cell-based, with a maximum resolution of 25m, but were primarily useful for testing the accuracy of other datasets, such as the raster soil data (*Section 3.2.7*). Limited vegetation data were also provided by United Utilities. These were detailed, but concentrated on a small area in the Forest of Bowland, including only a small part of that study area, and so were of limited use.

3.2.16 Two further datasets on the presence or absence of peat were made available by Lancashire County Council. The first was cell-based, with a resolution of 1km, and recorded the presence or absence of peat over a wide area, derived from pre-World War II Geological Survey drift mapping. The second was a vector-based vegetation survey that recorded the boundaries of areas of peat, but covered only the Anglezarke Moor study area and its immediate environs. There were some discrepancies between these datasets, such that some peat-rich cells in the first dataset overlay areas on the vector map, from the second dataset, that were shown to have no peat, hence these datasets were of only limited use.

3.2.17 ***Conclusions:*** from all of the available datasets, it proved possible to create a workable model that could predict both threat and archaeological resource (*Section 8.7*). The considerable variations in the amount or types of data available for each study area, however, made it difficult to apply tests and models consistently between them. The lack of detailed drift geological data for the Anglezarke Moor study area, for example, meant that it was possible to compare the surveyed peat extents with those obtained from the datasets in only three of the study areas. In this case, plotting the extent of peat on Anglezarke Moor could only be done using less accurate and less reliable datasets.

3.3 PALAEOENVIRONMENTAL DATASETS

3.3.1 An integral part of the Upland Peat Project was an extensive documentary search of the palaeoenvironmental literature. This included that relating directly to the study areas, but also incorporated information for the lowlands of north-west England, the broader upland area of Northern England, and the published literature concerning all aspects of upland peats. Local and national journals, books, grey literature, the Quaternary Research Association field guidebooks, and unpublished university theses were consulted.

3.3.2 In addition, the project team consulted DEFRA, United Utilities, English Nature (now Natural England), the relevant National Park Authorities, the National Trust, Forest Enterprises, and the fire services of Lancashire and Greater Manchester regarding their policies relating to upland peats. Information provided by these agencies has been both diverse and invaluable to this project, and includes the extent of the known archaeological record, existing threats, the ecosystems themselves, the restoration of the mires and how the threat of fire can be minimised. Along with these public agencies, individuals based in universities and in the wider community have given their time generously to facilitate many aspects of the study.

3.3.3 ***Lowland Wetlands:*** the study areas of the South-West Fells of Cumbria, Anglezarke Moor, and the Forest of Bowland are situated on the hill-slopes that rise up from the Lancashire and Cumbrian coastal plains. To understand the development of the modern landscape in the uplands, it is therefore necessary also to consider what has been taking place in the adjacent lowlands, and to see patterns of land-use as integrated and complementary, even in different topographical areas. For this reason, the literature relating to the lowland wetlands was significant. Palaeoecological studies of the lowland wetlands in the North West have a wide geographical coverage, but until recently the emphasis has been on vegetation history, climatic and sea-level change (*eg* Oldfield and Statham 1965; Hibbert *et al* 1971; Barnes 1975; Birks 1982). More recently, studies in Merseyside (Cowell and Innes 1994), Cumbria (Wimble *et al* 2000; Walker 2001; Hodgkinson *et al* 2000), Lancashire (Middleton *et al* 1995; Wells *et al* 1997) and Greater Manchester (Hall *et al* 1995) have helped to extend the dataset from the lowlands of north-west England.

3.3.4 The number of studies of direct relevance to archaeology is more limited, and these were often included as short appendices to archaeological reports (*eg* Pennington 1965a; Walker 1949). The recent increase in awareness by both archaeologists and palaeoenvironmentalists of the value of environmental data to enhance the archaeological record has, however, led to an increase in the use of biological indicators to inform that record. This is most notable in the publications of the North West Wetlands Survey (Cowell and Innes 1994; Middleton *et al* 1995; Hall *et al 1995*; Leah *et al* 1997; Leah *et al* 1998; Hodgkinson *et al* 2000) and at specific sites such as Glasson Moss (Cox *et al* 2001); Sparrowmire Farm (Heawood and Huckerby 2002); Drigg (LUAU 2001); Eskmeals (Tipping 1994), and Ehenside Tarn (Walker 2001) in Cumbria, and Briarfields (Wells and Hodgkinson 2001), near Blackpool, in Lancashire.

3.3.5 ***Upland Peat:*** by contrast, the record from the uplands has focused on specific areas, particularly the Peak District, the North York Moors, and the central massif of the Lake District. The coverage from other areas is often quite sparse, and there is only a single site in the Forest of Bowland AONB (Mackay and Tallis 1996), and a few sites from Anglezarke / Rivington Moors (Bain 1991; Barnes 1996). The central massif of the Lake District in Cumbria has been the subject of extensive studies during the second half of the twentieth century, including the work of Pennington (1964; 1965a; 1965b; 1970; 1973) and Walker (1965a), on material from the tarns and lakes. Although these studies originally lacked scientific dating, they continue to be of considerable value as they are often from entire depositional sequences, rather than from specific horizons, thus providing a regional picture of vegetation history, climatic change, and anthropogenic activity.

3.3.6 As with the lowlands, prior to 1990, few palaeoenvironmental studies were related directly to archaeology, although exceptions include work at Thunacar Knot, in Langdale (Fell 1954; Pennington 1973; 1975), Barnscar (Walker 1965a), and Brant Rake Moss (Pearsall and Pennington 1973, 235-6), both in the South-West Fells. More recently, sites on Anglezarke Moor (Bain 1991; Barnes 1996) and Seathwaite, Cumbria (Wild *et al* 2001), have incorporated archaeology, palaeoecology and geomorphology.

3.3.7 Given the project aim to understand the complexity of the past and present threats, and the management issues associated with the upland peats, the research has necessarily been extensive, ranging from the reports on the fire on Fylingdales Moor (Vyner 2005), reports of the Peak District Moorland Management Group (Anderson *et al* 1998; Phillips *et al* 1981; Tallis and Yalden 1983), to a detailed study of peat cutting in Derbyshire (Ardron 1999a). Many scientific papers have been consulted, including those by John Tallis (*eg* 1981; 1985a; 1985b; 1987; 1991; 1999) from the Peak District, and those by Jim Innes and Ian Simmons from the North York Moors (Simmons and Innes 1987; Simmons *et al* 1989). The comprehensive study by Simmons (2003) of the moorlands, including the upland peats of England and Wales, has perhaps above all others summarised all aspects of upland peats, and has guided the project towards many secondary sources.

4. IDENTIFICATION OF ARCHAEOLOGY – A METHODOLOGICAL CASE STUDY

4.1 INTRODUCTION

4.1.1 An important part of the project was to investigate methods of identifying archaeological remains that are buried beneath the peat. The aim was firstly to assess whether the techniques could identify archaeology, secondly, through what depth of peat the techniques could effectively be used, and thirdly, how efficient and cost-effective each technique was. The eventual outcome of the exercise was to be able to submit recommendations for the future application of these techniques. A range of techniques was explored, which included the prospection of peat scars, probing, test pitting, resistivity survey, and Ground Probing Radar.

4.1.2 ***Study Area:*** in order to provide an effective test, it was necessary to use an area which had a definite archaeological resource that could be tested by the various techniques. The principal area selected was therefore the site of Barnscar in the South-West Fells, as this has a very considerable archaeological resource, partially covered by differing depths of peat (Fig 16; Plate 1). This area had already been surveyed as part of the English Heritage-funded Lake District National Park Survey, which had revealed an extremely rich archaeological resource, recorded in detail in relation to the edges of the local mires (Quartermaine 1989; Leech 1983; Quartermaine and Leech forthcoming; Fig 17). The site at Barnscar comprises multi-period remains, thought to be principally Bronze Age in date, but probably later also, representing settlement sites and agricultural landscapes, which include complexities of cairnfield and field system. Indeed, it has been identified as one of the largest prehistoric cairnfields in the country (Quartermaine and Leech forthcoming). The key aspect of the area is that the peat cover varies across the landscape. In some places, there is no peat, allowing for excellent site visibility, whilst elsewhere, the peat generally occurs in patches and as localised mires, and archaeological features protrude through thin peat cover. On this basis, it was possible to put forward fairly reliable predictions of the existence of archaeological remains, even where site visibility was restricted.

4.1.3 The archaeological remains there are principally cairns, stone banks, and upstanding stone features. The structures can be quite substantial, making it easier to recognise their presence even under peat, and so improving the likelihood for success. It is recognised, however, in areas where the archaeological resource is less robust, the success of the various techniques will differ. In particular, the most typical archaeological resource to be found in the area of the western Pennines predominantly comprises lithic scatters, and the techniques for prospecting such a site type will inevitably be different from those appropriate for recovering structural features. While the outcome of the trial is geared primarily at the recovery of structural elements, the potential for techniques appropriate to the recovery of artefact-rich sites is also assessed as part of this programme (*Section 4.4*). To this end, the prospection of peat scars was used in all four study areas (*Section 4.2*), particularly where there was a likelihood of artefact-rich sites.

4.2 FIELDWALKING / PEAT SCAR PROSPECTION

4.2.1 All four study areas were intensively and systematically walked, in parallel traverses between 10m and 20m apart (*Section A1.2*). Any archaeological remains were recorded and accurately located using a hand-held GPS, and, as part of this fieldwalking exercise, all erosion patches and watercourse gullies were closely examined for any archaeological remains. Within the Langdale Fells study area (*Section A3.4*), every scar was recorded and accurately located using a hand-held GPS, irrespective of whether or not archaeology was present, but in the other areas the scars were only located if they contained an archaeological feature. The dimensions of each peat scar were recorded, along with whether or not the peat had eroded down to the mineral soil. In the case of Anglezarke Moor, where there had been recent fire damage, the extent of the burns was mapped by a combination of GPS survey and by digital plotting from aerial photographs taken following the fire (*Section A5.4*).

4.2.2 ***Peat Scars:*** the degree of peat erosion and scarring in each study area varied greatly, and thus the visibility of archaeology varied greatly also. The areas with the greatest degree of erosion were the Forest of Bowland and Anglezarke Moor, with approximately 30% of each study area being badly affected by scarring. The most severe erosion within the Forest of Bowland was in two areas, on the lower part of Stake House Fell (SD 552 495), and also on the higher areas of White Moss (SD 570 500). The Langdale Fells study area had suffered from scarring to a much lesser extent, with 101 recorded scars amounting to only approximately 2% of the transect. The South-West Fells had suffered very little peat erosion at all, with less than 1% of the overall study area having peat scars.

4.2.3 The peat erosion on Anglezarke Moor had been to an extent caused by major peat fires, particularly those of 1976 and 2003, which affected the western margins of the moor (*Section A1.2.1*). The visible scars have clearly developed through time, but were most probably initiated by these fires, and have expanded as a result of other erosional forces.

4.2.4 Within the Forest of Bowland, the lower area of erosion on Stake House Fell coincides with an area known to have been severely affected by fires during the Second World War (*Section A4.4.7*). It is probable, therefore, that these created the initial exposures, and subsequent erosion though drainage has expanded the damage, resulting in substantial peat scars. On the top of the moor at White Moss, severe peat erosion was indicated by the substantial numbers of peat scars, and there was also an indication of truncation as demonstrated by an Iron Age radiocarbon date obtained for the upper horizon within the peat core (*Section A4.5.6*). The causes of this erosion are likely to be multiple, although peat cutting is probably a major factor. There are several tracks accessing the lower margins of White Moss, which were intended to give access to the area for turbary (*Section A5.5.4*), and it is probable that peat cutting was responsible for the initial exposure, exacerbated by erosion. There were no straight-edged peat cutting scars evident, however, although subsequent erosion is likely to have distorted the shape of the scars, and their artificial origins are no longer evident.

4.2.5 The peat scars recorded in the Langdale Fells study area had multiple causes; some have clearly been formed directly by erosion of paths by walkers, but these represent only a very small percentage of the overall total (only five out of the 101 scars recorded); other contributory causes were drainage and stock pressure.

4.2.6 The extent to which these scars affect the drainage of the surrounding peat, thus creating more scars, remains unknown. The distribution of the peat scars through the study area is not even, with the vast majority of them being located in the southern half, in areas of greatest visitor and grazing pressure and on the steeper slopes.

4.2.7 The South-West Fells had the fewest scars of any of the areas examined, and where they were present they were invariably on steeply sloping ground. The vast majority of them were within the area of the Cockley Moss Col (Figs 18 and 20), and had very straight edges, implying that they were initially caused by peat cutting (Plate 8). No archaeology was identified during the examination of peat scars in this study area, all the identified sites being in areas where there was no peat, or only a shallow peat cover, so that the features would have been visible.

4.2.8 At the outset of the study, it was assumed that any artefactual assemblages would for the most part be found at the interface between the peat and the mineral soil, implying that there would only have been activity and exploitation prior to the humification of the soils and the development of peat. As a consequence, if a peat scar did not extend down to the peat/mineral interface, it was thought that there was a reduced likelihood of identifying archaeological material. In the majority of instances, lithics were indeed most commonly recovered from the mineral soil/peat interface, and all six lithic sites from Anglezarke Moor were on the mineral soil (*Section A5.3.1*). This has not always proved to be the case, however, as out of the eight finds of axe-working flakes in the Langdale Fells, three were found to be stratified actually within the peat, and not at the lower interface (*Section 5.3.1*). This would, in part, appear to reflect a well-documented early clearance episode, and a corresponding early peat initiation in Langdale (Walker 1965a; Pennington 1975). This clearance episode may reflect early activity relating to quarrying for implements rather than for agriculture, and hence the poor agricultural performance of the peaty soils would not be a factor in the clearance activity.

Study Area	**Area (km^2)**	**Days taken**	**Survey productivity (km^2 per day)**	**All sites identified by survey**	**Artefact sites**	**Sites identified in scars**
South-West Fells	1.25	3	0.42	69	1	0
Langdale Fells	2.4	8	0.31	8	8	8
Forest of Bowland	1.85	4	0.46	68	0	0
Anglezarke Moor	4.6	5	0.92	22	6	11
Total	**10.1**	**20**	**0.50**	**167**	**15**	**19**

Table 3: Fieldwalking / peat scar prospection statistics

4.2.9 The majority of sites identified were upstanding features (not artefact sites; Table 3), which were either on the top of the peat deposits or beyond the extent of the peat cover. This was particularly marked in the South-West Fells (Figs 18, 19, 20) and the Forest of Bowland (Fig 5), where the most common monument type recognised was the clearance cairn, usually in small cairnfield groups that had not been covered by peat. No sites were identified from peat scars in either the South-West Fells or the Forest of Bowland, and in the case of the Forest of Bowland, particularly, there was no shortage of peat scars. The absence of archaeology may indicate that there was only a low density of sites in these areas, and it is possible that the early peat inception in some areas discouraged agricultural activity, and that settlement and land improvement (*eg* stone clearance) was undertaken only on the lower, better drained ground. The higher ground, around White Moss and Stake House Fell, clearly saw such an early peat inception, with radiocarbon dates of 5720-5550 cal BC (6720±35 BP; SUERC-4505/GU-6058) and 3520-3350 cal BC (4645±35 BP; SUERC-4506/GU-6060), although the lower ground near Stake House provided an inception date of 760-380 cal BC (2365±40 BP; SUERC-4507/GU-6062), so that Bronze Age or earlier farming could have taken place there. The ground on this spur has a moderate slope, however, and nearby Nicky Nook would have presented a much better terrain for agricultural exploitation. It is therefore hardly surprising that an extensive cairnfield, potentially of Bronze Age date, is to be found there (Plate 9).

4.2.10 ***Productivity:*** the amount of ground that can be examined per day will vary in differing terrains. The main factor influencing this was proved to be the accessibility of the study area; for example, the least amount of ground covered each day was in the Langdale Fells study area, where a climb of an hour had to be undertaken before the southern end of the study area could be reached. Also, this was the only study area where each individual scar was recorded, and this took considerably more time than when only those with archaeology present were described.

4.2.11 Overall, the technique was relatively productive, and was able to examine between a third and one square kilometre of moorland per day (Table 3). Sites were revealed in all types of terrain, but because of the better site visibility in areas without peat cover, these inevitably revealed a richer resource, the majority of the sites being clearance cairns (119 cairns within a total of 167 sites). Sites were identified in areas of peat scars, albeit in lower numbers than in areas without peat, and this has confirmed some potential to reveal a significant archaeological resource. However, peat scars are not uniformally found within the landscape and tend to coincide with areas of steep gradient or those affected by poor drainage, which are not necessarily the same areas as those with the greatest archaeological potential. For example, the worst scarring within the Forest of Bowland is on the very high and poorly drained ground around White Moss and Stake House Fell, where there is little potential for anthropogenic activity, and perhaps not surprisingly no archaeological sites were identified. Significantly, though the great majority of the artefact sites (14) were identified from peat scars or exposures through the vegetation cover. As such, the technique is somewhat hit or miss and is not a reliable means of identification of archaeological resource within peatlands, though it does highlight those in immediate danger of damage.

4.3 PROBING

4.3.1 Probing was primarily undertaken on the South-West Fells around the Barnscar cairnfields, although a brief and unproductive *ad hoc* trial was also undertaken within the Forest of Bowland study area (*Sections 4.1.2* and *A1.3*). Two separate areas of Barnscar were examined to see if probing provided an effective technique for identifying archaeological features buried beneath the peat (Fig 21). The two areas were specifically chosen, since they either had archaeological features protruding out of the peat or contained monument groups which appeared to end at the edges of the peat. The areas were systematically probed on a 2m grid using steel rods of 5mm and 8mm diameter with depth markers. Where it was believed that a feature had been encountered, the extent and shape were defined by more intensive probing, marked with canes, and then located by GPS. By this method, a combined area of 5.13ha was probed. The depth of peat varied considerably, being as little as 0.1m in places and reaching 1.2m in others, although, for the most part, the peat depth was between 0.5m and 0.7m. The probing was undertaken by two people over the course of four days, which equates to 0.65ha per person per day.

4.3.2 The survey to the south of Barnscar and north of Black Beck covered an area of approximately 3.25ha (Fig 21) on the edge of an area exceptionally rich in archaeological monuments. The probing was concentrated along the edges of the peat nearest to the known monuments to try and determine if the perceived limit to the site group was actual or a product of increasingly poor site visibility. The peat depth ranged from 0.1m to 1.2m and in the event no potential archaeological features were identified, indicating that in this location the observed boundary of the cairnfield was the actual limit. There is therefore a probability that the adjacent poorly drained ground has not changed in extent since the cairnfield was established and would appear to have restricted the expansion of the land improvement in that direction.

4.3.3 The second area of probing was to the west of Black Beck, approximately 250m to the north-east of the first area (Fig 21). This covered approximately 1.9ha and contained cairns that could be seen to be partially covered by peat, which varied from 0.1m to 0.8m in depth. Six potential new cairns were identified, of which four were in the northern half of the area, amongst previously identified cairns that were seen to be protruding above the level of the peat (Fig 22). These new cairns were relatively small, being typically 2-3m in diameter, in comparison with the previously recorded cairns, which were 4-6m in diameter. A further two potential cairns were identified in the southern half of the area, where no features had been identified previously as it was covered by peat. One was 6m in diameter, 0.4m in height above the mineral soil surface, had a very regular shape, and was thought to be a cairn.

4.3.4 ***Detailed Probing Survey:*** following on from a rapid reconnaissance, a detailed sub-surface topographical survey was conducted on areas where an archaeological potential had been identified (Fig 22). The sub-surface survey was undertaken by means of a total station, using a prism mounted on top of the steel probe, to record points on a 2m grid across the mineral soil or bedrock underlying the peat. The data were then processed using Surfer32 and ArcView 9 to produce digital terrain models of the underlying land surface, including any archaeological features, which could be viewed as a contour map or a shaded relief map (Fig 23). The two areas (1 and 2) recorded by this technique were approximately 30m by 45m and 60m by 30m in size respectively, and both were surveyed in a single day, representing 0.15ha per person per day.

4.3.5 The sub-surface topographical survey confirmed the presence of the features identified in the initial probing survey (Fig 22) and provided a much clearer picture of their form and extent (Fig 23). In addition to confirming the existence of the cairns, the survey also identified a series of parallel ridges extending through Area 1, which had the appearance of cultivation marks and were orientated parallel to the lines of cairns. It also revealed a shallow bank at the western extent of the area. In Area 2, the sub-surface demonstrated occasional rocks and subtle natural variations, although, in addition to the previously identified cairn, a linear bank orientated towards the cairn was recognised.

4.3.6 ***Evaluation:*** three test pits were then excavated over the potential archaeological features identified by the detailed probing survey in Area 2 to test the validity of the technique (Fig 24). The smaller of the two potential cairns proved to be a single large stone (Trench 3), as had originally been suspected during the initial probing exercise. The second and larger potential cairn had a stone make-up typical of a clearance cairn, but had evidently suffered from water erosion, as there were erosion scars around the north-western and south-eastern sides (*Section A2.8.1*; Trench 1; Fig 25). The linear feature was found to comprise silty gravel and included no sizeable stone components, and, while an anthropogenic origin could not be excluded, there was equally the possibility that it had entirely formed by natural processes (Trench 2, Fig 26).

4.4 TEST PITTING

4.4.1 Test pitting was again only undertaken in the South-West Fells study area and entailed the excavation of small test pits ($0.2m^2$) with a shovel, through the peat down to the level of the underlying mineral soil, on an approximate 10m grid (*Section A1.4*) over an area of *c* 2ha (Fig 27). The purpose of these test pits was primarily the retrieval of artefacts, which were bagged, recorded and accurately located using a GPS. Where finds were encountered, the test pit was increased in size to $0.4m^2$ in order to assess the extent of the deposit, and additional test pits were dug at 1m intervals out from the original test pit until no further finds were encountered. In total, 200 test pits were excavated over the course of two and a half days by two people (0.4ha per person per day on a 10m grid). In the event, only one test pit (TP82) produced any finds, the butt end of a Group VI axe.

4.4.2 Although this trial had limited success in an area with a perceived potential for archaeological remains, test pitting has been used more successfully in the Great Langdale area in a previous study (Bradley and Edmonds 1993), where it was used by the University of Reading to test the extent of axe production beneath the peat on the plateau behind the Langdale Pikes, in an area where finds might be expected, but which had produced no material from a casual surface inspection. This entailed the excavation of 42, 1 x 1m square, trial trenches, of which six revealed deposits of flakes. This test pitting demonstrated that there was limited axe production immediately behind the Pike of Stickle in the area of the Dungeon Ghyll, behind Loft Crag (*op cit,* 85-6; Plate 10). For the present project, it was decided that there was no need to repeat the exercise in the Langdale Fells, principally because of the need to minimise any further disturbance to the peat in this sensitive area.

4.4.3 The University of Reading's test pit programme has been effective at revealing the extent of the buried archaeological resource, and demonstrates that the technique can be successfully applied where this is primarily expected to be artefacts. However, it was not a particularly efficient technique, as the 42 test pits were excavated over a substantial period (approximately 3 weeks) by a group of up to five archaeological students, and would therefore be a very expensive technique by comparison with other methods, such as the inspection of peat scars, which could cover the same ground in one day with two personnel.

4.5 GEOPHYSICAL SURVEY

4.5.1 ***Introduction:*** trials of two geophysical survey techniques, Resistivity and Ground Probing Radar (GPR), were undertaken, both in the vicinity of Barnscar (*Sections A2.10-1*; Fig 28), where the probing was also undertaken, so as to compare these with other techniques. Both resistivity and GPR proved to be very successful in identifying features of potential archaeological significance, despite the ground conditions, and, importantly, both techniques produced very similar results. Most of the GPR 'time-slice' plots correlate closely with the resistivity data (Figs 29 and 30), although the best match is at the 17.81ns (0.4m) and 22.19ns (0.6m) depths, which suggested that these were approximately the optimum depths for resistivity survey in this area.

4.5.2 The probing provided results (Fig 23) comparable to those obtained from both these geophysical survey techniques (Figs 29 and 31). In Area 1, both the GPR and the resistivity surveys clearly identified the same six cairns recognised by the probing survey, and the resistance survey revealed a low-resistance 'halo' around the cairns, which would typically represent an infilled ditch or cut, although this could not be confirmed by the GPR survey (Fig 32). A high-resistance anomaly, seemingly representing a curvilinear bank or ridge, was revealed around the south-western, western and north-western sides of the area surveyed by both resistance and GPR survey. The ridge may be geological in origin, although its proximity to a possible cairn may suggest that there is some association, and it may at least in part be a man-made structure. The probing indicated peat depths of 0.1m to 0.8m, tallying with the GPR survey, which indicated that the base of the peat was at a depth of *c* 0.7–0.8m.

4.5.3 In Area 2, there were some obvious higher resistance linear anomalies, aligned in a north-east/south-west direction, that are likely to have a geomorphological origin. There were also some high-resistance anomalies at the extreme eastern and southern edges of the area (R8; Fig 30), perhaps isolated features similar to those identified by GPR, and which are also tentatively interpreted as having natural origins.

4.5.4 ***Depth of features:*** one of the main advantages of GPR is its ability to be able to provide both horizontal and vertical data, and therefore, information on the depth of buried features (Fig 33). This is calculated from the velocity of the radar signal as it passes through the ground. However, depth information can only be accurately calculated if the velocity is constant throughout the profile, and reliable methods of ground truthing are used. Below-ground water content within peat basins can often vary considerably, which affects signal velocity and, therefore, apparent depth. The nature of the site chosen for examination, and its relatively remote location, precluded the use of antennae suitable for the WARR (wide-angle and refraction) method of velocity calculation, and so the curve-fitting method was used (Utsi 2005, 3). Thus is a method of depth calculation that can lead to inaccuracies of up to +/- 10%.

4.5.5 By its very nature, the twin probe array method of resistivity used for this survey does not provide accurate depth information. The resistivity data show all the anomalies for a given depth of penetration and consequently individual features cannot normally be assigned a particular depth. In general, the depth of penetration using a probe separation of 0.5m is between *c* 0.5m and 1m, depending upon ground conditions. Further, more precise, depth information could be attained by carrying out more detailed survey using differing probe arrays and separations. Of course, a manual probing survey, carried out using the same traverse and reading intervals on the grid as the resistivity survey, can provide depth information which can be set alongside the results of the resistivity survey.

4.5.6 ***Cost of Resistivity:*** a survey over 0.49ha of moorland was undertaken by OA North over two days (with two operatives), which amounted to a cost of £1098 (excluding VAT). A 1 x 1m survey is the minimum resolution from which meaningful data can be gained, and while the distance between survey centres can be reduced to increase resolution, this in turn results in increased cost. However, such high-resolution surveys will not be necessary if the anticipated targets are relatively large (3-4m wide) buried features. In normal circumstances, the area that can be surveyed, using a 1 x 1m survey within a single Geoscan RM15, is approximately 0.375ha per day, which equates to nine full 20 x 20m survey grids; this includes all setting out and referencing of survey grids. The area surveyed in this instance, however, was 0.49ha, which equated to approximately 12 full 20 x 20m survey grids, and was undertaken over two days, which is a 30% reduction in productivity. The primary reason for this was the remote location of the site from the nearest road, which necessitated four journeys on foot (each of 45 minutes) to transport all the survey equipment to the site at both the beginning and end of the survey. A second reason for slow progress was the rough ground conditions and waterlogged nature of most of the site, which impeded progress. While the use of off-road transport, such as All Terrain Vehicles (ATVs), would reduce travel times, it would obviously also incur additional costs.

4.5.7 ***Cost of Ground Probing Radar:*** the GPR survey was carried out by Utsi Electronics Ltd on exactly the same grid as that of the resistivity survey (0.49ha), in order to provide a comparable dataset. The survey was conducted over two days and the total cost was £2130 (exclusive of VAT). Typically, a GPR survey on a flat surface would cover upwards of 4500 linear metres per day with one (or two) operatives (0.45ha per day), including the setting out of the survey grids, and is more time-efficient than the resistivity (0.375ha per day). Time was saved in this instance, as the survey grid was already in place prior to the GPR survey; therefore, there would have been a reduction in productivity if the GPR survey had been undertaken in isolation. As with the resistivity survey, the distance from the nearest parking place and the ground conditions significantly affected productivity. GPR equipment is generally very bulky and requires the use of heavy lead-acid batteries and a four-wheeled ATV was needed to transport the survey equipment part way to the site, incurring additional costs. As a consequence, the survey took two days rather than the theoretical one day for grids of this size.

4.5.8 ***Comparison of the techniques:*** all three techniques (probing, resistivity and GPR) identified and characterised the six principal cairns, and each identified the bank at the western part of the area (Fig 32). However, the level of detail displayed varied substantially: notably, the resistivity survey was the least successful technique, as it missed a seventh cairn to the south of the area that was clearly revealed by both the probing and GPR. GPR undoubtedly showed a very high level of sub-terranean detail, particularly about the western bank, that was not shared by the other two techniques, and also presented a vertical depth to the deposits (Fig 33). Excepting all of the practical differences in implementing the surveys, the GPR technique is the most revealing and informative. The GPR, however, presented the greatest logistical difficulties for the survey, as the large aerials and batteries were difficult to transport to remote locations.

4.5.9 All the techniques are likely to be successful in locating stone features in peat, such as cairns, stone banks and walls, where there are high levels of contrast against the relatively homogeneous nature of most peat basins. Given that the surface features in stone-rich upland areas, such as the Lake District, are very commonly of stone construction, then this is not a major issue. However, they are not universally so, and a significant number of sites are represented solely by artefacts (*eg* most of the evidence for axe production in the Langdale Fells) and it is anticipated that these techniques will not usefully contribute to the discovery of such sites.

4.5.10 Monuments consisting entirely of earthworks are undoubtedly not as common within the uplands, by comparison with features largely constructed of stone, but they nevertheless exist. In theory, all three techniques will be able to identify them in such terrains as there is a clearly defined interface between peat and the compacted subsoil, which is revealed by the various methods. Even probing has been successfully employed in determining peat-filled ditches around round cairns (J Quartermaine *pers comm*), and resistivity and GPR would have little difficulty in revealing peat filled-ditches, although this has not been tested in the present survey.

4.6 PALAEOECOLOGICAL METHODS

4.6.1 The two principal aims of the palaeoecological studies were, firstly, to explore the potential for using palaeoecological techniques as a means of identifying anthropogenic activity, and to highlight the archaeoecological potential for specific peatlands by identifying such human activity. Secondly, it was to explore the recent history of the peatlands through evidence of peat cutting and truncation, in order to highlight the impact of past damage and present-day threats.

4.6.2 ***Transect Coring:*** cores were taken on either a systematic grid or along a linear transect, using a gauge auger, in each of the four study areas (*eg* Fig 34). Each core was located in the field using a hand-held GPS, and sediment descriptions were entered into a field notebook. The level of detail of the coring and the overall approach varied between the study areas, to provide differing data to assess which was the most effective and economic approach. The most detailed coring was undertaken in the Langdale Fells, where cores and sediment descriptions were taken every 50m, with intermediate probing for peat depth taken at every 10m. On Anglezarke Moor, just a single east/west transect across the centre of the moor was carried out, and in the Forest of Bowland, cores were taken more sporadically, wherever a change in surface conditions was apparent. Additionally, in the Forest of Bowland, points were taken at either end of areas of reclaimed grassland and areas of erosion. In the South-West Fells study area, a combination of both observation and coring was undertaken; the area was walked in a systematic grid pattern and cores were taken and the stratigraphy described every 100-200m, depending on the changes in the observed ground cover. This approach was relatively quick, provided a relatively detailed plan of the extent and depth of the peat in the study area, and proved to be the best compromise between economy of survey and detail of source data.

4.6.3 ***Analysis of Stratigraphic Data:*** in the project design (OA North 2003a), it was specified that small samples of peat would be taken in the field at specified levels within each core, in order to confirm field identification and to assess the pollen. A trial of this approach was undertaken in the Langdale Fells, where samples were taken from identified stratigraphic horizons; however, this proved to be very time consuming, as was the examination of these samples back in the laboratory. The method was consequently re-evaluated and it was concluded that, for the purpose of identifying very broad-scale changes in peat deposition in the wider locale, the taking of rapid sediment descriptions in the field would be both effective and efficient.

4.6.4 ***Detailed Cores:*** following the transect coring and discussions with Peter Marshall (former assistant English Heritage Radiocarbon advisor), two or three sampling sites were chosen within each study area in order to determine the nature and timing of peat inception and its subsequent expansion (*eg* Fig 35). These sampling sites formed the basis for more detailed palaeoecological work and provided material for radiocarbon dates (*Sections A2.12, A3.5, A4.5, A5.5 and A10*).

4.6.5 ***Palynological Analysis:*** the objectives of the analysis were specified in the project design (OA North 2003a) as follows:

1) to assess the palynological potential to sustain more detailed research in the future;
2) to undertake detailed analysis in order to interpret changes through time, to determine whether changes are more closely related to climate change, human influence, or both;
3) to undertake rapid analysis of samples for selected indicator taxa at horizons closely associated with proven archaeological resources, and peat inception;
4) to relocate particular horizons in earlier undated pollen diagrams;
5) to help to determine the nature of peat inception and its spread.

4.6.6 In practice, due to the limited resources (particularly the number of radiocarbon dates available), and the realisation that peat truncation/erosion was much more widespread than had originally been thought, the palynological objectives were refined as follows:

1) to determine the nature of peat inception and spread;
2) to provide a relative dating tool when compared to previously studied sites and with other sites in this study;
3) to determine evidence for truncation or hiatuses in peat deposition.

4.6.7 On Anglezarke Moor, where detailed palaeoenvironmental investigations had been carried out in the 1980s and 1990s (Bain 1991), pollen analysis of material in the deep peat at Sampling Site 1 was used as a means of determining whether the date of the surface of the peat could be cross-referenced with previous, dated, pollen diagrams. This reduced the need for radiocarbon dating; however, although the technique worked, the cost of preparation, pollen counting and diagram production probably matched, if not exceeded, the cost of a radiometric date at present-day rates.

4.6.8 In the Langdale Fells and the South-West Fells, where previous palaeoenvironmental investigations have produced a broad regional landscape history, pollen analysis was limited to material from the base of the peat, in order to determine the nature of peat inception. Where appropriate, pollen analysis was also carried out on the uppermost peat deposits in order to determine if there was any evidence for truncation, on the basis that, where the surface of the pollen was intact, modern pollen types, such as pine pollen from nearby plantations, would be present. This was successfully demonstrated on the South-West Fells, although there the level of pine was minimal. On Anglezarke Moor, a general increase in Ericaceous pollen after the Romano-British period provided a very general marker for the broad age of the surface of the peat.

4.6.9 Concentrating some pollen work on basal peat deposits proved to be very informative with regard to the nature of the immediate landscape of the site just prior to and at the time of peat inception. This demonstrated that, at all of the sites, except the Forest of Bowland Sampling Site 1, the earliest peat inception occurred under relatively stable conditions following a long period of human interference with the local vegetation. That the initial development occurred in areas of impeded drainage suggests that the topography was also a contributing factor. At the Forest of Bowland Sampling Site 1, peat inception was very early (5720-5550 cal BC (6720±35 BP; SUERC-4505 (GU-6058))) and was likely to have been a consequence of changes in climatic conditions.

4.6.10 Although these palaeoecological investigations proved extremely useful, the role of anthropogenic activity, as opposed to climate change, in peat initiation will still be an ongoing debate, and will not necessarily be resolved by the limited studies undertaken as part of the present project. The pollen indicated that there was evidence of human activity within the environs of the sample; however, the principal aims of this management-orientated project were to establish peat initiation dates and evidence of truncation, and in hindsight, a combination of radiocarbon dates and information from the coring (for topography and peat type) is likely to have provided sufficient information for this purpose without further analysis.

4.6.11 In the Forest of Bowland, where previous palaeoenvironmental work was limited, a very broad, but complete, pollen diagram was produced from the deepest, and what was originally thought to be the least truncated, peat at Sampling Site 1 (*Section A4.5.6*). It was anticipated that this would provide a framework with which to compare the other two palaeoenvironmental sites in the study area, thus limiting the need for radiocarbon dating. Although the diagram from Sampling Site 1 did highlight periods of increased human activity in the Forest of Bowland, and thus increased potential for discovering archaeological remains, its use for the relative dating of the surface of the other two sampling sites was found to be limited. The peat had been severely truncated and there was no overlap between this and either of the other sites, as both the surface of Sampling Site 1 and the base of Sampling Site 2 were dated to the Iron Age. The severe erosion on the periphery of the Forest of Bowland had produced a very patchy peat cover, with possible evidence of truncation and regrowth. Therefore, at this site, a decision was made to assess the feasibility of using palynological techniques to provide a quick method of determining past erosion episodes and therefore any possible hiatus in peat growth. A rapidly produced pollen diagram was generated from a section of peat in the area (Sampling Site 3); this concentrated on perceived stratigraphic horizons to save time and resources, but was able to confirm a probable hiatus in the peat. This provided reassurances that the approach to pollen analysis of rapid selective sampling is able to provides indications of truncation or breaks in peat formation.

4.6.12 ***Plant Macrofossil Analysis:*** plant macrofossil work was primarily limited to the residues from pollen preparations, and was useful for determining on-site mire development in relation to the local vegetation changes indicated by the pollen. Additionally, macroscopic charcoal was very useful for determining the burning of the mire surface and the possible associated human activity. Plant macrofossil analysis is much simpler and quicker to carry out than pollen analysis, and perhaps, in hindsight, more plant macrofossil work should have been implemented. Research by Tallis (1987), Tallis and Livett (1994), and Mackay and Tallis (1996) has used macrofossil indicator species, such as *Sphagnum* and *Racomitrium lanuginosum,* for identifying changes in the hydrology of the mires, and as chronological markers.

4.6.13 ***Radiocarbon Dating:*** the number of radiocarbon dates agreed with English Heritage was limited, and therefore alternative methods of relative dating were applied where possible (*Section A1.8*). Two/three peat inception dates were taken from each study area and this proved very informative in assessing the timing of initiation and the possible spread of peat. However, with so few dates, it was not clear whether peat encroachment was gradual or sporadic. In order to assess periods of possible increased anthropogenic activity at a site it would have been very useful to date, by radiocarbon assay, any macroscopic charcoal horizons discovered within the peat.

4.6.14 ***Recommendations for future rapid palaeoecological studies:*** the palaeoecological study started with a defined methodology (OA North 2003a), but this was adapted in the course of the programme to suit the needs of the study. In particular, the revised methodology was focused on the identification of past erosion episodes and peat truncation, as it was considered that these were especially important, given the amount of, hitherto unknown, erosion at many of the sites.

4.6.15 ***Transect Coring:*** any methodology used in the South-West Fells proved to be the most cost-effective for the level of detail required by the project, with cores taken on a 100-200m grid. It was found to be both quick and provided a relatively detailed plan of the extent and depth of the peat in the study area. In order to identify possible on-site anthropogenic activity and episodes of past erosion, a very useful element of the stratigraphic work proved to be the identification of charcoal horizons and the identification of possible stratigraphic breaks. This was particularly useful on marginal peat, where it helped to determine episodes of erosion and redeposition of peat.

4.6.16 ***Radiocarbon Dates***: any programme should incorporate sufficient dates to be able to inform the history of peat inception and truncation, with dates taken from the base and surface of the peat from sample sites scattered across the study area. The latter should be implemented alongside detailed stratigraphic work in order to identify any stratigraphic breaks or redeposited surface peat following a period of erosion. If charcoal horizons are discovered in the peat, then the extent of these should be mapped and they should be dated to establish the age of any on-site human activity.

4.6.17 ***General Palaeoecological Analysis:*** this should be targeted so as to answer specific questions; examples where this should be undertaken would include areas where very little or no palaeoenvironmental work has been carried out, such as in the Forest of Bowland. There, a pollen type-site should be chosen in order to identify periods of increased human activity, thus improving the chances of discovering archaeological sites.

4.6.18 ***Targeted Palaeoecological Analysis:*** another very useful role of pollen analysis would be in identifying stratigraphic breaks in the peat, thereby highlighting episodes of past erosion. At both Anglezarke Moor and in the Forest of Bowland, changes in the peat stratigraphy were accompanied by sudden changes in the diversity, type, and concentration of pollen, thus indicating a possible break in deposition or truncation. Plant macrofossil analysis is much simpler and quicker to carry out than pollen analysis, and can be used to identify changes in the hydrology of the mires (Tallis and Livett 1994; Mackay and Tallis 1996).

4.7 METHODOLOGICAL ASSESSMENT

4.7.1 ***Cost Analysis:*** an assessment of cost has been applied to the reconnaissance techniques (Table 4), which are ordered according to productivity, that is area examined per day.

Technique	Average area per day (ha)	Total no of ha surveyed	Total no of sites identified	Average no of sites/features per ha
Fieldwalking/ peat scar prospecting	52	1012	167	0.165
Probing	1.25	5.1	6	1.2
Test pitting	0.8	0.31	1	0.5
Detailed Probing survey	0.3	2	7	23
GPR	0.245	0.49	13	53
Resistivity	0.245	0.49	9	36

Table 4: Productivity of the reconnaissance techniques

4.7.2 This reveals some interesting statistics. Firstly, fieldwalking / peat prospection was extremely rapid (52ha per day) but by the same token produced only a small number of sites per hectare. The detailed probing survey, the resistivity survey and the GPR survey all produced exceptionally high numbers of sites per hectare, but the survey area was within a known cairnfield, and consequently the numbers of sites found would be expected to be high. If the study area had been located *c*

200m to the north, it is probable that a very different set of statistics would have been produced.

4.7.3 ***Fieldwalking / Peat Scar Prospecting:*** probably the most successful technique for identifying the archaeological resource of a peatland area is that of fieldwalking, combined with the prospection of erosion scars. More sites were identified using this technique than were found by any other method (Table 4), and it could cover a far larger area of ground in a given time than any of the other techniques. However, the majority of these new sites were not seen in peat scars but were, in fact, on the edges of peatland, rather than protruding from or hidden by, the peat. For example, all 68 sites identified in the Forest of Bowland were from areas with little or no peat cover. Similarly, in the South-West Fells, the majority of sites identified were on the periphery of mires and had only very shallow peat cover. In areas of deep peat, site identification was either limited to relatively recent sites on top of the peat or sites exposed within peat scars. As different areas suffer from differing degrees of erosion, there will inevitably be a bias in the results towards areas with greater site visibility, as a result of erosion, and the surveys on Anglezarke Moor and in the Langdale Fells have demonstrated that a significant number of sites can be revealed from the examination of peat scars (Table 4), which are abundant in these areas. What is significant, though, is that the Forest of Bowland had no shortage of peat scars, and there were huge areas (Plate 6) where erosion had exposed the mineral soil, yet no archaeology was identified, prompting the conclusion that there were few sites in these areas and that the archaeological potential of the higher moors of Lancashire is low.

4.7.4 One of the significant advantages of the technique is that it has the potential to reveal not only structural features, such as cairns and banks, but also artefacts, as was effectively demonstrated on Anglezarke Moor and the Langdale Fells (Table 3). This is immensely important for the identification of more ancient archaeological sites, such as Mesolithic camp sites, which are primarily revealed by lithic scatters, and has a significant advantage over many of the other remote-sensing techniques, which can only reveal structural components.

4.7.5 Given that future management-orientated surveys will probably be targeted on areas with perceived severe erosion, the technique is appropriate, in that it is most effective in areas with severe erosion scarring. However, even on moors that have suffered very severe erosion, such as the Forest of Bowland, there will still be substantial areas without scars, and there is a case for utilising other exploration techniques in these areas.

4.7.6 ***Probing:*** the initial reconnaissance probing survey proved to be the most rapid of the below-ground investigation techniques, being able to cover quite a large area of peat in a relatively short space of time (1.25ha per day), five times faster than could be achieved by GPR or resistivity survey. It has the advantage over the examination of peat scars that it can be used in areas without erosion, but has the disadvantage that it can only identify structural components, rather than sites comprising only artefacts. It is most effective in detecting stone structural features or negative features filled with peat or other soft material, but can also, though less effectively, reveal wooden features. It has a considerable advantage over the geophysical survey techniques in that it only uses minimal equipment, just steel probes and a hand-held GPS, and this is easily transportable to remote areas. As such, probing surveys could potentially be undertaken alongside, and in conjunction with, peat scar surveys. The technique can identify features beneath peat up to 1.5m deep and provides an indication of the depth of these features; both of these aspects give it an advantage over resistivity survey, which is effectively limited to a depth of 0.5m and provides no indication of the depth at which features occur. One of the main problems when carrying out probing surveys is that the identification of potential targets is subjective and depends largely upon the experience of the operative; the precise shape and characteristics of the feature can be difficult to ascertain, and there is potential for confusion between cairns and natural outcrops, for example. Once a potential site has been identified, there is a case for undertaking a more intensive survey, such as a detailed probing survey or a geophysical survey, to refine further the character of the site.

4.7.7 ***Test Pitting:*** although test pitting looks on paper to be fairly productive, in reality it has proved to be of only limited success. Around 200 0.2m² test pits were excavated over an area of 2ha over 2.5 days. These pits were only of any use in looking for artefacts, as they were too small to differentiate between structures and naturally occurring stones. Also, once the peat depth exceeds 0.5m, they become difficult to excavate without opening a larger area. From the 200 test pits excavated, only one artefact was recovered, which is a fairly low success rate, particularly given that the work was done within the environs of one of the largest cairnfields (Barnscar) in Northern England. However, where lithics were expected, as on the Langdale Fells, the use of test pitting was successful and was able to define the extent of activity away from the principal axe-production areas (Bradley and Edmonds 1993). So, in selected instances, the technique has proved to be successful, although as a general reconnaissance tool it does not appear to be particularly effective or efficient. Despite its limitations, it is the only technique that has the potential to identify artefacts away from peat scars, and may have some validity in targeting reconnaissance surveys for lithic sites.

4.7.8 ***Detailed probing survey:*** the detailed probing survey was an addition to the original methodologies that were defined in the project design (OA North 2003a), and, when used in conjunction with the rapid probing survey, proved to be very effective in the identification and mapping of buried features. It would not be economical for initial prospection, as it is quite time consuming (only approximately 0.3ha was surveyed in one day); however, once potential sites have been identified, the technique can pick up subtle features which would not necessarily be identified by rapid probing (such as the putative cultivation furrows seen in Area 2 (Fig 23)). While the timescales for conducting the fieldwork do not differ appreciably from those for either the resistivity or the GPR surveys, the amount of time needed to process the data is greatly reduced, and therefore it is considerably more economical as a result. The equipment for this type of survey is also much more portable than that for either of the geophysical techniques; it requires only a total station, a tripod, and a probe, all of which can be comfortably carried by two people, even to remote locations.

4.7.9 ***Resistivity:*** resistivity, along with GPR, was the least productive of all the techniques, since it examined only 0.245ha per day. Resistivity is clearly effective in highlighting features of possible archaeological importance, and it revealed more than the detailed probing, but its usefulness as a technique is limited by the need for additional survey using different probe arrays (such as pseudoslices) or additional ground truthing, in order to gain depth information. If depth information is not required, then resistivity can provide a reasonably effective method for locating features. While it was significantly cheaper than the GPR survey, which required considerable data processing, the GPR provided a considerably better resolution and was able to define features that could not be identified from the resistivity data. The technique occupies the uncomfortable middle ground between the cheap and cheerful and the more expensive all-embracing techniques, and cannot be fully justified on either economy or quality. It does, however, have considerable advantages over the GPR in that its equipment, while bulky, does not require an ATV to transport it.

4.7.10 ***Ground-Probing Radar:*** this is the ultimate technique for detecting structural features below peat; the resolution of the stone-based features is extremely good and surpasses that from either the resistivity or the detailed probing survey. It can potentially recover 53 features per hectare (Table 4), though that statistic is biased by the fact that this survey was undertaken within a cairnfield. It also has the very significant ability to be able to identify archaeology from beneath relatively deep peat, can define the depth of the identified features, and if the sampling centres are close enough, plan information in the form of 'time-slice' plots. This is of course at some considerable cost, as not only is there low productivity in the field (0.245ha per day) but it also requires considerable data processing, such that it was nearly twice as expensive to undertake as the resistivity survey. These costs may be offset by the usefulness of the information about the depth of features provided by this technique. The equipment is not particularly portable because of the large numbers of lead-acid batteries and the large aerial. Where surveys are required in remote areas, GPR may prove too difficult to undertake without significant logistical support, and thus it would perhaps be best suited to those sites that are near a road. Although GPR can provide depth information, ground truthing by physical methods, such as probing or from the examination of borehole information, has been shown still to be the most reliable and precise way of calibrating the GPR data.

4.7.11 ***Palaeoenvironmental Field Survey:*** the effectiveness of the technique varied in the different study areas. It was considered that the level of survey undertaken in the South-West Fells was an appropriate and cost-effective strategy to make a practical, and an informed, judgement as to the extent and condition of the peat. It was demonstrated that in areas such as the South-West Fells and the Langdale Fells, where the topography is variable and the peat resource is patchy, a walkover survey, followed by more detailed recording of the peat depths and stratigraphy of the larger peat bodies, and a single sample from smaller bodies, was an effective means of assessing peat condition. The Lake District, however, is anomalous in terms of English upland areas, because of the steep and rugged nature of the terrain, which has inhibited the true development of blanket mires, whereas the more rounded nature of the Forest of Bowland and Anglezarke Moor are more amenable landscapes for the formation of upland peat. In these landscapes, there is a more predictable pattern of peat development, and again a grid of transect coring, coupled with a limited number of dates, to establish the period of peat inception and the date of the top of the peat, will provide an effective indicator of condition, truncation and the duration of peat formation.

4.7.12 ***Conclusions:*** each technique has its own positive and negative aspects and it would seem that the most effective approach for assessing the archaeological resource of an upland environment containing peat would be to use a combination of techniques as appropriate. The most appropriate range of techniques would depend upon the aims of the specific study, the extent of the area of investigation, the type and depth of peat cover, and the nature of the anticipated archaeological resource. These would need to be assessed and a strategy combining the most appropriate techniques would then need to be devised. For example, in the instance of a rapid management survey across a moor where the predominant archaeology is expected to be stone structures, there would be a requirement to assess quickly, and more specifically cheaply, the archaeological potential of the area. One possible strategy would be to use fieldwalking / peat scar prospection, and then, if a substantial area of moorland without peat scars is identified, this should be subject to rapid probing along linear transects across the area. As the probing does not need bulky equipment, this can be carried out at the same time as the fieldwalking, and thus the probing could follow on directly, without even returning to a vehicle. Such an approach could be developed into a rapid integrated prospection technique that provides the best opportunity for quickly assessing the archaeological potential of a moor.

5. SUMMARY OF THE CASE STUDIES

5.1 INTRODUCTION

5.1.1 This section aims briefly to summarise and draw together the results of the archaeological and palaeoecological case studies from the four study areas (these are examined in detail in *Sections A2-A5*). The archaeological survey methods were applied specifically to identify new sites, and the palaeoecological survey broadly mapped the modern extent and depth of the peat, attempted to establish the date of peat inception, and, by pollen and plant macrofossil analysis, the local and regional vegetation contemporary with peat initiation. Both survey approaches were intended to achieve an understanding of the mechanisms that had brought about the large-scale erosion of the peat resource, to identify the future threats that may continue to cause erosion, and to develop techniques for the future discovery of the archaeological resource sealed by the peats.

5.2 SOUTH-WEST FELLS

5.2.1 The extent and depth of the peat in the South-West Fells relates directly to the topography of the study area, with the deeper peats being recorded adjacent to streams, such as Black Beck (close to Barnscar), and in areas of impeded drainage, such as the plateau behind the Knott (Plate 11) and the col between Stainton Pike and Hesk Fell (Fig 3). Elsewhere, the cover was patchy and, because of the steep terrain, was often confined to wet flushes.

5.2.2 The archaeological survey recorded new sites of both prehistoric and more recent date (Figs 18, 19 and 20). It demonstrated the existence of three previously unknown cairnfields in the western part of the study area, on the plateau behind the Knott (Fig 19), with a total of 40 clearance cairns and two putative burial cairns (*eg* Plates 12 and 13). The cairns were randomly distributed in two of the cairn groups (G2 and G3), but in the third (G1) they were in compact linear groupings and were associated with a putative round-house (SW188). The random nature of the cairns in G2 and G3 suggests that they were likely to represent primary clearance, possibly dating to the earlier Bronze Age, and those of G1 were possibly of a later Bronze Age date (for a discussion of chronology, see Quartermaine and Leech forthcoming).

5.2.3 Because the palaeoenvironmental analysis was focused on peat inception, rather than the recording of a more complete record of vegetational change (Figs 36, 37 and 38), the study did not provide environmental data from the Bronze Age to support evidence of activity during this period. Peat started to form on the plateau behind the Knott (Sampling Site 2; Fig 35) at 3370-3090 cal BC (4553±35 BP; SUERC-4524), however, placing it firmly in the Neolithic period, and the pollen assemblage suggests that some clearance of the forest had already taken place by this date (Fig 37).

5.2.4 The field survey did not record any other unknown prehistoric sites in the eastern part of the study area, but did identify five areas of historical peat cutting at Cockley Moss/Hesk Fell (SW152-4, SW156 and SW157; Fig 20; Plate 14). The two areas on Hesk Fell were 20 x 20m and 25 x 50m in extent, and the three at Cockley Moss were 30 x 80m in extent. A peat scale (SW151) identified as a

Type B, as defined by Winchester (1984), was also recorded at Cockley Moss. Analysis of peat depths across the areas demonstrated that the most substantial depth of peat was in the Cockley Beck area (Fig 39), and peat cutting there was confirmed by analysis of the pollen data at Sampling Site 3 (Fig 38), since the pollen from near the top of the peat recorded a heather moorland consistent with that recorded at Devoke Water (Pennington 1965b) and Tewit Moss (Quartermaine and Leech forthcoming), in contrast to the grass and sedge community present today. The implication is that the peat has been truncated.

5.2.5 Developing on from the field survey a programme of probing was undertaken across the western part of the study area (Fig 21), which proved very successful in an area to the east of Black Beck, adjacent to the previously identified BS VI cairnfield (Fig 17), recording new cairns in an area where some stone could be seen to be protruding from the peat (Fig 22). Following on from the initial probing survey, more detailed probing was undertaken (Fig 23) which modelled the peat/mineral soil interface (*Section 4.6.4*) and confirmed the presence and extent of the structures lying within or beneath shallow peat deposits. Geophysical techniques of resistivity and ground-penetrating radar were also undertaken in the same area and proved successful in identifying potential stone archaeological features within and beneath the peat (Figs 29, 31 and 32; Plate 15).

5.2.6 The importance of the palynological and scientific dating evidence from Sampling Site 1 (near Black Beck; Fig 36) and Sampling Site 2 (on the Knott; Fig 37) cannot be emphasised too strongly. Inception dates from the Neolithic period from both sites, of 3360-3020 cal BC (4490±40 BP; SUERC-4523 (Sampling Site 1)) and 3370-3090 cal BC (4553±35 BP; SUERC-4524 (Sampling Site 2)) were associated with strong clearance signals in the pollen record, suggesting that the landscape at Barnscar and the Knott were extensively cleared at that time. This early clearance may have caused an increase in run-off from Barnscar into the Black Beck valley, so initiating peat formation. If, as the pollen record suggests, the land was already substantially cleared on Barnscar and the Knott when peat inception occurred, there exists the possibility that some of the clearance cairns may pre-date the Bronze Age.

5.2.7 In contrast, at Cockley Moss and Hesk Fell (Sampling Site 3; Fig 38), where no prehistoric features were identified, peat started to form much later, in the Bronze Age, at 1920-1680 cal BC (3480±40 BP; SUERC-4522/GU-6078), when the landscape was already extensively cleared; as supported by the pollen record (Fig 38). There is therefore likely to have been some anthropogenic activity around Cockley Moss and Hesk Fell at this time even if, as the topography suggests, the peat had started to form within an area of impeded drainage. However, there still remains a discrepancy between the archaeological and the palaeoecological record, with no evidence of clearance activity within the immediate area of the sampling sites. This lack of evidence may be related to visibility, however, rather than their actual absence.

5.3 THE LANGDALE FELLS

5.3.1 The programme of fieldwalking and peat-scar prospecting in the Langdale Fells study area (Figs 4 and 40) was primarily intended to search for the waste products of Neolithic axe working, which used a thin band of volcanic rock as a source (Fig

41), and built upon previous survey work, undertaken in 1984 (Claris and Quartermaine 1989; Fig 42). The survey identified 101 peat scars and, of these, eight were found to contain archaeological remains (Fig 43). These findspots were all in the area around the Langdale Pikes and Harrison Combe (Figs 44 and 45), in the general area of the Langdale axe factories, and the finds were mainly flakes or rough-outs. A few of the flakes (at Sites L15, L21 and L28) were embedded within the peat/mor-humus, rather than being at the interface with the mineral soil, as had been expected. A flake layer at the previously identified Site 123 was also embedded in this organic material, and charred *Empetrum nigrum* seeds from within this were dated by AMS techniques to 5968-5732 cal BC (6965±30 BP; KIA23485; Fig 46) (OA North 2004a). This, together with the pollen data from Sampling Sites 1 and 4, which indicate more recent peat initiation dates (*Section 5.3.7*), suggest that these basal deposits accumulated very slowly.

5.3.2 The sites identified in the survey were within a relatively localised area, being typically on the plateau immediately behind the Langdale Pikes or in a line extending out from the area of Loft Crag towards Stake Beck (Fig 44). These sites were remote from outcrops of the fine-grained Group VI tuff used in axe production, and the implication is that they defined a broad band of activity that followed a more sheltered, potential route, rather than the present footpath into Borrowdale. Because the identified sites were in peat scars, their distribution was inevitably biased towards those areas with the greatest erosion; however, there were substantial numbers of scars from which no sites were recorded, on the gentle moorland of Thunacar Knott and High Raise (Fig 47).

5.3.3 The scars (Fig 47), although associated with worn footpaths in the southernmost parts of the study area, were more prevalent along the ridge that extends between the Langdale Pikes and the lower slopes of High Raise on the gentle moorland of Thunacar Knott and High Raise. The scars did not appear to coincide with the lines of drainage but were irregular in shape, and were considered, in the field and from examination of aerial photographs, not to be associated with peat cutting. However, the character of a few of the scars does suggest that some small-scale domestic cutting may have taken place in the Langdale area. The peat scar at Sampling Site 1 (Plate 16) clearly showed a rectangular pattern in the modern vegetation behind the exposed peat scar, suggesting that it was a product of peat cutting. In general, though, natural erosion has made it difficult to distinguish between this process and peat that has been modified, possibly through cutting.

5.3.4 Ardron (1999b, 80) noted that peat cutting was important in the uplands of Cumbria in the post-medieval period, when woodland was restricted, being reserved for charcoal production. The evidence for peat cutting, in the form of peat tracks, is well documented; in particular, there are peat tracks up from the Wythburn Valley, Grasmere, to the High Raise area, adjacent to Troughton Beck to Martcrag Moor, and on the path up to Pike Howe. All these trackways are less than 1-2km from the gentle moorland of Thunacar Knott and High Raise. However, relatively few peat-cutting scars have been identified. Two areas of scars have been recorded (by the National Trust survey of Great Langdale; Lund and Southwell 2002) at Tarn Crag (NTSMR 20855) and under Pike Howe; the latter area comprises a shallow, rectangular depression (9m long by 3m or 4m). Another example, at *c* 470m AOD (NTSMR 20855), is described as being to the east of a peat hut, reached by a path from Millbeck (*ibid*).

5.3.5 While the peat tracks were invariably deliberately-constructed tracks, there is also an extensive network of footpaths, which are visible as erosion scars, and some may be of considerable antiquity, either originating as access routes between the valleys of the Central Lake District, for example from Langdale to either Grasmere, Borrowdale or Thirlmere, or they have been used by farmers for stock herding. One in particular, leading from the summits of the Langdale Fells into Langstrath, is followed by a line of axe-working sites, and it may be that it reflects the line of a communication route in the Neolithic period.

5.3.6 The palaeoenvironmental survey allowed a detailed map of the depth and extent of the peat deposits to be produced (Fig 47), the deeper peat being recorded at the southern end of the study area, in hollows and on small plateaux and ledges. Elsewhere, it rarely exceeded a depth of 0.40m, although there were some pockets where it was deeper. At the southern end of the study area, true peat generally developed above a layer of mor-humus, which was sometimes related to an iron pan, suggesting impeded drainage. Many of the peat profiles contained evidence of increased inwash (sandy material), which was possibly related to forest clearance and/or climatic deterioration.

5.3.7 The results of the palaeoecological survey in the Langdale Fells demonstrated that peat initiation occurred at 2470-2200 cal BC (3865±35 BP; SUERC-4521/GU-6076) adjacent to the Pike of Stickle axe factories, and at 1380-1050 cal BC (2980±35 BP; SUERC-4517/GU-6074) at Sampling Site 2 on the slopes of High Raise (Fig 48). This suggests that peat initiation occurred earliest at the southern end of the study area, then spread northwards and upwards during the Late Neolithic period and the Bronze Age (Figs 49, 50 and 51). Pollen analysis from the underlying mor-humus and basal peat (at Sampling Sites 1 and 4; Figs 49 and 51), both at the southern end of the study area, suggest that heather had already become established prior to peat inception (at 2470-2200 cal BC). It would also appear that the landscape had been subject to burning activity at, and before, this date, as evidenced by the charred *Empetrum nigrum* seeds from Site 123 (Fig 46), which were dated to 5968-5732 cal BC (6965±30 BP; KIA23485). These results suggest that peat formation occurred sometime after the main phase of clearance activity at the site, by which time the uplands were predominantly cleared.

5.3.8 Perhaps the most striking feature from Sampling Sites 1 and 4 is the apparent similarity in the pollen record in the transition from the mor-humus to peat, with no major changes in the pollen assemblages (Figs 49 and 51). The development of the mor-humus itself, plus the presence of an iron pan at the very base of the peat at Sampling Site 1, suggests that waterlogging and podsolisation would have inhibited vertical drainage and facilitated the development of blanket mire (Birks 1988). The high values of *Sphagnum* spores within the iron-rich deposit at Sampling Site 1 suggest that local conditions had become wetter. The evidence suggests that the vegetation and soil conditions on the Langdale Fells underwent a great deal of modification for a long time prior to the initiation of the peat, and this may have been, in part, anthropogenically driven. Peat formation began some time after the main period of forest clearance of the uplands, and represents a period when certain environmental thresholds had been reached. This goes some way towards explaining the age differential between the Mesolithic radiocarbon date for the Site 123 axe-flaking deposit, and the Late Neolithic to Early Bronze Age peat-humus interface just above it (*Section A3.5.9*). Evidently, given the elevated character of the terrain, no soil or peat formation developed over the axe debitage for some considerable period following the axe-production episode. Alternatively, the differences in the dating could be explained by the working floor becoming embedded into much older, soft organic material. Today, where stones have been placed on paths that cross an area of peat or mor-humus, they quickly become trodden into the underlying matrix, and these might in the future be interpreted as being contemporaneous with the peat. A subsequent minor clearance episode was registered just above the base of the peat at Sampling Site 4, related to a substantial peak in microfossil and macrofossil charcoal (Fig 51). Without a radiocarbon date, however, the age of this phase of activity is uncertain. It is probable that it is more recent than the basal peat, which has been dated to 2470-2200 cal (3865±35 BP; SUERC-4521/GU-6076).

5.4 FOREST OF BOWLAND

5.4.1 In the Forest of Bowland (Figs 5 and 52), the archaeological survey identified a total of 68 new sites, of which the majority were clearance cairns within a single cairnfield at Nicky Nook (*Section A4*; Figs 53 and 54; Plate 9). The distribution of the cairns appears to be random, suggesting that this was a product of primary clearance of the forest, a phenomenon that has most commonly been associated with Bronze Age activity (Quartermaine and Leech forthcoming). The remaining sites were two probable burial cairns (*eg* Plate 17), a small enclosure, and three quarries.

5.4.2 The peat scars in this study area were very extensive, but no archaeology was recorded from them (Plate 18); however, as many had been subjected to high-energy water erosion, any lithics originally buried may have been washed away. The primary cause of the erosion which had destroyed much of the peat on the upper slopes of Stake House Fell was a combination of peat cutting or fire. The tenant farmer from Stake House Farm described the track, which is now used for shooting access, as formerly being a cart track that was used for peat cutting. However, large areas of the peat on Stake House Fell are known to have been destroyed by fire in the Second World War and following a very dry, hot summer in 1947 (Mackay and Tallis 1996). The margins of these areas have been further eroded to leave extensive bare patches with some peat hags. At present, natural drainage is considered to be the most active form of erosion on the more central parts, and has exacerbated the earlier damage, also forming an extensive reticulated network of gullies in some possibly unburnt areas, for example at White Moss (SD 570 505).

5.4.3 Peat cores were taken (Sampling Sites 1-3) in a line descending from the summit of White Moss (Figs 55 and 56). Peat inception on the high plateaux occurred in the Mesolithic period, 5720-5550 cal BC (6720±35 BP; SUERC-4505 (GU-6058) Sampling Site 1; Fig 56) and gradually spread down towards the coastal plain. At Sampling Site 2, which was situated at an altitude of 392.35m between Sites 1 and 3, peat inception was dated to 3520-3350 cal BC (4645±35 BP; SUERC-4506 (GU-6060) (Fig 56)), in the Neolithic period, whereas at Nicky Nook, on the south-western periphery of Stake House Fell, peat only started developing at 760-380 cal BC (2365±35 BP; SUERC-4507 (GU-6062)), in the Iron Age. This date appears to be synchronous with a phase of very wet conditions in the stratigraphy at Fenton Cottage, some little distance to the west, in Over Wyre District (Middleton *et al* 1995; Wells *et al* 1997).

5.4.4 Recently, it has been suggested that the spread of peat may have been controlled by agricultural activity, rather than the more usual supposition that activity caused land to become impoverished and to be abandoned, allowing peat to develop (Tipping *et al* 2007). At Oliclett in Caithness, blanket peat was thought to have been initiated on the higher ground, from which it spread out; however, in marginal areas, prehistoric farming continued from the Early Bronze Age to *c* AD 200, with no evidence for Late Bronze Age abandonment. It is therefore possible that Bronze Age communities were being restricted to the marginal land of Nicky Nook, as a result of the downward expansion of the peat from the higher Pennine Fells and the expansion of the lowland mires of the Fylde, as was found at Fenton Cottage and Winmarleigh Moss (Middleton *et al* 1995; Wells *et al* 1997). As climatic conditions worsened in the Iron Age, people perhaps abandoned the land, allowing the peat on the south-western periphery of Stake House Fell to form. However, it is not clear if the agricultural activity, represented by the cairnfield on Nicky Nook, was instrumental in delaying peat initiation in this area. Although no peat was recorded on Nicky Nook itself, the cairnfield does demonstrate potential Bronze Age activity in close proximity to Stake House Fell.

5.4.5 The pollen and charcoal evidence from Sampling Site 1 (FB 7; Fig 57) suggest that there were limited openings in the woodland in the Mesolithic period by 5720-5550 cal BC (6720±35 BP; SUERC-4505 (GU-6058)), which, although there are no recorded Mesolithic sites in the Bowland Fells, does fall within the pattern of Mesolithic activity from elsewhere on the higher parts of the Pennines (Tallis and Switzur 1990). Following this, there was a period of woodland regeneration, which was interrupted by a sharp increase in non-arboreal pollen and a corresponding decline in elm and pine. This has been interpreted as the Elm Decline (*Section A4.5.11*), which has been dated regionally at Red Moss near Bolton (Hibbert *et al* 1971) to 3959-3656 cal BC (5010±80 BP; Q912) and ascribed by Barnes (quoted in Middleton *et al* 1995) to 3970-3340 cal BC at Moss Farm, Over Wyre, to the west of the Forest of Bowland study area. The date of the Elm Decline at Sampling Site 1, and at other sites regionally, is similar to the peat inception at Sampling Site 2, where there are marked clearance signals in the pollen diagram (Fig 58). It also appears to be synchronous with the start of a predominantly organic accumulation at Fenton Cottage, Over Wyre (Middleton *et al* 1995; Wells *et al* 1997), which has been dated to 3950-3370 cal BC (4860±110 BP; GU-5148) and follows the Lytham VI transgressive overlap at *c* 4450-3697 cal BC (Tooley 1978), when sea-level fell.

5.4.6 A preliminary examination of a core from Sampling Site 1 identified a layer of tephra shards at a depth of 0.72-0.74m from the modern ground surface. This tephra has not been characterised, but potentially could date the peat at this level. At the nearby site of Fenton Cottage, Over Wyre, tephra from Hekla 4, dated to just before 2042-1642 cal BC (3790±100 BP; GU-5167), was identified in a flooding horizon (Wells *et al* 1997) and led to the suggestion that Kate's Pad, a prehistoric trackway, was constructed in the Bronze Age (Middleton *et al* 1995). However, it must be emphasised that the tephra from the Forest of Bowland may not originate from the same volcanic eruption as that at Fenton Cottage.

5.4.7 The palaeoecological record from the three sampling sites from this survey clearly show continuing anthropogenic activity throughout prehistory (Figs 57, 58 and 59), although the archaeological record is restricted to sites from the Bronze Age and post-medieval period. These were largely identified by a survey of the extensive United Utilities Forest of Bowland estate (LUAU 1997).

5.5 ANGLEZARKE MOOR

5.5.1 The archaeology of Anglezarke Moor (Figs 6 and 60), like that in the South-West Fells and the Langdale Fells, was well understood before the present survey, with a considerable part of the study area having been extensively surveyed in 1983-5, following a large fire (Howard-Davis 1996). This earlier survey (Fig 61), together with some much older archaeological records and a detailed palaeoecological study by Bain (1991), provided a benchmark that allowed the present study to compare the condition of both the known archaeology and the peat on the moor with that from the 1980s.

5.5.2 The present archaeological field survey identified 19 new sites from the western part of the study area (Fig 62), which visual inspection demonstrated has seen the greatest level of erosion. The new sites comprised nine cairns, six lithic find spots, three structures and the probable site of a campfire (*Section A5*); the structures are somewhat enigmatic and one (A104) is thought to be modern.

5.5.3 The lithic find spots were more widespread, although three were on the western slopes of Hurst Fell, that had been eroded by fire. Only two sites produced more than a single worked flint, but Site A111 (Fig 62), because of the relatively close concentration, may be a working floor. Although the lithic finds reinforce the evidence for prehistoric activity, they are undiagnostic and cannot be assigned to a specific period.

5.5.4 The cairns identified in this survey, together with those previously known, were found in two discrete areas on Stronstrey Bank (Fig 63), which were 300m and 100m across respectively, and probably indicate the existence of a cairnfield (*eg* Plates 19 and 20). The erosion since the 1984/5 survey in this area has exposed most of the cairns, and it is anticipated that ongoing erosion will expose further sites. The topography of Stronstrey Bank is a raised, but gently sloping, natural bench, set above a lowland plain (Plate 21). It has the general character of terrain where extensive cairnfields have been found on the uplands of the south-west and west Cumbrian fringe (Quartermaine and Leech forthcoming) and also at Nicky Nook, in the Forest of Bowland (*Section 5.4.1*); it is therefore perhaps likely that such a bench was extensively exploited in the prehistoric period.

5.5.5 The palaeoecological survey identified a considerable variation in the depth of the surviving peat, from 3.50m to 0.30m, and at the western end of the study area, on the slopes of Hurst Hill, it decreased from 1.60m to 0.30m over a distance of *c* 200m (Fig 64). Pockets of deeper peat are visible, but generally the deposits are less than 0.35m deep. In general, the remaining peat in the Hurst Hill area forms a network of peat hags, numerous erosion patches and drainage gullies. A great deal of the peat is likely to have been lost in this area, caused, in part, by the high incidence of wild fires, which would dry out the peat surface, and subsequent weathering by water and wind.

5.5.6 The survey made extensive use of Bain's comprehensive palaeoecological study of the area (1991), and two sampling sites were selected to provide a context with respect to the earlier work (Fig 65). The first of these was on the relatively deep peat near Black Hill Lower (SD 64659 18318) and was selected to test the feasibility of using the previous palynological study as a relative dating tool. The second, on the shallow peat on the western periphery of the plateau on Hurst Hill (SD 62549 17528), was selected to see whether the pollen assemblages from near the top of the profile might indicate if the surface peat remained intact. Unlike the earlier work, both the basal peat and that from near the surface of the profile were scientifically dated.

5.5.7 The dating of the basal peat at Sampling Site 1 (Fig 65) gave a peat inception date of 3800-3650 cal BC (4945±35 BP; SUERC 4512 (GU-6066)), which is similar to that of 3660-3360 cal BC (4740±70 BP; HAR-6210) at Black Brook (Bain 1991). By comparing the pollen record from a number of Bain's (1991) sites with that from the basal peat at Sampling Site 2 (where peat inception was dated to 2200-1940 cal BC (3685±35 BP; SUERC 4515 (GU-6070))), it would appear that there was a rapid expansion of the peat on Anglezarke and Rivington Moors during the Bronze Age.

5.5.8 The surface date, from Sampling Site 1, of cal AD 1060-1280 (845±35 BP; SUERC 4512 (GU-6066)) and that from Sampling Site 2 of cal AD 1630-1950 (210±40 BP; SUERC 4514 (GU-6068)) suggest that a substantial depth of peat has been lost from the more central areas; however, Bain (1991, 300) has identified (from discontinuities in the pollen record) at least one episode of peat loss and regrowth from the periphery of the moor (Pikestone Ploughings and Pikestone). It is possible, therefore, that Anglezarke Moor has suffered a long history of peat loss and regrowth, although the causal agencies are unknown.

5.5.9 The palaeoecological data from this study (Figs 66 and 67), and from the earlier work of Bain (1991), suggests considerable modification to the vegetation from *c* 2700 BC to the present day, with increased levels of activity in the Neolithic period, Neolithic/Early Bronze Age, the Late Roman/early-medieval and medieval periods. It is possible that the latter may mark the beginning of a long period of erosion as a result of, initially, peat cutting, and subsequently fires.

5.6 CONCLUSIONS

5.6.1 Newly identified archaeological sites were recorded in each of the four study areas by a combination of fieldwalking and the examination of peat scars; however, the actual numbers of new sites were relatively low. In the South-West Fells, this number was increased by the testing of methods, such as probing, trial pitting and geophysical techniques, to locate features buried within or beneath the peat (*Section 5.2.5*).

5.6.2 The palaeoenvironmental survey has highlighted the individual character of the peat distribution and has established the patterns and dates of peat inception in each of the four study areas. In the Forest of Bowland and on Anglezarke Moor, there is a trend for peat to have developed first on the higher ground and then to have moved downwards; in the former, this was dated to 5720-5550 cal BC (6720±35 BP; SUERC-4505), in the Mesolithic period, and in the latter, the oldest date recorded by Bain (1991), from the mor-humus beneath the peat, was 4710-4340 cal BC (5660±80BP; HAR-6207). Whilst in the South-West Fells and the Langdale Fells the dating of peat inception is more complex, it would appear to relate to activity represented by the abundant archaeological remains.

5.6.3 The palaeoenvironmental survey and desk-based study have identified modifications to the vegetation from the Mesolithic period through to the present day in all four study areas, which may, in part, have their origins in anthropogenic activity, although the evidence for past settlement is not always visible on the ground.

5.6.4 Peat seems to have eroded to a greater or lesser extent in all four study areas. In the South-West Fells, this erosion was less severe than in the other areas, but even there, there had been extensive peat loss on Cockley Moss/Hesk Fell as a result of historical peat cutting. On Anglezarke Moor and in the Forest of Bowland the likely causes of erosion were both catastrophic fires and peat cutting, exacerbated by natural and artificial drainage, whereas in the Langdale Fells, footpath erosion, caused by high visitor numbers, as well as drainage, the climate and sheep farming, have all contributed to the very fragmented nature of the peat resource. No direct evidence of historical peat cutting was recorded there, but is likely to have played a part, as in most other areas of the uplands in Britain.

6. UPLAND PEATLAND ENVIRONMENT

6.1 INTRODUCTION

6.1.1 The detailed work for the case studies has documented the identifiable areas of peat in conjunction with a rapid palynological assessment. The selected dates for peat inception obtained during this project have provided an indication of when and within what context the peat developed (*Section 6.2*). In addition, dates taken at or near the surface of peat deposits have provided an assessment of the present condition of the peat, its survival and the extent to which any buried archaeological resource is under threat (*Section 6.3*). This, with the known archaeological resource, provides an approximate guide to the type and general area where buried archaeological material might be recovered.

6.2 PEAT INCEPTION

6.2.1 ***South-West Fells:*** the range of dates obtained for peat inception from the South-West Fells has a relatively narrow span, extending from the Neolithic period to the Bronze Age. No correlation with altitude was identified (*Section A2.12*), but the western, and therefore the wetter, side of the ridge forming the South-West Fells demonstrated earlier peat inception than that to the east (Fig 35).

6.2.2 ***Sampling Sites 1 and 2 (SD 13741 95509 (152.79m AOD / 14655 95410 (307.08m AOD):*** the evidence from Sampling Sites 1 and 2, situated at the lowest and intermediate altitudes of the study area and on the western side of the ridge, suggests that the peat there developed simultaneously at around 3000/3300 cal BC (Site 1: 3360-3020 cal BC (4490±40 BP, SUERC-4423); Site 2: 3370-3090 cal BC (4530±35 BP, SUERC-4524)). It is possible that woodland clearance was instrumental in its development, as the pollen assemblage in the base of the peat at both sites indicates a landscape of relatively open shrub/woodland with disturbance indicators (Figs 36 and 37) and there was evidence for possible cereal cultivation at Sampling Site 1.

6.2.3 The limited pollen evidence obtained from these sites, when placed alongside the geomorphology of the peat deposits, suggests that peat development was confined to areas of impeded drainage. At Sampling Site 1, peat was concentrated in and around an existing stream, Black Beck, and at Sampling Site 2, it was in two basins, separated by a ridge of higher ground, aligned north / south. Additionally, the pollen evidence from the two sites suggests that the peat was maintained in a wet mire system, which did not develop and spread as ericaceous blanket peat.

6.2.4 ***Sampling Site 3 (Cockley Moss) (SD 16321 95153 (402.67m AOD)):*** Sampling Site 3 (Fig 38), which has been dated to 1920-1680 cal BC (3480±40 BP; SUERC-4522), is the highest site in the South-West Fells study area (Plate 22) and is in an area of blanket peat, which developed under relatively open conditions up to *c* 1500 years later than the peat from the lower two sites. The cause of this later peat initiation is unclear, but it appears to have occurred at a time of a general acceleration in peat growth in central Cumbria (Pearsall and Pennington 1973). In contrast to Sampling Sites 1 and 2, blanket peat development did take hold at Sampling Site 3, resulting in a depth of peat of 3m.

6.2.5 The causes of the relatively early peat inception on the lower slopes (Sampling Sites 1 and 2) compared to other areas of peat development in Cumbria (*Section A2.12.10*) are unclear, but it is possible that early woodland clearance played a major role. In contrast, the development of the blanket peat at Sampling Site 3, dated to the Early Bronze Age, is broadly consistent with other peat inception dates in this study (*Section 6.2.1*).

6.2.6 ***The Langdale Fells:*** much of the pollen evidence from the Central Lake District area indicates that episodes of clearance became most marked after the Elm Decline at *c* 3000 BC (Pennington 1965a; 1965b; 1975; Walker 1965a). These clearance episodes are registered in a number of tarn deposits near to Langdale, including Blea Tarn (NY 293 043) and Red Tarn Moss (Wrynose (NY 267 038)), where a stratigraphic change at the start of the Sub-Boreal period (*c* 3000 BC; Pennington 2003, 67) is believed to represent increased erosion (Pennington 1965b). Additionally, Pennington (2003) suggests that soil changes, associated with the replacement of forest by heather after *c* 3000BC, led to increased acidification of the soils, which in many places, such as in areas of impeded drainage, led to the development of peat.

6.2.7 In the Langdale Fells, two samples (Sampling Sites 1 and 4) were taken near the Langdale Pikes and a third near to the summit of High Raise (Fig 48). The inception dates have a relatively narrow range between the Late Neolithic period and the late Bronze Age; again, there is no correlation between altitude and peat inception (*Section A3.5*).

6.2.8 ***Sampling Sites 1 and 4 (NY 27434 07469 (660.72m AOD) and NY 27560 07370 (659.31m AOD)):*** peat inception in the Langdale Fells occurred initially at the southern end of the study area, between Pike of Stickle (NY 273 073) and Harrison Stickle (NY 282 073), where natural ponding would have occurred. The base of the peat at Sampling Sites 1 and 4 (Fig 48) has been dated to 2140-1830 cal BC (3620±40 BP; SUERC-4516) and 2470-2200 cal BC (3865±35 BP; SUERC-4521), respectively. Both of these dates are similar to that of peat inception at Red Tarn Moss, to the south-west of the Langdale Pikes, which has been dated to 2582-2042 cal BC (3890±90 BP; NPL-122; Pennington 1975). Although the pollen evidence from Sampling Sites 1 and 4 suggests that peat developed in a relatively open, possibly cleared, landscape, the shift from the basal mor-humus to peat itself took place under relatively stable conditions (D Robinson *pers comm*). The base of the Sampling Site 4 core was on top of a Neolithic axe-factory site (Site 123; Plate 23; OA North 2004a) and the results reinforce the emerging picture that peat inception on the high fells around Great Langdale took place following a long history of human modification of the landscape. The reason for the date of peat inception at these three sites is not entirely clear, but it is broadly consistent with a number of other dates from this project (*Section A3.5.3-7*).

6.2.9 ***Sampling Site 2 (NY 27837 09020 (675.26m AOD)):*** although the pollen records from many of the tarn deposits surrounding Great Langdale show a recovery of woodland after the Neolithic period (*eg* at Blea Tarn and Red Tarn (Pennington 2003)), the higher fells around Angle Tarn, Red Tarn (Helvellyn) and Great Langdale show an expansion in heathland and the persistence of open conditions. The fact that these tarns are situated in some of the highest places from which palaeoenvironmental data have been obtained suggests that altitude, and therefore severe climatic conditions, may have been influential in this development. By

1380-1050 cal BC (2980±35 BP; SUERC-4517) peat development in the Langdale Fells had moved northwards as far as High Raise (Sampling Site 2). Assuming constant and progressive development, peat apparently spread from Sampling Sites 1 and 4 to Sampling Site 2 at a rate of 1.2-3.8m/year^{-1} (calculated using the calibrated radiocarbon age of the peat from each site against the distance; see *Section A10* for details of the dates).

6.2.10 ***Forest of Bowland:*** peat inception in the Forest of Bowland has a broad date range, from the Mesolithic period to the Iron Age, and seems to follow a fairly steady development, with the earliest inception on the highest ground, and the latest on the lower ground (*Section A4*).

6.2.11 ***Sampling Site 1 (SD 5764 5085) (c 450m AOD):*** the earliest date of peat inception was provided by Sampling Site 1 (Fig 55) at 5720-5550 cal BC (6720±35 BP; SUERC-4505), at White Moss, which forms one of the highest points in the study area (*c* 450m AOD). The pollen from this Mesolithic basal deposit records a wooded landscape with openings of grass, grassland herbs and heather (Fig 57). The presence of sedge pollen and *Sphagnum* spores suggests that the local ground conditions were wet. It is possible that the macrofossil charcoal present in the peat at this level originates from anthropogenically induced burning; however, natural fires cannot be ruled out. Although the pollen evidence indicates small-scale clearance in the area, there is little to indicate why peat developed so early, when compared to other study areas. One explanation could be that, as topographically this forms a col, the area was one where water collected, although it also formed a watershed. It is possible that this type of topography, coupled with a shift to warmer and wetter conditions in the Atlantic Period (at *c* 5500 BC), was instrumental in this very early blanket peat development, particularly when coupled with some loss of tree cover through anthropogenic activity.

6.2.12 ***Sampling Site 2, Stake House Fell (SD 5568 4990) (c 395m AOD):*** by the Neolithic period, peat had developed at Sampling Site 2 (3520-3350 cal BC (4645±35 BP; SUERC-4506)), in a relatively open landscape with less than 50% tree/shrub pollen (Fig 58). It is currently unclear whether the peat spread from Sampling Site 1 to this point, or whether several areas of peat developed asynchronously within the Forest of Bowland, and expanded to form the blanket coverage of today. Nonetheless, if a constant and progressive encroachment is assumed between the two sites (Fig 55), then peat spread from Sampling Sites 1 to 2 at a rate of 1.015-1.185 m/year^{-1} (calculated using the calibrated radiocarbon age of the peat from each site against the distance). It is possible that this encroachment was a consequence of the progressive clearance of the area, which, based on the pollen evidence, ultimately developed into a heather-rich landscape at some time during the Neolithic period. It is also possible, however, that the acidification of ground conditions destroyed and naturally inhibited the growth of trees, thus accentuating the spread of peat.

6.2.13 ***Sampling Site 3 (SD 35499 44941) (c 350m AOD):*** by the Iron Age (760-380 cal BC (2365±40 BP; SUERC-4507)), blanket peat had developed at Sampling Site 3 (Fig 55), which is on the very margins of the peat mass within the Forest of Bowland study area. By this time, the landscape had become progressively open (Fig 59), and the pollen evidence was consistent with the heather-dominated Iron Age landscape seen in the uppermost deposits from Sampling Sites 1 and 2 (Fig 57 and 58). Assuming that the blanket peat encroached outwards from Sampling Site 2, it spread at a rate of *c* 2.59-3.14 m/year $^{-1}$, which is potentially double the rate of peat encroachment from Sampling Site 1. Without more dates and detailed stratigraphic work in this area, it is impossible to be certain whether this encroachment was a gradual progression or sporadic. However, it is possible that an acceleration in peat growth occurred following the Late Bronze Age/Early Iron Age climatic downturn (Bell and Walker 1992), and, indeed, a significant peak in *Sphagnum* is registered at *c* 0.30m from the surface of the peat at Sampling Site 1 (where the surface was dated to 490–380 cal BC (2350±35 BP; SUERC-4504/GU-6056)). Evidence from Fenton Cottage (SD 4035 4495), a lowland site to the west of the Forest of Bowland, also indicates a shift to wetter conditions at 742-421 cal BC (2530±80 BP; GU-5162; Middleton *et al* 1995).

6.2.14 ***Anglezarke Moor:*** peat inception at Anglezarke has a narrow span that extends between the Neolithic period and the early Iron Age. The older peat is on the higher ground.

6.2.15 ***Sampling Site 1 (SD 64659 18318) (342.27m), Black Brook (SD 6316 1849), Round Loaf (SD 6340 1798) (Bain 1991)):*** peat inception on Anglezarke Moor occurred on the central flat plateau during the late fourth millennium cal BC (Fig 65; *Section A5.5.3*), at a time of increased woodland disturbance and evidence for burning. As in the Langdale Fells (*Section 3.5.8*), the development of a woodland mor-humus preceded peat development and the change between the two occurred under relatively stable conditions.

6.2.16 ***Sampling Site 2 (SD 63084 17990) (316.95m), Round Loaf (SD 6340 1798), Winter Hill (SD 6574 1475) (Bain 1991):*** the dating evidence from Anglezarke Moor suggests that peat initiation away from the central plateau occurred considerably later, starting in the first half of the third millennium cal BC (Fig 65; *Section A5.5.9*). This phase was accompanied by a significant rise in plants of disturbed ground and ericaceous pollen, and appears to signify a period of increased human activity in the area. Assuming a constant and progressive development, then the peat spread from Sampling Site 1 to Sampling Site 2 at a rate of 0.92m – 1.18m/year^{-1}.

6.2.17 ***Summary and Conclusion:*** the evidence from the dated cores suggests that peat inception took place at a significantly early date in the Forest of Bowland by comparison with the other study areas. This early development is likely to have been influenced by the topography and a shift to the warmer and wetter conditions of the Atlantic Period, dated regionally at Red Moss, Greater Manchester, to 6217-5743 cal BC (7101±120 BP; Q-916; Hibbert *et al* 1971). At around 3500 cal BC, a time of peat encroachment at Forest of Bowland Sampling Site 2, peat inception is identified on Anglezarke Moor and the South-West Fells. On Anglezarke Moor, the peat inception followed a period of woodland mor-humus development and was associated with clearance and burning activity. In the South-West Fells, peat development took place in a relatively open, possibly cleared, landscape in areas of impeded drainage.

6.2.18 At around 2000/2500 cal BC, there appears to have been a relatively widespread period of peat initiation and expansion, which was especially marked in the Langdale Fells and on Anglezarke Moor. A possible explanation for this period of expansion could be the effects of Hekla 4, dated to just before 2042-1642 cal BC (3790±100 BP; GU-5167) at Fenton Cottage (E Huckerby *pers comm*; Middleton *et al* 1995), and it is possible that the tephra layer discovered in the Forest of Bowland profile (Sampling Site 1) was evidence of the same event. The pollen data from Fenton Cottage indicate a temporary shift to wetter conditions above the tephra layer; however, as in the Forest of Bowland, immediate changes in the vegetation above layers of tephra are not always apparent (Middleton *et al* 1995).

6.2.19 Peat inception on Anglezarke Moor developed over a broad period within the Holocene. In the Forest of Bowland, peat inception, and evidence for a period of increased waterlogging at *c* 500 cal BC, may be linked to climate deterioration. It is also possible, however, that the effects of increased wetness could be very site-specific, depending on the topography and the interplay of other influences, such as human interference. In particular, drainage and burning activity may mask the effects of natural changes, such as changes in climate.

6.2.20 Climate, as in the Forest of Bowland, may be a controlling factor in early, Mesolithic peat initiation at the sites. However, increased woodland clearance during the Neolithic period, as on the South-West Fells and Anglezarke Moor, meant that both topography and human agency were also contributing factors. A widespread phase of peat development/spread at *c* 2500/2000 cal BC could be related to a period of climatic downturn, and similarly, any subsequent expansion could be attributed to the same. However, once peat development and associated human activity had taken hold at a site, it is often difficult to identify any single causative factor for its spread.

6.3 PEAT CONDITION

6.3.1 ***South-West Fells:*** peat development in the South-West Fells study area has largely been determined by the topography, with much of it forming in areas of impeded drainage, such as small basins (*eg* Sampling Site 1 (SD 1374 9550), and Sampling Site 2 (SD 1465 9541)). Although no radiocarbon dates were taken from the surface of the peat deposits in these areas, the pollen and the diatom evidence from this study suggest that the peat is relatively intact and free from disturbance. Pollen analysis, carried out on the basal and surface deposits, indicated no disturbance to these horizons and there were no obvious stratigraphic breaks in peat deposition evident in the profile; however, given the age of its inception and the depth, it is possible that some peat may have been lost in the past. Only 1m of material had developed at Sampling Sites 1 and 2, where peat inception was dated to the Early Neolithic period (*c* 3300-3000 cal BC) (*Section A2.12.8*), which may suggest that there had been some truncation.

6.3.2 The deepest peat in the South-West Fells study area was situated on Cockley Moss, where an area of blanket peat up to 2m deep had developed (Fig 68). Although this peat appears to have developed much later than in the areas of impeded drainage lower down the slope to the east, the topography, which resembles a col, has encouraged a much more extensive peat deposit to develop. Generally, the peat is in good condition; however, there is evidence of peat-cutting scars (Plate 8). In the areas of most intensive peat cutting, at least 2m of peat has been removed but, at present, the effects are limited to the extraction features themselves (Plate 24), and very little subsequent erosion appears to have taken place away from the scars.

6.3.3 ***Langdale Fells:*** the Langdale Fells are renowned to hill walkers, and were included in the present study primarily to determine the effects of visitor pressure on areas of upland peat. The pathways taken by walkers are well mapped and tend to follow higher ground between the peaks, which, by their very nature, avoid areas of deep peat deposits. It is those footpaths that cross the hollow in the southern part of the

Langdale Fells, between Harrison Stickle and Pike of Stickle (NY 277 074), that have caused the most damage to the peats (Fig 47). The damage is most marked in the areas of deeper valley peat, where the footpaths merge with areas of natural drainage (Plate 5); otherwise, damage is limited to seasonal routes. Many of these paths, however, extend over axe-production sites, which are therefore subject to direct erosion. Footpath maintenance has also had a considerable impact on the axe-working remains, and has necessitated mitigation excavation in advance of the works, notably at Site 123 behind Loft Crag (OA North 2004a; Plate 25). However, the construction of paved paths has had the considerable advantage of channelling visitor traffic along a narrow route, and has prevented erosion on either side of the path, as had previously been the case. On the southern shoulder of Harrison Stickle, the erosion scar prior to footpath repair had been *c* 20m across, and has now been narrowed to a paved path that is less than 1m across (Quartermaine 1994; Plate 26).

6.3.4 Although the effects of footpath erosion are clearly evident in Great Langdale, it appears that other, much more damaging processes, are serving to erode the peat. These processes are most marked in the southern part of the study area, where the deepest peat deposits were encountered. There, the effects of what appears to be erosion by drainage and natural wastage is much more widespread. Peat hags of up to 2m deep have developed and are dissected by gullies (Plate 27), and in a number of places, drainage channels have actually developed at the base of the peat, which have caused the surrounding deposits to slump. Towards the centre of the study area, just south-west of High Raise (Fig 47), the lower land widens, leaving a westerly-facing slope. There the erosion pattern takes on a slightly different form, with many of the scars running along the slope (as opposed to up/down the slope, as is common with gully erosion). It is possible that these scars developed as a result of peat slumping at the break of slope; however, the effects of peat cutting cannot be ruled out.

6.3.5 A research programme carried out in the early 1990s (Quartermaine 1994) highlighted the severe damage that intensive sheep grazing had had on the vegetation of the Langdale Fells. The damage appears to have been most marked on the stands of heather and bilberry, as sheep tend to ignore the tough grasses and sedges now prevalent in the area. The effects of trampling and the creation of sheep tracks were also seen as being causative factors in the erosion processes. It is evident from the pollen record that heather was once much more widespread in Great Langdale, and has been targeted by sheep on marginal sites, where suitable forage is limited. It is possible, therefore, that the loss of vegetation cover during periods of over-grazing has exposed peat surfaces, making them more susceptible to weathering and erosion. In addition, sheep typically shelter against exposed peat sections and, by direct erosion and localised trampling, increase the extent of the scars.

6.3.6 ***Forest of Bowland:*** it was initially anticipated that the peat deposits in the Forest of Bowland study area would be relatively intact because of the limited threats of tourism and associated accidental burning. However, in reality, the loss of peat in the area was surprisingly great, which was in part due to a series of extreme fire events that had occurred in the 1940s, and destroyed *c* 400ha of moorland near Stake House Fell (SD 555 498; J Hickling *pers comm*; Mackay and Tallis 1996). Sampling Site 3, which is on Stake House Fell (Fig 55), also exhibited a break in the stratigraphy and pollen record, which indicates that an erosion event has occurred in the past, which has sealed the intact peat by *c* 0.25m of redeposited material. Exacerbating the effects of this exceptional erosion event is the action of peat cutting and weathering.

6.3.7 The blanket peat, situated away from the areas of intensive erosion, was much more intact, and areas of relatively flat ground and gentle slopes were covered by up to 2m of peat, albeit occasionally dissected by grips and natural drainage gullies. Although the area has evidently been subject to regular controlled burns for grouse shooting, the effects on the peat and vegetation appear to be limited and, out of all four of the study areas, the Forest of Bowland was the most heavily vegetated.

6.3.8 In the Forest of Bowland, the most marked and active erosion, and therefore the most immediate threat, appears to be from the effects of natural drainage, which was most marked at White Moss (SD 575 505), situated in a large basin or possible col. There, water erosion has formed a reticulate network of closely spaced 2m deep drainage gullies (Plate 6), which have eroded through the peat to bedrock. The gullies appear to represent Bower's (1961) 'Type 1' dissection, which was confined to deep peat on relatively flat areas. The fact that a great deal of surface peat has also been lost in this area is supported by a date of 490-380 cal BC (2350±35 BP; SUERC-4504) from the surface of the peat (Sampling Site 1), which suggests that over 2000 years of palaeoecological history has been lost. It is highly unlikely that natural drainage erosion has truncated the peat to this depth, and it is most probably, albeit in part, attributable to peat cutting.

6.3.9 The two different types of active erosion in the Forest of Bowland are manifested very differently on the ground. On the shallower peat margins, which were likely to have been subjected to the exceptional burning event and peat cutting, widespread 'blanket' erosion has occurred, leaving extensive bare patches of mineral soil or bedrock, with occasional upstanding peat haggs (Plate 28). Some areas have revegetated, but essentially the weathering processes have now removed any remaining peat. In the central area of deep peat, the gully erosion has left a reticulate pattern of peat with very closely spaced gullies. Research carried out by Wishart and Warburton (2001) on the erosion of gully systems in the Cheviot Hills shows that, once incision to the base of the peats has occurred, a parallel retreat of the gully sides takes place. This area, by its very nature, is subjected to constant water erosion and therefore it is inevitable that the peat will eventually be completely eroded.

6.3.10 ***Anglezarke Moor:*** the condition of the peat in the Anglezarke Moor study area appears to be highly variable and has been determined by a number of factors. On the central, relatively flat plateau, north-east of Hurst Hill, where the deepest peat was encountered (Fig 64), severe erosion was limited to areas of drainage, where gullies up to 2.5m deep had incised through the peat, and these were in part straight and parallel-sided, indicating that they had an artificial origin (Plate 4). However, at the lower, northernmost ends, the gullies followed erratic natural courses, indicating that the grips had been fed into natural gullies. It was unclear what effect the gullies have had on the adjacent peat, although it would appear that a zone of peat running parallel with the gullies has been affected by the erosion, where large blocks of peat have slumped into a channel (Plate 29). This conforms to the conclusions of Wishart and Warburton (2001), indicating the pattern of retreat of gully sides in deep gullies; it would appear that the tops of the gullies widen faster from block collapse of the upper peat.

6.3.11 Generally, the deeper peat away from the gully systems appears to be relatively intact, with little evidence of stratigraphic breaks. Material taken from near the surface of the deeper peat, from two sites on the central plateau, has provided dates of cal AD 1224-1430 (650±80 BP; HAR-6418 (Bain 1991)), and cal AD 1060-1280 (845±35 BP; SUERC-4511). This suggests that they have been truncated to similar depths, or indeed represent a time when agricultural practices on Anglezarke Moor, such as the burning of heather to provide improved forage for livestock, became more intensive, and restricted the production of surface peat. Both the palynological and documentary evidence indicates a large expansion of human activity on Anglezarke Moor from the 1400s (Bain 1991). The popularity of grouse shooting from the 1900s onwards in northern England has also encouraged regular heather burning, which continues today on Anglezarke Moor. Evidence from the Pennines suggests that repeated heather burning significantly reduces the rate of peat accumulation (Garnett *et al* 2000).

6.3.12 The effects of modern managed heather burning is evident on the peat surface on Anglezarke Moor, in the form of increased erosion on the surface of the bare peat following loss of cover immediately after burning (Fig 60); however, it is probable that the effects are relatively minor. The deepest peat on Anglezarke Moor is in the extreme north-eastern area, which is wetter, dominated by grasses, and has not been subject to the regular, managed heather burning carried out on the central plateau. In this area the peat is up to 3m deep, and it is possible that on the central plateau, where the peat is no more than 2.5m deep, at least 0.50m worth of peat has been truncated or has failed to develop.

6.3.13 The main, and most severe, erosion on Anglezarke Moor is in the far south-western section, extending from Pike Stones (SD 6250 1720) to Hurst Hill (SD 630 179). Although the dating and pollen evidence from a number of sites there suggest that peat inception occurred in the Late Neolithic/Early Bronze Age (Sampling Site 2; Bain 1991), no more than 0.50m (or sometimes none) of the peat survives. Additionally, the peat that does survive has been subjected to a number of erosion and regrowth episodes, illustrated by hiatuses in both the stratigraphy and pollen record; ironically, the surface of the peat there is younger that that on the central plateau. The exact timing of these erosion episodes is difficult to determine, given the calibration errors involved with more recently deposited material; however, there is evidence to suggest that at least one erosion event had occurred prior to the AD 1400s (Bain 1991). This highlights the fact that widespread erosion on this part of Anglezarke Moor is not just a recent phenomenon. Indeed, work carried out in the southern Pennines by Tallis (1987) suggests that peat erosion at Holme Moss, near Holmfirth, and to the south-east of Anglezarke, had been active for four to five centuries, and concentrations of burnt plant material at certain levels within the peat indicates that the drier eastern half of the moor had been burnt at least once in the eighteenth century.

6.3.14 Although it is difficult to determine exactly how much peat has been lost from Anglezarke Moor, assuming that peat accumulation in this area is consistent with that elsewhere, comparisons with the deeper peat suggest that, potentially, up to 1.60m of peat has been lost. It is evident that this part of Anglezarke Moor has also been subject to a number of recent wild fires, which have exacerbated an already dwindling peatland resource. It may not be coincidental that this area is nearest to a country road and several access points.

6.3.15 ***Conclusions:*** the study has shown that all four of the areas covered by the project have undergone varying amounts of peat loss. The most undisturbed and intact deposits were those in the South-West Fells of Cumbria, where threats from both tourism and fire are limited. The observed effects of sheep farming and natural drainage are also minimal there, and it appears that the only real threat has come from past peat cutting. Even these areas, however, have revegetated and little in the way of weathering has occurred.

6.3.16 The effects of tourism, in the form of footpath erosion, are, as one would expect, most marked in the Langdale Fells. However, on the whole, footpath erosion was limited to the pathways themselves and was only severe in areas where footpaths merged with deep deposits of peat and drainage channels. In both the Langdale Fells and the Forest of Bowland, natural drainage erosion appears to be having a very marked effect on the peat deposits, and this is perhaps the threat that may prove the hardest to manage. In addition, the effects of over-grazing, especially in the Langdale Fells, may be contributing to this erosion, as this was clearly a significant factor governing the loss of vegetation and the erosion of bare peat surfaces.

6.3.17 It appears that the most damaging anthropogenic threat has come from the effects of wild fires, which, on both Anglezarke Moor and in the Forest of Bowland have removed vast areas of peat cover. Although the damage is immense, these ‘extreme’ events are sporadic and in many areas regeneration of the peat surface has occurred, limiting the effects of wind and rain erosion. Although the ‘managed’ burning of heather for the grouse-shooting industry is a regular practice, and may prove detrimental to peat development over time, one positive aspect could be its role in controlling the growth of tall stands of woody heather, which is more susceptible to igniting and fuelling ‘wild fires’. The catastrophic fire documented in the Forest of Bowland in 1947, for example, followed a period of decline in land management due to a shortage of gamekeepers after the Second World War (Mackay and Tallis 1996).

6.3.18 The South-West Fells have relatively limited visitor pressure, and are subject to ‘normal’ levels of grazing, so there is only a limited risk of accidental/ deliberate fire, and there are reduced amounts of vegetation (fuel); consequently, there is a low risk of wild fire. There are relatively limited indications of ongoing erosion and as such there is only a small anticipated threat to any buried archaeological resource. The Langdale Fells have considerable visitor pressure, which increases the risk of fire, but very little vegetation because of over-grazing, so any fire is unlikely to develop into a wild fire. The erosion scars indicate that there is a threat from drainage and sheep erosion, which have the potential to expose and damage any buried archaeological resource. The Forest of Bowland study area has low visitor pressure, and, though there has been a history of wild fires, these were at times when there were few gamekeepers to manage the land, and today there is only a small perceived risk of such wild fires. The area has considerable scarring, indicative of both historical and ongoing erosion, and as a result there is a moderate to high threat to any buried archaeology. Anglezarke Moor has considerable visitor pressure and is under-grazed, and as a result it has a recent history of wild fires, and the risk of future wild fires is very high. The peat is in places relatively shallow and there are substantial areas of exposed mineral soil. The existing scars are being eroded by natural processes and there is a generally high risk for the disturbance and erosion of any underlying archaeological remains.

6.4 RELATIONSHIP OF THE ARCHAEOLOGICAL RESOURCE TO PEAT DEVELOPMENT

6.4.1 It is important to understand the relationship between the identified archaeological resource and the development of the peat, in order to inform predictions of where and in what context archaeological remains may be found beneath or adjacent to peat. To this end, the locations of dated archaeological remains were compared with the model of how and when peat developed in each of the study areas (*Section 6.2*). In all instances, the transects were designed to build on the results of earlier archaeological surveys, and it is from these earlier datasets that the analysis has been drawn.

6.4.2 ***South-West Fells:*** the identified archaeology on the western slopes of the South-West Fells for the most part comprises the extremely complex Barnscar cairnfield (Fig 17; Quartermaine and Leech forthcoming), which relates to two clear episodes of development. The earliest of these was a small radial-shaped field system that extended out from a large house platform, which were associated with a cairnfield; there was evidence of lynchets associated with this field system and an indication that the identified fields were at least in part cultivated (*ibid*). Typologically, such a settlement is fairly well developed and there is an implication that this was a secondary phase of agricultural activity that had probably started with a simple random cairnfield. The chronology for the settlement is uncertain; however, an antiquarian excavation by Lord Muncaster of cairns on Barnscar revealed inverted cinerary urns (Dymond 1893, 186) and there is a possibility that these were the same urns that were subsequently identified at Muncaster Castle, and dated by Fell (Walker 1965b, 64-6) as being collared urns of Middle Bronze Age date. Although the dating is clearly uncertain, there is an implication of activity on the site during the Bronze Age. Certainly, the character of the cairnfield and its settlement would accord with examples elsewhere in the region of a more diagnostic Bronze Age date (Quartermaine and Leech forthcoming).

6.4.3 The second phase of activity was a field system superimposed across the earlier one and extending out from a Romano-British type of complex enclosed settlement. The inferred chronology has been reinforced by a trench excavated by G de G Sieveking in 1957, through the external bank of the settlement, which produced a Romano-British brooch. Unfortunately, the results of this work have never been published (C Richardson *pers comm*).

6.4.4 The analysis of the base of Sampling Site 1 revealed a Neolithic inception date of 3360-3020 cal BC (*Section A2.12.7*), associated with pollen indicating relatively open shrub / woodland with disturbance indicators and, incredibly, a single grain of cereal pollen. Neolithic cereal pollen has been found on sites on the coastal plain, such as at Barfield Tarn (Pennington 1975) and Ehenside Tarn (Walker 2001), but it has never previously been recovered from an upland context. Cereal pollen does not travel particularly well and this implies that the site from which it originally came was not far removed from the sample site; as such, it is unlikely to have originated on the coastal plain. However, given that it was only a single grain, the possibility of contamination cannot be dismissed.

6.4.5 The removal of the trees on the raised ground on either side of Black Beck would have increased the run-off into the beck, and made the ground adjacent to it considerably wetter, and there is a possibility that this act of clearance precipitated the formation of peat there.

6.4.6 The implications of this are that there was some agricultural activity at Barnscar that dates back to the Neolithic period, and therefore considerably earlier than is implied by the typological evidence of the physical remains on the site. While this is in itself a remarkable result, the site of Barnscar is in any case remarkable; it is the largest and most complex cairnfield in Northern England and has within it over 875 monuments (Quartermaine and Leech forthcoming). A site of this scale and complexity is likely to have been a product of a more extended period of occupation than a more basic cairnfield, and it is perhaps not surprising, therefore, that this site should have an origin earlier than is known at other cairnfields.

6.4.7 The probing survey was intended to establish the existence of any buried cairns around the margins of the Black Beck peat, and was able to identify buried cairns at the BS VI element of the cairnfield (Figs 17 and 22); however, despite being undertaken systematically across the area of mire between the large BS IV element of cairnfield to the west and Black Beck, there were no buried cairns revealed in this location (*Section A2.7.1*). The observed cairns extend close to the present margins of the mire and the implication of the probing survey is that the original edge of the cairnfield closely matched the present mire edge, and in only four instances (BS 326-7 and BS 329-30) are there cairns on the margins of the peat. Given that the mire had its origins before the major expansion of the cairnfield, this correlation between cairnfield and mire implies the margins of the mire have not significantly changed since the Bronze Age, and it has not subsequently expanded to engulf some of the cairns. It would also suggest that the cairnfield respected the edges of the mire and did not expand into the poorly drained ground.

6.4.8 ***The Langdale Fells:*** the remains of the internationally important Neolithic axe factories surround the summits of the Langdale Fells, which reflect a massive early industrial exploitation of a fine-grained tuff that outcrops on the Langdale Pikes (*Section A3.3.6*; Fig 41). The main concentration of axe-working sites is around the south-western faces of the Pikes, but there is a lower concentration of sites that extends back from the Pikes across the peat-covered plateau. It has been suggested (Claris and Quartermaine 1989) that these extend along presumed communication routes towards Borrowdale, and there is at least one probable camp site within this general area (Thunacar Knott; Clough 1973). The axe working has a fairly broad chronology, of which the latest evidence is generally quarry sites from the face of Pike of Stickle (*eg* Site 95 (Claris and Quartermaine 1989)), dated to 3517–3103 cal BC (4590±50BP; BM 2627; Bradley and Edmonds 1993). An earlier date has been obtained from a site on the bench below Thorn Crag (Site 187 (Claris and Quartermaine 1989)), where charcoal from immediately below a layer of waste flakes produced a date of 4041–3662 cal BC (5080±90BP; OxA-4212; Hedges *et al* 1994, 360–1; *Section A3.3.11*); this coincides with the beginnings of forest clearance identified in the pollen sequence at Blea Tarn (Pennington 2003). Perhaps the most curious dates comes from the excavation of Site 123, on the plateau behind Loft Crag, provided by an accelerator date of a charred *Empetrum nigrum* seed from within a deposit of axe waste. The date obtained was 5968–5732 cal BC (6965±30BP; KIA23485; OA North 2004a; *Section A.3.12*), implying a Mesolithic date for axe manufacture; however, there is the possibility that the seed originated from an earlier ground surface beneath the flakes, which would suggest a very early Mesolithic clearance / burning episode. In either instance, it is potentially very important.

6.4.9 ***Peat Inception:*** the dates of the inception of the blanket peat at all three sampling sites in the Langdale Fells indicate that peat formed in the Bronze Age, some time after the Neolithic axe production had ceased. This relationship between the peat and the archaeological remains is particularly evident at Site 123, where the peat formed directly on top of the axe-working floor, and, although the dated sample from the peat was only just above (*c* 70mm) the working floor (which was also dated), there was seemingly a chronological gap of *c* 3500years. The implication is that the mineral soil was initially exposed to the elements for a considerable period and that there was thereafter only a very slow soil build up. This is perhaps not that surprising; soil deposition at these altitudes being undoubtedly very slow, and the fact that so many axe-factory sites are known in the Langdale / Scafell Pike area reflects the fact that many of them are still exposed to the elements after *c* 5500years (*eg* Plate 30).

6.4.10 However, in contrast to that, there were also several working sites discovered during the present survey, where the flake material was within the peat, rather than at its base (Sites L2, L15, L21 and L28; Fig 43). Although no peat inception dates were obtained from these sites, it may be suggested that either peat formation in these localities was earlier than elsewhere or axe production was later, or even a combination of the two. The majority of the axe-factory sites in Great Langdale had been exposed to the elements for a considerable period prior to peat formation and are therefore unlikely to be associated with any preserved organic remains, whereas these new sites potentially formed within the peat and raise the possibility that they incorporate the preservation of all-important organic remains. As such, these sites are potentially very important, and their condition is deteriorating since they have become exposed.

6.4.11 ***Forest of Bowland:*** the archaeology in the Forest of Bowland study area was found to be densely concentrated around the undulating, and largely peat-free, landscape of Nicky Nook; of the 61 sites recorded, 57 were within the Nicky Nook cairnfield (Fig 54). The cairnfield comprises a large number of essentially randomly distributed cairns, albeit with a line of cairns marking the southern edge. Within the group is a putative enclosure, and also two large cairns that are well-defined, prominent, and which have the potential to have been round funerary cairns (*Section A4.4.2*). The essentially random distribution of the cairns would suggest that it was a primary cairnfield, being a product of land improvement following the initial clearance of the forest (Quartermaine and Leech forthcoming). If it were confirmed that the large cairns were funerary, then this would imply a Bronze Age date for the cairns, and by association the cairnfield also. The general character of the Nicky Nook cairnfield is closely comparable to a number of the cairnfields on the South-West Fells, which are also tentatively dated to the Bronze Age. Nicky Nook seems to have been a relatively isolated area of marginal upland that was cleared of forest and improved by the clearance of waste stone into piles. There was little evidence of a rationalised field system within the cairnfield and thus it might be that this land was improved for pasture.

6.4.12 By contrast, on the sloping spur to the east that makes up the remainder of the study area, no sites were identified (Fig 53), despite the fact that there were considerable exposures through the peat to the underlying mineral soil or bedrock on Stake House Fell. Generally, though, there is a significantly lower concentration of archaeological remains within the Forest of Bowland when compared to other uplands in the North West (LUAU 1997). Indeed, this is reflected within the present-day landscape, which has been subject to considerably less anthropogenic impact than almost any other English upland area; in particular, very little of the landscape has been enclosed or improved, and substantial areas of the Lakeland massif have no vehicular access.

6.4.13 The Forest of Bowland had the earliest peat inception of any of the four study areas, the peat initiation at White Moss being of Mesolithic date (5720–5550 cal BC; 6720±35 BP; SUERC-4505/GU-6058; *Section A4.5.6*). By the Neolithic period (3520–3350 cal BC; 4645±35 BP; SUERC-4506/GU-6060; *Section A4.5.7*), the peat formation had extended down to Stake House Fell, and during the Bronze Age only the lower slopes were free of peat. The presence of significant deposits of peat would have discouraged agricultural exploitation of the marginal land on the moderate slopes of Stake House Fell, and, although there was intensive agricultural activity on the adjacent Nicky Nook, probably during the Bronze Age, the poorly drained and acidic soils of Stake House Fell are likely to have discouraged any eastwards expansion. Of course, this absence of sites on the eastern side of the study area could simply reflect poor site visibility because of the peat cover, but, because of the historical fires across Stake House Fell, there are in actuality substantial exposures through the peat that are almost as extensive as those on Anglezarke Moor. Where it differs from Anglezarke Moor, though, is that there are seemingly no archaeological remains.

6.4.14 ***Anglezarke Moor:*** Anglezarke Moor can lay claim to having been exploited by man over a considerable period, dating back to the Mesolithic period and culminating with relatively modern remains in the form of mines and quarries. The Mesolithic period is represented by lithic sites that are spread across most parts of the moor, epitomised by that at Rushy Brow (SD 6329 1769), to the east of Hurst Hill, which was excavated in 1986 (Howard-Davis 1996). The Neolithic period is also represented by lithic sites in the western part of the study area, principally Stronstrey Bank, but also by two chambered cairns, which are the only examples of such monuments in Lancashire. The larger of the two, Pike Stones, is a chambered long cairn at an altitude of *c* 275m AOD, near the western edge of the moor, and the other is a round chambered cairn (*op cit*, site 40) at the northern end of Stronstrey Bank (*c* 220m AOD). This activity potentially coincided with a major clearance episode in the late Neolithic / Early Bronze Age that was identified from palaeobotanical cores (*Section A5.5.4*; Bain 1991).

6.4.15 The occupation / exploitation seemingly continued into the Bronze Age, albeit only at the westernmost, and lower, margins of the moor. Bronze Age lithics have been recovered from the area of Stronstrey Bank, where there is a probable cairnfield on its eastern margins. Stronstrey Bank is a wide, flat, natural bench at an altitude of on *c* 220m AOD, and is adjacent to well-drained lowlands (Plate 21). It is the sort of natural upland terrain that is ideal for any agricultural exploitation, and where the presence of a cairnfield could be sensibly predicted. In addition to the agricultural activity, there is also an elliptical, kerbed cairn (Howard-Davis 1996; site 73) near Jepson's Gate (SD 6239 1734), which was probably a funerary monument. It was exposed as a result of a moorland fire in the early 1980s and was excavated in September 1983.

6.4.16 There were no sites confirmed as dating to the Iron Age, Roman or early medieval periods; however, the palaeobotanical evidence indicates that there was a significant modification of the Anglezarke uplands in the Late Roman/early medieval period, probably as a result of human intervention. There was a long parallel-walled structure (*op cit*, site 72) within the peat near Jepson's Gate (SD 6248 1737), which was essentially undated but, given that it was within the peat, it evidently post-dated the *c* 1250 BC inception date (Barnes and Bain 1985) and is likely to be Iron Age or later.

6.4.17 In the last 250 years, in this area the moors have been subject to extensive extraction, from peat cutting around Jepson's Gate and Ferney Slacks, to mines on Brown Hill, and the southern end of Stronstrey Bank. There was extensive quarrying for the millstone grit that underlies the moor, represented by a millstone quarry at the northern end of Stronstrey Bank, which has considerable numbers of millstone wasters (*Section A5.3.13*).

6.4.18 ***Peat Inception:*** the earliest inception date for the peat on Anglezarke Moor was from Black Brook (Sampling Site 1), which was early Neolithic (3800–3650 cal BC; 4945±35 BP; SUERC-4512/GU-6066), and there was a later Neolithic / Early Bronze Age peat inception at Sampling Site 2 at Hurst Hill (2200–1940 cal BC; 3685±35 BP; SUERC-4515/GU-6070). By the later Bronze Age (*c* 1250 BC), the peat had spread as far as Jepson's Gate (Barnes and Bain 1985). Mesolithic activity would therefore have been unrestricted by peat development, and the general scatter of Mesolithic sites across the moor, from Rushy Brow and Black Brook, is testament to that. However, activity from the Neolithic period was concentrated on the lower western flanks of the moor, reflected in the lithics and funerary monuments, and there is a possibility that, at least in part, this reflects peat formation having made the higher, and more eastern, land agriculturally unviable. By the Bronze Age, activity was solely concentrated on the Stronstrey Bank terrace and the lower slopes of Jepson's Gate, which would have been the only area that was free of peat at that time.

6.4.19 The initial formation of the peat is likely to have been precipitated by local deforestation at the hands of a Neolithic population, and yet, once initiated, the blanket peat has spread down the slopes, making the moorland agriculturally untenable. The steady retreat of human activity down the slope with time would appear to indicate that man has been steadily losing the battle against the forces of nature, and any subsequent activity appears to have been localised and seemingly short-lived. Not until the post-medieval period, when the mineral potential of the moor was realised, was there any significant resurgence of activity.

6.4.20 ***Conclusions:*** the relationship between archaeology and the peat varies across the four study areas. In the South-West Fells, the peat was in a fairly static state, fairly localised, and for the most part had not engulfed the archaeology. By the same token, the archaeology had not, for the most part, been established on or in the peat, but instead appears to have avoided it. Consequently, in terms of the archaeological remains, the indications are that what is visible on the surface is in actuality, for the most part, what is in existence. There is little justification in doing much below-peat investigation in this area as any archaeology is likely to be on the adjacent better-drained ground.

6.4.21 In the Langdale Fells, the putative camp sites away from the main areas of axe production are likely to be in an area on the plateau behind the Pikes, and they will in many instances be beneath the peat. As some of these are actually within the peat, the considerable possibility is raised that there are the organic remains of temporary camps surviving within these peats. The Langdale Fells are consequently an area which has considerable potential for below-peat investigation.

6.4.22 In the Forest of Bowland, the early inception of the peat and its steady spread downslope made the land agriculturally unviable and would have discouraged anthropogenic activity. On this basis, the potential for archaeological remains exists only on the very lowest slopes of Stake House Fell, which were engulfed by peat at a relatively late date. The area round Nicky Nook has never been covered by peat and has considerable potential for archaeology, but it is also clearly evident on the surface, and therefore there is little justification for below-ground investigation in order to discover new sites.

6.4.23 Anglezarke Moor had a later peat inception, allowing Mesolithic activity across the whole study area, but from the Neolithic period, peat was expanding from the higher fells, forcing later activity onto the lower ground, which was then still free of peat. Although the later activity is found on the lower ground, there is still considerable potential for Mesolithic remains on the higher fells, as typified by the Rushy Brow site (Howard-Davis 1996), and there is considerable potential for below-peat investigation across the whole area.

7. ARCHAEOLOGICAL POTENTIAL OF THE UPLAND PEATS

7.1 THE POTENTIAL OF THE UPLANDS

7.1.1 The uplands of England contain some of the most remarkable extant archaeological resources in the UK, reflecting the fact that the marginal land has been unintensively worked in the last few hundred years, which has afforded a unique survival of archaeological landscapes. Where peat is not present, the wealth of these landscapes is self evident; areas such as the South-West Fells of Cumbria have been so intensively exploited in the past that they contain upwards of 10,000 prehistoric monuments, comprising extensive cairnfields, field systems, settlements, and numerous burial monuments. They provide the opportunity to examine the character, form and development of rural settlement through a substantial period of the later prehistoric, as well as the medieval and, to a lesser extent, the Roman periods. Notably, the site of Barnscar contains upwards of 900 monuments, and exhibits a complex development of settlements and field systems that appear to date from the Neolithic period through to the Roman period (*Section A2.3)*; Quartermaine and Leech forthcoming).

7.1.2 Much of this area is free of peat, hence the excellent site visibility, but there are areas of peatland within it, and many other, upland areas have the potential for a similar wealth of archaeological remains, but the added bonus that they also have the potential for the survival of organic remains, since the sites are protected by peat. This is particularly characteristic of sites that are associated with the peats themselves, including wooden tracks to allow the crossing of large tracts of mire; these are most commonly found in lowland contexts, but they are also found within the uplands, often to enable access to peat cutting areas. A remarkably well-built timber track was identified from a peat section at Ferney Slacks, on Anglezarke Moor (Plate 31); it was constructed of saw-cut timbers, so it was not of particular antiquity, and was evidently intended to allow wheeled vehicles to remove peat from the moors. Other finds from within, as oppose to beneath, the peat include a longbow from blanket peat above Moffat (at an altitude of 660m AOD), Dumfriesshire, which was a chance find in 1990, and has been dated to 4224-3653 cal BC (5090±100BP; OxA-3540; Sheridan 1999). Votive or sepulchral features have also been a noted element within peat, extending across a broad date range. Examples include a prehistoric cist at White Horse Hill (SX 6175 8550), at the centre of Dartmoor, which had been cut into the peat. The peat level with the base of the cist produced dates of 3650-3100 cal BC, while peat at the level of the top of the cist had a date of 2200-1890 cal BC (J Marchand (Dartmoor NPA) *pers comm*). There was also a remarkable find, the Deskford Carynx, from raised peat deposits at Leitchestown Farm, Deskford, in north-eastern Scotland. The carynx is a ceremonial animal-headed horn, dating to the Roman period, which had been deliberately dismantled, before being inserted into the peat, possibly as a votive offering (Hunter 2001). When discovered, the carynx had a wooden tongue operated by springs, but this element has subsequently been lost.

7.1.3 The archaeological resource within peat displays a broad diversity of character and date, and serves to reinforce the importance of the material from the upland peats. When the 1984 survey of Anglezarke Moor was undertaken (Howard-Davis 1996), a long, linear dry-stone structure was found, set within the peat near Jepson's Gate (site 72; SD 6248 1737); this comprised parallel walls, within which there were smaller cells. At the time, the structure was severely degraded, and with the ongoing erosion in this area, it has now been lost, and as a consequence its interpretation is insecure. Given that it was within the peat, it evidently post-dated the *c* 1250 BC inception date for the peat (Barnes and Bain 1985), and is thus likely to be of Iron Age or later date.

7.1.4 ***Prehistoric Activity:*** the archaeological resource preserved beneath the peats is varied in character, and may comprise early agricultural settlement features engulfed by peat, or, for example, the axe-working sites of Great Langdale. Recently, a group of new axe-working sites has been discovered on the edge of Martcrag Moor (Plate 32), where footpath erosion has cut through the peat (OA North 2009). The eroded footpath is 300m long, and for the most part only 1.5m wide, so it represents a tiny proportion of the peatlands of Martcrag Moor, but it has so far exposed eight new axe-working sites. This raises the possibility that there are vast numbers of sites still to be discovered under the, as yet undisturbed, peatland in this area. Because the sites have only recently been exposed, they are in very good condition, and provide an indication of the methods of working. For example, there are two adjacent scatters only 1.5m apart, one comprising coarse working flakes and the other fine working flakes, which would suggest that the work was done by two workers simultaneously, one concentrating on the coarse working and the other on fine working.

7.1.5 The sites are on the line of a suggested access route that leads into Borrowdale, which raises the possibility of camp sites in the environs, similar to that postulated at nearby Thunacar Knott (Clough 1973). Peat formed directly on top of the working floors, which will allow the use of pollen analysis to establish the environmental context at the time of peat inception, and, by linking the result with a full sequence from nearby Langdale Combe (Walker 1965a), can establish how this fits in with the wider vegetation history of Great Langdale. At least one of the sites has peat beneath the axe waste, suggesting that axe manufacture occurred at around the time of peat inception.

7.1.6 ***Peat Inception:*** whilst these axe-working sites clearly highlight the potential of extractive sites to be revealed beneath the peats of the Langdale Fells and the rest of the Central Lakeland Fells, the majority of archaeological remains within the uplands of Britain relate to subsistence, and agricultural exploitation of the marginal lands. It cannot be assumed that all peatlands have an equal potential to protect such sites, since the extent to which archaeological remains exist beneath the peat largely depends on the date at which the peat began to form in any given area. Once peat has developed, the value of the land for farming is limited, which discourages settlement and any associated activity. Inception dates from areas of peat, in the Neolithic period, for example, would mean that evidence for Mesolithic activity may exist beneath the peat, but there will almost certainly be an absence of later activity, unless it relates specifically to the peat itself. There is a proliferation of Mesolithic material across the moors of the Central Pennines, with sites ranging from small hunting camps to the large and long-lived gathering places, reused many times, of the type characterised by Warcock Hill South in West Yorkshire (Radley and Mellars 1964). The places where only early material is identified are to a great extent an indication of early peat inception. Areas where peat developed later, particularly towards the fringes of moorlands, are likely to have been occupied during later prehistory before they were covered by peat. Hence the survival of abundant later prehistoric remains on the lower slopes of Anglezarke Moor reflects not only that the peat is thinnest there, and therefore vulnerable to erosion, but also that the peat inception was later, so settlement and farming activity had occurred before the peatlands grew. This indicates that, as a gross generalisation, the lower fringes of moorlands tend to have greater potential for archaeological remains, with a wider timespan, but are also under the greatest threat. This is of course not a consistent generalisation, since at Barnscar, on lower marginal slopes, peat developed around Black Beck from the Neolithic period (*Section A2.3.14*), but then did not expand significantly. There was thus little or no expansion of peats over the BS IV cairnfield; however, a short distance away at the BS VI cairnfield there was some peat encroachment of the cairnfield (Fig 17).

7.1.7 ***Roman and later activity:*** although there has been an emphasis on the recording of prehistoric remains beneath the peats, in part reflecting the extent of prehistoric activity within the uplands and the fact that much of the peat began to develop some 3-5000 years ago, there is also some potential for activity from later periods within these contexts. Complex enclosed settlements, traditionally dated to the Roman period, are occasionally wholly or partly preserved beneath peat, and even such monuments as the Roman fort at Hardknott and the Roman road at High Street are partially covered (*eg* Quartermaine and Leech forthcoming).

7.1.8 The fact is that the peat provides such an impenetrable cover that it is not until it suffers catastrophic damage that any indication of the underlying archaeological resource is revealed. Therefore, although this project has identified limited amounts of new archaeological remains in the Langdale Fells and the South-West Fells, it is at sites such as Anglezarke Moor and Fylingdales Moor, which have been severely affected by major fires, that an enormous wealth of archaeological remains have been revealed (*Section 2.10.13*). At Fylingdales Moor, the loss of heather and organic soils as a result of the wild fire in 2003 revealed an enormously rich archaeological landscape, which included a complex of cairnfields and settlements, along with funerary / ritual monuments and some internationally important prehistoric rock art (Vyner 2005). The survival was such that even subtle striation marks, from peat cutting, and wheel ruts were revealed on the underlying substrate (N Redfern *pers comm*). The archaeological resource was not limited to prehistoric remains as there was also considerable evidence of military activity from the post-medieval period, including militia camps, Second World War dugouts, and spent ammunition, demonstrating that the area has been used as a military training ground for a considerable period. The loss of the peat has allowed the reconstruction of a complex and developing landscape over the last 5000 years, and provided an insight into the complex process of exploitation and reclamation of these marginal lands, but this was largely at the expense of the survival of the remains, which were substantially and rapidly damaged once they had been exposed. Anglezarke Moor similarly has a wealth of cairnfields, prehistoric funerary remains, and structures of later periods that were formerly preserved within or beneath the peats, but are now exposed and have been damaged as a result of the loss of the peat.

7.1.9 ***The future:*** in archaeological terms, the peatlands of the British uplands inevitably get overshadowed by the adjacent peat-free areas, largely because of the dramatic differences in site visibility; however, the peat-covered lower slopes in particular have the potential to contain just as great an archaeological resource as the peat-free areas. These areas have considerable potential for the new discovery of archaeological remains within an upland context, and therefore they need to be subject to comparable levels of management to those areas with a confirmed archaeological resource. To this end, a mechanism needs to be developed to take into account the differences of site visibility when establishing management regimes for the uplands.

8. THE DEVELOPMENT OF A MODEL

8.1 INTRODUCTION

8.1.1 One of the primary aims of the project was to determine the feasibility of creating a GIS model that would predict where the greatest areas of threat to upland peats are, and to predict where the greatest concentrations of archaeological remains would be found. In the event, this was achieved by creating two separate models: the first for the erosion threat and the second for archaeological potential. These could then be combined to highlight hotspots within the peat where previously unknown archaeology might also be at threat. The first model identified the different factors that cause erosion and damage to the peat and located those areas where the cumulative threat from these factors is the greatest. The second identified common environmental parameters governing the location of known archaeological sites and identified those areas, not previously investigated, that also contain the same environmental parameters. By implication, these could also have potential for buried remains. By overlaying these two models it is possible to highlight 'hotspots' where there is both a high potential threat to the peat and the possibility of undiscovered archaeology. The development of the models drew upon data from all four survey areas, but the threat model was largely based upon Anglezarke Moor because of the varied nature of the threats to the peatland, and the archaeological model was largely based upon the South-West Fells because of the rich and well-documented archaeological resource there.

8.2 MAPPING THE EXTENT OF THE PEAT

8.2.1 Before the models could be created, it was necessary to map the known extent of the peat in the four study areas. This was done using a combination of documentary (*Section 3*) and field survey (*Section 4*) evidence. A draft outline of the extents in each area was first mapped using British Geological Survey (BGS) soil maps and this was then overlain on air photography, to ascertain whether changes in soil types were identifiable from the aerial photographs; if so, the draft extents were altered accordingly. Finally, the survey data were added and the extents were adjusted accordingly. The accuracy of the BGS data was tested when compared to the results of the coring survey (Fig 68).

8.2.2 To test the validity of this approach, three areas were chosen that were not part of the initial survey, but which included a boundary between the peat and a contrasting soil type; in all instances the areas were adjacent to the original study areas. Palaeoenvironmentalists ground-truthed the soil types to map the change from one type to another. When the additional data were included in the mapping, it tended to agree roughly with the plotted extent, indicating that the initial identification of the peat had been successful. If further ground-truthing was needed, the procedure was then repeated until there was a degree of confidence in the defined mapped extent. The accuracy of the original BGS data is represented on Figure 34 when compared with the results of the coring survey in the South-West Fells.

8.2.3 Once the extent of the peat in each study area had been mapped, the depth measurements collected in the field surveys were used to create contour models of peat depth (*eg* Fig 39). As the results of the survey were in the form of an array of points, it was necessary to employ some statistical interpolation to predict the depth in those areas that were not covered. The statistical method used was kriging, which is suited to an irregular distribution of points and smoothly varying landforms (Hageman and Bennett 2000).

8.2.4 In order to avoid abrupt changes in depth at the boundary from one soil type to another, the assumption was made that peat depth could be defined as zero at the boundaries. This is not a totally accurate assumption, given that the boundary between soil types tends not to be sharp, but instead there tends to be a gradual change over some distance from one soil type to another, with a mixture of the different types in between. However, as the aim was to define the trends rather than provide an accurate representation of peat depth across the wider area, this was considered to be an acceptable assumption.

8.3 CREATING THE THREAT MODEL

8.3.1 In basic terms, the various threats to the peat comprise those that can be portrayed on a map, such as erosion, and those that cannot, such as those that are erratic, such as one-off catastrophic events, or those that occur at different times of the year, for instance. Of those that could be mapped, some could not be mapped explicitly, such as grazing, because no numerical data were available for the study areas.

8.3.2 The remaining quantifiable and mappable threats can be split into three basic types. The first consists of factors like slope and altitude that make it more likely for erosion to occur. For these threats, areas of land more likely to be at risk could be highlighted within the GIS. The second type consists of factors that cause erosion to the peat either from the margins of scars and gullies or from the surface. These were analysed by calculating the rate at which they cause erosion to occur, leading to the creation of buffer zones for the type of threat around particular geographical or topographical features. The final type of threat to the peat is the threat of fire, either accidental or deliberate.

8.3.3 ***Creating the Threat Model:*** the first stage in creating the threat model was to map the features or attributes causing the threats, such as altitude, footpaths, or drainage channels; they were mapped using a combination of raster and vector mapping and air photographs.

8.3.4 ***Producing Buffers:*** once overlays of these existing threats had been produced, buffer zones were created around each feature. As each threat causes erosion at a different rate, the size of the buffer zone around each type of feature was different. Three buffers were created around each feature, according to the amount of erosion that may be caused over periods of 5, 10 and 20 years, based on the rates outlined below (*Section 8.3.5*). For the threat of fire, rates could not be used, as fires are by their very nature one-off events, and in this case buffer zones were created by identifying the rough location of the fires, the distance away from footpaths and roads where most fires are started, and the distance that they tend to spread (S Yearsley *pers comm*).

8.3.5 ***Calculating rates of erosion:*** erosion rates are normally quoted in the literature as amounts of surface-lowering in millimetres per year, in other words the reduction in the depth of the peat over a year from a particular type of erosion. It is possible to use this data in the threat model in two ways: the first is to model the reduction in the depth of the peat directly, over 5, 10 and 20 years. Secondly, the amount of marginal reduction can be estimated, *ie* the amount that a scar or erosion channel would have widened, or a boundary retreated, over that period.

8.3.6 The Moorlands Restoration Project is the primary source of data on rates for the surface-lowering of peat (Anderson *et al* 1998). This identified four topographical scenarios (Table 5) that set out the types of erosion, including the range of angles of the eroding face of the peat.

Topographical type	**Description**	Angle of Slope (θ - in degrees)	**Surface Lowering Rate (h- in mm per year)**
1	Sloping sides of drainage gullies incised into peat	15-60	11.9
2	Gently sloping expanses of bare peat at margins of peat blankets	10-20	28.7
3a	Limited areas of periodic or more sustained water flow on floors of main gullies	5-40	5.5
3b	Limited areas of periodic or more sustained water flow on localised steeply sloping areas	60-85	5.5
4	Burnt litter	-	10.1

Table 5: Surface-lowering rates for each of the topographical types outlined in the Moorlands Restoration Project (Anderson et al *1998)*

8.3.7 For each of the scenarios outlined in Table 5, it was possible to calculate the marginal retreat of the peat using simple trigonometry:

If d_{max} is the maximum rate of marginal retreat, h is the surface lowering, and θ_{min} is the minimum angle of slope then:

$d_{max} = h/\tan \theta_{min}$.

From that formula, the maximum retreat over 5, 10 and 20 years can be calculated using simple multiplication, then converted into metres, as shown in Table 6.

Topographical type	**Marginal Retreat (d - in mm per year)**	**Retreat after 5 years (m)**	**Retreat after 10 years (m)**	**Retreat after 20 years (m)**
1	44.4	0.814	1.628	3.256
2	162.8	0.222	0.444	0.888
3a	3.2	0.016	0.032	0.064
3b	62.9	0.315	0.629	1.258
4	-	-	-	-

Table 6: Marginal retreat rates and total retreat after 5, 10 and 20 years, for each of the topographical types outlined in the Moorlands Restoration Project

8.3.8 Values in Table 6 were used to create three buffers around the features in the overlay for each threat, depending on the topographical type that each threat represented.

8.3.9 ***Type 1 Threats:***

1. Altitude: it is clear (Bower 1961, 20) that erosion of peat is more extensive at higher altitudes. Tallis (1998, 106) suggests that in the west of the UK 'the erosion is particularly characteristic …above 400m'. Other reports (Phillips *et al* 1981) suggest 450-500m as the cusp height, based on the Pennines (the Lake District and other areas of upland may, however, be different). Digital elevation models (with a cell size of 5 x 5m) were created from the original contour data (*Section 3.2.6*). An overlay was created as a worst-case scenario, that highlighted all land above an altitude of 400m as at threat (*eg* Fig 69).

2. Slope: peat development and subsequent erosion are dependent on slope (Bower 1961, 26-7), but this is an extremely complex relationship that could not be fully investigated within this project. It is clear, however, that peat development is less common on slopes of greater than 20° (*op cit*, 22), and that there is a threshold angle of 15-17° over which footpaths tend to erode actively (Coleman 1981, 129). Consequently, all land within the study areas with a slope of greater than 17° was highlighted (*eg* Fig 70).

8.3.10 ***Type 2 Threats:***

3. Peat Margins: these were mapped from documentary sources such as soil and geology maps, aerial photographs, and the results of the palaeoenvironmental survey undertaken during the project. These were classified as Topographical Type 2 threats according to Table 6, and buffers were drawn on the inside of the peat margin to simulate the retreat of the margins over time.

4. Shallow Peat: contour maps of the peat were produced and the amount of surface-lowering in metres after 5, 10 and 20 years was calculated. New contour maps, simulating the peat depths after these periods, were created by subtracting the amount of surface-lowering from the original contour map. Any negative values, in other words where the original depth was less than the amount of surface-lowering, were set to zero to indicate that there would no longer be any peat there at that time (Fig 71).

5. Footpaths: footpaths cause erosion in two ways. Firstly, the paths tend to widen with continued use; secondly, paths tend to act as drainage channels, as their bases are typically below the surface of the surrounding vegetation and soil. This then exacerbates the widening of the path, as people try to avoid walking in muddy/wet areas. In the Langdale Fells, footpaths, such as Harrison Path, have expanded to widths of up to 25m over a period of 30 years, and this does not include the area impacted on by the drainage of the path. On Anglezarke / Rivington Moors, 50m-wide paths are becoming increasingly common (*Section 2.9.26*).

The paths themselves were mapped primarily using the Ordnance Survey landline vector mapping, although in some cases this was not adequate for mapping all of the paths within the study area (*Section 3.2*). Additional paths were mapped using the 1:10,000 and 1:50,000 raster mapping, and air photographs. The source of each path was recorded (in other words which dataset had been used to digitise it), along with its classification as a footpath, bridleway, road, track, or unadopted path. From this, the unadopted paths were removed and included only in the overlay of historical paths and hollow-ways.

Within the study areas, there was evidence of path widening in the Langdale Fells and on Anglezarke Moor of 20m scars forming over 30 years (J Quartermaine *pers comm*). Examination of the air photographs for the study areas, with an emphasis on Anglezarke Moor, suggested that this was a more realistic rate than utilising the extreme, 50m cases. This led to buffers of 2.5m, 5m and 10m over the 5, 10 and 20 year periods.

6. Historical paths and hollow-ways: unadopted paths and tracks were mapped from the Ordnance Survey Landline data, and enhanced as described above. Historical paths that no longer exist on the modern mapping may not be subject to the visitor pressures that affect footpaths and bridleways, but have the potential to act as drainage gullies; consequently, they were digitised by hand from the Ordnance Survey First Edition Rasters. These features have been treated as Topographical Type 1 drainage gullies and have been buffered according to Table 6.

7. Extant rivers and streams: rivers and streams were mapped directly from the Ordnance Survey Landline vector data and were classified as Topographical Type 3B drainage; they were buffered according to Table 6.

8. Existing damage to vegetation cover and peat: existing vegetation and erosion damage was mapped from air photography and the project field surveys. They were classified as Topographical Type 2 drainage, and were buffered according to Table 6, with the caveat that the central, damaged or eroded areas were included within the highest risk buffer.

8.3.11 ***Type 3 Threats:***

9. Accidental Fire: there is a clear correlation (*Section 2.10*) between visitor pressure on well-known paths and accidental fires. Work in the Pennines by the Moors for the Future Partnership has kept detailed records of incidences of fire in the Peak District National Park, and this shows a clear correlation between the location of fires and the route of the Pennine Way (*Section 2.10.25*). The Moors for the Future Partnership suggest buffer sizes of 50m, 100m and 200m (D Boys *pers comm*), and these parameters have been used to create buffers around Public Rights of Way, such as footpaths and bridleways.

10. Arson/Wild Fires: deliberate fires appear to have a different pattern (S Yearsley *pers comm*), along with a larger area of risk (unlike accidental fires, deliberate fires often have more than one starting point and the fire service is often not called out immediately, so the fire spreads more quickly). In the absence of any detailed analysis of the location of deliberate fires, it was decided to create buffers around urban areas and roads, with buffers of 500m and 1km (Fig 72).

8.3.12 ***Raster Analysis:*** in order to view the cumulative effect of the buffer zones relating to these threats, it was necessary to convert each overlay into a cell-based (raster) image. The basis for this technique is to overlay a grid of cells across the study area and assign to each cell in the grid a value based on some parameter. In this study, the chosen parameter was a measure of the total threat, which was calculated using the values of the individual buffers, multiplied by an overall score for each threat category, based on its perceived importance (E Huckerby *pers comm*).

8.3.13 The size of the cells used in the raster analysis can have a profound effect on the statistical validity of the ensuing calculations, and also on the physical size of the computer files produced. Too large a cell size leads to an over-simplification of the data, yet too small a size leads to unmanageably large files. In this project, the size of the smallest buffer limited the size of the cells (to 0.22m), as a larger cell size would lead to the values of more than one buffer being merged into a single cell. To highlight the fact that points within the inner buffer around a threat would be at higher risk than those in the outer buffer, the buffers were assigned the values 3, 2 and 1, moving outwards from the threat. Everything outside the buffer was assigned a value of zero.

8.3.14 The scores for each category of threat were assigned as shown in Table 7. Consequently, for example, the different values for the layer created by the threat to shallow peat were 3 for the outermost (20 Year) buffer, 6 and 9, whereas the values for the layer created for the threat relating to rivers were 5, 10 and 15.

Threat Category	**Score**
Historical or unadopted paths	1
Existing erosion	2
Peat margins	3
Shallow peat	3
Footpaths	4
Accidental fire	5
Rivers	5
Arson	6

Table 7: Weighted values given for each Type 2 or 3 Threat Category

8.3.15 Once a raster grid had been produced for each threat overlay, it was possible to assess the cumulative effect of the threats in each study area, which was done by producing a final raster grid, the cell values of which equalled the sum of the values in the cells of the individual rasters. Hence, if a cell had a footpath threat value of 12 and a river threat value of 5, then the total combined threat would be 17. This technique resulted in a new raster grid that represented the total combined threat to the peat within the study areas. From this, it was possible to select the areas under the greatest combined threat (Figs 73, 74, 75 and 76).

8.4 RESULTS: THE THREAT MODEL

8.4.1 ***South-West Fells:*** the South-West Fells study area has an overall threat score that varies from 0 to 47 (Fig 73). It contains land above 400m in altitude, and there are many areas of slope steeper than 17°, implying that both Type 1 threats are present. No historical paths could be seen within the study area, although there are several unadopted paths and Public Rights of Way that may have had historical origins. The remaining Type 2 threats are all represented, and the Type 3 threat of accidental fire was also considered relevant. However, the threat of arson was considered unlikely because of its remoteness from urban areas. Furthermore, it has no history of fire and the moor is well grazed; this threat was therefore not included.

8.4.2 The zones of lowest threat, scoring 5 or below, comprise the majority of peat within the study area. The mid-scoring zone, from 5 to 20, includes a large area of erosion on Cockley Moss, and short sections of bridleway running through the north-west and south-east corners of the study area. Archaeological sites within this zone consist mainly of prehistoric clearance cairns, but also some post-medieval peat cutting and structures relating to post-medieval farming.

8.4.3 The higher scoring zones, from 20-40, comprise the drainage systems running through the study area, and the buffers around the short section of bridleway running through the south-east corner of the study area. There are several clearance cairns in this zone, that were identified during the Lake District National Park Survey (Quartermaine and Leech forthcoming (Hesk Fell)), and these are mostly clustered on or near the bridleway at the south-east end of the transect.

8.4.4 The highest scoring zones, with a score above 40, comprise extremely localised areas where sections of the drainage system are crossed by paths and other threats, or where footpaths pass through areas of shallow peat. The largest section in this zone is situated in the south-east corner of the study area, on the lower slopes of Hesk Fell, but only a single prehistoric clearance cairn is known in this area.

8.4.5 In conclusion, the large majority of this study area has low threat scorings, mainly because the low visitor pressure reduces the direct impact from erosion and accidental fire. However, the peat is relatively shallow, and located in discrete areas. This means that the risk from marginal retreat should probably be considered as a greater threat than in other areas. The area also has a great number of known archaeological sites, and thus any threat needs to be taken very seriously.

8.4.6 ***The Langdale Fells:*** the Langdale Fells study area has an overall threat score varying from 1 to 65 (Fig 74). The entirety of the transect is above 400m in altitude, and there are many areas of slope steeper than 17°, implying that both Type 1 threats were present. No historical paths were identified within the area, although there are several unadopted paths and Public Rights of Way that may have had historical origins; however, there is the potential that some of the general routes were in use in the Neolithic (*Section A3.3.9*). The remaining Type 2 threats are all represented, and the Type 3 threat of accidental fire was also considered. However, the threat of arson is thought to be unlikely, given the distance from urban areas, and because there is no history of fire in this part of the Lake District.

8.4.7 Almost all the archaeological sites that have been discovered within the study area are concentrated in a narrow band at the southern end, and are related to the outcropping of Group VI tuff, and the axe factories on the slopes of Pike of Stickle, Loft Crag, and Harrison Stickle. Evidence for archaeological sites further north is limited, and those sites that have been discovered comprise small occasional Type D sites (*Section A4.4*; Claris and Quartermaine 1989), typically in a broad corridor extending out from the Pikes and into Langstrath.

8.4.8 The areas of lowest threat, scoring 5 or below, are those with the deepest peat. These are situated away from the various paths and drainage systems. No archaeological sites have been discovered in these areas, in part because they are so isolated and in part because there is relatively little disturbance of the peat and hence no exposure of the mineral soils.

8.4.9 The middle scoring zones, from 5 to 20, are situated in a sweeping band from north of Pike of Stickle and Harrison Stickle, avoiding the rocky slopes of Thunacar Knott, High Raise and Low White Stones to the east, and the steeper slopes down to Langdale Combe and Langstrath Beck (Plate 32). There are higher scoring zones within these areas, representing the various Public Rights of Way, unadopted paths and drainage systems running through them. There are a small number of archaeological sites within this zone, including the axe factories at Thunacar Knott, Dungeon Ghyll Force, and the edge of Martcrag Moor, along with stray finds of flakes identified during the present survey.

8.4.10 The higher scoring zones, from 20-40, generally follow the three main Public Rights of Way through the study area. These run east/west along its southern limit, from Harrison Stickle to Pike of Stickle, north/south along the eastern limit from High Raise to Harrison Stickle, and south-west /north-east from Stake Pass to High Raise. Areas where the main paths pass through zones of deeper peat have a lower threat score. The drainage channels running through the peat in the northern part of the study area are also included in this zone, as are some isolated areas of shallower peat. Within this zone are several axe-factory sites, all located close to the southern limit of the study area, and several new sites were discovered during the present survey, in erosion scars.

8.4.11 The highest scoring zones, above 40, are mainly restricted to the footpaths themselves, and the very highest scoring zones occur where these footpaths cross areas of steeper slope, such as the crossing over the Langdale Pikes. This is a very small area, and as such one would expect only a small number of archaeological sites within it; however, in fact there are at least five documented sites within these areas (sites 111, 152, 219, 220, 221; Claris and Quartermaine 1989), all located on the paths. The reality is that the greater erosion in these areas has exposed axe-production sites that would otherwise have been buried and therefore not known, and hence the relatively large number of sites in this small area is a reflection of the erosion.

8.4.12 On the very steep faces of the Langdale Pikes, outside the study area, the gradient is too steep to have allowed peat development, and the thin vegetation there is very vulnerable to all forms of erosion, which include human agency, such as scree running down the South Scree, and particularly over-grazing (Quartermaine 1994). This has resulted in the exposure of axe-factory sites (Claris and Quartermaine 1989) and at the same time is contributing to severe ongoing erosion.

8.4.13 In conclusion, the areas at greatest threat within the Langdale Fells study area are also the areas with the highest concentration of known archaeological sites, and include the east/west path between Harrison Stickle and Pike of Stickle. This to an extent reflects the fact that sites are only revealed as a result of erosion, and so site distribution will inevitably be biased towards the areas of greatest erosion. However, there are substantial areas of scarring in the central and northern parts of the study area (Plate 33), but examination of these has not identified any axe-working sites, indicating that axe working was concentrated in the southern part of the transect.

8.4.14 ***Forest of Bowland:*** only the Type 1 threat of slopes greater than 17° was present, as none of the land within the study area was above 400m in altitude. The Type 2 threats present in the Forest of Bowland study area were: current erosion, historical paths, drainage channels, public footpaths, shallow peat, and peat margins. The study area was also felt to be at threat from accidental fire but not arson, as there is little visitor pressure and historically has had no clear occurrences of arson, although there have been some catastrophic accidental fires.

8.4.15 The combined threat score for the Bowland study area ranged from 0 to 64, with the great majority of the peat scoring 20 or less (Fig 75). This largely low score is a reflection of the fact that there are few footpaths through the peat, so threat from visitor pressure and drainage is reduced. The areas of steeper slope seem to make little difference to the overall threat score, in that they do not appear to have a higher score than their shallower-sloping neighbours.

8.4.16 The zone of lowest threat, scoring 5 or less, constitutes the areas of deepest peat within the study area. The largest of these was situated in the north-eastern part, with two smaller zones situated further west. Within these low-scoring zones were areas with higher scores, mainly as a result of patches of extant erosion, and localised features, such as streams. The mid-scoring zone, from 5 to 20, encompasses most of the remaining area, excluding the drainage systems running into the River Calder.

8.4.17 The higher scoring zones, above 20, represent patches of extant erosion within the deeper areas of peat, and also include the drainage systems within the low and mid-scoring zones, and a narrow band running north-south down the north-western margin of the peat. This is the route of the only Public Right of Way running through the peat within the study area, and as such, its environs are under additional threat from accidental fire and the ongoing erosion from scars caused by earlier fires. The Right of Way itself is one of the few zones to score above 40 within the study area.

8.4.18 ***Anglezarke Moor:*** only the Type 1 threat of slopes greater than 17° was present, as none of the land within the study area was above 400m in altitude. The Type 2 threats present were current erosion, historical paths, drainage channels, public footpaths, shallow peat, and peat margins. The Anglezarke Moor study area was considered to be at threat from both accidental fire and arson. The combined threat score ranged from 0 to 67, and thus it was the highest scoring study area, which may be a result of the higher risk of arson (Fig 72), a problem that was not considered significant in the other study areas.

8.4.19 The lowest scoring zones, with scores of 5 or less, consist of one large area, extending from Round Loaf, north-east across Black Hill Upper into Bromily Pastures, with discrete smaller zones to its north and west (Fig 76). The main zone comprises a large area of relatively deep, undisturbed and uneroded peat, on a level slope, with no Public Rights of Way crossing it. There are several unadopted or unofficial paths crossing this zone, though, mostly converging on Round Loaf. On the aerial photographs, these paths showed little or no evidence of erosion, and were identified purely by their shape and slight changes in vegetation cover. It is likely that each individual path is under relatively little pressure from visitor numbers, as there is no prescribed route to the summit of the hill, and the pressure is spread across all of the paths. Relatively few archaeological sites have been identified in this zone, and those that have comprise mainly Mesolithic flint scatters and occasional cairns (*Section A5.3.1*).

8.4.20 The middle-scoring zone, with scores ranging from 5 to 20, wraps around the lowest scoring zones, but does not extend to the margins of the peat. It represents those areas of shallower peat that do not fall within the buffer zones for accidental fire or arson, and excludes the very localised areas close to rivers, Public Rights of Way, extant patches of erosion and steeper slope, which have a higher score. Again, few archaeological sites have been identified in this zone, but those that have are mainly prehistoric chipping floors and finds of waste flakes. Many of the finds in this zone were discovered after earlier episodes of erosion had exposed the mineral soil beneath the peat.

8.4.21 The zones with scores of 20 to 40 highlight those areas that fall within the limits of the buffer zones for arson and accidental fire (Fig 72), or the localised areas of higher threat within the mid-scoring zone, such as drainage channels and areas of extant erosion. These zones do not, however, represent those areas with a combined threat from accidental fire and arson. This is an area with a relatively high concentration of archaeological remains, in part because the considerable extant erosion has exposed the remains, but it also includes the natural terrace of Stronstrey Bank (Howard-Davis 1996, 145), which is relatively flat, well-drained and has a considerable potential for settlement activity (*Section A5.3.2*). The archaeology in this zone includes prehistoric clearance cairns, a chambered round cairn (*op cit*, site 40), and several lithic scatters, mainly Mesolithic in date but also with a Neolithic/Early Bronze Age element (*ibid*). In the present survey, additional small clearance cairns and lithic scatters have been identified (*Section A5.3.2*), reflecting the fact that continued erosion from fire or other peat damage has exposed sites that were not evident in the 1983/4 surveys. Further south, towards Jepson's Gate, are further lithic scatters (Howard-Davis 1996, sites 62-4), a kerbed cairn (*op cit*, site 73), and a stone bank complex (*op cit*, site 72) that post-dates the formation of the peat in the later Bronze Age. The nearby chambered long cairn at Pike Stones (*op cit*) is just outside the boundary of the peat. Later archaeological sites include features associated with quarrying and lead mining.

8.4.22 The highest scoring zones, with a score of 40 and above, are much smaller in area. They represent those areas with a combined threat from accidental fire and arson, and are both within 1000m of a settlement, and also fall within 200m of a Public Right of Way.

8.4.23 Geographically, these zones include the western limits of the study area, closest to Chorley and Adlington. Some drainage channels and extant erosion that are within the buffer zone for arson, but outside the buffer zone for accidental fire, also fall within this higher category. The archaeological sites discovered in this zone vary from prehistoric clearance cairns discovered in peat scars, and complexes of walls sited on top of the peat, post-dating peat formation. There is a particularly concentrated area of sites in the Jepson's Gate area in the south-west of the study area, which has shallow peat, by comparison with the Anglezarke plateau, and has been subject to several fires that have severely truncated the peat deposits (*op cit*, 145). As an area that has been subject to more erosion, it is uncertain whether the concentration of sites represents genuinely high levels of prehistoric activity, or higher site visibility because of the abundant erosion scars. In practice, it is probably a combination of the two.

8.4.24 Other zones scoring above 40 include the footpaths within the combined buffer zones for arson and accidental fire, but also a long section of the primary footpath running east/west through the study area, from White Coppice, north of Round Loaf, across Great Hill, to the car park north of Old Man's Hill. This footpath follows the peat margins for much of its length within the study area, extends through sections where there are steeper slopes, and follows alongside Black Brook and other streams and drainage channels for some of the distance. The footpaths that join this main path, from places such as Brinscall to the north of the study area, are also high-scoring areas of threat. Finally, small parts of the western peat margin are also in this highest threat band; they are within the arson and accidental fire buffer zones, and also score highly because they are in the buffer zone for the peat margin. There are only a very few sites in this zone, as it is so small. The Lancashire HER records a cairn (PRN 4001) and a stone bank of unknown date (PRN 4000) in the area closest to Jepson's Gate and a small area of ridge and furrow (PRN 9194) in the north-eastern part of the study area.

8.4.25 ***Cross-site Comparison:*** the Anglezarke Moor study area has the highest combined threat, as it is at risk from arson, in a way that the other study areas are not, but even when that is taken into account it still has a higher combined threat than the others. This is partly because of the linear features running through it, creating threats: the large number of Public Rights of Way has increased the threat from visitor pressure, and also the chance of marginal erosion of the peat. There are also areas with a high combined threat, such as patches of extant erosion, which will be subject to expansion by natural drainage, that are also within buffer zones for arson and accidental fire. The other study areas typically have larger zones of low to middle threat, with smaller localised zones of higher threat. In general, the areas of highest threat are easy to predict, being those areas closest to Public Rights of Way and drainage systems.

8.4.26 This technique, of quantifying the threats in an area, could potentially be applied to other regions. It is not a predictive model, in that it does not highlight areas of previously unknown threat, but it does quantify the known threats and highlights their cumulative impact. It draws on information that is readily available from a documentary study, does not require a site investigation, and could be economically applied to other peatlands.

8.5 CREATING THE ARCHAEOLOGY MODEL

8.5.1 There were several pitfalls to be avoided in creating the archaeology model. The use of predictive modelling can be criticised as a philosophical approach, but there are methodological issues to be aware of as well. The model can only be as good as the data that are used to create it, and in particular it is important to consider whether the lacunae in the known data distribution are a result of gaps in the survey, or genuine gaps in the distribution.

8.5.2 In order to address this issue, the archaeological distributions in the four study areas were studied, with particular emphasis being given to the sources from which the sites had been identified. While some survey work had been undertaken in the Langdale Fells and Anglezarke Moor areas, it was focused on specific issues rather than covering the whole area. The Forest of Bowland study area had not been the subject of any major survey, the archaeological sites having largely been discovered during small-scale localised surveys and from chance finds; it was therefore felt that these were not a reliably consistent dataset. Consequently, it was decided that the South-West Fells material should alone be used in the creation of a model, as there is relatively good site visibility and because a detailed survey of the archaeology had been undertaken across the wider area (Quartermaine and Leech forthcoming). This provided a comprehensive dataset with which to create and test the validity of the model.

8.5.3 In creating this model, it was understood that it would only be applicable to the very particular landscape and types of archaeology that are present on the South-West Fells, and as such could not and should not be applied wholesale to another part of the country. Instead, this part of the project was concerned with creating, and refining, a methodological toolkit to provide guidance for the creation of models elsewhere.

8.5.4 In order to be able to test the success, or otherwise, of this model, only the section of the LDNPS survey (Quartermaine and Leech forthcoming) that fell within the study area was used during the spatial analysis, which left a large section of the original survey outside this that could be used to ground-truth the validity of the model.

8.5.5 ***Brief Methodology:*** the first stage in creating the archaeology model was to collate all the archaeological sites within the study area, which included the results of the LDNPS survey (Quartermaine and Leech forthcoming), all the HER data from the Lake District National Park Authority, all HER data from the National Trust, and the new archaeological data from the present survey. All duplicate sites were removed (mainly HER sites that were originally sourced from the LDNPS), and all sites were categorised into three very broad periods.

8.5.6 The purpose of categorising the sites was to differentiate between the contrasting uses of the landscape, as different landscape uses would have had different locational requirements. The first category included prehistoric funerary and ritual monuments, as it was perceived that these may have had preferred locations, emphasising maximum visibility. The second was small-scale farming and settlement, lasting from the prehistoric period through to the medieval period. The final type was post-medieval industry and settlement.

8.5.7 All archaeological sites were appended to a single point data overlay for each period, within the GIS, and this was subsequently converted into a raster grid with a 5 x 5m cell size, to correspond to the cell-size used in the digital elevation model. Within each period overlay, cells were given a value of 1 if they contained archaeology and 0 if they did not.

8.5.8 The effect of converting vector point data into a raster grid is that points very close together (smaller than the cell size for the grid) will be merged into the same cell in the grid, reducing the total number of sites. This is ameliorated to some extent by choosing the smallest possible cell size, but cannot be totally avoided if sites are closely clustered together.

8.5.9 The second stage in creating the model was to identify correlations, or lack thereof, between the archaeological sites and a set of environmental parameters. The parameters chosen were altitude, slope and aspect (direction of slope). Other parameters could have been chosen, and are often suggested in other studies of this kind, such as proximity to water; however, on the South-West Fells, very few sites are far from a water source!

8.5.10 There are many statistical tests for correlation that can be used, and they are all suited to different types of data, but in the event it was decided to use the Kolmogorov-Smirnov Goodness of Fit (KS) test (Kvamme 1990). This test is particularly suitable for this type of usage as it compares an empirical sample distribution against a background distribution (Wheatley 1995). It can, for example, be used to compare the degree of slope in all grid cells containing archaeology of a particular period to the degree of slope in all the grid cells across the whole study area. If there is a higher frequency of sites on a particular degree of slope than the frequency for the whole study area, then there is said to be a correlation between the location of sites and the degree of slope.

8.5.11 Once a correlation, or lack of, was identified, the categories were weighted according to the amount of correlation. Within each category, the value (*eg* degree of slope) was weighted according to the number of sites occurring within it. The category weighting was then multiplied by the value weighting to give an overall weight.

8.5.12 New raster grids of slope, altitude and aspect were then produced, whose cells contained the total weight for that category. When these raster grids were added together, this produced a final grid showing the combined weighting for each parameter, with cells of higher value representing the greatest potential for archaeology.

8.5.13 These weightings were then applied to other areas surveyed by the LDNPS programme (Quartermaine and Leech forthcoming), and the archaeology for those areas was overlain on top. This tested the correlation between the overlay showing archaeological potential and the known archaeology in an area that was not used in the construction of the model (Fig 77).

8.6 RESULTS: THE ARCHAEOLOGY MODEL

8.6.1 Across the whole South-West Fells area, there was a total of 2507 known archaeological sites, mainly clearance cairns, and these could be broken down into periods (Table 8). When converted into a raster grid (*Section 8.5.6*), this resulted in a difference of only 77 sites or approximately 3%, indicating that, at this cell resolution, there were relatively few multiple sites within a single raster cell. The difference between the point data and raster data for each period is shown below in Table 9.

Period	**Total Sites Point Data**	**Total Sites Raster Data**	**Difference**	**Percentage Difference**
Unknown	34	29	5	14.7
Neolithic	25	24	1	4
Prehistoric to Medieval	2339	2283	56	2.4
Post-medieval to Modern	109	94	15	13.8
Grand Total	**2507**	**2430**	**77**	

Table 8: Number of sites of each period in the South-West Fells, and the difference between the raster and vector datasets

8.6.2 Kolmogorov-Smirnov (KS) tests were conducted on the archaeological raster data, testing it for correlation with altitude, slope and aspect, which were all abstracted from the contour data (Table 9).

Environmental Parameter	**Period**	**Correlation: Yes (Y) or No (N)**	**dMax**	**Value at which dMax occurs**
Slope	Unknown	N	0.14	n/a
	Neolithic	N	0.17	n/a
	Prehistoric to Medieval	Y	0.27	0-10°
	Post-medieval to Modern	N	0.06	n/a
Aspect	Unknown	N	0.1	n/a
	Neolithic	Y	0.44	SW-W
	Prehistoric to Medieval	Y	0.2	SE-S
	Post-medieval to Modern	Y	0.19	S-SW
Altitude	Unknown	Y	0.25	300-325m
	Neolithic	Y	0.42	225-250m
	Prehistoric to Medieval	Y	0.39	250-275m
	Post-medieval to Modern	Y	0.25	225-250m

Table 9: Results of the KS Test for archaeology of different periods against environmental parameters in the South-West Fells study area

8.6.3 Table 9 suggests that there is a correlation between the position of all archaeological sites and altitude, a correlation of all sites excluding those of unknown date with aspect, and a correlation of prehistoric sites with slope. The final columns in Table 9 show dMax, and the value at which dMax occurs. dMax is the magnitude of the difference between the frequency of cells with archaeological sites in, and the background frequency of all cells; the value at which dMax occurs is therefore the value at which the strongest correlation occurs.

8.6.4 As the final column in Table 9 shows, the strongest correlation between the positions of prehistoric sites is with a slope of 0-10°, an aspect of south-east to south, and an altitude of 250-275m above sea level. Due to the fact that almost 94% of the archaeological sites in the study area are nominally prehistoric/medieval in date, only the KS results for the prehistoric to medieval period were used to create the weightings for the model.

8.6.5 Of the environmental factors used in the tests, altitude has the largest value for dMax, so this category was given the highest weighting (Table 10).

Environmental Parameter	**Category Weighting**
Altitude	5
Slope	2
Aspect	1

Table 10: Category weightings for environmental parameters in the South-West Fells

8.6.6 The weighting for each value in each category was based on the number of sites (Table 11).

Number of Sites	**Value Weighting**
0	1
1-100	2
101-250	3
251-500	4

501-750	5
751-1000	6
1001-1250	7
1251-1500	8
1501-1750	9
> 1750	10

Table 11: Value weightings for environmental parameters in the South-West Fells

8.6.7 Weighted raster grids were then created, with an extent much larger than the original study area, with each cell in the grid having a value equal to the Value Weighting multiplied by the Category Weighting. This gave weighting ranges as follows:

Altitude: 1-50

Slope: 1-20

Aspect: 1-10.

8.6.8 When added together, the total weighting range was between 4 and 50. For simplification of the results, these were grouped into bands (Table 12). Table 12 shows the breakdown of sites within each weighting band when applied to the larger extent.

Weighting Band	**Number of Neolithic Sites**	**Number of Pre-historic to Medieval Sites**	**% of Prehistoric to Medieval Sites**	**Number of Post-medieval to Modern Sites**	**Number of Sites of unknown period**	**Number of Sites of all periods**	**% Sites of all periods**
0-5	0	0	0	0	0	0	0
5-10	0	0	0	0	0	0	0
10-15	0	1	0.02	10	6	17	0.36
15-20	1	15	0.33	15	5	36	0.76
20-25	1	130	2.88	8	7	146	3.10
25-30	1	323	7.16	17	12	353	7.49
30-35	8	320	7.09	10	3	341	7.24
35-40	1	1019	22.57	9	9	1038	22.03
40-45	20	2004	44.40	24	3	2051	43.54
45-50	1	702	15.55	20	6	729	15.47
Total	**33**	**4514**	**100**	**113**	**51**	**4711**	**100**

Table 12: Number of sites within the wider South-West Fells Study Area within each weighting band

8.6.9 Table 12 shows firstly that, within the wider study area, over 88% of the sites of all periods fall within the top four weighting bands, which rises to over 89% of all prehistoric sites. Nearly 60% of prehistoric sites fall within the top two weighting bands, compared to 59% of all sites. The slightly higher values for prehistoric sites reflect the fact that the weighting values were calculated using the KS results for the prehistoric period, but the closeness of the two results reflects the fact that 96% of all the sites are prehistoric.

8.6.10 The high percentage of prehistoric sites falling within the areas of highest potential implies that the model was a success. However, the relatively even spread of sites of other periods shows that the model cannot be applied wholesale.

8.6.11 Overall, this would indicate that there is a remarkably close correlation between where the archaeological monuments were predicted to be and where they actually were identified. Interestingly, however, there are several areas that appear in the top weighting bands, but do not contain any known archaeological sites. There are a number of possible explanations for this: firstly, some represent areas of enclosed land, which were not surveyed as part of the LDNPS project, so it is possible that there are sites there that have yet to be discovered. It is, though, also likely that techniques for improving the land in these enclosed areas will in the past have caused some sites or site groups to be destroyed.

8.7 COMBINING THE ARCHAEOLOGY AND THREAT MODELS FOR THE SOUTH-WEST FELLS

8.7.1 Once the two models were created, it was possible to overlay them and highlight those areas that were both under threat and which had a large potential for archaeology. This was undertaken only in the reduced-size area that was used for the threat model (Fig 78).

8.7.2 Simply overlaying the two models produced a complex result with many combinations of values for levels of threat and potential for archaeology. It was decided to simplify the two models into three grades: low, medium and high, which could then be combined to give a straightforward result. The threat and archaeological potential layers were classified into three grades (Table 13) based on the values used in the discussion above:

Threat Score	**Simplified Value**
No threat	0
0-5	1 (Low)
5-20	2 (Medium)
20-55	3 (High)

Archaeological Potential Weight	**Simplified Value**
No potential	0
0-10	1 (Low)
10-30	2 (Medium)
30-50	3 (High)

Table 13: Simplified threat and archaeological potential scores

8.7.3 These two simplified layers were then combined to create a new layer that had a unique value for each combination of the constituent layers that was present within the reduced area of interest. The combinations present were classified, as in Table 14.

Threat Value	Archaeological Potential Value	Combined Score	Overall Classification
0	1	1	1
0	2	2	2
0	3	3	2
1	2	2	1
1	3	4	2
2	2	4	2
2	**3**	**5**	**3**
3	**2**	**5**	**3**
3	**3**	**6**	**3**

Table 14: Overall combined threat and archaeological potential scores

8.7.4 The three values highlighted in bold in Table 14 represent the zones that have the greatest potential for archaeology and the greatest threat. In total, 47 known sites fall within this zone (Fig 78), which seems a low number, but reflects the fact that the areas of threat are specifically applied to areas of peat, which, as has been demonstrated (*Section 8.5.1*), has low site visibility. On this evidence, though, there is potential for a buried archaeological resource within these areas, as has been demonstrated by probing and geophysical techniques at the BS VI cairnfield (Fig 17).

8.8 CONCLUSIONS

8.8.1 ***Threat Model:*** the technique used for quantifying the cumulative threat in an area seems to be successful and could be applied elsewhere. If used elsewhere, however, it would be necessary to go through the process of establishing what the threats are in any new region, as these will differ, along with the relative effects and importance of those threats. This project has therefore defined a methodology, rather than a model, that could be applied wholesale elsewhere.

8.8.2 The overall result of mapping the threats has, in some ways, highlighted the obvious and logical, as it is possible to gain a broad idea of the threats in a region simply by looking at a map. For example, a map will show the routes of paths and the courses of rivers, and the contours will provide an indication of the topography, highlighting areas of steep slope and high altitude. However, this approach objectively highlights the cumulative effect of the threats in a way that is difficult to achieve otherwise.

8.8.3 To refine this model, and truly gain an advantage in using it over the simple map-based common-sense approach, it would be necessary to make the threat model more complex, by including other datasets. A particular example would be a vegetation survey, which could help in the identification of areas of peat (J Huntley *pers comm*), and also could provide more detail on threats (different vegetation types have different burning characteristics in fires (S Yearsley *pers comm*)).

8.8.4 Further potential refinements to the model include other types of threat, such as visitor numbers, sheep density and climate data. These could only be drawn in a broad-brush manner, and would be modelled directly as a cell-based raster. For example, a grid could be produced of an area that showed the average rainfall per square metre in each cell. The cells would probably be 1 x 1km in size, but this could provide an overall indication of the level of rainfall in an area, and could provide comparative data with other areas.

8.8.5 Other refinements could include the modelling of peat formation and destruction, which would allow the creation of a more detailed model of erosion, but would require the inclusion of geological, hydrological and vegetation data. This would require an increased level of expertise in hydrological modelling, and was certainly beyond the scope of the present project.

8.8.6 ***Archaeological Potential Model:*** the technique developed in this project for modelling the archaeological potential of the South-West Fells appeared to be successful. A small area was used to define the effect of certain environmental parameters on the position of archaeological sites across a much broader area. The results of these tests were then used to produce a weighted map of environmental parameters over a much wider area. When the known archaeological sites in this wider area were overlain on this map, over 88% of all sites fell within the top 40% of the weighting bands, indicating a close correlation between the predicted archaeological potential and the actual resource.

8.8.7 Further studies in this study area might consider surveying those areas of enclosed land that score highly in the model, as these are zones where there is the greatest threat of land improvement and which also have considerable potential for an archaeological resource. However, while this is undoubtedly the case, the enclosed land has little potential to include extant peatlands and therefore, from the perspective of the present project, would be excluded.

8.8.8 Consideration should also be given to those sites that do not fall within the highest bands. These raise questions as to whether they represent a different use of the land, or increased population pressure that has led to less suitable locations being occupied. Alternatively, there may be other parameters that are important in the positioning of sites that have not been considered within this study.

8.8.9 ***A toolkit for application to other areas:*** in order to apply either of these models to other regions, the following methodology would need to be followed. First, the relevant data would need to be acquired. Raster and vector mapping (Landline or Mastermap), both modern and old, are essentials. Contour data are vital for creating the digital elevation model necessary for extracting slope and aspect data. Once the threats that are applicable in the new area are decided on, then vector maps of their location must be created. Often this is a case of extracting information from the Landline or Mastermap and then augmenting it with information from the old and modern raster mapping. Threats that exist as numeric data, such as the visitor numbers or rainfall data described above, do not need to be mapped in this way.

8.8.10 Once the threats have been mapped, buffers need to be created around them, with the width and value (decreasing with distance from the threat) as appropriate. These can then be converted into cell-based raster data, with the value of the buffer as the value stored in the cell. All the raster threat data can then be added together to produce an overall score, such that those cells with the highest score are deemed to have the greatest overall threat.

8.8.11 To apply the archaeology model, the first step is to amalgamate all the information about known archaeological sites in the area, and to assess the accuracy and reliability of that resource, taking into account possible biases in the identification of sites, or obvious lacunae in their distribution. The archaeological dataset must be checked for quality and consistence, particularly in classifying sites by period and by site type. Unless a full survey of the area has been undertaken, the identification of sites may well be biased towards areas of development, such as settlements. Any such biases will have an adverse effect on the results of the statistical tests. An alternative approach in this case is to redefine the environmental parameters responsible for the location of archaeological sites of each type and period once the archaeological data are in place. This may be different from one region to the next; for instance, the weightings used in the South-West Fells could not be applied to the Forest of Bowland, or even the Northern Lake District. Consequently, an essential stage in applying this technique elsewhere would be to establish the interaction between archaeological sites and their environment. If the archaeological dataset is believed to be relatively complete, then the statistical KS tests can be used to establish any statistical correlation between environmental parameters and site location.

8.8.12 If there are problems with the archaeological dataset, such as known biases, or lacunae, then the environmental parameters responsible for influencing site location can be estimated in advance, based on prior knowledge of the region, or an idea of the type of landscape being studied. Known sites can then be studied to see if they fit the parameters, taking into account any obvious biases in their location. If this is a success, then the parameters can be used in the model. Otherwise, the parameters can be refined as appropriate.

9. RECOMMENDATIONS FOR THE MANAGEMENT OF THE UPLAND PEATS

9.1 INTRODUCTION

9.1.1 The primary aim of the Upland Peats Project has been to develop a management strategy that can be applied across all of England's uplands, that will be both effective in its implementation, and which will make most effective use of the available resources. Given that there are in the region of 2160sqkm of upland peats in Northern England alone, this is an enormous task, and it is recognised that any effective solution cannot be achieved by one agency alone. To address these issues, there have been detailed discussions with all interested parties across the country, culminating with a seminar, held at Lancaster University, to discuss the issues and to seek a way forward that is deemed to provide a long-term solution to the preservation of the peat. This discussion attempts to address the concerns and guidance of many environmental bodies, and Natural England in particular, and has been circulated to such organisations to ensure that it reflects current views, and that the recommendations are regarded as providing workable management solutions.

9.2 THREATS AFFECTED BY PLANNING CONTROLS

9.2.1 This study into the upland peat resource has examined all threats, from both an historical and current perspective. Some, such as peat cutting, no longer have a significant impact, though it is widely accepted that they have in the past substantially damaged the peatlands. Prior to the present project, it had been perceived that development-led threats, such as forestry and wind farms, were a major threat to the future survival of peats. As a consequence, the original concept for the management of the upland peats (OA North 2003a) was that it should be co-ordinated through the planning and curatorial authorities, and that there would be a need to produce a hazard map that could in effect be presented alongside the SMR / HER to highlight areas of potential and threat. This would therefore have provided the means to inform planning authorities, and provide a degree of protection through the planning process. This approach has been undermined by the recognition, in the course of this project, that the planning process has relatively little impact upon the management of the uplands, and that there are already mechanisms in place to address commercial development of the peatlands.

9.2.2 While forestry had been a major issue in the past, it is no longer considered to be a major threat at present, in part because there is considerable reluctance from the National Parks to allow wholesale expansion of commercial coniferous forestry onto the uplands (ADAS and OA North 2008). Outside the National Parks, there are less controls, but there are nevertheless considerable environmental pressures in place that discourage new forestry operations. Major forestry developments would typically require either the implementation of an Environmental Impact Assessment (EIA) to examine the impacts of the development on any archaeological resource, or an archaeological investigation as part of the PPG16-led planning process (DOE 1990). Small-scale biodiverse plantations, associated with the rewilding of landscapes, such as that in Ennerdale (OA North 2003c), are more likely to receive planning approval, but these are in areas that have already been severely blighted by intense forestry and are, in any case, of considerably reduced impact by comparison with major plantations.

9.2.3 Wind farms are typically sited on the highest points of hills, where there are the strongest winds. These can cause both localised disturbance through the establishment of the turbines and access tracks, but also have a much more extensive impact, resulting from the changed drainage patterns caused by extending a large network of access roads and cables through the peat. The impact of both the turbines and, to an extent, the access tracks upon identified archaeology can be reduced by careful planning of their siting, which means that the impact of wind farms on the known historic environment can be relatively limited (English Heritage 2005). However, the resultant loss of protective peat cover over large areas of the uplands, as a result of the increased drainage to the peatlands, can have a much wider and more detrimental impact on the buried remains. The greatest concern is that, aside from the threats already identified, there is still much that is unknown regarding the true impact of large-scale wind farm projects on the wider landscape (Douglas 2006).

9.2.4 Control over the siting of wind farms is achieved through national planning policies (eg *Planning Policy Statement 22* (Office Deputy Prime Minister 2004)). Wind farms are also subject to Environmental Impact Assessment (EIA) regulations, requiring the completion of a full Impact Assessment prior to development. The degree to which the issues of archaeological potential are addressed will be dependent on the level of current knowledge regarding the historical component of the landscape. This means that areas which have received little survey work in the past may be at greater risk from the development; however, archaeological curators can, and do, recommend surveys ahead of any development. While the EIA process will not necessarily prevent the establishment of wind farms on peatlands, it provides a means to investigate the archaeological and environmental potential of a landscape, at the developer's expense, and obviates the need to draw upon the limited resources of national agencies to achieve the same ends.

9.2.5 Instead, the results of the present study indicate that the major threats to upland peats are much more insidious, and are occurring sometimes without any obvious indication; these relate to fire, drainage, and stocking levels, and are more within the sphere of land management than planning. Consequently, the means to address the threats to the archaeological resource need to coexist with the policies of upland management and entail a co-operation with those agencies that are actively involved with the management of the uplands (particularly Natural England, DEFRA and the National Park Authorities).

9.3 MOST SIGNIFICANT MANAGEMENT-RELATED THREATS

9.3.1 ***Drainage:*** artificial drainage is in one sense an historical problem, in that cutting grips for drainage was widely prevalent in the 1960s and 1970s as a result of agricultural expansion, and it is estimated that 1.5 million hectares of blanket peat were drained (Holden *et al* 2004). The intention was to lower the water table, removing surface water and thus improving moorland for grazing and game, although the effectiveness of these drainage schemes has been debated (*ibid*). The obvious inference from this is that, although an area might previously have been subject to drainage, there is no certainty that all waterlogged deposits have been desiccated and destroyed. However, those deposits which have dried out will have suffered irreversible changes in their physical character, leading to accelerated decomposition and wastage, in addition to the physical impact of the cutting of drainage channels. If there is one conclusion that has emerged from this study, it is that the precarious ecological equilibrium that has preserved the peats so far is a complex one. Subtle changes in the environment, such as those arising from drainage, can disrupt that equilibrium and irrevocably damage the peats. Not only this, but the damage is actually being done under the surface, so that there are few indicators on the surface until it is too late.

9.3.2 Although artificial drainage is now rarely practised, the after-effects of the drains are still causing considerable ongoing degradation to the peats, desiccating them and resulting in a gradual, but insiduous, loss of sub-surface peat. The grips (drains) can be blocked, resulting in the rewetting of the moor, but many of them have become very substantial and this is a costly, and time-consuming, exercise. Increasingly, however, there are moves, for environmental reasons, to undertake programmes of block gripping, and particularly so on land owned by water companies as water catchment for reservoirs. Water companies spend a considerable amount of money each year treating water to remove discolouration, and the erosion of peat soils is a significant cause of this discolouration. In response to this, there is a considerable effort to tackle the impact of soil erosion in the uplands, including programmes of grip blocking and the management of upland vegetation. The protection of upland soils and the careful management of hydrology have direct benefits for the buried archaeology. However, there are concerns amongst the archaeological curators of the National Parks (ADAS and OA North 2008) that the methodologies used for grip blocking are not conducive to the preservation of archaeological remains and that the process can, in some instances, be causing more harm than good. Some schemes entail blocking grips with heather bales, for example, and are generally beneficial, whereas others entail the mechanical removing of peat from one area to fill the grips in another (essentially robbing Peter to pay Paul). In the latter method, there can be localised disturbance causing damage to the pollen record and any buried archaeology, and there can also be vehicle damage to the peats from the use of inappropriate machinery.

9.3.3 ***Stocking Levels / Fire Risk:*** on moors that are subject to regular grazing, the stocking levels are an important factor. Very intensive grazing results in the loss of the protective vegetation, and also restricts the ability of the peat to regenerate. Removal of vegetation cover exposes the peat to other forms of erosion, resulting in scars and corresponding erosion. Sheep themselves will exacerbate the problem by sheltering in peat cuts, undermining them and substantially expanding them. The reverse situation, where the moor is not effectively grazed or the vegetation is not removed by controlled burning, results in a very substantial mass of vegetation on top of the peat, including substantial amounts of gorse. If, or when, a fire occurs on the moor, the mass of vegetation provides an immense reserve of fuel, which turns a small moorland fire into an uncontrollable wild fire, and the high temperatures cause everything to burn, not just the surface vegetation, leading to loss of peat. Discussions with the Manchester Fire Service have demonstrated that there are large numbers of fires on the moors, but that only a limited number of these develop into major wild fires; those that do get out of control almost always relate to the height and flammability of the vegetation. Fylingdales Moor had not been grazed for a number of years prior to the fire and was thus a disaster waiting to happen (*Section 2.10.34*). The reverse situation occurs in the Langdale Fells, which have huge numbers of visitors per year and there is thus a considerable threat from an accidentally discarded match or cigarette, but they have always been heavily grazed, and correspondingly, they have never had a major fire incident. Clearly, there is a need for a compromise between over-exploitation of the moor and managerial abandonment, and achieving this balance will go some considerable way to affording longevity to the peatlands.

9.4 HIGHER-LEVEL STEWARDSHIP SCHEME

9.4.1 A primary recognition of the present project is that the solution to the ills that are faced by the uplands, and their accompanying peatlands, cannot come through the planning authorities, but instead is a land management issue that needs to be addressed by all major landowners, agencies and tenants. Given the diversity of ownership and interested parties, solutions providing real impact would need to be channelled through a national scheme that affords benefit for both the landowners and the environment, and such a scheme is conveniently is now in place through the Higher Level Stewardship scheme (HLS), managed by Natural England (http://www.Defra.gov.uk/erdp/schemes/hls/ default.htm). The aims of the scheme are primarily:

- Wildlife conservation;
- Maintenance and enhancement of landscape quality and character;
- Natural resource protection;
- Protection of the historic environment;
- Promotion of public access and understanding of the countryside.

9.4.2 As such, the scheme provides payments to landowners and tenants in return for the implementation of a management regime for the land that is specifically designed to afford the conservation measures that are most pertinent for the individual land block. In the case of upland peats, this can entail defining grazing regimes, which is essential, as too intensive grazing reduces the protective vegetation cover, whilst too little grazing results in a dense vegetation cover that makes the moorland susceptible to rampant wildfire. If erosion has resulted in the creation of peats scars, HLS schemes can provide for their reseeding with grass to prevent wind erosion. On grouse moors, where there is little or no grazing, it is essential that an appropriate level of controlled burning is implemented to keep the vegetation down, but this should not be so extensive as to restrict recovery. HLS schemes can provide for the blocking of grips, to control drainage and to reverse the damage caused to the upland environment by decades of inappropriate artificial drainage. The HLS schemes can be devised to target the specific needs of each individual moor, to ensure that the landscape is preserved, and that there are adequate measures in place to protect the peat deposits. Those areas with footpath erosion can have the routes diverted either permanently or temporarily (the creation of 'resting paths') or footpath scars can be subject to repair, if they are beyond natural regeneration through management. Those areas of the moors that are most vulnerable, and which have been the worst affected, can be highlighted and be specifically incorporated into management agreements. Protection of the historic environment is a primary aim and a scheme can be individually designed to afford protection to monuments and archaeological landscapes within the extent of the area covered by the scheme.

9.4.3 Although in theory these schemes can help to arrest the decline in the condition of the peatlands, they are expensive and take some time to establish, so in the short term there is a need to prioritise the establishment of schemes on the moorlands in greatest need, both from the ecological and archaeological perspective. However, such targeting raises the issue of prioritising the needs of biodiversity, and similar ecological concerns, with those of the archaeology. The historic environment has been given equal consideration with the natural environment in the schemes, and for the most part concern for peatlands is an issue common to archaeologist and ecologist alike. There is thus an opportunity to work with Natural England to ensure that the implementation of HLS schemes can benefit these common causes.

9.4.4 Although heritage is built in as a factor in these programmes, the decisions for targeting HLS at present are largely made for non-archaeological reasons, because they tend to be made by ecologists and because the archaeological information provided to them from the HERs is site specific and makes no allowance for the potential wealth of archaeological landscapes. This latter aspect is a major problem for upland management, as there is a widely-held perception that the archaeological resource, and heritage generally, is localised and can be defined by dots on a map. There is little legal concept of archaeological landscapes, within the existing designation of Scheduled Monuments, and within the Historic Environment and National Monument Records. While Scheduled Monuments are defined as extending to the precise observed limits of the surface expression of a monument, Sites of Special Scientific Interest (SSSIs), in contrast, define very large areas of the uplands. It is therefore hardly surprising that the justification for establishing an HLS is more effectively influenced by the SSSI covering much of an upland estate, than a localised Scheduled Monument in one corner. This situation will undoubtedly be improved by the anticipated enactment of the Heritage Protection Bill, which will reform and unify the terrestrial and marine heritage protection systems in England and Wales. If it goes ahead in its present form, it will put in place a unified heritage protection system that is easier to understand and use, more efficient, accountable and transparent. It will remove unhelpful distinctions between different designation regimes (listing, scheduling, registering) to deliver a system that works for the whole historic environment. In particular, it will enable the designation of whole archaeological landscapes on the basis of a perceived potential for buried archaeological remains, or scattered surface indicators. However, while this would provide the legal framework for a reorganisation of heritage designation, there would inevitably be an extended period, and considerable efforts by English Heritage, before such landscape designations would be of sufficient number to have any significant impact on upland management.

9.4.5 ***Premier Archaeological Landscapes (PALs):*** there is a need for key archaeological landscapes to be recognised for their importance by land managers and curators, and to be given appropriate consideration in terms of their over-arching management. To this end, a very significant management project has been undertaken in Dartmoor, called 'The Dartmoor Vision Project', which aimed to establish a coherent and equitable vision for Dartmoor which had management goals to avoid conflict between differing priorities for the local environment. To achieve this, a range of statutory agencies came together to discuss how they would like the moorland to look in 25 years time and to develop a strategy to achieve these changes; these agencies were: Natural England, English Heritage, the Rural Development Service (RDS), the Environment Agency, Defence Estates, the Dartmoor National Park Authority and the Dartmoor Commoners' Council. To overcome conflicting management priorities, landscapes were identified which best represented the characters they wished to preserve. Premier Archaeological Landscapes (PALs) were designated as sites where the interests of the archaeological heritage were paramount. This means that all other management considerations are secondary within these sites, and it thus provides a clear focus for land managers, who previously may have had conflicting goals for management.

9.4.6 The *Dartmoor National Park Management Plan* (2007-2012) noted that many of the sites chosen as PALs contained features of national or international importance. The range of PALs was intended to represent the range of current and past uses for the landscape which contribute to its unique nature and the sense of place it engenders in people who experience it. PALs differ from other historical designations because the focus is on the landscape, preserving both the individual features and the landscape from which they derive their context. They are a focus both for management and for research, encompassing the 14 most significant archaeological sites / landscapes within the Dartmoor National Park. The ambition for PALs is to bring the landscapes into active management, with criteria identified to inform condition assessments. Management plans dictate the appropriate management needed to bring each of these landscapes into good condition, and will favour the preservation of the archaeological resource.

9.4.7 The most important feature of the Dartmoor project was the interaction with the wide range of stakeholder groups to identify appropriate priorities for management. However, it is recognised that, often, designation as a PAL is insufficient to secure long-term management goals, and that archaeological priorities still struggle to maintain recognition of their significance compared to the well-supported and well-documented ecological designations. In particular, it was felt that archaeology would benefit from similar European designations and national public service agreement targets (D Griffiths, Dartmoor National Park Authority *pers comm*).

9.4.8 Despite the need for legal reinforcement for the PALs, this enlightened programme could serve as an effective template for similar schemes in other National Parks and AONBs, and would create the concept of the recognition of important archaeological landscapes as the basis for establishing heritage-led HLS schemes and also general upland management. Such schemes need to be focused, so as to afford protection to those areas with a very rich archaeological landscape, rather than being targeted on the basis of individual Scheduled Monuments. In this way, it will be possible for those fragile, archaeologically important, landscapes to be preserved by appropriate management strategies. The process needs to target areas of known archaeological resource, but also those which are potentially obscured by peat cover. Guidance on these issues needs to be provided by experienced landscape archaeologists, with knowledge specific to the uplands of the pertinent regions, and in accordance with a rapid, largely desk-based, process that allows for a coarse assessment of archaeological landscape potential (eg *Section 8.8.9*).

9.5 INTRODUCTION TO LANDSCAPE ASSESSMENT

9.5.1 The present study has highlighted a need to define a strategy that will be effective in reversing the trends in the deterioration of the upland peats, and can highlight those areas of greatest archaeological potential. Given the enormous extent of the peatlands, this is a huge undertaking and cannot be achieved by one single agency; instead, there needs to be a collaboration between all interested environmental and archaeological agencies. It is suggested that a similar approach to that initiated in the Dartmoor Vision Project should be extended across the rest of the country. This would potentially see Natural England, English Heritage, the Rural Development Service (now Natural England), the Environment Agency, the National Park Authorities, AONBs and the County Councils all working in partnership to oversee an environmental management that is conducive to ecology and heritage alike. In this situation, the key partner is Natural England, as it manages the Environmental Stewardship Scheme, but English Heritage would have an important part to play in defining those landscapes that need preferential treatment in order to protect the heritage. This approach is similar to that of the PALs of Dartmoor, although these were defined purely on the basis of the surface expression of the monuments, such as field systems and settlements. While this approach will undoubtedly be effective in those areas of English upland where there are not extensive peat deposits, such as the South-West Fells of the Lake District, it has considerable limitations in areas of blanket peat. Areas with thick peat may, and undoubtedly do, have valuable archaeological remains, but they are not evident from the surface expressions; it is therefore necessary to define landscape priorities in terms of other criteria. Given the limitations of site visibility in the area, there is a need to make a number of assumptions to estimate the archaeological potential, based on areas where there are dense archaeological remains in areas without peat, so that the same principles can be extended to peat-covered areas.

9.5.2 Areas of marginal land with gently sloping terrain, just above an area of flat land where there is documented early activity, are clearly key locations (*Section 8.8.6*). Comparable areas with peat cover would include, for example, Anglezarke Moor, and the marginal slopes to the north-east and south-west of the Eden Valley. High level and steep-sided uplands, remote from the valley edges, typically have few archaeological sites, and this includes much of the central massif of the Lake District. It is interesting to note that even on the South-West Fells, the higher slopes, and along the top of the ridge, have very few archaeological monuments. This generalisation is based upon the principle that settlements and funerary activity extend out from lowland areas onto adjacent and visually associated uplands. There are, of course, notable exceptions to this principle, where activity relates, for example, to mineral or geological extraction, in which case the archaeological remains relate directly to the outcropping of the source material. In the case of the Langdale Axe Factories, the distribution of sites is across the most inaccessible parts of the Lake District, an area that would not typically be exploited for agriculture, and the distribution can be predicted in terms of the outcropping band of fine-grained tuff which served as the source for the area.

9.5.3 While it is possible to predict, with varying amounts of success, those areas that have the greatest archaeological potential, it is also probable that there is some archaeological material beneath most of the areas of peats. It is clearly neither economic nor feasible to investigate the extent of such remains, and, in any case, if the peat is in good condition, there is no need to investigate further because it provides adequate protection against damage or degradation of the buried resource. If, on the other hand, there is a significant threat to the peat, then any underlying archaeological material has the potential to be affected or even destroyed. On this basis, an area of peatland that is subject to severe erosion, from whatever cause, has greater need of management attention than an area that has considerable archaeological potential, but is unthreatened.

9.5.4 Using the two fundamental tenets of archaeological potential and perceived threat, it is possible to define areas of upland peat that warrant protection both for their archaeological potential, even though there are no or relatively few observed monuments on the surface. Through a rapid assessment of the moors, it is possible to score each moor on the basis of its condition, threats, environmental potential, and archaeological potential within each specific region. Those moors that get the highest scoring are in effect the moors that are in greatest need of managerial attention, preferably through an HLS scheme. Recommendations for moors to be put forward for such a scheme can be made to Natural England, and in theory it would be possible to prioritise HLS schemes for those landscapes that would benefit the most. While similar processes will undoubtedly be enacted by Natural England in advance of the establishment of such schemes, these proposals would be specifically targeted to highlight the specific needs of the peatlands as opposed to other aspects of an Environmental Stewardship Scheme, and would provide a comparative assessment of the needs of the peats on one moor against all others within a specific region. At the same time, it will bring the wider ecologically-driven perspective of heritage and the archaeological sites on a moor into the equation.

9.5.5 Such an assessment needs to extend across the whole country and, consequently, the methodology needs to be rapid, cost-effective, and largely desk-based. It would need to be able to compare different areas of moorland within each region and make a qualitative decision as to which areas warrant the most intensive management.

9.6 AIMS OF LANDSCAPE ASSESSMENT

9.6.1 ***Aims:*** the over-arching aim of any assessment of the heritage of the uplands would be to define those areas that have the greatest archaeological potential, irrespective of whether they are covered by blanket peat or not. It would also need to assess the condition of the uplands, determining the level of threat to any actual or potential archaeological resource, be it buried or not. In practice, though, the assessment of the peatland areas would be reliant more on the condition of the peats and a predictive determination of archaeological potential, than on an observed resource. It is suggested that recommendations be made to Natural England for the selection of HLS schemes, and that prescriptive methodologies for the long-term conservation of the archaeological resource and their ecological context be developed.

9.6.2 ***Objectives:*** the modelling that was developed as part of the present project (*Section 8*) was defined to operate in conjunction with the HERs and it has proven successful, in that it was able to target areas of archaeological potential objectively as well as areas of threat, which have been borne out by site inspection. However, the model was based on fairly detailed information that had been obtained by field investigation within the four study areas of the project. If such a detailed strategy were to be applied to other areas of moorland, it would be necessary to capture a large amount of data, such as sample peat depths and ground investigation, which, given the extent of uplands across the country, would be an extremely expensive and time-consuming process. Thus, while the original modelling process was a success, it does not provide an economic solution for addressing the major problems that have beset upland peats. Instead, it is proposed that the archaeological potential be defined on the basis of slope, altitude, proximity to significant archaeological landscapes, geological sources of material, and monuments and landscapes at the periphery of the peat. The assessment of the uplands would occur in three stages; the first would be a wholly desk-based process to assess the archaeological significance and condition of the uplands across a whole region, which would prioritise as much as 20% of the uplands. The second stage would entail rapid and non-intensive fieldwork to clarify further the archaeological and environmental potential of moorland areas selected by Stage 1, and would refine the areas of potential to something like 10% of the overall upland mass. The third stage would be to define an appropriate management strategy, in consultation with the landowners, that would address the principal environmental and archaeological needs of these uplands.

9.6.3 ***Stage 1:***

- identify the extent of the peatlands, thereby determining which areas will be assessed on the basis of their surface remains (*eg* the PALs approach) or their potential for buried remains;
- identify the known archaeological resource from NMR and HERs;
- use contour data to produce a model of the surface topography;
- assess the condition of and threat to the monuments and the peatlands, and highlight those areas that are in greatest need of formal management;
- define areas on the basis of condition and potential that need to be subject to further assessment as part of Stage 2.

9.6.4 ***Stage 2:***

- make contact with landowners of prioritised upland areas, and thereby establish a first-hand assessment of condition and potential;
- undertake rapid fieldwork, entailing a quick inspection of peat exposures and coring to determine peat depths;
- further refine the archaeological prioritisation of the uplands.

9.6.5 ***Stage 3:***

- submit recommendations for implementation of HLSs to Natural England, and make suggestions for an appropriate management strategy, in consultation with the landowners, that would address the principal environmental and archaeological needs of the upland.

9.7 INTRODUCTION TO METHODOLOGY

9.7.1 The approach defined below for assessing areas that require higher levels of management on the basis of their archaeological potential needs to be applied across the whole uplands, not only those areas covered by peat. The aim is to define areas of archaeological potential irrespective of the peat covering; however, it is recognised that differences in approach need to be applied to areas which have peat cover, and those that do not. To this end, the first stage is to define the extent of the peatlands, and thereafter apply a different ring-fencing strategy to the different types of terrains.

9.7.2 In all respects, the strategy recognises that it needs to be applied across the whole country and therefore needs to be as economic a system as possible; thus, at the initial stage, it is entirely desk-based. The Stage 1 outcome would be a series of areas defined that are deemed to have considerable archaeological potential, and would be narrowed down to a smaller proportion of the total, on an educated estimation, somewhere in the region of 20% of all uplands. The limitations of this approach are that there will be an inevitable loss of accuracy and reliability in this initial selection. Stage 2 of the selection process, however, would allow for limited fieldwork to evaluate the areas, and a dialogue with land managers, which would significantly improve the reliability of the assessment of archaeological potential. This would result in a refined selection of areas of potential and threat. The final stage (Stage 3) would entail the submission of recommendations for the management of the selected areas to Natural England and provision for detailed management prescriptions conducive to the preservation of the archaeological heritage.

9.8 STAGE 1 - DATA CAPTURE

9.8.1 Given the scale of the task, the Stage 1 process for initial selection can only define areas of archaeological potential on a largely subjective basis, and would only be as reliable as the data used. There is a recognition that the source data would be of different qualities, and where possible alternative sources of data should be used to qualify the initial dataset. Notably, the soils data have been compiled over an extended period and are not consistent; consequently, aerial photographic sources should also be used, where possible, to check for the presence of peat. Given the national scale of the study and the need for over-arching consistency, the process would need to be undertaken within a GIS environment, which would be able to integrate and compare a varied set of digital datasets.

9.8.2 ***Identification of Peatlands:*** the first stage of the proposed selection process would be to establish the extent of the peat cover within each upland environment, and could be achieved by use of soil mapping in conjunction with vertical aerial photography. This strategy, experimented with during the present study, was found to be an effective method of determining peat cover, although it did need some refinement in the light of field investigations in the study areas. The soil maps provide an indication of which uplands have peat, and the approximate extent of this; the more precise extent can be established from aerial photography. However, it is essential that colour aerial photographs are used as there is a need to be able to recognise the differences in vegetation, which can only be seen in colour.

9.8.3 ***Identification of Documented Archaeological Resource:*** there is a need to incorporate into the GIS the documented archaeological resource from the HERs and the NMR, both for the uplands that are being assessed, and the adjacent lowlands. This would inform the selection of those areas without peat, and also the potential of areas with peat, by examining the archaeological resource on land adjacent to the peatlands. It must be recognised, however, that there are limitations to the making of judgements simply on the basis of documented archaeological remains; for example, a substantial archaeological resource can be an indicator that there is only limited coverage of peat, or may be an indicator, as on Anglezarke Moor, that the peat has been subject to severe erosion, thereby exposing the underlying archaeological resource. Even within areas of blanket peat there is potential for exposed archaeological remains; for example, some massive funerary cairns are large enough to extend up above the peat, and burnt mounds can often be found at stream edges, where peat cover has been washed away. A very considerable number of archaeological sites may simply be an indicator that detailed survey work has been undertaken, as on the South-West Fells of the Lake District (Quartermaine and Leech forthcoming). While an absence of documented archaeology may indicate the presence of blanket peat, which has covered early human activity, alternatively, it may be an area that has had a peat build-up for such a long time that it has discouraged anthropogenic activity. Therefore, while accessing the documented archaeological resource for the uplands is an essential prerequisite, the evidence that this reflects must be qualified by other environmental datasets and detailed analysis.

9.8.4 ***Modelling the Topography:*** certain topographical locations have little potential for archaeological remains, such as steep craggy slopes, whereas other, more gently sloping, terrains favour settlement. There is a need to access contour data for the uplands under consideration, and incorporate this into the GIS; this should allow the modelling of the surface topography, which can then be subject to searches to highlight areas that favoured past activity.

9.8.5 While flatter lands favour agricultural and settlement activity, areas of mineral extraction are determined by the outcropping of source minerals. In areas where there are documented extraction remains, there is a need to draw upon geological mapping to identify the potential extent of historical extraction activity.

9.8.6 ***Identification of Threat:*** there are two stages to the determination of threat; the first is a rapid assessment as part of the initial Stage 1 desk-based selection process, and the second is a more in-depth assessment as part of the Stage 2 refinement process. The initial assessment is reliant upon the identification of peat scarring, for which the best indicator is aerial photography. The most reliable form of aerial photography is low-level oblique photography, but it would certainly not be economic to fly and photograph all the English uplands as part of the Stage 1 process. The initial assessment would, therefore, be on the basis of vertical air photography, preferably colour photography, where available, and recent photography should be used to establish, as far as is possible, the present condition of the uplands.

9.8.7 An initial assessment of threat should be made upon the basis of the density of scarring across a moor, which should be combined with the contouring data within the GIS to examine the extent to which high densities of scarring relate to steeper sloping uplands. In this way, the results of the survey can be analysed both geographically and statistically, providing a more rigorous approach to the assessment.

9.9 STAGE 1: INITIAL AREA SELECTION

9.9.1 The selection of archaeologically important landscapes would be undertaken by comparing areas within distinct upland blocks, which may or may not be defined by conservation and planning boundaries. Hence, the study should compare all upland areas within an individual National Park or AONB (where these exist), and select a proportion of each upland area as Archaeologically Important Landscapes. This would need to reflect a substantial reduction of the total area of upland (to, say, 20% (*Section 9.7.2*)), but in practice the proportion would be determined by the archaeological potential of the respective areas.

9.9.2 ***Peat-Free Landscapes:*** the first stage of the initial selection would be to identify areas with blanket peat and those without. For areas without peat cover, significant archaeological landscapes can be defined in a similar way to the PALs of the Dartmoor Vision Project, which would mean examining the HER data for the uplands and identifying large groups of broadly contemporary monuments that form coherent landscapes. The extents of previous upland surveys should be assessed, so as to gauge if the distribution of monuments within the HER reflects a high density of anthropogenic activity or simply areas that have been subject to intensive reconnaissance. This process should be undertaken in conjunction with the archaeological curators to establish their perception of which are the most important landscapes within their areas, which should be combined with the assessment of the HER data. Up to *c* 20% of the peat-free land should be selected in this manner.

9.9.3 ***Peat-Covered Landscapes - Analysis of the Documented Archaeological Resource:*** a process of analysis needs to be undertaken to search for significant groupings of monuments in the HER within, or immediately adjacent to, peatlands, which are broadly contemporary, comparative in form, and which may be an indication of an extended archaeological landscape. Similarly, if there are significant, early monuments, either within the area of peatlands or immediately adjacent, these should be highlighted, as they could be a surface indicator of a much more extensive buried resource. Examples of significant monuments include round cairns and burnt mounds. If there are site groups adjacent to peatlands, then an area of peatland up to 400m away from the documented remains could be ring-fenced as having potential. Areas of broad potential, on the basis of the documented resource, should be defined as such within the GIS.

9.9.4 ***Peat-Covered Landscapes - Analysis of the topography:*** within the GIS environment, searches should be made for the following:

- areas between 100m and 380m AOD should be selected;

- shallow slopes;
- areas within 5km of the coastal plain, large flat valley floors or vales (*eg* Vale of York);
- areas within 1km of narrow principal valleys.

The results of these searches should be combined, highlighting those areas that have a topography that is conducive for settlement and agricultural exploitation.

9.9.5 ***Peat-Covered Landscapes - Analysis of Peat Scarring:*** the evidence for peat scarring should be used to target moors that are perceived as having suffered severe erosion, which would allow for the management of areas that are in greatest need. Areas with above-average densities of peat scarring should be highlighted and defined within the GIS.

9.9.6 ***Peat-Covered Landscapes - Ring Fencing:*** the results of the analysis of the archaeological resource, topography and peat scarring should be combined and a reduced proportion of the peat-covered areas should be ring fenced. In practice, the proportion of the total would be determined by the actual archaeological potential in each instance, but would need to reflect a substantial reduction, such as *c* 20% of the total, for the overall process to be able to define areas that are small enough to enable the implementation of workable management practices.

9.9.7 These areas would then be combined with the ring fencing of the peat-free areas to make up the initial Significant Archaeological Landscapes selected for each individual upland region.

9.10 STAGE 2: REFINEMENT OF THE AREA SELECTION

9.10.1 The initial selection would have been largely made on the basis of archaeological potential, but with the Stage 2 refinement, the emphasis for the selection would be upon assessing the threats to the landscape and determining which have the greatest need for environmental management to protect the peats. There are two routes into this; the first is to examine present land management strategies, and to determine if these are prejudicial to the long-term survival of the peatlands. The second is to look at evidence of historical erosion as an indicator of present and future threat.

9.10.2 ***Land Management:*** having selected a shortlist of moors and estates, it is necessary to refine further the selection to determine their condition and their environmental needs. The most effective means to achieve this is by talking to the land agents, land managers and owners who have an intimate knowledge of their moors. It is proposed that a questionnaire should be sent to each pertinent land agent to allow them to provide a personalised assessment of the state of their moor. This would establish what the moor is used for, how it is managed (*eg* the number and frequency of burns on a grouse moor), how many sheep are grazed, the number and extent of any SSSIs, history of drainage, visitor pressure, numbers of tenants / commoners, a general take on the moor’s condition, and long-term plans for the management of the moor. This would also examine the impact of erosion, and incidents of fire. Since the answers to such questions are bound to be somewhat subjective, it would be necessary to devise a scoring scheme to allow a more objective analysis of the results.

9.10.3 ***Aerial Photography:*** the limitation of vertical aerial photography in determining peat condition is that its coverage is often patchy, some is in black and white, and, worst of all, it is often taken from 10,000 feet, so that it shows only limited amounts of detail. The solution, as demonstrated by the present project, is to use oblique low-level photographs, where these are available, but these cannot be obtained from the NMR, as its obliques rarely show blank areas of moorland without archaeology. In any case, there is a need to use photography that provides an up-to date record of the moor's condition. Instead, it is suggested that oblique air photographs should be taken of the entirety of each moor under review. Although this may seem like an expensive option, in actuality many moors can be covered in a single hour of flight and thus the technique is relatively cheap; this then becomes a relatively economic means of identifying scarring and erosion. This aerial photography will provide a more reliable and consistent means of determining peat scars and erosion, and can reveal the history of burns, both deliberate and inadvertent. This data should be acquired before the fieldwork takes place, so that it can inform the targeting of field survey to establish peat depth.

9.10.4 ***Fire:*** one of the principal threats to the moorlands is from fire, and there is a need to recognise which moors are under the greatest threat, and to establish management regimes to minimise the risk. Some moors are subject to regular wild fires, which can get out of hand and cause enormous damage to the peatlands and underlying archaeological resource in certain climatic conditions. Establishing these risks can be easily established by having discussions with the local fire service, to find out which moors have repeated wild fires, and where the fires tend to be started.

9.10.5 This, however, is only one aspect of the issue, as the moors that are most susceptible to extreme wild fires do not have a history of fires, as earlier conflagrations will have consumed reserves of vegetational fuel. The 'extreme risk' areas that are most liable to be affected by massive, devastating wild fires, such as that on Fylingdales Moor (*Section 2.10.34*), are those that have huge reserves of dense vegetation, such as gorse or heather, which has been allowed to grow high and 'leggy'. These, once they burn, result in very high temperatures, which make them very difficult to control and result in the burning of the underlying peat. Such areas may not get much visitor pressure and so will not be subject to repeat fires, but when they do occur the impact can be enormous. The key aspect here is to be able to determine the level of vegetation build-up across the moors, which could provide a large fuel source for any fire. To this end, the most effective approach is again to discuss such worries with the land agents to establish what stock levels are on their moor, and what steps have been taken to restrict vegetation development, such as controlled burns. Those areas that are not actively managed by grazing or burning should be perceived as being at high risk, even if they are remote from any significant visitor pressure and have no history of fires.

9.10.6 The risk of devastating wild fires can also be reduced by establishing fire plans for each moor, as, for example, was done in the Peak District. There, a fire-fighting resources group, called the Fire Operations Group (FOG) (S Heath, Greater Manchester Fire Service *pers comm*; *Section 2.10.23*) was established in 1996. It consists of fire officers of the constituent fire services serving the Peak District, and those persons involved in fire-fighting, such as gamekeepers, National Trust

Wardens and National Park Rangers. Its aim is to co-ordinate information on the location of personnel, water supplies, routes for access to moorland and the provision of fire-fighting equipment, and to compile fire plans for each moor. Moors under the over-arching protection of such a group are under less threat from wild fires than those that are not, and consequently would have a lower threat rating in the refined assessment. By the same token, the proposed assessment would recommend that any moor that is outside such controls should implement a fire plan as part of the HLS management prescription.

9.10.7 ***Fieldwork:*** in addition to the desk-based assessment, there is also a need to make an on-site assessment of the condition of the selected moorland, and its peat. This would, of necessity, be a very quick assessment and would entail no more than a rapid transit of the area, typically taking one day to investigate the peat on each moor. This would entail the establishment of peat depths across the moor using a gouge auger, and would establish the ground conditions, and the surface conditions of the peat. An examination of peat scars can be undertaken at the same time to establish the existence of any underlying archaeological remains. The aims of this exercise should be in part to make an assessment of which moors warrant more intensive management care, but also to determine what is the most appropriate management strategy necessary to rectify the individual problems of each moorland.

9.10.8 ***Refinement of Ring Fencing:*** the results of the detailed assessment of threat and condition should be combined with the results of the initial assessment to be able to refine the overall assessment of management needs. This would reassess the boundaries of the ring fencing, and exclude whole areas, so that the proportion of areas recommended for more intensive management are likely to be brought down from *c* 20% to *c* 5-10% of the peat-covered areas.

9.11 STAGE 3: RECOMMENDATIONS FOR UPLAND MANAGEMENT

9.11.1 The final stage of the process is to rationalise the assessment, and submit recommendations, with justifications, to Natural England, to allow them to incorporate the results within their process for selecting HLS schemes. This would incorporate recommendations for both the areas of peatland, assessed on threat and archaeological potential, and the peat-free areas, assessed on the documented resource. In addition, it would be appropriate to make recommendations for the management prescriptions that need to be incorporated into the HLS, so as to preserve the protective, overlying peat, and also the underlying archaeological resource. Such prescriptions could include controls on grazing, controls on vegetation by burning, fire plans, movement of feeding troughs, and restriction of vehicular activity.

10. BIBLIOGRAPHY

10.1 Cartographic Sources

British Geological Survey, 1992 Lake District, Sheet 54ºN 04ºW Solid Geology, 1:250000

Lawes Agricultural Trust, 1970 Soil Survey of England and Wales (Lancashire), 1:250,000

National Soil Map digital data set (NatMap 1000), LandIS, Cranfield University

Ordnance Survey, first edition 6" to 1 mile map (1857) Swaledale

10.2 Secondary Sources

Aaby, B, 1976 Cyclic climatic variations in climate over the past 5500 years reflected in raised bogs, *Nature,* **265**, 281-4

ADAS and OA North 2008 *Conservation of the Historic Environment in England's Uplands*, unpubl rep

Agate, E, 1983 *Footpaths: a practical conservation handbook*, Wallingford

Aldhous, JR, and Mason, WL (eds), 1994 Forest nursery practice*, Forestry Commission Bulletin* **111**, London

Andersen, ST, 1979 Identification of wild grass and cereal pollen, *Danmarks Geologiske Undersøgelse, Årbog*, **1978**, 69-92

Anderson, P, 1986 *Accidental Moorland Fires in the Peak District*, Bakewell: Peak Park Joint Planning Board

Anderson, P, 1997 Fire Damage on Blanket Mires, in Tallis *et al* 1997, 16-28

Anderson, P, 1998 Hydraseeding at Holme Moss, in Anderson *et al* 1998, 89-98

Anderson, P, and Tallis, JH, 1981 The nature and extent of soil and peat erosion in the Peak District, in Phillips *et al* 1981, 52-64

Anderson, P, Tallis, JH, and Yalden, DW, 1998 *Restoring moorland: Peak District Moorland Management Project Phase III*, Peak District National Park Planning Board, Bakewell

Anderson, R, 2001 Deforesting and Restoring Peat Bogs, *Forestry Commission Technical Paper,* **32**, Edinburgh

Annable, R, 1987 *The Later Prehistory of Northern England,* BAR, Brit Ser, **160**, Oxford

ApSimon, AM, 1977 The finds: Palaeolithic, Mesolithic, Neolithic, and Bronze Age, in PA Rahtz, and E Greenfield, *Excavations at Chew Valley Lake, Somerset*, Dept Environment Archaeol Rep **8**, London, 171-201

Ardron, PA, 1999a *Peat cutting in Upland Britain, with special reference to the Peak District and its impact on Landscape, Archaeology and Ecology*, unpubl PhD thesis, Univ Sheffield

Ardron, PA, 1999b The impact of peat cutting on fauna and flora, in ID Rotherham (ed), *Peatland Ecology and Archaeology: management of a cultural landscape,* Landscape Archaeology and Ecology, **4**, Sheffield, 10-27

Armstrong, AM, Mawer, A, Stenton, FM, and Dickins, B, 1952 *The Place-Names of Cumberland, Part II1: Introduction,* English Place-Name Soc, **22**, Cambridge

Backshall, J, 1999 Managing bracken in the English uplands, *Enact,* **7**(**2**), 7-9

Backshall, J, Manley, J, and Rebane, M, 2001 *Upland Management Handbook, English Nature*, Peterborough

Bain, MG, 1991 *Palaeoecological Studies in the Rivington Anglezarke Uplands, Lancashire*, unpubl PhD thesis, Univ Salford

Barnes, B, 1975 *Palaeoecological studies of the late Quaternary in the North West Lancashire lowlands*, unpubl PhD thesis, Univ Lancaster

Barnes, B, 1996 The palynological context, in Howard-Davis 1996, 137

Barnes, B, and Bain, MG, 1985 *Palaeoenvironmental Studies of the Rivington-Anglezarke Uplands, Report, 1983-1985*, unpubl rep

Barnes, FA, 1963 Peat Erosion in the southern Pennies: problems of interpretation, *East Midland Geographer,* **3(4)**, 215-22

Barnes, F, and Hobbs, JL, 1950 Newly discovered flint chipping sites in the Walney Island locality, *Trans Cumberland Westmorland Antiq Archaeol Soc,* n ser, **50**, 20-9

Bayfield, NG, and McGowan, GM, 1986 *Footpath Survey* - ITE Report 1, Institute of Terrestrial Ecology, Banchory

Bell, M, and Walker, MJC, 1992 *Late Quaternary environmental change: physical and human perspectives*, Harlow

Bidwell, P, Snape, M, and Croom, A, 1999 *Hardknott Roman Fort*, Cumberland Westmorland Antiq Archaeol Soc Res Rep, **9**, Kendal

Birks, HJB, 1982 Mid-Flandrian forest history of Roundsea Wood, National Nature Reserve, Cumbria, *New Phytol*, **90**, 339-54

Birks, HJB, 1988 Long-term ecological change in the British uplands, in MB Usher and DBA Thompson (eds), *Ecological change in the uplands*, Brit Ecol Soc Spec Publ, **7**, Oxford, 37-56

Birks, HJB, 1989 Holocene Isochrone Maps and Patterns of Tree-Spreading in the British Isles, *J Biogeog*, **16**, 503-40

Birnie, RV, 1993 Erosion rates on bare peat surfaces in Shetland, *Scottish Geog Mag,* **109(1)**, 12-17

Bonsall, JC, 1981 The coastal factor in the Mesolithic settlement of the North West England, in B Gramsch (ed), *Mesolithikum in Europa*, Veröffentlichungen des Museums für Ur – und Frühgeschite, Potsdam, 451-73

Bonsall, C, Sutherland, D, Tipping, R, and Cherry, C, 1986 The Eskmeals project 1981-5: an interim report, *Northern Archaeol*, **7/1**, 3-30

Bonsall, C, Sutherland, D, and Payton, RW, 1994 The Eskmeals coastal foreland: archaeology and shoreline development, in J Boardman and J Walden (eds), *Cumbria Field Guide*, Quat Res Assoc, Oxford, 90-103

Bower, MM, 1959 *An investigation of erosion in blanket peat,* Unpubl MSc thesis, Univ London

Bower, MM, 1960a Peat erosion in the Pennines, *Advancement of Science,* **64**, 323-31

Bower, MM, 1960b The erosion of blanket peat in the southern Pennines, *East Midland Geographer*, **2(13)**, 22-33

Bower, MM, 1961 The distribution of erosion in blanket peat bogs in the Pennines, *Trans Inst British Geog*, **29**, 17-30

Bower, MM, 1962 The cause of erosion in blanket peat bogs: A review of evidence in light of recent work in the Pennines, *Scottish Geog Mag*, **78**, 33-43

Bradley, R, and Edmonds, M, 1993 *Interpreting The Axe Trade: Production and Exchange in Neolithic Britain,* Cambridge

Bragg, OM, 1995 Towards the ecohydrological basis for raised mire restoration, in BD Wheeler, SC Shaw, WJ Fojten, and RA Robertson (eds), *Restoration of Temperate Wetlands,* Chichester, 305-14

Bragg, OM, and Tallis, JH, 2001 The sensitivity of peat-covered upland landscapes, *Catena*, **42(2-4)**, 345-60

Bronk Ramsey, C, 1995 Radiocarbon Calibration and Analysis of Stratigraphy: The OxCal Program, *Radiocarbon,* **37,** 425–30

Bronk Ramsey, C, 1998 Probability and dating, *Radiocarbon*, **40**, 461–74

Brooks, S, and Stoneman, R, 1997 *Conserving Bogs: the management handbook*, The Stationery Office, Edinburgh

Brown, IJ, 2002 Some notes on peat workings and turbary rights, *Mining Hist*, **15/1**, 52-5

Bu'lock, JD, 1958 The Pikestones: a chambered long cairn of Neolithic type on Anglezarke Moor, Lancashire, *Trans Lancashire Cheshire Archaeol Soc*, **68**, 143-6

Bunch, B, and Fell, C, 1949 A stone axe factory at Pike of Stickle, Great Langdale, *Proc Prehist Soc*, **15**, 1-20

Burgess, C, 1985 Population, climate and upland settlement, in D Spratt and C Burgess (eds), *Upland settlement in Britain: the 2nd millennium and after,* BAR Brit Ser, **143**, Oxford, 195-230

Burt, TP, and Gardiner, AT, 1984 Run-off and sediment production in a small peat-covered catchment: some preliminary results, in TP Burt and DE Wallings (eds), *Catchment experiments in fluvial geomorphology, Procedings IGU Commission meeting, Exeter and Huddersfield, 1981*, Norwich, 133-51

Burt, TP, Heathwaite, AL, and Labadz, JC, 1990 Run-off production in peat covered catchments, in MG Anderson and TP Burt (eds), *Process studies in hillslope hydrology*, Wiley, 463-500

Burton, RGO, and Hodgson, JM, 1987 *Lowland Peat in England and Wales*, Soil Surv Spec Surv, **15**, Harpenden

Butcher, DP, Labadz, JC, Potter, AWR, and White, P, 1993 Reservoir sedimentation rates in the southern Pennine Region, UK, in J McManus and R Duck (eds), *Geomorphology, and Sedimentology of Lakes and Reservoirs*, Chichester, 73-92

Callow, WJ, Baker, MJ, and Pritchard, DH, 1963 NPL radiocarbon measurements I, *Radiocarbon*, **5**, 34-8

Callow, WJ, and Hassall, GI, 1969 National Physical laboratory radiocarbon measurements VI, *Radiocarbon,* **1l/l,** 130

Caporn, S, 1998 Air pollution and its effects on vegetation, in Anderson *et al* 1998, 28-35

Carling, PA, 1986 Peat slides in Teesdale and Weardale, Northern Pennines, July 1983: description and failure mechanisms, *Earth Surface Processes and Landforms*, **11**, 193-206

Caseldine, C, and Hatton, J, 1993 The development of high moorland on Dartmoor: fire and the influence of Mesolithic activity on vegetation change, in F Chambers (ed), *Climate Change and human impact on the landscape,* London, 119-32

Chappell, S, 1987 *Stone Axe Morphology and Distribution in Neolithic Britain,* BAR Brit Ser, **177**, Oxford

Charman, D, 2002 *Peatlands and Environmental Change,* Chichester

Cherry, J, 1965 Flint chipping sites at Drigg, *Trans Cumberland Westmorland Antiq Archaeol Soc* n ser, **65**, 66-85

Cherry, J, and Cherry, P, 1973 Mesolithic Habitation Sites at St Bees, Cumberland. *Trans Cumberland Westmorland Antiq Archaeol Soc,* n ser, **73**, 47-66

Cherry, J, and Cherry, P, 1986 Prehistoric Habitation Sites in West Cumbria: Part IV, The Eskmeals Area, *Trans Cumberland Westmorland Antiq Archaeol Soc,* n ser, **86**, 1-19

Cherry, J, and Cherry, P, 1987 Prehistoric Habitation Sites in West Cumbria: Part V, Eskmeals to Haverigg, *Trans Cumberland Westmorland Antiq Archaeol Soc,* n ser, **87**, 1-10

Clark, JGD, 1954 *Excavations at Star Carr*, London

Claris, P, and Quartermaine, J, 1989 The Neolithic Quarries and Axe Factory Sites of Great Langdale and Scafell Pike: A New Survey, *Proc Prehist Soc,* **55**, 1-25

Clement, S, 2005 *The future stability of blanket peat following historical erosion and recent revegetation*, Durham

Clough, CT, 1888 The Geology of the Cheviot Hills (5), *Memoirs of the Geological Survey,* HMSO, London

Clough, THMck, 1973 Excavations on a Langdale axe chipping site in 1969 and 1970, *Trans Cumberland Westmorland Antiq Archaeol Soc,* n ser, **73**, 25-46

Clough, THMcK, and Cummins, WA, 1988 *Stone Axe Studies Vol 2, The petrology of prehistoric stone implements from the British Isles*, CBA Res Rep, **67**, London

Clymo, RS, 1992 Productivity and decomposition of peatland ecosystems, in OM Bragg, PD Hulme, HAM Ingram, and RA Robertson (eds), *Peatland Ecosystems and man: an Impact assessment,* International Peat Society, Finland, 3-16

Coleman, R, 1981 Footpath Erosion in the English Lake District, *Applied Geog*, **1**, 121-31

Coles, B, and Coles, J, 1986 *Sweet Track to Glastonbury*, London

Coles, J, Hibbert, FA, and Orme, BJ, 1973 Prehistoric roads and tracks in Somerset - III - The Sweet Track, *Proc Prehist Soc*, **39**, 256-93

Countryside Commission, 1970 *Demand for outdoor recreation in the countryside*, London

Cowell, R, 1996 The Upper Palaeolithic and Mesolithic, in R Newman (ed), *The Archaeology of Lancashire,* Lancaster, 19-31

Cowell, RW, and Innes, JB, 1994 *North West Wetlands Survey, The Wetlands of Merseyside*, Lancaster Imprints, **2**, Lancaster

Cox, M, Chandler, J, Cox, C, and Tinsley, H, 2001 The archaeological significance of patterns of anomalous vegetation on a raised mire in the Solway Estuary and the processes involved in their formation, *J Archaeol Sci*, **18**, 1-18

Crisp, DT, 1966 Input and output of minerals for an area of Pennine moorland: The importance of precipitation, drainage, peat erosion and animals, *J Applied Ecol,* **3**, 327-47

Crisp, DT, Rawes, W, and Welch, D, 1964 A Pennine peat slide, *Geog J*, **130**, 519-24

Crofton, HT, 1902 How Chat Moss broke out in 1526, *Trans Lancashire Cheshire Antiq Soc*, **20**, 139-45

Crow, P, 2002 *A soil guide to longevity: Woodland soil chemistry and implication for the archaeological resource,* MSc dissertation, Univ Reading

Crow, P, 2004 *Trees and Forestry on Archaeological sites in the UK: A review document,* Environmental Research Branch web version, http://www.forestry.gov.uk/pdf/FR_archaelogical_review.pdf/$FILE/FR_archaelogical_review.pdf

Crowther, RE, Low, AJ, and Tabbush, PM, 1991 Establishment and Tending in Hibberd 1991, 41-80

Darbishire, RD, 1873 Notes on discoveries in Ehenside Tarn, *Archaeologia,* **44**, 273-92

Dartmoor NPA, 2003 *Dartmoor National Park Local Plan*, Bovey Tracey

Dartmoor NPA, 2007 *The Dartmoor National Park Management Plan 2007-2012,* Bovey Tracey

Darvill, T, and Fulton, A, 1998 *The Monuments at Risk Survey of England 1995, Main Report*, Bournemouth and London

Davies, P, and Loxham, J, 1996 *Repairing upland path erosion, a best practice guide*, LDNPA and the National Trust, Cirencester

Dawkins, B, 1900 On the exploration of prehistoric sepulchral remains of the Bronze Age at Bleasdale by S Jackson, *Trans Lancashire Cheshire Antiq Soc,* **18**, 114-24

Day, SP, and Mellars, PA, 1994 'Absolute dating', dating of Mesolithic human activity at Star Carr, Yorkshire: new palaeoecological studies and identification of the 9600BP radiocarbon "plateau", *Proc Prehist Soc*, **60**, 417-22

Diemont, H, Hillegers, PJM, Joosten, H, Kramer, K, Ritzema, H, Rieley, J, and Wosten, H, 2002 *Fire and Peat Forests, What are the solutions*, http://www.aseanbiodiversity.info/Abstract/51003237.pdf

Dixon, DD, 1903 *Upper Coquetdale: its history, traditions, folklore and Scenery*, Newcastle upon Tyne

Dobson, MC, and Moffat, AJ, 1993 *The potential for woodland establishment on landfill sites,* Department of the Environment, London

DOE, 1990 *Planning Policy Guidance Note,* **16**, *Archaeology and Planning,* London

Douglas, E, 2006 The hidden cost of wind turbines, *New Scientist,* 08 July 2006, 36

Dresser, Q, 1970 *A study of sampling and pretreatment of materials for radiocarbon dating*, unpubl PhD thesis, Queen's Univ Belfast

Dymond, CW, 1893 Barnscar: an ancient settlement in Cumberland, *Trans Cumberland Westmorland Antiq Archaeol Soc*, n ser, **12**, 179-87

Edmonds, M, 2004 *The Langdales: Landscape and Prehistory in a Lakeland Valley*, Stroud

Ellis, CJ, and Tallis, JH, 2001 Climatic control of peat erosion in a North Wales blanket mire, *New Phytol*, **152(2)**, 313-24

English Heritage, 1991 *Management of Archaeological Projects*, 2nd edn, London

English Heritage, 2002 *English Heritage Strategy for Wetlands*, unpubl doc

English Heritage, 2005 *Wind Energy and the Historic Environment,* London www.english-heritage.org.uk

English Heritage, 2006 *Management of Research Projects in the Historic Environment (MorPHE*), London

English Nature, 2004 *Sustainable grazing in the English Uplands*, External Relations Team, Peterborough

European Union, 2000 Directive 2000(60)EC of the European Parliament and council establishing a framework of community action in the field of water policy, *Official J European Community*, OJ L327, 1-72

Evans, MG, Burt, TP, Holden, J, and Adamson, JK, 1999 Run-off generation and water table fluctuations in blanket peat: evidence from UK data spanning the dry summer of 1995, *J Hydrol,* **221(3-4)**, 141-60

Evans, MG, and Warburton, J, 2005 Sediment budget for an eroding peat-moorland catchment in northern England, *Earth Surface Processes and Landforms*, **30**, 557-77

Evelyn, J, 1661 *Fumifugium or The Inconvenience of the Aer and Smoak of London dissipated. Together with some Remedies humbly Proposed By J.E.Esq; To His Sacred Majestie, And To the Parliment now Assembled*, Godbid, London 1914

Faegri, K, and Iversen, J, 1989 *Textbook of modern pollen analysis*, 4th edn (eds K Faegri, PE Kaaland, and J Iversen), Copenhagen

Farley, JA, 1815 *General View of the Agriculture of Derbyshire with Observations on the Means of Its Improvement* 1, London

Farrer, W (ed), 1903 *Lancashire Inquests, Extents and Feudal Aids, AD1205 - 1307*, Lancashire Cheshire Record Soc, **48**, Liverpool

Farrer, W, and Brownbill, J, 1911 *A history of the county of Lancashire*, Victoria County History **5**, London

Fell, CI, 1950 The Great Langdale stone axe factory, *Trans Cumberland Westmorland Antiq Archaeol Soc*, n ser, **50**, 1-13

Fell, CI, 1954 Further notes on the Great Langdale axe factory, *Proc Prehist Soc*, **20**, 238-9

Fisher, AS, Podniesinski, GS, and Leopold, DJ, 1996 Effects of drainage ditches on vegetation patterns in abandoned agricultural peatlands in central New York, *Wetlands,* **16**, 397-409

Forestry Commission, 1995 *Forestry and Archaeology Guidelines,* HMSO, London

Foss, PJ, and O'Connell, CA, 1996 *Irish Peatland Conservation Plan 2000*, Irish Peatland Conservation Council, Dublin

Francis, IS, 1990 Blanket peat erosion in a mid-Wales catchment during two drought years, *Earth Surface Processes and Landforms*, **15**, 445-56

Freeman, S, Bishop, P, Bryant, C, Cook, G, Fallick, A, Harkness, D, Metcalfe, S, Scott, M, Scott, R, and Summerfield, M, 2004 A new environmental sciences AMS laboratory in Scotland, *Nuclear Instruments and Methods in Physics Research B*, **223-4**, 31-4

Garnett, MH, Ineson, P, and Stevenson, AC, 2000 Effects of burning and grazing on carbon sequestration in a Pennine blanket bog, UK, *The Holocene*, **10**(6), 729-36

Goode, DA, and Ratcliffe, DA, 1977 Peatlands, in DA Ratcliffe (ed), *A nature conservation review*, **1/8**, Cambridge, 206-44

Grace, J, and Unsworth, MH, 1988 Climate and microclimate of the Highlands, in MB Usher and DBA Thompson (eds), *Ecological change in the uplands*, Spec publ, Brit Ecol Soc, Oxford, 137-50

Graystone, P, 1992 *Walking Roman Roads in Bowland,* Lancaster

Greenwood, M, and Bolton, C, 1955 *Bolland Forest and the Hodder Valley,* privately publ

Grieve, IC, Davidson, DA, and Gordon, JE, 1995 Nature, extent and severity of soil erosion in upland Scotland, *Land Degradation and Rehabilitation*, **6**, 41-55

Grimm, E, 1991 *TILIA and TILIGRAPH*, Illinois

Hageman, JB, and Bennett, DA, 2000 Construction of digital elevation models for archaeological applications, in K Westcott and R Brandon (eds), *Practical Applications of GIS for Archaeologists: A predictive modelling kit*, London, 113-21

Hall, D, and Coles, J, 1994 *Fenland Survey. An essay in landscape and persistence,* English Heritage, Archeol Rep **1**, London

Hall, D, Wells, CE, and Huckerby, E, 1995 *North West Wetlands Survey, The Wetlands of Greater Manchester*, Lancaster Imprints, **3**, Lancaster

Hallam, J, nd *Archaeological excavation on Anglezarke Moor and Rivington*, unpubl rep

Harrod, TR, McHugh, M, Appleby, PG, Evans, R, George, DG, Haworth, EY, Jornung, M, Housen, G, Leeks, G, Morgan, RPC, and Tipping, E, 2000 *Research on the quantification and causes of upland erosion*, Final Report to MAFF (Project SP0402), unpbl rep

Haselgrove, C, 1996 The Iron Age, in R Newman (ed), *The Archaeology of Lancashire,* Lancaster, 61-74

Haworth, E, de Boer, G, Evans, I, Osmaston, H, Pennington, W, Smith, A, Storey, and P, Ware, B, 2003 *Tarns of the Central Lake District*, Ambleside

Heathwaite, AL, 1993 Disappearing peat - regenerating peat? The impact of climate change on British peatlands, *Geog J*, **59(2)**, 203-8

Heawood, R, and Huckerby, E, 2002 Excavation of a burnt mound at Sparrowmire Farm, Cumbria, *Trans Cumberland Westmorland Antiq Archaeol*, 3 ser, **2**, 29-50

Hedges, REM, Housley, RA, Bronk Ramsey, C, and Van Klinken, GJ, 1994 Radiocarbon dates from the Oxford AMS System: Archaeometry Datelist 18, *Archaeometry,* **36,** 337-74

Hibberd, BG (ed), 1991 Forestry Practice, *Forestry Commission Handbook,* **6***,* HMSO, London

Hibbert, FA, Switzur, VR, and West, RG, 1971 Radiocarbon dating of Flandrian pollen zones at Red Moss, Lancashire, *Proc Royal Soc*, **B 177**, 161-76

Higgitt, DL, Warburton, J, and Evans, MG, 2001 Sediment Transfer in Upland Environments, in DL Higgitt and EM Lee, *Geomorphological Processes and Landscape Environments,* Oxford, 190-214

Higham, M, 1978 *Forest of Bowland, a study in continuity with particular reference to the Dark Ages and Middle Ages*, unpubl MA thesis, Univ Hull

Higham, M, 1989 Lead Mining in Bowland, *Old West Riding,* n ser, **9**, 32-5

Hobbs, RJ, 1986 Mire morphology and the properties and behaviour of some British and foreign peats, *Quarterly J Engineering Geol*, **19**, 7-80

Hodgkinson, D, Huckerby, E, Middleton, R, and Wells, CE, 2000 *North West Wetlands Survey, The Lowland Wetlands of Cumbria*, Lancaster Imprints, **8**, Lancaster

Holden, J, 2001 Recent reduction of frost in the North Pennines, *J Meteorol*, **26(264***)*, 369-74

Holden, J, and Adamson, JK, 2002 The Moor House long-term upland temperature record - new evidence of recent warming, *Weather,* **57**, 119-27

Holden, J, Chapman, PJ, and Labadz, JC, 2004 Artificial drainage of peatlands: hydrological and hydrochemical process and wetland restoration, *Progress in Physical Geography*, **28(1)**, 95-123

Houlder, CH, 1979 The Langdale and Scafell Pike axe factory sites: a field survey, in THMck Clough and WA Cummins (eds), *Stone Axe Studies*, London, 87-9

Howard-Davis, C, 1996 Seeing the sites: Survey and excavation on the Anglezarke Uplands, Lancashire, *Proc Prehist Soc*, **61**, 133-66

Hughes, AJG, and Roebuck, BA, 1991 Harvesting, in Hibberd 1991, 81-125

Hughes, RA, 1988 *Geology of the Trough of Bowland area (SD 66 SW)*, British Geol Surv Tech Rep, WA/87/46, unpubl rep

Hulme, PD, and Birnie, RV, 1997 Grazing-induced Degradation of Blanket Mire, in Tallis *et al* 1997, 163-73

Hunter, F, 2001 The Carynx in Iron Age Europe, *Antiq J*, **81**, 77-108

IFA, 2008 *Standards and guidance for the collection, documentation, conservation and research of archaeological materials*, Reading

Imeson, AC, 1971 Heather burning and soil erosion on the North Yorkshire Moors, *J Applied Ecol,* **8**, 537-42

Ingram, HAP, 1992 Introduction to the hydroecology of mires in the context of cultural perturbation, in OM Bragg, PD Hulme, HAP Ingram, and RA Robertson, (eds), *Peatland Ecosystems and man: an Impact Assessment*, International Peat Society, Finland, 67-93

Isaac, EK, 1972 *A geographical and field guide to Anglezarke Moor*, Chorley

Ivanov, KE, 1981 *Water Movement in Mirelands,* New York

James, NDG, 1981 *A History of English Forestry*, Oxford

Kenyon, D, 1991 *The Origins of Lancashire,* Manchester

King, L, 2004 *Diatom records in sediment samples from the South-West Fells*, Lancaster Univ, unpubl rep

Kvamme, KL, 1990 One-sample Tests in Regional Archaeological Analysis: New Possibilities Through Computer Technology, *American Antiq*, **55.2**, 367-81

Labadz, JC, Burt, TP, and Potter, AWR, 1991 Sediment yield and delivery in the blanket peat moorlands of the Southern Pennines, *Earth Sciences and Landforms*, **16**, 255-71

Lamb, HH, 1977 *Climate, past, present and future. 2: climatic history and the modern world*, Cambridge

Lamb, HH, 1981 Climate from 1000 BC to 1000 AD, in M Jones and G Dimbleby (eds), *The Environment of Man: the Iron Age to the Anglo-Saxon Period*, BAR, Brit Ser, **87**, Oxford, 53-65

Leah, M, Wells, CE, Appleby, C, and Huckerby, E, 1997 *The Wetlands of Cheshire*, Lancaster Imprints, **5**, Lancaster

Leah, M, Wells, CE, Huckerby, E, Stamper, P, and Welch, C, 1998 *The Wetlands of Shropshire and Staffordshire*, Lancaster Imprints, **7**, Lancaster

Lee, JA, Press, NC, Woodin, SJ, and Ferguson, P, 1987 Responses to acidic deposition in ombrotrophic mires in the UK, in TP Hutchinson and KM Meema (eds), *Effects of atmospheric pollutants on forests, wetlands and agricultural ecosystems*, Berlin, 549-60

Lee, JA, Tallis, JH, and Wooden, SJ, 1988 Acidic deposition and upland vegetation, in MB Usher and DBA Thompson (eds), *Ecological change in the uplands*, Spec publ, **7**, Brit Ecol Soc, Oxford, 151-62

Leech, RH, 1983 Settlements and groups of small cairns on Birkby and Birker Fells, Eskdale, Cumbria: survey undertaken in 1982, *Trans Cumberland Westmorland Antiq Archaeol Soc*, n ser, **83**, 15-26

Lees, JAG, 1998 Lancaster Property Services; scientific consultants: MAFF, The Game Conservancy, in Anderson *et al* 1998, 76

Lindsay, R, 1995 *Bogs: The Ecology, Classification and Conservation of Ombrotrophic Mires,* Scottish Natural Heritage, Perth

Lindsay, R, and Immirzi, CP, 1996 *An inventory of lowland raised bogs in Great Britain*, Scottish Natural Heritage Res Surv Monitoring Rep, **78**, Scottish Natural Heritage, Edinburgh

Loveday, R, 2002 Duggleby Howe revisited, *Oxford J Archaeol,* **21**, 135–46

LUAU, 1994 *Blengdale Forest Plantation, Cumbria: Archaeological Watching Brief*, unpubl rep

LUAU, 1997 *North West Water's Forest of Bowland Estate, Lancashire, Archaeological Survey*, unpubl rep

LUAU, 1999 *Shoulthwaite stratigraphic survey, Thirlmere, Cumbria*, unpubl rep

LUAU, 2000 *Preliminary palynological analysis of post-Bronze Age deposits at Littlewater, Cumbria*, unpubl rep

LUAU, 2001 *Drigg, Cumbria: Assessment of Archaeological Evaluation*, unpubl rep

Lund, J, and Southwell, C, 2002 *An Archaeological Monitoring Report for the Great Langdale Valley,* The National Trust, unpubl rep

Lynch, F, 1966 The Pikestones, Anglezarke, Lancs, *Proc Prehist Soc*, **32**, 347-8

Mackay, AW, and Tallis, JH, 1994 The recent vegetational history of the Forest of Bowland, Lancashire, UK, *New Phytol*, **128**, 571-84

Mackay, AW, and Tallis, JH, 1996 Summit-type Mire Erosion in the Forest of Bowland, Lancashire, UK: Predisposing Factors and Implications for Conservation, *Biol Conservation,* **76,** 31-44

Mallik, AU, Gimingham, CH, and Rahman, AA, 1984 Ecological effects of heather burning, water infiltration, moisture retention and porosity of surface soil, *J Ecol*, **72**, 767-76

Maltby, E, Legg, CJ, and Proctor, MCF, 1990 The ecology of severe moorland fire on the North York Moors: Effects of the 1976 and subsequent surface and vegetation development, *J Ecol*, **78**, 490-518

Manby, TG, 1979 Typology, materials and distribution of flint and stone axes in Yorkshire, in T Clough and WA Cummins (eds), *Stone Axe Studies,* London, 65-81

Manby, TG, 1986 The Bronze Age in Western Yorkshire, in TG Manby and P Turnbull, *Archaeology in the Pennines,* BAR Brit Ser, **185**, Oxford 55-126

Marshall, JD, and Davies-Shiel, M, 1969, *The industrial archaeology of the Lake Counties*, Beckermet

Mayfield, B, and Pearson, MC, 1972 Human interference with north Derbyshire blanket peat, *East Midland Geographer*, **12**, 245-51

McEwan, LJ, and Wither, CWJ, 1989 Historical records and geomorphological events: the 1771 'eruption' of Solway Moss, *Scottish Geol Mag*, **105**(**3**), 149-57

McHugh, M, Harrod, T, and Morgan, R, 2002 The extent of soil erosion in upland England and Wales, *Earth Surface Processes and Landforms*, **27**/1, 99-107

McMahon, 1991 Forest Roads, in Hibberd 1991, 126-34

Middleton, R, 1996 The Neolithic and Bronze Age, in R Newman (ed), *The Archaeology of Lancashire,* Lancaster, 35-60

Middleton, R, Wells, CE, and Huckerby, E, 1995 *The wetlands of North Lancashire*, Lancaster Imprints, **4**, Lancaster

Middleton, R, Tooley, MJ, and Innes, J, forthcoming *The wetlands of South-West Lancashire*

Mills, D, 1976 *The Place-names of Lancashire*, London

Ministry of Agriculture Fisheries and Food (MAFF), 1994 *The Heather and Grass Burning Code*, London

Ministry of Agriculture Fisheries and Food (MAFF), 2000 *Search on the quantification and causes of upland erosion,* MAFF Research and Development Final Project Rep SP0402, unpubl rep

Ministry of Health, 1954 *Mortality and Morbidity during the London fog of December 1952, Committee Mortality and Morbidity Report*, London

Ministry of Housing and Local Government, 1956 *Clean Air Act*, London

Mook, WG, 1986 Business meeting: recommendations/resolutions adopted by the Twelfth International Radiocarbon Conference, *Radiocarbon*, **28**, 799

Mook, WG, and Waterbolk, HT, 1985 *Radiocarbon Dating: European Science Foundation Handbook for Archaeologists* **3**, Strasbourg

Moore, PD, and Bellamy, DJ, 1974 *Peatlands, Elek Science*, London

Moore, PD, Evans, AT, and Chater, M, 1986 Palynological and stratigraphic evidence for hydrological changes in mires associated with anthropogenic activity, in KE Behre (ed), *Anthropogenic indicators in pollen diagrams*, Rotterdam, 209-20

Moore, PD, Webb, JA, and Collinson, ME, 1991, *Pollen Analysis*, 2nd edn, Oxford

Moseley, F, 1978 *The Geology of the Lake District*, Yorkshire Geol Soc, Occ Publ, **3**, Leeds

Mosley, MP, 1972 Gully systems in blanket peat, Bleaklow, North Derbyshire, *East Midland Geographer,* **5(5)**, 235-44

Musson, C, 1947 A Bronze Age cave site in the Little Bowland area, *Trans Lancashire Cheshire Antiq Soc,* **59**, 161-9

Muschamp-Perry, JJ, 1893 The waterspout (or cloud burst) on the Cheviots, in GJ Symons and H Sowervy Wallis (eds), *British Rainfall 1893: on the distribution of rain over the British Isles during the year of 1893*, London, 14-15

National Trust, 2002 *An archaeological monitoring report for the Great Langdale Valley*, unpubl rep

Newman, R, 1996 Medieval Rural Settlement, in R Newman (ed), *The Archaeology of Lancashire,* Lancaster, 109-24

OA North, 2003a *The Upland Peats: Project Design for a North West Pilot Study*, unpubl rep

OA North, 2003b *Sutton Bank Roulston Scar, Sutton Bank, North Yorks: Assessment and Watching Brief*, unpubl rep

OA North, 2003c *Ennerdale Historic Landscape Survey*, unpubl rep

OA North, 2004a *Site 123, Harrison Coombe, Great Langdale*, unpubl rep

OA North, 2004b *South West Campus, Lancaster University, Lancaster, Excavation Assessment Report*, unpubl rep

OA North, 2005 *Stickle Tarn, Great Langdale, Cumbria: Archaeological Survey Report*, unpubl rep

OA North, 2007 *Scout Moor Wind Farm, Rochdale: Watching Brief Report*, unpubl rep

OA North, 2009 *Martcrag Moor Axe Factory Sites, Great Langdale, Cumbria: Archaeological Recording Survey Report*, unpubl rep

OA North forthcoming Excavations of Langdale Axe Factories in advance on path repair work, at Langdale Combe, Thorn Crag and Harrison Stickle shoulder

Office of the Deputy Prime Minister 2004 *Planning Renewable Energy, Planning Policy Statement* **22**, HMSO, London

Oldfield, F, and Statham, DC, 1965 Stratigraphy and pollen analysis on Cockerham and Pilling Mosses, *Mem Proc Manchester Lit Phil Soc*, **107**, 70-85

Otlet, RL, 1977 Harwell radiocarbon measurements II, *Radiocarbon* **19**, 400–23

Otlet, RL, 1979 An assessment of laboratory errors in liquid scintillation methods of ^{14}C dating, in R Berger, and HE Suess (eds), *Proc Ninth Internat Radiocarbon Conference*, California, 256–67

Patterson, G, and Anderson, R, 2000 *Forests and Peatland Habitats,* Forestry Commission Guideline Note, Edinburgh

Pearsall, WH, and Pennington, W, 1973 *The Lake District: A landscape history*, The New Naturalist, London

Pennant, T, 1774 *A tour in Scotland and voyage to the Hebrides 1772*, Chester

Pennington, W, 1964 Pollen Analyses from the Deposits of Six Upland Tarns in the Lake District, *Phil Trans Royal Soc London*, Ser B, **248**, 205-43

Pennington, W, 1965a Appendix, in Cherry 1965, 82-5

Pennington, W, 1965b The interpretation of some post-glacial vegetation diversities at different Lake District sites, *Proc Royal Soc London*, Ser B, **161**, 310-23

Pennington, W, 1969 *The history of British Vegetation*, Bath

Pennington, W, 1970 Vegetational History in the north-west of England: a regional synthesis, in D Walker and RG West (eds), *Studies in the vegetational History of the British Isle,* London: Cambridge, 41-79

Pennington, W, 1973 Pollen analysis at the Langdale axe chipping site, in Clough 1973, 25-46

Pennington, W, 1975 The effect of Neolithic man on the environment in north-west England: the use of absolute pollen diagrams, in JG Evans, S Limbrey, and H Cleere (eds), *The Effect of Man on the Landscape: The Highland Zone,* CBA Res Rep, **11,** London, 74-86

Pennington, W, 1978 Quaternary geology, in Moseley 1978, 207-25

Pennington, W, 1991 Palaeolimnology in the English Lakes: some questions and answers over fifty years, *Hydrobiologia*, **214**, 9-24

Pennington, W, 2003 Evidence from the tarns of vegetation, soils, climate and human settlement, in Haworth *et al* 2003, 20-8

Phillips, J, Tallis, JH, and Yalden, D, 1981 *Peak District Moorland Erosion study: Phase I Report*, Bakewell

Plint, RG, 1962 Stone axe factory sites in the Cumbrian Fells, *Trans Cumberland Westmorland Antiq Archaeol Soc*, n ser, **62**, 1-26

Porter, J, 1973 *The reclamation and settlement of Bowland, with special reference to the period AD1500-1650*, unpubl PhD thesis, Univ London

Porter, J, 1980 *The Making of the Central Pennines,* Ashbourne

Porter, M, 1989 *Pennine Way Management Project*, *Second Annual Report 1988-89*, Peak Park and Countryside Commission, Bakewell

Porter, M, 1990 *Pennine Way Management Project, Final Report,* Peak Park and Countryside Commission, Bakewell

Powell, TGE, Corcoran, JXWP, Lynch, F, and Scott, JG, 1969 *Megalithic enquiries in the West of Britain*, Liverpool

Quartermaine, J, 1989 Interim results of survey work on Stockdale Moor and Town Bank, West Cumbria, *Trans Cumberland Westmorland Antiq Archaeol Soc*, n ser, **89**, 25-31

Quartermaine, J, 1990 Nether Wasdale Common/Scale Farm and Charlesground Gill Surveys: Interim Report, *Contrebis,* **16**, 5-8

Quartermaine, J (ed), 1994 *Langdale Erosion Research Project*, LUAU unpubl rep

Quartermaine, J, and Leech, RH, forthcoming *Archaeological landscapes of the Cumbrian uplands; results of the Lake District National Park Survey*

Rackham, O, 1986 *The history of the countryside*, London

Rackham, O, 1990 *Trees and Woodland in the English Landscape*, London

Radley, J, 1962 Peat Erosion on the High Moors of Derbyshire and West Yorkshire, *East Midland Geographer,* **5(17)**, 40-50

Radley, J, 1965 Significance of major moorland fires, *Nature*, **205**, 1254-9

Radley, J, and Mellars, PM, 1964 A Mesolithic structure at Deepcar, Yorkshire, England, and the affinities of its associated flint industries, *Proc Prehist Soc*, **30**, 1-24

Raistrick, A, 1934 Preliminary excavation of an earthwork at Eastington, West Yorkshire, *Yorkshire Archaeol J,* **31**, 44-8

Raistrick, A, 1973 *Lead Mining in the Mid-Pennines*, Early Metalliferous Mining Hist Monog, **14**, Truro

Raistrick, A, and Jennings, B, 1989 *A history of lead mining in the Pennines*, Otley

Ratcliffe, D, and Oswald, PH, 1988 *The flow country*, London

Rhodes, N, and. Stevenson, AC, 1997 Palaeoenvironmental evidence for the importance of fires as a cause of erosion in British and Irish blanket peats, in JHR Tallis and PD Hulme (eds), *Blanket mire degradation: causes, consequences and challenges*, UK, Macaulay Land-use Research Institute, Aberdeen, 67-78

Riley, DN, 1957 Neolithic and Bronze Age Pottery from Risby Warren and other occupation sites in North Lincolnshire, *Proc Prehist Soc*, **23**, 40-56

Royal Commission on Environmental Pollution, 1996 *Sustainable use of soil*, 19th Rep **CM3165**, HMSO, London

Shaw, RC, 1956 *The Royal Forest of Lancaster*, Preston

Shaw, SC, Wheeler, BD, Kirby, P, Phillipson, P, and Edmunds, R, 1996 *Literature review of the historical effects of burning and grazing of blanket bog and upland wet heath*, English Nature Res Rep, **172**, Peterborough

Sheridan, A, 1999, Rotten Bottom: the discovery of Britain's oldest bow, in R M Tipping, *The Quaternary of Dumfries and Galloway; Field Guide*, Quat Res Assoc, London, 168-70

Shimwell, D, 1974 Sheep grazing intensity in Edale, 1692-1747, and its effects on blanket peat erosion, *Derbyshire Archaeol,* **94**, 35-40

Shimwell, D, 1981 People Pressure and Footpath Erosion, in Phillips *et al* 1981, 148-71

Shore, JS, 1988 *The radiocarbon dating of peat fractions in relation to pollen analysis*, unpubl PhD thesis, Univ Leeds

Shotter, D, 1993 *Romans and Britons in North-West England,* Centre for North-West Studies, Lancaster

Shotton, FW, Blundell, DJ, and Williams, REG, 1967 Birmingham University Radiocarbon Dates I, *Radiocarbon,* **9**, 35-7

Shotton, FW, Blundell, DJ, and Williams, REG, 1969 Birmingham University Radiocarbon Dates III, *Radiocarbon,* **11**, 263-70

Simmons, IG, 2003 *The Moorlands of England and Wales*, Edinburgh

Simmons, IG, 2004 *The Moorlands of England and Wales: An environmental history 8000 BC - 2000 AD*, Edinburgh

Simmons, IG, and Innes, JB, 1987 Mid-Holocene adaptations and later Mesolithic disturbance in northern England, *J Archaeol Sci*, **14**, 1-20

Simmons, IG, Turner, J, and Innes, JB, 1989 An application of fine-resolution pollen analysis to later Mesolithic peats of an English Upland, in C Bonsall (ed), *The Mesolithic in Europe*, Edinburgh, 206-17

Slota Jr, PJ, Jull, AJT, Linick, TW, and Toolin, LJ, 1987 Preparation of small samples for ^{14}C accelerator targets by catalytic reduction of CO, *Radiocarbon*, **29(2)**, 303–6

Sobee, FJ, 1953 *The History of Pilling*, Exeter

Stace, C, 1991 *New Flora of the British Isles,* Cambridge

Stead, IM, Bowker, JB, and Brothwell, D (eds), 1986 *Lindow Man: the body in the bog*, London

Stevenson, AC, Jones, VJ, and Batterbee, RW, 1990 The causes of peat erosion: a palaeolimnology approach, *New Phytol*, **114**, 727-35

Stewart, AJA, and Lance, AN, 1991 Effects of moor-draining on the hydrology and vegetation of Northern Pennine blanket bog, *J Applied Ecol,* **28**, 1105-17

Stonehouse, P, 1988 Mesolithic sites on the Pennine watershed, *Greater Manchester Archaeol J*, **3**, 5-17

Stonehouse, P, 1994 Mesolithic sites on the Pennine watershed, part II, *Archaeol North West (CBA North West Group)*, **2 (2) [No 8]**, 38-47

Stuiver, M, and Kra, RS, 1986 Editorial comment, *Radiocarbon*, **28(2B)**, ii

Stuiver, M, and Polach, HA, 1977 Reporting of ^{14}C data, *Radiocarbon*, **19**, 355–63

Stuiver, M, and Reimer, PJ, 1986 A computer program for radiocarbon age calculation, *Radiocarbon*, **28**, 1022–30

Stuiver, M, and Reimer, PJ, 1993 Extended ^{14}C data base and revised CALIB 3.0 ^{14}C age calibration program, *Radiocarbon*, **35**, 215-30

Stuiver, M, Reimer, PJ, Bard, E, Beck, JW, Burr, GS, Hughen, KA, Kromer, B, McCormac, G, van der Plicht, J, and Spurk, M, 1998 INTCAL98 Radiocarbon age calibration, 24,000-0 cal BP, *Radiocarbon*, **40**, 1041–83

Tallis, JH, 1964 Studies on southern Pennine peats, III, The behaviour of Sphagnum, *J Ecol*, **52**, 345-53

Tallis, JH, 1973 Studies on Southern Pennine Peats, Direct observations on peat erosion and peat hydrology at Featherbed Moss, Derbyshire, *J Ecol,* **61**, 1-22

Tallis, JH, 1981 *Uncontrolled fires, Moorland erosion study*, in Phillips *et al* 1981, 176-82

Tallis, JH, 1985a Mass movement and erosion of a Southern Pennine blanket peat, *J Ecol*, **73**, 283-315

Tallis, JH, 1985b Erosion of blanket peat in the southern Pennines: new light on an old problem, in RH Johnson (ed), *The geomorphology of north-west England*, Manchester, 313-36

Tallis, JH, 1987 Fire and flood at Holme Moss: erosion processes in an Upland Blanket Mire, *J Ecol*, **75**, 1099-129

Tallis, JH, 1991 Forest and moorland in the South Pennine uplands in the mid-Flandrian period. III: The spread of moorland - local, regional and national, *J Ecol*, **79**, 401-15

Tallis, JH, 1995 Blanket mires in the upland landscape, in BD Wheeler, SC Shaw, WJ Fojten, and RA Robertson (eds), *Restoration of temperate wetlands*, Chichester, 495-508

Tallis, JH, 1997a The Southern Pennines: An Overview of Blanket Mire Degradation, in Tallis *et al* 1997, 9-11

Tallis, JH, 1997b Peat erosion in the Pennines: the badlands of Britain. The Macauley Land-use Research Institute, Aberdeen, UK, *Biologist*, **44**, 277-79

Tallis, JH, 1998 Growth and degradation of British and Irish blanket mires, *Environmental Rev*, **6**, 81-122

Tallis, JH, 1999 The uplands: human influences on the plant cover, in EF Greenwood (ed), *Ecology and Landscape Development: A history of the Mersey Basin*, Liverpool, 109-21

Tallis, JH, and Livett, EA, 1994 Pool and Hummock patterning in a Southern Pennine blanket mire: stratigraphic profiles in the last 2800 years, *J Ecol*, **82**, 775-88

Tallis, JH, Meade, R, and Hulme, PD, 1997 *Blanket Mire Degradation: Causes, Consequences and Challenges,* The Blanket Mire Degradation Conference, University of Manchester, Mires Research Group, Macauley Land Use Research Institute, Aberdeen

Tallis, JH, and Switzur, VR, 1973 Studies on southern Pennine peats. A radiocarbon dated pollen diagram from Featherbed Moss, Derbyshire, *J Ecol*, **61**, 743-51

Tallis, JH, and Switsur, VR, 1990 Forest and moorland in the South Pennine uplands in the Mid-Flandrian period II, The hillslope forests, *J Ecol*, **78**, 857-83

Tallis, JH, and Yalden, DW, 1983 *Peak District Moorland Restoration project: Phase 2 Report*, Peak District National Park Planning Board, Bakewell

Tamers, MA, 1965 Routine carbon-14 dating using liquid scintillation techniques, in RM Chatters and EA Olson (eds), *Radiocarbon and Tritium Dating: Proceedings of the Sixth International Conference on Radiocarbon and Tritium Dating*, Washington DC, 53–67

Taylor, BJ, Burgess, IC, Land, DH, Mills, DAC, Smith, DB, and Warren, PT, 1971 *British Regional Geology: Northern England*, London

Tipping, R, 1994 Williamson's Moss: Palynological Evidence for the Mesolithic-Neolithic Transition, in J Boardman and J Walden (eds*), Cumbria Field Guide*, Quat Res Assoc, Oxford, 104-28

Tipping, R, Tisdall, E, Davies, A, Wilson, C, and Yendell, S, 2007 Living with peat in the flow country: prehistoric farming communities and blanket peat spread at Oliclett, Caithness, northern Scotland, in Scottish Wetland Archaeology Project (ed), *Archaeology from the Wetlands: Recent perspectives - Proceedings of the 11th WARP Conference*, Edinburgh, 165-74

Tomlinson, RW, 1981 The erosion of peat in the uplands of Northern Ireland, *Irish Geog*, **14**, 51-64

Tooley, MJ, 1978 *Sea level changes: the coast of North-West England during the Flandrian stage*, Oxford

Townend, J, Shotbolt, L, and Anderson, R, 1997 Hydrological effects of forest plantations on blanket peat at Rumster Forest, Caithness, in Tallis *et al* 1997, 85-6

Troels-Smith, J, 1955 Characterisation of unconsolidated deposits, *Danm Geol Unders*, **IVR**, **3**(101), 1-73

Tucker, G, 2003 *Review of the impacts of heather and grassland burning in upland soils, hydrology and biodiversity*, English Nature Res Rep, **550**, Peterborough

Turner, RC, 1986 Discovery and excavation of the Lindow Bodies, in Stead *et al* 1986, 10-3

UK Climate Change Impacts Programme, 2005 Climate impacts, http:// www.ukcip.org.uk/ default.asp, Accessed July 2005

Utsi, E, 2005 *Ground penetrating radar survey of two areas on Birkby Fell, Cumbria*, unpubl rep

Van de Noort, R, 2004 *The Hunter Wetlands: the archaeology of a dynamic landscape, Macclesfield*

Van de Noort, R, Fletcher, W, Thomas, G, Carstairs, I, and Patrick, D, 2001 *Monuments at Risk in England's Wetlands (Draft V.2*), unpubl rep

Varley, WJ, 1938 The Bleasdale Circle, *Antiq J,* **18**, 154-71

Vyner, B, 2005 *Stony Marl, Howdale, Stoupe Brow Moors, Mossey Moor, Fylingdales, North Yorkshire: Report on walk-over survey of the fire sites*, unpubl rep

Walker, D, 1949 *Report on preliminary investigations of peats of the Pilling district with special reference to the age of Kate's Pad*, unpubl rep

Walker, D, 1965a The Post-Glacial Period in the Langdale Fells, English Lake District, *New Phytol*, **64**, 488-510

Walker, D, 1965b Excavations at Barnscar, 1957-58, *Trans Cumberland Westmorland Antiq Archaeol Soc*, n ser, **65**, 53-65

Walker, D, 2001 The dates of human impacts on the environment at Ehenside Tarn, Cumbria, *Trans Cumberland Westmorland Antiq Archaeol Soc*, 3 ser, **1**, 1-20

Walsh, B, and Anderson, P, 1998 Spreading Heather seed on burnt heather moorland and Burbage Moor, in Anderson *et al* 1998, 67-72

Warburton, J, Evans, MG, and Johnson, RM, 2003a Discussion – The extent of soil erosion in Upland England and Wales, *Earth Surface Processes and Landforms,* **28**, 219-23

Warburton, J, Higgitt, D, and Mills, A, 2003b Anatomy of a Pennine Peat Slide, Northern Pennines, *Earth Surface Processes and Landforms,* **28**, 457-73

Warburton, J, Holden, J, and Mills, AJ, 2004 Hydrological controls of surficial mass movements in peat, *Earth-Science Rev*, **67**, 139-56

Watson, A, and Miller, GR, 1976 *Grouse Management*, Institute of Terrestrial Ecology, Banchory, Game Conservancy, Booklet **12**, Cambridge

Wells, CE, and Hodgkinson, D, 2001 A Late Bronze Age skull and associated worked wood from a Lancashire Wetland, *Proc Prehist Soc*, **67**, 163-74

Wells, C, Huckerby, E, and Hall, V, 1997 Mid- and late- Holocene vegetation history and tephra studies at Fenton Cottage, Lancashire, UK, *Vegetation Hist Archaeobot*, **6**(**3**), 153-66

Wheatley, D, 1995 Cumulative Viewshed Analysis: a GIS-based Method for Investigating Intervisibility, and its Archaeological Application, in G Lock and Z Stancic (eds), *Archaeology and GIS: A European Perspective*, London, 171-86

Wheeler, BD, and Shaw, SC, 1995 Restoration of Damaged Peatlands, *Bull Internat Peat Soc*, **26**, 51-8

Wild, C, Wells, C, Anderson, D, Boardman, J and Parker, A, 2001 Evidence for Medieval clearance in Seathwaite Valley, Cumbria, *Trans Cumberland Westmorland Antiq Archaeol Soc*, 3 ser, **1**, 53-68

Wimble, G, Wells, CE, and Hodgkinson, D, 2000 Human impact on mid- and late Holocene vegetation in south Cumbria, UK, *Vegetation Hist Archaeobot,* **9**, 17-30

Wightman, WE, 1966 *The Lacy Family in England and Normandy 1066-1194*, London

Winchester, AJL, 1984 Peat Storage Huts in Eskdale, *Trans Cumberland Westmorland Antiq Archaeol Soc,* n ser, **84**, 103-15

Winchester, AJL, 1987 *Landscape and Society in Medieval Cumbria*, Edinburgh

Winchester, AJL, 2000 *Harvest of the hills; rural life in Northern England and the Scottish Borders*, 1400-1750, Edinburgh

Wishart, D, and Warburton, J, 2001 An assessment of Blanket Mire degradation and peatland gully development in the Cheviot Hills, Northumberland, *Scottish Geog J,* **117.3**, 185-206

Worrall, F, Reed, M, Warburton, J, and Burt, TP, 2003 Carbon budget for a British upland peat catchment, *The Science of the Total Environment*, **312**, 133-46

Yalden, PE, and Yalden, DW, 1988 The level of recreational pressure on blanket bog in the Peak District National Park, England, *Biological Conservation*, **44**, 213-27

Yorkshire Dales National Park Committee (YDNPC), 1993 *Three Peaks Project, Project Report 1986-92*, Grassington

Yorkshire Post - 31st December 2004 Society wants Moors stone to go on display

Yeloff, DE, Labadz, JC, Hunt, CO, Higgitt, DL, and Foster, IDL, 2005 Blanket peat erosion and sediment yield in an upland reservoir catchment in the southern Pennines, UK, *Earth Surface Processes and Landforms,* **30**, 717-33