FOREST OF BOWLAND
Area of Outstanding Natural Beauty

Climate Change Adaptation Plan

FOREST OF BOWLAND

Area of Outstanding Natural Beauty

Atkins Ltd

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Glossary of terms

Term or acronym	Definition
AONB	Area of Outstanding Natural Beauty
BAP	Biodiversity Action Plan
BHS	Biological Heritage Site – Lancashire County Council designated sites
CFMP	Catchment Flood Management Plan
Clough	A moorland valley cut by a stream
CRoW Act	Countryside and Rights of Way Act (2000)
Ecosystem services	Ecosystem services are the range of goods and services provided by natural ecosystems from which humans derive benefit. The Millennium Ecosystem Assessment identified four types of ecosystem services: provisioning services such as food and forestry, energy and fresh water; regulating services such as climate regulation and water purification; supporting services such as soil formation and pollination; and cultural services such as recreation, inspiration and sense of place.
ELS	Entry Level Stewardship Agri-environment scheme open to all farmers across all farming types, including the uplands. ELS requires a basic level of environmental management.
HLS	Higher Level Stewardship Agri-environment scheme which aims to deliver significant environmental benefits in high priority situations and areas. Requires a higher level of environmental management than ELS.
IPCC	Intergovernmental Panel on Climate Change
Landscape Character Type	Distinct landscape types within the Forest of Bowland AONB. Identified from Forest of Bowland AONB Landscape Character Assessment (Lancashire County Council 2009).
LPA	Local Planning Authority

NCA	National Character Area England has been divided into areas with similar landscape character which are called National Character Areas (NCAs).
RIGS	Regionally Important Geological Sites
RSPB	Royal Society for the Protection of Birds
SCaMP	Sustainable Catchment Management Programme A programme developed by United Utilities in conjunction with the RSPB which aims to apply an integrated approach to catchment management.
Soilscapes	A 1:250,000 scale, simplified soils data set covering England and Wales. It was developed by the University of Cranfield from the more detailed National Soil Map with the purpose of communicating a general understanding of the variations which occur between soil types. See www.landis.org.uk/soilscapes
SSSI	Site of Special Scientific Interest – national designation
SPA	Special Protection Area – international designation
UKCIP	United Kingdom Climate Impacts Programme
UKCP09	United Kingdom Climate Projections 2009
Vaccaries	Medieval cattle farms common in the area, still visible in enclosure patterns today.

Executive summary

The Forest of Bowland Area of Outstanding Natural Beauty (AONB) climate change adaptation plan aims to provide a suite of adaptation actions which are designed to reduce the vulnerability of the landscape character and ecosystem services. The plan should be a resource for local practitioners involved in planning and delivering land management and should assist in the development of plans which take account of the need to adapt to the likely impacts of climate change.

The adaptation action plan has been developed based on an assessment of the vulnerability of assets which contribute to landscape character and ecosystem services and identification of actions to reduce vulnerability. The assessment has been carried out based on the methodology developed by Natural England for the Character Area Climate Change Project[1].

Vulnerability assessment

Vulnerability has been defined by the Intergovernmental Panel on Climate Change (IPCC) as a function of a system's exposure and sensitivity to climate impacts and its capacity to adapt[2], where:

- Sensitivity refers to the degree to which a system is affected by weather or climate related stimuli[3];
- Exposure refers to the extent to which the system is subject to the weather or climate variable in question; and
- Adaptive capacity refers to the ability of a system to adjust to climate change, to moderate potential damage or to take advantage of opportunities[4]

Through considering vulnerability, natural environment assets which contribute to landscape character and ecosystem services have been classified as more, moderately or less vulnerable.

More vulnerable assets

The vulnerability assessment highlighted peat areas of the AONB as more vulnerable to climate change. Soils and habitats associated with peat areas are considered vulnerable to drying out but also flooding. This could affect biodiversity and the character of upland landscapes. Ecosystem services such as carbon sequestration, water resources and preservation of buried archaeology would also be negatively affected by loss of peat habitats and soils.

Habitats associated with water such as purple moor grass and rush pasture, upland springs and flushes, ponds and wet woodland are also considered to be more vulnerable to the impacts of climate change, particularly drier summers. Loss of wetland and open water habitats would not only have a detrimental effect on biodiversity but could reduce the freshwater provisioning and flood alleviation services they provide.

Designed landscapes are considered to be more vulnerable to the impacts of climate change as historic value lies in the particular design, species choice and layout of these places. Designed landscapes are likely to be particularly vulnerable to changes in species composition and loss of veteran trees which could alter landscape character and people's sense of place.

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[1] *Natural England, 2009a, b, c and d and Natural England forthcoming*

[2] *IPCC, 2007*

[3] *IPCC, 2007*

[4] *IPCC, 2007*

Fishing is important to the economy and attracts many visitors. Fisheries are likely to be more vulnerable to climate change, particularly low flows and poor water quality which affect fish spawning habitat. If fish fail to migrate or breed successfully, fisheries in the Forest of Bowland could become depleted.

Footpaths and bridleways provide an important recreation resource in the Forest of Bowland but are more vulnerable to the impacts of climate change, particularly waterlogging and erosion. Patterns of usage may also change as a result of climate change, with potential increase in demand.

Adaptation action plan

The adaptation plan is designed to be used to assist practitioners develop and deliver land management plans which reduce the vulnerability of the Forest of Bowland AONB to the impacts of climate change. These actions form the adaptation plan which is presented in this report. Two types of adaptation actions have been identified:

- *Strategic actions* are high-level actions which are applicable across the whole AONB. These actions provide a framework for adaptation in the AONB and should be considered in the development and delivery of all land management programmes.
- *Specific actions* apply to certain landscape character types or ecosystem services. In many cases, these build on the strategic actions, providing more detail about where actions should be undertaken.

Adaptation actions are arranged alongside individual assets but also under headings of landscape character and ecosystem services. It is intended that practitioners 'dip-in' to the action plan to identify adaptation actions appropriate to their target area, depending on the assets, landscape character and ecosystem services present.

Many of the suggested actions are not new ideas but are drawn from current understanding of good conservation practice which involves increasing resilience to a range of pressures. Much work has already been undertaken in the Forest of Bowland to manage semi-natural habitats and improve their health. Work has been particularly focused in upland areas where large areas have been re-wetted and replanted through Higher Level Stewardship (HLS) and United Utilities' and the RSPB's Sustainable Catchment Management Plan (SCaMP). To date, less management has been undertaken in the fringe and lowland areas of the Forest of Bowland and these areas could be a focus for future activity. Restoring, re-creating and re-connecting clough woodland, grassland and wet woodland could reduce the vulnerability of fringe and lowland areas to the impacts of climate change, increasing overall resilience.

Many of the actions involve reviewing and adapting existing management plans and practices. Given that adaptation involves delivering good conservation practice, it is important that it is embedded into existing plans and agreements. It will be necessary to regularly review plans and agreements to ensure they take account of the impacts of climate change and maximise opportunities to deliver adaptation.

In order to be sustainable it is important that adaptation actions do not have unintended negative impacts on the natural environment and that potential conflicts are recognised early. It is recommended that before undertaking any of the suggested actions, an assessment of potential environmental impact is made and measures taken to mitigate potential negative impacts.

1. Introduction

1.1 Context

The natural environment is important for the habitats and species it supports and for the benefits it provides society. People enjoy a wide range of services from the environment and its ecosystems: food and water, clean air, storage of carbon, regulation of hazards such as flooding and opportunities for recreation. Distinctive landscapes, shaped over thousands of years by natural processes and human land use, give both local communities and visitors a 'sense of place'.

However, the natural environment is vulnerable to climate change[5]. While landscapes are dynamic and have responded to changes in the past, the scale and pace of potential change in response to a changing climate may be unprecedented in recent human history. This is likely to have implications for biodiversity and the wide range of benefits and services obtained from ecosystems and landscapes. At the same time appropriate land management to preserve and enhance ecosystems can help buffer society from a changing climate. Appropriate adaptation action for the natural environment will therefore be essential and form an important part of an overall adaptation effort.

We have a good idea of how the climate might change[6], including inevitable change over the next 20 to 30 years, and some information about the possible consequences for different aspects of the natural environment[7]. However, consequences of climate change are likely to vary greatly from place to place. For this reason, adaptation is likely to be a very time- and place-specific activity.

Spatially, large scale adaptation approaches are likely to be important; this is not a new idea in conservation[8] but climate change and its potential to further enhance the 'fluidity'[9] of landscapes in time and space makes it a particularly relevant issue to adaptation[10]. The recently published Lawton Review, Making Space for Nature, sets out a number of recommendations for practical action to achieve a coherent and resilient ecological network in England. The Review summarises what needs to be done to re-build nature as 'more, bigger, better and joined' [11]. Central to the delivery of this vision is a large scale approach to conservation and adaptation. It is also important that we try to take an integrated and sustainable approach to considering vulnerability and adaptation[12].

The concept of 'landscape' is particularly useful to address both scale and sustainability issues. Landscape provides an important spatial element and has great potential to act as an integrating framework that helps us to consider a range of aspects of the natural environment in a holistic way, consider how changes to physical features of the landscape will affect the things that society values and benefits from, and focus our adaptation responses on maintaining or enhancing those things in the face of inevitable change.

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[5] *Hopkins, et al., 2007; Mitchell et al., 2007; IPCC 2007; Rozenzweig et al., 2008*

[6] *Murphy, et al., 2009*

[7] *For example Hopkins, et al., 2007; Mitchell et al., 2007*

[8] *Noss, 1983*

[9] *Manning, et al., 2009*

[10] *Opdam and Wascher, 2004*

[11] *Lawton, et al., 2010*

[12] *Macgregor and Cowan, 2010*

In this study the Forest of Bowland Area of Outstanding Natural Beauty (AONB) is the geographic unit used to explore vulnerability and adaptation. Studying the AONB provides an opportunity to consider vulnerability and adaptation at a 'landscape scale'; but it is distinct enough to enable us to explore the possible implications of climate change and adaptation actions in specific parts of the AONB.

The adaptation action plan has been developed based on an assessment of the vulnerability of assets which contribute to landscape character and ecosystem services in the AONB and identification of actions to reduce vulnerability. The landscape character types are drawn from the Forest of Bowland AONB Landscape Character Assessment[13] and can be seen in Figure 1.1. Boundaries of the two National Character Areas (NCAs) which are part of the AONB are shown in Figure 1.2. Ecosystem services are the range of goods and services provided by natural ecosystems from which humans derive benefit[14].

1.2 Study aim

The Forest of Bowland AONB climate change adaptation plan aims to provide a suite of adaptation actions which are designed to reduce the vulnerability of the landscape character and ecosystem services to the impacts of climate change. The plan should be a resource for local practitioners involved in planning and delivering land management and should assist in the development of management plans which take account of the need to adapt to the likely impacts of climate change.

The assessment has been carried out based on the methodology developed by Natural England for the Character Area Climate Change Project[15].

1.3 Guide to using the adaptation plan

The adaptation plan is designed to be used to assist practitioners develop and deliver land management plans which reduce the vulnerability of the Forest of Bowland AONB to the impacts of climate change.

The report is arranged as follows:

Chapter 2: Methodology – description of the steps taken to assess the vulnerability of the natural environment to the impacts of climate change and identify adaptation actions;

Chapter 3: Adaptation action plan – presentation of adaptation actions identified as a result of the study;

Chapter 4: Discussion and conclusion – highlights key messages to consider when developing adaptation action plans and identifies areas for further research;

Appendix A – background information about the approach taken in the study;

Appendix B - further information on the project methodology; and

Appendix C – maps of the study area and natural environment assets.

[13] *Lancashire County Council, 2009*

[14] *Parliamentary Office of Science and Technology, 2007*

[15] *Natural England, 2009a, b, c and d and Natural England, forthcoming*

The adaptation action plan for the Forest of Bowland AONB is presented in Chapter 3. Two types of adaptation actions have been identified:

Strategic actions are high-level actions to reduce vulnerability which are applicable across the whole AONB. These actions provide a framework for adaptation in the AONB and should be considered in the development and delivery of all land management programmes.

Specific actions apply to certain natural environment assets, landscape character types or ecosystem services. In many cases, these build on the strategic actions, providing more detail about where actions should be undertaken.

The vulnerability of individual natural environment assets and specific adaptation actions are summarised in Tables 3.1 – 3.5 in Chapter 3. The specific actions are also arranged under headings of landscape character type and ecosystem services in Table 3.6. More detailed descriptions of the specific actions, including locations in the Forest of Bowland where they would be appropriate and possible delivery mechanisms are also provided.

It is intended that practitioners 'dip-in' to the strategic and specific actions to identify appropriate actions at a range of scales, from individual assets up to the whole AONB. For example, if practitioners are interested in adaptation actions for a specific habitat or soil type, Tables 3.1 and 3.2 may be the most useful starting point for identifying specific actions. If a practitioner is interested in adaptation actions for a particular landscape character type or ecosystem service, Table 3.6 is likely to be the most useful starting point. If practitioners are interested in identifying assets and ecosystem services in the two NCAs, Figure 1.2 illustrates the NCA boundaries.

Regardless of the starting point for identifying adaptation actions, practitioners would be advised to consider the strategic actions in developing any adaptation plans as they provide principles for adaptation which apply at a range of scales across the whole AONB area.

Sources of information in this report for identifying adaptation actions depending on the scale of interest are summarised in Table 1.1 below.

Table 1.1 – Sources of information in this report for identifying adaptation actions

Scale of interest	Source for identifying adaptation actionis	
Assets Habitats, species, soil types, geodiversity features, historic environment features, natural resources and other landscape features	Tables 3.1 – 3.5 and accompanying descriptions of specific actions	Also consider strategic actions
Landscape character types From the Forest of Bowland AONB Landscape Character Assessment (see Figure 1.1)	Table 3.6 and accompanying descriptions of specific actions	
Ecosystem services	Table 3.6 and accompanying descriptions of specific actions	
National Character Areas	Figure 1.2, Tables 3.1 – 3.5, Table 3.6 and accompanying descriptions of specific actions.	
Whole AONB	Strategic actions	

Figure 1.1 – Landscape character types in the Forest of Bowland AONB

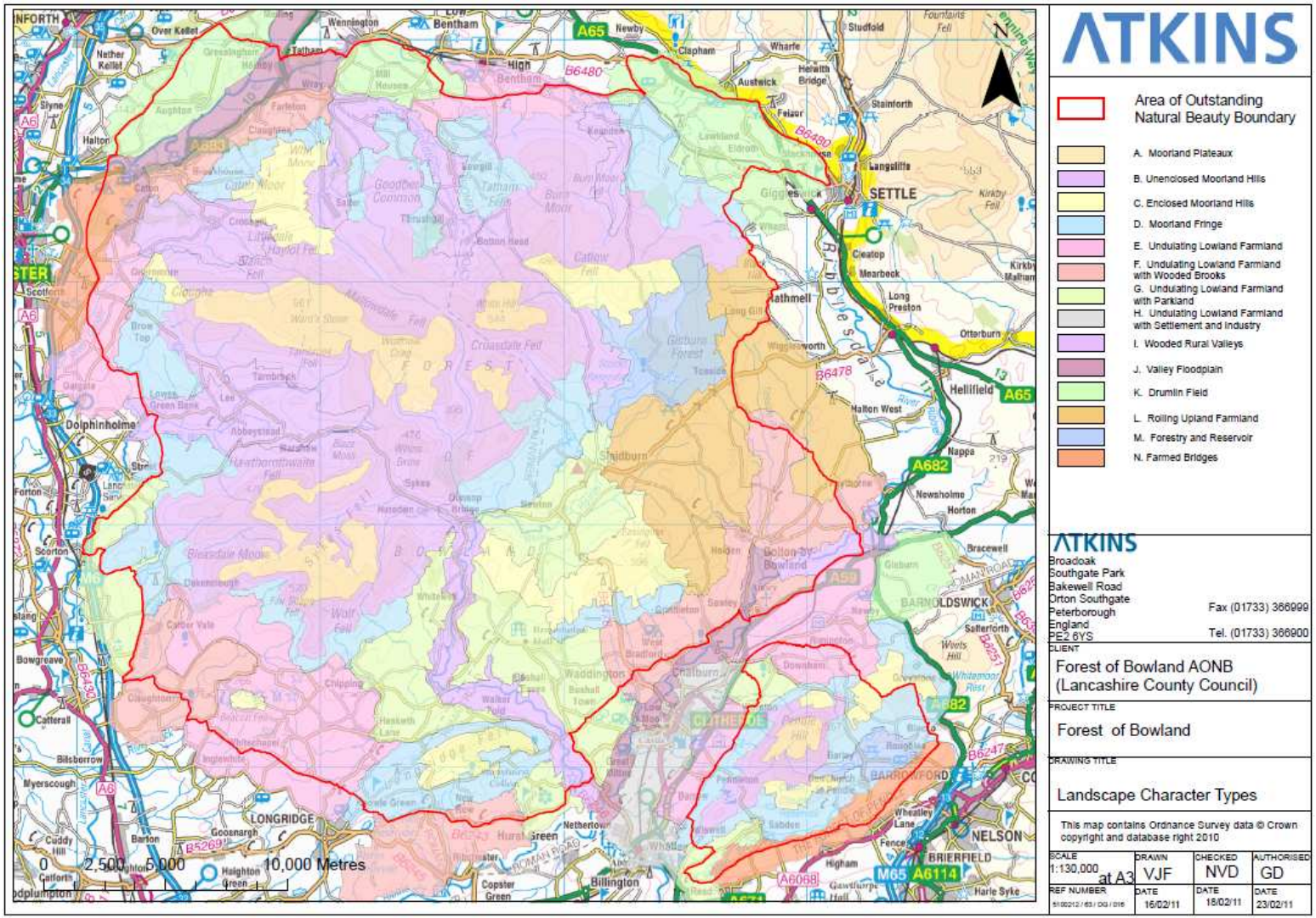
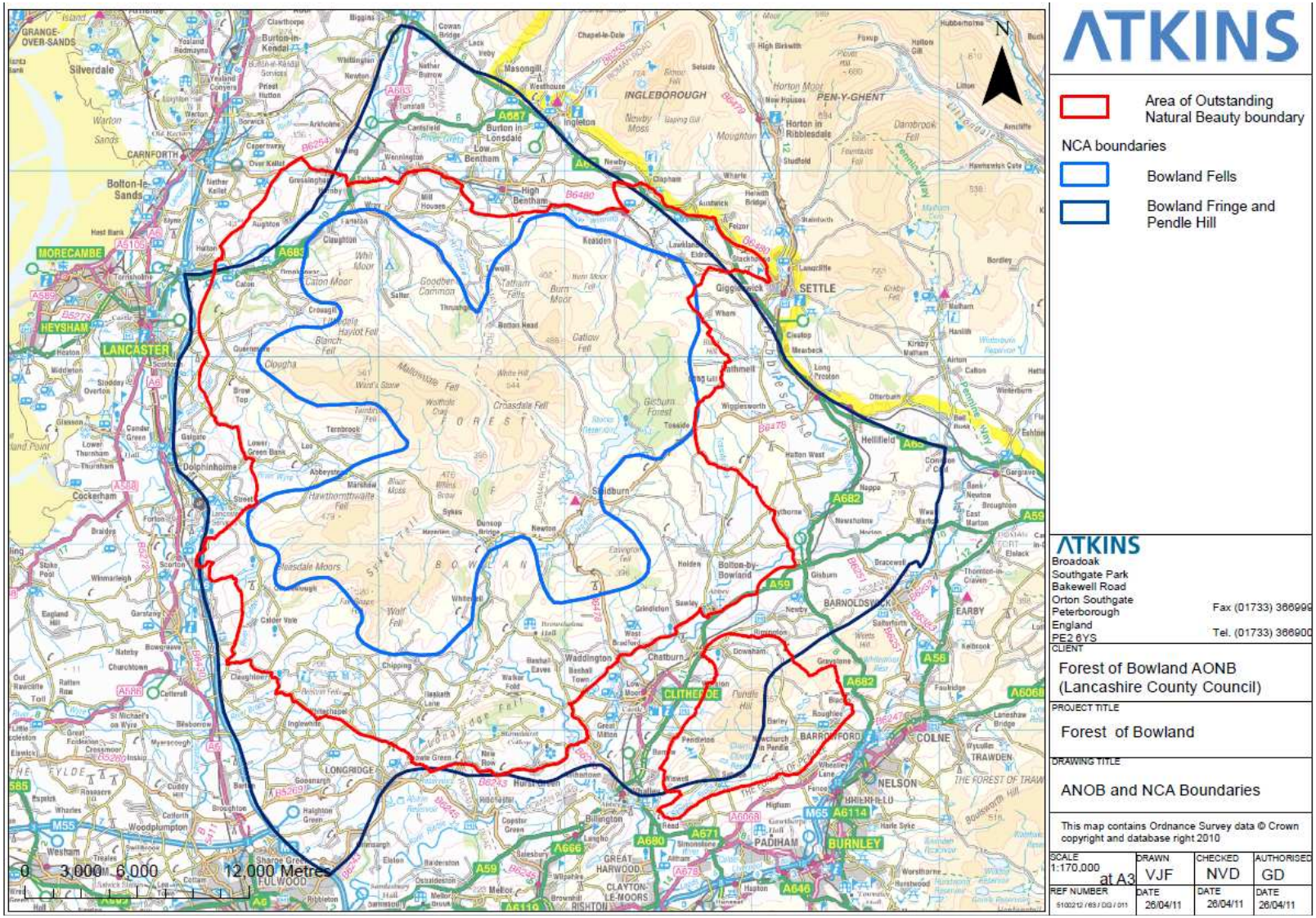


Figure1.2 - AONB and NCA boundaries



2. Methodology

2.1 Introduction

The methodology followed in this study was based on the method developed by Natural England for its Character Area Climate Change project. The methodology is underpinned by three main concepts:

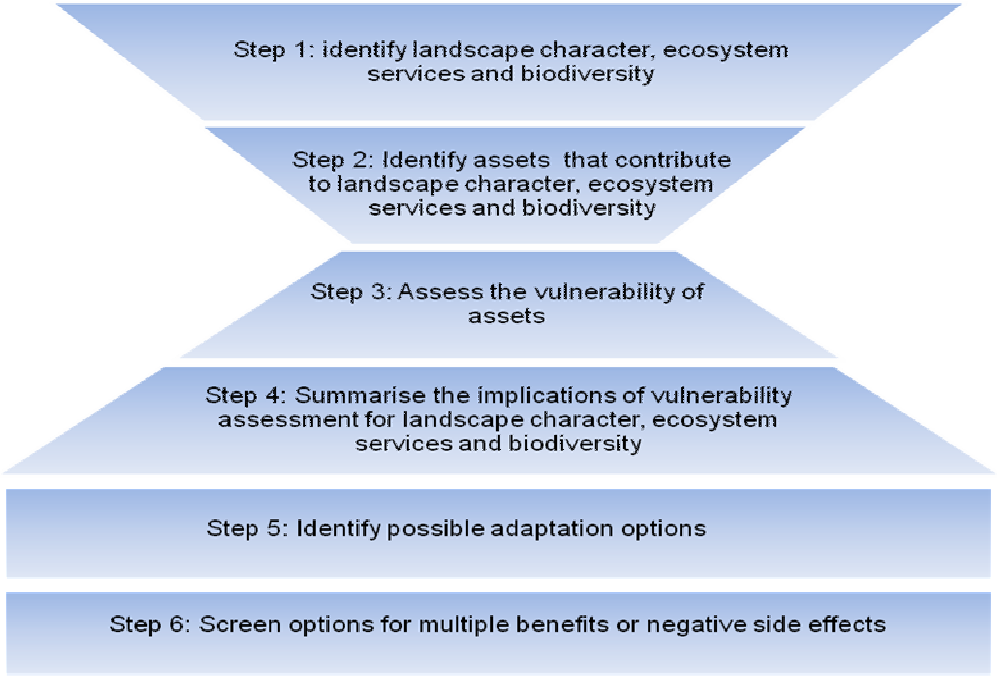
- Sustainable adaptation;
- Using a vulnerability approach to assess the potential impacts of climate change; and
- Using landscape as an integrating framework for adaptation.

The conceptual approach to the methodology is described in more detail in Appendix A.

The method consisted of six steps, see Figure 2.1. The starting point was to identify the most important aspects of landscape character, ecosystem services and biodiversity and the physical assets which make the most important contribution to them. We then assessed the vulnerability of those physical assets, and from this we inferred the possible implications for landscape character. We also identified possible adaptation actions to address vulnerability before screening them to identify actions that would have multiple benefits, and any potential conflicts between actions.

The project was carried out in two phases: initially the steps were followed in a desk based assessment. The outputs of the desk based assessment were then reviewed and refined through consultation with local stakeholders. Consultation was undertaken through two workshops as well as via telephone and email. The first workshop was held in October 2010 and the second in March 2011.

Figure 2.1 – Methodology for assessing vulnerability and identifying adaptation actions[16]



[16] *Natural England, forthcoming*

2.2 Methodology

Step 1 – Identification of landscape character, ecosystem services and biodiversity

The landscape characteristics, biodiversity and ecosystem services of the Forest of Bowland AONB were identified through a review the Forest of Bowland Landscape Character Assessment and other documents including:

- Bowland Fells National Character Area (NCA) and Bowland Fringe and Pendle Hill NCA descriptions and ecosystem service tables;
- Forest of Bowland AONB Sense of Place Toolkit;
- Discover Bowland brochure; and
- Geology and Landscape of Lancashire[17]

Step 2 – Identification of contributing assets

The assets which contribute to the landscape characteristics, ecosystem services and biodiversity were identified through reviewing the documents listed in Step 1 and stakeholder consultation. A stakeholder workshop was held in October 2010. Participants were asked to identify key habitats and species, access and recreation assets, historic environment assets, natural resource assets and other landscape features in each of the landscape character types from the Forest of Bowland AONB Landscape Character Assessment. Assets which contribute to ecosystem services were also identified at the workshop.

The results of Steps 1 and 2 were summarised in a table which sets out landscape character types and ecosystem services and the assets which contributed to them (see Appendix B). Stakeholders were invited to comment on the table via email and a final list of assets which contribute to the landscape characteristics, ecosystem services and biodiversity of the Forest of Bowland was identified.

Many of the assets have been mapped using GIS data from the Forest of Bowland AONB, Natural England and the Environment Agency. The maps are presented in Appendix C. The maps illustrate assets for which information is available and do not necessarily include every asset. There are some types of assets which do not lend themselves to mapping (for example, aspects of aesthetic value and sense of place).

Step 3 – Identification of how assets may be vulnerable to the impacts of climate change

The vulnerability of assets to the impacts of climate change was initially carried out as a desk based exercise, considering the exposure, sensitivity and adaptive capacity of the asset:

- Exposure - broad climate change variables consistent with headline messages for the north west of England from UKCP09 were used to consider exposure (see Box 1);
- Sensitivity - the desk based assessment of the sensitivity of assets to climate change was informed by material prepared by Natural England as part of its Character Area Climate Change Project ; and
- Adaptive Capacity - information on the adaptive capacity of assets was gathered through reviewing the Forest of Bowland AONB Landscape Character Assessment and material prepared by Natural England as part of its Character Area Climate Change Project.

Taking these factors into consideration, each asset was given a relative vulnerability rating (more vulnerable, moderately vulnerable or less vulnerable), see Table 2.1.

[17] *Williams and Rhodes, 2008*

Box 1: UKCP09 headline messages for the north west of England, 2080s medium emissions scenario

Hotter summers – the central estimate of increase in summer mean temperature is 3.7°C; it is very unlikely to be less than 2.0°C and is very unlikely to be more than 5.9°C.

Warmer winters – the central estimate of increase in winter mean temperature is 2.6°C; it is very unlikely to be less than 1.4°C and is very unlikely to be more than 4.0°C.

Drier summers – the central estimate of change in summer mean precipitation is -22%; it is very unlikely to be less than -43% and is very unlikely to be more than 0%.

Wetter winters – the central estimate of change in winter mean precipitation is +16%; it is very unlikely to be less than +3% and is very unlikely to be more than +34%.

Table 2.1 – Relative vulnerability ratings used in the project

Relative vulnerability rating	Description
More vulnerable	Asset is likely to be significantly changed or destroyed as a result of climate change. Adaptation action should be implemented as a matter of priority.
Moderately vulnerable	Asset may be changed as a result of climate change. Careful management or monitoring is likely to be required to support adaptation.
Less vulnerable	Asset is less likely to be significantly changed as a result of climate change or change may be beneficial. Adaptation action may be necessary, but other assets should be considered with greater urgency.

The output of the desk based vulnerability assessment was a series of draft vulnerability tables. These tables were presented to stakeholders at the March 2011 workshop. Participants were asked to review the assessment and refine it based on their in-depth knowledge of the assets. Participants were asked to focus on providing locally specific information with regards to 'adaptive capacity', considering questions such as:

- Can the asset move in response to climate change?
- Can the asset can regenerate and how fast?
- Are there suitable and accessible areas for assets to move to in the landscape (i.e. habitat connectivity)?
- What is the current condition of the asset?
- Are there any existing pressures other than climate change which could reduce the asset's ability to adapt?
- Is the asset already subject to management plans which can be updated to take account of climate change?

The vulnerability assessment tables were updated based on the comments received at the workshop and can be seen in Chapter 3. Further detail on the execution of Step 3 can be found in Appendix B.

Step 4 – Implication of climate change for landscape characteristics and ecosystem services

The potential implications of climate change for the landscape character and ecosystem services were identified by considering the cumulative effects of the asset vulnerabilities identified in Step 3. Statements about the potential implications for landscape character and ecosystem services were developed and can be seen in Appendix B. The statements are not definitive; they are intended to illustrate the possible implications of climate change on landscape characteristics and ecosystem services, based on the vulnerability assessment.

Step 5 – Identification of potential adaptation actions

Potential adaptation actions to address the vulnerability of the Forest of Bowland AONB to the impacts of climate change were identified. An initial list of actions was identified from a combination of published literature[18] , along with the outputs of the Natural England Character Area Project .

The initial list of adaptation actions were arranged under headings of landscape character and ecosystem services. These actions were discussed with stakeholders at the workshop held in March 2011. Participants were asked to refine the adaptation actions based on their knowledge of the area and were specifically asked to consider the following questions:

- Is the action listed under the appropriate heading of landscape character, ecosystem services or biodiversity? If not, should it be moved or removed from the list?
- Are there specific locations in the AONB where these actions should be targeted? Can we give place names / make the actions more geographically specific?
- Are there any examples of this action already occurring in the Forest of Bowland? Who/where/what/how etc.
- Are there any adaptation actions missing? If so what are they?

The adaptation action column of the vulnerability tables were updated based on the comments received at the workshop.

Step 6 - Identification of strategic adaptation actions, synergies and conflicts

In this project, strategic actions are high-level actions to reduce vulnerability which are applicable across the whole AONB. Specific actions are those which apply to particular landscape character types or ecosystem services. Strategic actions were identified through consultation with participants at the March 2011 workshop.

It is important that suggested adaptation actions do not have unintended negative impacts on the natural environment. It is also important to recognise actions which are likely to deliver multiple benefits in terms of reducing vulnerability ('win-win' actions): for example grip blocking, which could deliver benefits for biodiversity, landscape character and ecosystem services.

At the workshop in March 2011, participants were asked to consider potential conflicts associated with the actions. Where conflicts were identified, participants were asked to consider whether conflict could be reduced through changing the wording of the action or whether it should be removed. Win-win actions were also identified at the workshop by looking across the landscape character types and ecosystem services and identifying repeated actions. The resulting strategic and specific adaptation actions developed in Steps 5 and 6 are presented in Chapter 3.

[18] *Hopkins, et al., 2007; Mitchell et al., 2007*

3. Adaptation action plan

3.1 Introduction

In this Chapter the results of the vulnerability assessment and identification of adaptation actions to address vulnerability are presented. Adaptation actions have been split into 'strategic actions' and 'specific actions' where:

- Strategic actions - high-level actions to reduce vulnerability which are applicable across the whole AONB. These actions provide a framework for adaptation in the AONB and should be considered in the development and delivery of all land management programmes.
- Specific actions - apply to individual natural environment assets, landscape character types or ecosystem services. In many cases, these build on the strategic actions, providing more detail about where actions should be undertaken.

3.2 Strategic actions

Increase the area of semi-natural habitat

Increasing the area of semi-natural habitat in the Forest of Bowland is important for reducing many of the vulnerabilities identified. The area of semi-natural habitat in the AONB can be increased by restoring existing areas, expanding existing areas and creating new habitats. More detail about the types and locations of potential habitat creation can be found in the specific actions.

Increase connectivity of habitats

As well as increasing the area of semi-natural habitat in the Forest of Bowland AONB, it is important to increase the connectivity of habitat patches. This will allow habitats and species to move in response to climate change, increasing the resilience of the landscape. Habitat connectivity can be increased by focusing habitat creation on joining up existing patches.

Promote greater environmental heterogeneity

Diverse landscapes are thought to be more resilient to the impacts of climate change as they provide opportunities for habitats and species to move and adapt to changing conditions. Heterogeneity can be increased through measures which promote mosaics of habitats with different microclimates and vegetation heights.

Where possible, adopt adaptive management approaches

Adaptive management is a way of managing resources, such as natural environment resources, through monitoring the results of management activity and then adapting management decisions in line with the information gathered .

Seek to reduce sources of harm and pressure not linked to climate change

The legacy of past sources of pressure on the natural environment may restrict the ability of habitats to respond effectively to climate change. Examples include upland drainage, agricultural diffuse pollution, water abstraction or development leading to habitat fragmentation. Reducing these sources of pressure will increase the resilience of the landscape to climate change by increasing the adaptive capacity of assets.

Monitor assets

There is a large degree of uncertainty about the vulnerability of the natural environment to the impacts of climate change. It is therefore important to monitor assets to identify how they are responding to climate change and use this information to develop adaptation responses (see paragraph above about adaptive management). It is suggested that monitoring in the Forest of Bowland focuses on characteristics species or species known to be at the edge of their range. It is also important to monitor non-biodiversity assets such as historic environment assets and geomorphological processes.

Review and update management plans to take account of climate change

There are a number of management plans and schemes which cover natural environment assets, for example stewardship agreements, soil management plans, succession plans in designed landscapes and forestry plans in

commercial plantations. It is important that these plans consider the impacts of climate change and the need for adaptation responses (which reduce vulnerability). Where possible, climate change adaptation should be embedded in existing plans.

Ensure current agreements are enforced and plans are adhered to

As well as reviewing and updating existing management plans and agreements, existing plans which benefit climate change adaptation should be enforced.

Build climate change into spatial planning agenda

There are opportunities to build climate change adaptation into the local planning framework; green infrastructure has a particular important role to play in supporting community resilience whilst delivering wider biodiversity and landscape benefits. As part of this approach the existing or potential functionality of sites should be considered in terms of their ability to support climate change adaptation whilst also enhancing biodiversity within the AONB.

3.3 Specific actions

The specific actions required to reduce the vulnerability of individual natural environment assets are presented in the final column of Tables 3.1 – 3.5. Specific actions are also presented by landscape character type in Table 3.6 and described in more detail below.

Table 3.1 - Vulnerability of habitats in the Forest of Bowland to the impacts of climate change

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Blanket bog Found in the moorland plateaux, unenclosed moorland hills, enclosed moorland hills landscape character areas. Supports hen harrier, red grouse, golden plover and curlew. Supports Manchester Treble-bar and a rare spider, *Clubiona norvegica* at Caton Moor. Contributes to provision of fresh water, climate regulation, water quality and flood alleviation service. Also preserves buried archaeology.	Drier summers Hotter summers Wetter winters Warmer winters Intense rainfall events	Sensitive to higher temperatures combined with reduced summer rainfall which will increase evapo-transpiration, lowering the water table. Surface layer of peat is sensitive to oxidation and decay if allowed to dry out – already some evidence of erosion of the blanket bog, resulting in the formation of peat hags. Sphagnum is sensitive to mould attack during warmer winters Risk of flooding may lead to bog burst.	*Environmental*: as ombrotrophic systems, bogs cannot be 'topped up' from water elsewhere if summer rainfall is deficient, so have low adaptive capacity. Current condition is poor in places due to overgrazing, burning and drainage. Some areas are well managed though. Adaptive capacity limited by topograhy. *Management*: summer water deficit could compromise attempts at restoration. Sites are often in anagement e.g. SCaMP / HLS so capacity to manage for climate change is increased. Blanket bog on United	More vulnerable		Adopt management practices to increase and stabilise ground water levels Restore upland mire communities and bog-mosses Restore areas of eroded and exposed peat Identify the amount of carbon stored in blanket bog Monitor peat depth Monitor key species Monitor burning practices

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
			Utilities land generally in better condition than that on land used for grouse shooting.			

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Lowland raised bog (valley mires) Very limited although found in valley floodplain, rolling upland farmland and drumlin fields landscape character areas e.g. Austwick and Lawkland Mosses SSSI Contributes to provision of fresh water, climate regulation, water quality and flood alleviation service. Also preserves buried archaeology.	Drier summers Hotter summers Wetter winters Intense rainfall events	Sensitive to higher temperatures combined with reduced summer rainfall which will increase evapo-transpiration, lowering the water table. Surface layer of peat is sensitive to oxidation and decay if allowed to dry out. Already seeing some drying out in Forest of Bowland. Risk of flooding may lead to bog burst.Sensitive to intense rainfall events in summer.	*Environmental*: ombrotrophic systems cannot be 'topped up' from water elsewhere if summer rainfall is deficient, so have low adaptive capacity. Current condition is poor in places due to overgrazing, burning and drainage – reduces adaptive capacity. *Management*: summer water deficit could compromise attempts at restoration. Sites are often in management already e.g. Lancashire Peat Project so capacity to manage for climate change is increased.	More vulnerable		Adopt management practices to increase and stabilise ground water levels Ensure sufficient lag area around sites to prevent drying out Restore bog-mosses Restore areas of eroded and exposed peat Identify the amount of carbon stored in lowland raised bogs Monitor peat depth Manage scrub on sites

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Purple moor grass and rush pasture Found in unenclosed moorland hills, enclosed moorland hills landscape character arease.g. Robert Hall Moor. Supports red shank and snipe and breeding waders such as lapwing and curlew. Supports fresh water, water quality, climate regulation and flood alleviation services.	Hotter summers Drier summers	Sensitive to drought and changes in height of the water table. Sensitive to flushes drying up. Sensitive to a longer growing season leading to loss of some mire species, scrub invasion / woodland succession or shift in habitat type to fen or swamp in wet conditions. Sensitive to change in agricultural practice e.g. intensification or abandonment. Sensitive to wildfire.	*Environmental:* Many sites have been lost to agricultural improvement – now a fragmented habitat. Scarcity of suitable substrate limits adaptive capacity. *Management:* Depends on water levels and competing demands for water.	More vulnerable	Rodwell *et al*., 2007 Berry *et al*., 2003 Hopkins *et al*, 2007 Preston *et al*., 2002	Adopt management practices to increase and stabilise ground water levels. Encourage appropriate levels and types of stocking, cattle in particular. Manage and control scrub. Review frequency of bracken removal. Monitor key species.

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Upland hay meadows Found in undulating farmland with wooded brooks, valley floodplains and rolling upland farmland landscape character areas. E.g. Barn Gill Meadow SSSI, Myttons Meadow SSSI and Langcliff Cross Meadow SSSI Supports food production and pollination services.	Hotter summers Warmer winters Wetter winters Drier summers Intense rainfall events	Sensitive to change in species composition due to longer growing seasons. Montane plant species may lose climate space and lowland species may extend their range. Sensitive to a reduction in frost events – some species need low winter temperatures to prevent respiratory rundown of carbohydrate and protein resources in the bulky rhizome. Sensitive to an increase in frequency of storms which may prevent cutting. Could be an opportunity to take two cuts of hay annually.	*Environmental*: may depend on connectivity of habitat. Montane plants may have nowhere to go in response to climate change. Past farming practices such as fertilising and early harvesting of hay meadows means some areas of this habitat are in a degraded condition. *Management*: loss of suitable agricultural machinery. Some areas are already in management through HLS so may have higher management capacity.	More vulnerable		Upland hay meadow creation. Promote the return of semi-improved grasslands to species-rich grassland. Adapt the management of hay meadows. Encourage appropriate stocking levels and types. Monitor key species – *Alchemilla, Trollius, Conopodium.*

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Wet woodland Found in wooded rural valleys landscape character area. Supports fresh water, water quality, flood alleviation, climate regulation, pollination services	Drier summers Wetter winters	Sensitive to severe drought in summer when reservoir of seepage water runs dry. Sensitive to drying up of flushes. Could lead to significant vegetation change towards mixed decidious woodland. Sensitive to cycles of wetting and drying and loss through erosion. Soil chemistry could change, more alkaline soils could assist species to adapt.	*Environmental:* availablility of water, primarily groundwater, for maintenace of habitat contributes to adaptive capacity. Lack of connectivity reduces adaptive capacity. *Management:* flood prevention measures (hard defences) can reduce adaptive capacityTrees can help to stabilise banks (but can also increase flood risk)	More vulnerable	.	Plant new woodlands and extend and connect existing woodlands. Increase genotypic variation in woodlands by planting a range of genotypes. Restoration and re-creation of wet woodland.

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Upland springs and flushes Found in Dunsop Valley, Brennand Valley, moorland plateaux, unenclosed moorland hills, enclosed moorland hills and moorland fringe character areas. Marshaw Clough and along Calder Vale.	Drier summers	Sensitive to drought. Sensitive to increases in nutrient loading. Also sensitive to shading by trees if there are changes in species composition or more vigourous vegetation growth. Possible increase in *molinia.*	*Environmental*: adaptive capacity is reduced as the habtiat is constrained by topography and has little scope to move.	More vulnerable		Restoration and re-creation of wet grassland.

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Ponds and open water Found in forestry and reservoir, valley floodplains and wooded rural valleys landscape character areas. Supports breeding and over wintering wildfowl and waders. Supports food production, fresh water, flood alleviation and recreation services	Hotter summers Drier summers Intense rainfall	Sensitive to eutrophic symptoms where nutrient loads are high. Could lead to greater frequency and duration of toxic algae blooms and increased risk of invasivive plants. Sensitive to drying out leading to loss of fish spawning habitat. Changes in sedimentation can also affect these habtiats. Sensitive to loss of connectivity with other freshwater habitats. Wading birds sensitive to changes in habitat.	*Environmental:* adaptive capacity dependent on water rentention capacity within catchment and hydrological connectivity between open waters and wetlands. Most pond taxa are capable of rapid dispersal. *Management*: if the landscape can be adapted to provide sufficient sites then communities will be sustainable. Perverse incentives under rural payment schemes - exclude ponds, reducing capacity to manage.	More vulnerable	McKee *et al*., 2002 Balayla and Moss, 2002 Jeffries, 2005	Enclosure of livestock to protect sensitive habitats. Look for flood storage opportunities. Create new ponds in appropriate areas. Reduce nutrient loading by sensitive management in surrounding areas.

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Lowland mixed deciduous woodland Undulating lowland farmland with wooded brooks, wooded rural valleys, drumlin fields, forestry and reservoir and farmed ridges landscape character areas. Supports wild garlic and bluebells. Supports fresh water, water quality, flood alleviation, timber, energy, climate regulation, pollination, tranquillity and recreation services	Hotter summers Drier summers Warmer winters Intense rainfall events	Sensitive to drought and changes in temperature which could cause a shift in the composition of vegetation types and species. Competition from invasive species - potential establishment of species from further south in Europe e.g. Holm oak. Also sensitive to increased fire risk although less so than wood pasture as it tends to be wetter. Also sensitive to competition from invasive species as well as pests and diseases. .	*Environmental*: older trees tend to have lower adaptive capacity. Ground flora has low adaptive capacity as it requires suitable habitat to be established before it will move. Additional pressure on ground flora from recreation where routes go through this habitat. *Management:* there is variabilty in management of this habitat – there are few schemes covering woodland due to lack of landowner investment.	Ground flora – more vulnerable	Broadmeadow & Ray, 2005 Wesche, 2002 Harrison *et al*., 2001	Plant new woodlands and extend and connect existing woodlands. Improve management of existing woodlands e.g. coppicing, restocking, stockproofing. Increase genotypic variation in woodlands by planting a range of genotypes. Monitor pests and disease. Woodland creation and management linked to wood-fuel production.

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
		This woodland is found along watercourses - ground flora is senstive to erosion and sedimentation		Trees – moderately vulnerable		

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Lowland meadows Found in the moorland fringe, undulating lowland farmland with wooded brooks, undulating lowland farmland with grassland, wooded rural valleys, valley floodplains and rolling upland farmland landscape character areas e.g. Far Holme Meadow, Tarnbrook Meadows and Clear Beck Meadow, New Ing Meadow SSSIs Supports great burnett and marsh marigold. Also breeding waders - lapwing, curlew, redshank, snipe, oystercatcher. Supports food production and pollination services.	Hotter summers Drier summers Warmer winters Wetter winters	Wet elements sensitive to drought and indirect impact of changes in plant phenology. Change in species mix towards stress-tolerant species. Could see a shift towards dry grassland. Sensitve to fire during dry periods. Dry elements sensitive to flooding which may change species composition (may be occuring at New Ing Meadow) and prevent cutting. Habitat likely to remain but to become less diverse.	*Environmental:* wet meadows are reliant on water availability, meadows with available water have higher adaptive capacity. Adaptive capacity limited by fragmentation and isolation of habitat. *Management*: lack of desigation reduces capacity to manage habitat.	Moderately vulnerable	Dunnet *et al.*, 1998 Gowing, 2004 Gowing *et al.* 2002 Hopkins *et al.* 2007 Rodwell *et al.* 2007 Walmsley *et al.* 2007	Encourage appropriate levels, cycles and types of stocking Promote the return of semi-improved grasslands to species-rich grassland Monitor key species Restoration and re-creation of wet grassland Adapt the management of hay meadows

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
		Sensitive to changes in farming practise as a result of climate change, particularly intensification. Vertebrates are sensitive to extremes occuring in any season				

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Lowland calcareous grassland Found in undulating lowland farmland with parkland landscape character area. E.g. Hodder Valley. Supports food production and pollination services.	Hotter summers Drier summers Warmer winters Wetter winters Intense rainfall events	Sensitive to changes in composition of species due to changes in rainfall regimes and increased temperatures. Potential for increased bracken growth. Sensitive to an increase in fires, drought and parching, erosion leading to damage to lower plant assemblages. Species which survive may become more dominant, reducing diversity.	*Environmental*: habitat on drought-prone soil so is already partially adapted to dry conditions. Plants with underground storage organs or deep roots may have greater adaptive capacity. Adaptive capacity limited by underlying geology and availability of calcareous soils. *Management*: adaptive capacity can be reduced by the response of other sectors to climate change e.g. changes in management, increased woodland planting and increases in visitor numbers.	Moderately vulnerable		Encourage appropriate levels, cycles and types of stocking. Promote the return of semi-improved grasslands to species-rich grassland. Monitor key species Adapt the management of hay meadows.

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Upland mixed ashwoods Found in unenclosed moorland hills, undulating lowland farmland with wooded brooks, wooded rural valleys landscape character areas. Supports roe deer and badgers. Supports fresh water, water quality, flood alleviation, climate regulation, pollination, tranquillity and recreation services.	Hotter summers Drier summers	Sensitive to changes in species composition may lead to shift in the relative contributions of the sub-types of upland ash. There may be potential for expansion of the 'dry' forms down slope on hot sites. Also sensitive to changes in ground flora composition. Wet parts of the habitat sensitive to flushes drying up. Sensitive to fire. May be sensitive to impacts of late frosts (although may occur less frequently) Sensitive to invasive species.	*Environmental*: lower adaptive capacity on south-facing slopes. The north west of England is projected to warm less than the south and east where this type of woodland has lower adaptive capacity. Adaptive capacity restricted due to small amount of suitable substrate (neutral and calcareous soils). Past grazing pressure may reduce adaptive capacity.	Moderately vulnerable	Broadmeadow & Ray, 2005 Wesche, 2002 Harrison *et a*l., 2001	Plant new woodlands and extend and connect existing woodlands. Increase genotypic variation in woodlands by planting a range of genotypes. Monitor pests and diseases. Woodland creation and management linked to wood-fuel production.

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Upland oakwoods Found in unenclosed moorland hills, enclosed moorland hills, undulating lowland farmland, undulating lowland farmland with wooded brooks, wooded rural valleys (Lune valley) and valley floodplains landscape character areas. Relict oaks found at the top of cloughs. Supports pied flycatcher, wood warbler and redstart. Also Atlantic bryophyte communities.	Drier summers Hotter summers	Sensitive to stress caused by drought and disease. Sudden oak death has not yet reached Bowland but could become more of a threat. Sensitive to changes in community composition - shift in the relative contributions of the sub-types of upland oak. Possible increased invasion of oakwoods by beech, conifers, sycamore and Himalayan balsam and change in ground flora composition.	*Environmental:* trees on well-drained, south facing slopes have lower adaptive capacity. Well established woodland communities are reasonably tolerant to temperature and precipitation change (within normal tolerances) but fragmented nature of habitat reduces adaptive capacity. Exisiting sources of harm (e.g. deer) in the AONB reduce adaptive capacity	Moderately vulnerable	Broadmeadow & Ray, 2005 Wesche, 2002 Harrison *et al*., 2001 Natural England survey on potential for upland oak woodland in the Forest of Bowland	Plant new woodlands and extend and connect existing woodlands. Increase genotypic variation in woodlands by planting a range of genotypes. Monitor pests and diseases. Woodland creation and management linked to wood-fuel production. Monitor Atlantic bryophyte communities.

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Supports fresh water, water quality, flood alleviation, climate regulation, pollination, tranquillity and recreation services		Sensitive to changes in grazing levels which could prevent regeneration. Open mossy areas sensitive to drying out in summer. Atlantic bryophyte communities are very sensitive to drying out.				

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Wood pasture and parkland Found in undulating lowland farmland, undulating lowland farmland with parkland landscape character areas. Supports fresh water, water quality, flood alleviation, climate regulation, pollination, tranquillity and recreation services	Drier summers Wind	Sensitive to drought and transpiration losses which can lead to loss of specialist associated species e.g fungi, saproxylic invertebrates. Sensitivity to drought can enhance risk of trees succombing to pests and diseases (although there is uncertainty over diseases). Sensitive to fire especially where tall grass heath present. Sensitive to changes in land use and the response of farmers to climate change (e.g. whether trees are re-planted).	*Environmental*: habitats on south facing slopes have lower adaptive capacity than those on sheltered valley sides. Ancient trees are already subject to multiple stresses and cumulative damage. Organisms adapted to veteran trees tend to be highly specialised with limited powers to disperse to other sites. *Management*: some areas of parkland are in fragmented ownership, making management more difficult. Some trees are 'landmark' trees with particular importance in the landscape and could be hard to replace.	Moderately vulnerable		Increase genotypic variation in woodlands by planting a range of genotypes. Plant replacement trees appropriate to climate. Monitor veteran trees. Monitor pests and diseases. Ensure appropritate grazing and tree protection from stock.

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Fens and swamps Small patches along river valleys, linked to bog remnants. Found in enclosed moorland hills, moorland fringe, undulating lowland farmland with wooded brooks, undulating lowland farmland with parkland and drumlin fields landscape character areas. Supports wading birds e.g. curlew, lapwing and snipe. Supports fresh water, water quality, flood alleviation, climate regulation services.	Drier summers Hotter sumemrs Intense rainfall	Sensitive to drought which leads to higher evapostranspiration and drying out of the fens and swamps. Also reduction in water quality due to less dillution of pollutants. This may lead to shift in community composition, oxidation of peat and subsequent release of nutrients. Sensitive to higher water temperature. Sensitive to high intensity rainfall and flooding. This may lead to ingress of pollutants and nutrients in runoff.	*Environmental*: fens encompass a wide range of habitat types, many of which will respond to climate change in different ways. These habitats are very fragemented and their small size may reduce adaptive capacity. *Management*: in some places the adaptive capacity of fen habitats may be constrained by water abstraction and / or nutrient enrichment from runoff from surrounding land.	Moderately vulnerable		Monitor key species Restoration and re-creation of wet grassland. Look for flood storage opportunities.

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Rivers and streams Fast flowing moorland streams found in moorland plateaux, unenclosed moorland hills, enclosed moorland hills, undulating lowland farmland, undulating lowland farmland with wooded brooks, undulating lowland farmland with settlement and industry, wooded rural valleys and valley floodplains landscape character areas.	Hotter summers Drier summers Wetter winters Intense rainfall	Sensitive to drought leading to low flows, poorer water quality and reduced habitat volume. Sensitive to higher temperatures which lead to thermal stress. Increased runoff leading to enhanced nutrient and sediment delivery causing eutrophication and also increased hydraulic scour of rivers.	*Environmental*: river species near the southern limit of the temperature tolerance have low adaptive capacity. Bankside and riverine vegetation can increase adaptive capacity. Adaptive capacity can depend on size of water course.Water courses adjacent to pastoral fields may have lower adaptive capacity due to nutrient inputs. Rivers and streams in the AONB generally have room to move and are relatively natural systems, increasing adaptive capacity.	Moderately vulnerable	O'Connell *et al*., 2004 Mainstone, 2000 Conlan *et al*., 2007	Enclosure of livestock to protect sensitive habitats. Look for flood storage opportunities. Review soil management plans. Ensure catchment scale action such as grip blocking upstream to decrease nutrient and sediment loading. Allow natural river flows and geomorphology.

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Supports riparian birds such as grey wagtail, dipper and common sandpiper. Also European eel, Atlantic salmon, brown/sea trout, brook lamprey in the Ribble and Loud, Mearley and Wigglesworth sub-catchments Supports food production, fresh water, flood alleviation, sense of place and recreation.		Sensitive to flashier flow regimes which destablise existing riverine sediments and river banks. Sensitive to increase in algae during warmer conditions.	*Mangement:* increased water demand in extreme dry periods can exacerbate ecological problems of low river flows and reduce adaptive capacity. Adaptive capacity may bereduced in rivers with surface water abstractions or which are used for energy schemes. Increased pressure for flood defences may lead to less dynamic river systems and impact on proteced species. Additional pressure from recreational uses.			

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Upland heath Found in the moorland plateaux, unenclosed moorland hills, enclosed moorland hils and moorland fringe landscape character areas. Supports golden plover, curlew, red grouse, hen harrier, peregrine, merlin, black backed gull. Contributes to food production, recreation (game shooting), pollination and tranquillity.	Higher annual average temperatures	Fairly robust to a wide range of climatic conditions. Sensitive to change in species composition leading to a shift from low lying upland heathland to lowland heathland. Possible decrease in *calluna* and increase in bell heather. Upland heath could expand into blanket bog areas as soils dry out. Possible spread of invasive species e.g. bracken and Himalyan balsam (may not be climate related, more management related). Possibly more susceptible to disease and pests	*Environmental*: current condition is poor in places due to over grazing and over burning. Condition of heath varies with land ownership. *Management*: some areas are already improving due to management. Some areas of the moors are under Environmental Stewardship. Areas managed for grouse shooting may have lower adaptive capacity.	Less vulnerable		Return semi-improved rough pasture and grass moorland to upland heath communities, where appropriate Encourage appropriate levels, cycles and types of stocking Review frequency of bracken removal Review heather burning plans

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
		e.g. heather beetle. Could have implications for grouse shooting. Sensitive to fire and uncontrolled burns, particularly if winter is wet and spring is dry. Sensitive to nitrate deposition.				

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Lowland dry acid grassland Found in moorland fringe and drumlin fields landscape character areas. Supports food production service.	Drier summers Warmer winters	Sensitive to drought and scorching although associated invertebrates and bird species may be more sensitive than flora. Very sensitive to bracken invasion as a result of fewer frost events. Sensitive to increase in fire risk	*Environmental:* habitat already on drought-prone soil so is already partially adapted to dry conditions. However, capacity to adapt to longer drought events may be low.	Less vulnerable		Encourage appropriate levels, cycles and types of stocking Review frequency of bracken removal Promote the return of semi-improved grasslands to species-rich grassland Monitor key species

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Hedgerows Found in undulating lowland farmland, undulating lowland farmland with wooded brooks, undulating lowland farmland with settlement and industry, valley floodplain, drumlin field landscape character areas. Supports food production and soil formation services.	Drier summers Higher annual average temperatures Wetter winters	Sensitive to drought and reduced soil moisture content. Species composition may change e.g. more beech may be planted, but hedgerows likely to remain. Sensitive indirectly to intensification of farming leading to removal of hedgerows. Wooded species sensitive to prolonged flooding during the growing season.	*Environmental*: condition of hedgerows depends on ownership. Older hedgerows likely to have lower adaptive capacity. *Management*: opportunities to manage through agri-environment schemes could increase adaptive capacity. Shorter hedge laying season (start in Nov now rather than Oct)	Less vulnerable	Broadmeadow *et al*., 2005 Broadmeadow, 2002	Review headgerow management. Use drought tolerant genotypes and locally sourced stock for replanting. Monitor flowering dates for hawthorn.

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Coniferous forest Found in forestry and reservoir landscape character area e.g. Gisburn Forest, Brennand valley and on Longridge Fell. Supports timber, water resources and quality, flood alleviation, climate regulation and recreation services	Drier summers Hotter summers	Sensitive to drought and transpiration losses which can cause stress and leave trees more vulnerable to pests and diseases. Sensitive to new pests and diseases.	*Environmental*: habitats on south facing slopes have lower adaptive capcity than those on sheltered valley sides. *Management:* areas are likely to be highly managed with scope for management change in response to climate change.	Less vulnerable		Plant new woodlands and extend and connect existing woodlands. Increase genotypic variation in woodlands by planting a range of genotypes. Monitor pests and diseases. Woodland creation and management linked to wood-fuel production. Review forest management plans

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Roadside verges	Hotter summers Drier summers Wetter winters Intense rainfall	Sensitive to drying out during summer and change of species composition. Also sensitive to flooding – road run-off likely to be directed to verges.	*Management:* likely to be managed already to some extent and has potential to be managed in future.	Less vulnerable		Increase sensitivity of vegetation management where appropriate Harvest seed for expansion of other grassland habitats. Monitor key species e.g. Twayblade, *Alchemilla.*

Table 3.2 - Vulnerability assessment of geodiversity and soils in the Forest of Bowland AONB

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Peaty, slowly permeable, wet, very acid upland soils Supports climate regulation, fresh water and water quality services	Drier summers Intense rainfall events	Sensitive to drying out and erosion leading to loss of peat store. Sensitive to gullying and hagging which results due to high overland flow during intense rainfall events.	*Environmental:* some soils are in poor condition due to historic drainage. *Management*: adaptive capacity depends on water level and scope to raise level.	More vulnerable		Review soil management plans. Adopt management practices to increase and stabilise ground water levels. Restore areas of eroded and exposed peat. Monitor peat depth.

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Very acid loamy upland soils: wet peaty surface Supports climate regulation, fresh water and water quality services	Drier summers Intense rainfall events	Sensitive to drying out and erosion leading to loss of peat store. Sensitive to gullying and hagging which results due to high overland flow during intense rainfall events.	*Environmental:* some soils are in poor condition due to historic drainage. *Management:* adaptive capacity depends on water level and scope to raise level.	More vulnerable		Review soil management plans. Adopt management practices to increase and stabilise ground water levels. Restore areas of eroded and exposed peat. Monitor peat depth. Encourage appropriate levels, cycles and types of stocking.

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Blanket bog peat soils Supports climate regulation, fresh water and water quality services	Drier summers Intense rainfall events	Sensitive to drying out, oxidation and loss during droughts. Sensitive to gullying and hagging which results due to high overland flow during intense rainfall events.	*Environmental:* some soils are in poor condition due to historic drainage. *Management*: adaptive capacity depends on water level and scope to raise level.	More vulnerable		Review soil management plans. Adopt management practices to increase and stabilise ground water levels. Restore areas of eroded and exposed peat. Monitor peat depth.

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Naturally wet, loamy and clayey floodplain soils	Wetter winters Intense rainfall events	Sensitive to flooding and increased risk of deposition from flood waters. Also sensitive to waterlogging and compaction when wet and more prone to erosion.	*Environmental:* areas of bare soil or those where organic matter contents are low will have low adaptive capacity. *Management:* cultivated soils are likely to have lower adaptive capacity.	Moderately vulnerable		Review soil management plans. Encourage appropriate levels, cycles and types of stocking.
Slow permeable, seasonally wet, acid loams and clay	Wetter winters Intense rainfall events	Sensitive to compaction when wet. Also sensitive to erosion. Sensitive to deposition of pollutants during flood events.	*Management:* Clay soils with a high shrink swell potential will become harder to manage.	Moderately vulnerable		Review soil management plans. Encourage appropriate levels, cycles and types of stocking.

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Shallow lime rich soils over chalk or limestone Supports food production service	Drier summers Intense rainfall events	Sensitive to drying out, oxidation and loss during droughts. Soil organisms are sensitive to drought as activity is reduced. Also sensitive to erosion by intense rainfall and wind.	*Environmental:* soils are shallow so have low adaptive capacity. Areas of bare soil have lower adaptive capacity. *Management*: cultivated soils are likely to have lower adaptive capacity.	Moderately vulnerable		Review soil management plans.

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Isolated hills and reef-knolls Found in undulating lowland farmland with parkland, undulating lowland farmland with settlement and industry landscape character areas e.g. Clitheroe Reef Knolls SSSI Supports sense of place and knowledge services	Hotter summers Wetter winters	Sensitive to increased rates of weathering and erosion.	*Environmental:* reef knolls are made of calcareous material which has a low resistance to erosion, thus adaptive capacity is low.	Moderately vulnerable		Review advice to landowners and managers about vegetation maintenance to support conservation of steep scarps, crags and rock screes. Increase frequency of vegetation management important geological sites.

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Gritstone terraces and escarpments Found in moorland plateaux, unenclosed moorland hills landscape character areas e.g. Bowland Knotts. Supports sense of place and soil formation services	Hotter summers Wetter winters	Sensitive to increased rates of weathering and erosion. Sensitive to increased vegetation growth obscuring feature. Also sensitive to changes in agriculture – change in grazing regime.	*Environmental:* Gritstone is a relatively hard, resistant rock (compared to shale or limestone) so has higher adaptive capacity.	Less vulnerable		Review advice to landowners and managers about vegetation maintenance to support conservation of steep scarps, crags and rock screes. Increase frequency of vegetation management important geological sites.

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Boulders, crags and glacial erratics Found in moorland plateaux, unenclosed moorland hills, enclosed moorland hills landscape character areas e.g. The Great stone of Fourstone near Bentham. Supports sense of place and knowledge services	Hotter summers Wetter winters	Sensitive to vegetation growth during longer growing seasons which obscures the geodiversity feature. Also sensitive to increased rates of weathering and erosion.	*Environmental:* adaptive capacity depends on the type of rock and how resistant to erosion it is.	Less vulnerable	Prosser *et al.*, 2006 Dickson *et al.*, 2007	Review advice to landowners and managers about vegetation maintenance to support conservation of steep scarps, crags and rock screes .

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
River and stream valleys (cloughs) Found in moorland plateaux, unenclosed moorland hills (e.g. Little Mearly Clough SSSI), enclosed moorland hills, undulating lowland farmland, undulating lowland farmland with wooded brooks landscape character areas. Supports flood alleviation, water quality, freshwater, sense of place and recreation services.	Wetter winters Intense rainfall events Hotter summers	Sensitive to flooding leading to increased erosion and sedimentation. Changes in erosion can lead to migration of the channel. Also sensitive to increased vegetation growth which can trap sediment and lead to channel migration.	*Environmental:* capacity to adapt may depend on whether rivers and streams have room to move. Rivers and streams in Bowland are generally un-confined therefore have higher adaptive capacity. *Management*: landowners may want rivers and streams to remain in a fixed position. Adaptive capacity may depend on presence of flood defence structures on rivers streams. Smaller streams in the Forest of Bowland are unlikely to have flood defence structures.	Less vulnerable	Prosser *et al.,* 2006	Increase frequency of vegetation management important geological sites.

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Braided river systems E.g. Langden Valley	Drier summers Wetter winters Intense rainfall events	Sensitive to flash flood events. Also sensitive to drying out in summer	*Environmental*: natural processes will continue. Relatively high adaptive capacity in Bowland as rivers have room to move.	Less vulnerable		
Rocky outcrops Found in unenclosed moorland hills, enclosed moorland hills (e.g. Bowland Knotts RIGS), undulating lowland farmland with parkland, rolling upland farmland, forestry and reservoir and drumlin fields landscape character areas. Supports sense of place, knowledge and soil formation services	Hotter summers Wetter winters	Sensitive to vegetation growth during longer growing seasons which obscures the geodiversity feature. Also sensitive to increased rates of weathering and erosion.	*Environmental:* adaptive capacity depends on the type of rock and how resistant to erosion it is.	Less vulnerable	Prosser *et al.,* 2006 Dickson *et al*., 2007	Review advice to landowners and managers about vegetation maintenance to support conservation of steep scarps, crags and rock screes. Increase frequency of vegetation management important geological sites.

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Exposures of fluvial and glacial drift Found in undulating lowland farmland with wooded brooks (e.g. Bashall Brook RIGS and Grindleton Dyke RIGS), undulating lowland farmland with parkland, undulating lowland farmland with settlement and industry, valley floodplains, rolling upland farmland and forestry and reservoir landscape character areas. Supports soil formation services	Hotter summers Wetter winters	Sensitive to increased rates of weathering and erosion.		Less vulnerable	Prosser *et al.,* 2006 Dickson *et al*., 2007	Increase frequency of vegetation management at important geological sites.

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Freely draining floodplain soil Supports flood alleviation service	Wetter winters Intense rainfall events	Sensitive to flooding and increased risk of deposition from flood waters. Also sensitive to compaction when wet and more prone to erosion.	*Environmental:* areas of bare soil or those where organic matter contents are low will have low adaptive capacity. *Management:* cultivated soils are likely to be more unstable and have lower adaptive capacity.	Less vulnerable		Review soil management plans. Encourage appropriate levels, cycles and types of stocking.
Freely draining slightly acid loamy soils Supports food production and flood alleviation services	Drier summers Intense rainfall events	Sensitive to drying out, oxidation and loss during droughts. Also sensitive to erosion during flood events.	*Environmental:* coarser textured (sandy) or shallower variants of this soil type are increasingly drought-prone and have lower adaptive capacity. Soils on steeply or moderately sloping land have lowest adaptive capacity.	Less vulnerable		Review soil management plans.

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Waterfalls and gorges Found in wooded rural valleys landscape character area. Supports sense of place	Wetter winters Intense rainfall events	Sensitive to flooding leading to increased erosion and sedimentation.	*Environmental:* adaptive capacity depends on the underlying rock type and how resistant to erosion it is.	Less vulnerable	Prosser *et al.,* 2006	
Oxbow lakes Found in valley floodplains landscape character area. Supports flood alleviation service	Wetter winters Intense rainfall events	Sensitive to flooding and increased sediment deposition leading to infilling of lakes. Process of forming oxbow lakes is generally insensitive to climate change although an increase in erosion rate may increase rate of geomorphological processes.		Less vulnerable	Prosser *et al.,* 2006	Look for flood storage opportunities.

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
River terraces Found in valley floodplains, wooded rural valleys (e.g. Hodder River Section SSSI) landscape character areas. Supports knowledge services	Wetter winters Intense rainfall events	Sensitive to flooding leading to increased erosion. Also sensitive to increased vegetation growth which can trap sediment and obscure the feature.	*Environmental:* adaptive capacity depends on the underlying rock type and how resistant to erosion it is.	Less vulnerable		Increase frequency of vegetation management important geological sites.
Drumlins Found in drumlin fields landscape character area. Supports sense of place.	Hotter summers Wetter winters	Sensitive to increased rates of weathering and erosion although change is only likely to occur over long time horizons (>100 years).		Less vulnerable		

Table 3.3 - Vulnerability of historic environment assets in the Forest of Bowland AONB

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Buried archaeology Thought to be found in peat soils although we don't know what is there e.g. moorland plateaux and moorland fringe landscape character area. Also in valley floodplains. Supports sense of place, recreation and knowledge services.	Hotter summers Drier summers Wetter winters	Sensitive to lower soil moisture content leading to drying out and erosion of soil. Cracking or heaving of soils can lead to exposure of assets. Sensitive to changes in soil chemistry (e.g. pH) and erosion caused by wetter conditions and flooding. Sensitive to crystallisation and dissolution of salts caused by wetting and drying which may damage archaeology. Sensitive to fires which may expose buried archaeology.	*Environmental*: each asset is a unique, non-renewable record. Extent of sensitivity is different for each asset but most have low tolerance of change before damage occurs. Depends on soil type – in peat soils waterlogging has preserved deposits anaerobically and they have a low adaptive capacity. *Management:* little capacity for management. Once damaged or destroyed, assets cannot be replaced.	More vulnerable	English Heritage, 2008	Adopt management practices to increase and stabilise ground water levels. Restore areas of eroded and exposed peat. Review heather burning plans. Monitor peat depth. Review soil management plans. Monitoring and recording of buried archaeology in floodplains.

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Designed landscapes Found in undulating lowland farmland (generally 50-150m elevation) with parkland, farmed ridges landscape character area e.g. Quernmore Park Hall, Cow Ark, Browsholme Hall, Stonyhurst College and Abbeystead. Supports sense of place, recreation, knowledge and pollination services	Drier summers Hotter summers Wetter winters Intense rainfall events	Sensitive to changes in growing seasons leading to community composition and loss of characteristic vegetation e.g. native beech is sensitive to hot, dry conditions and may be replaced with other species. Veteran trees are sensitive to storm damage. Parkland trees are highly sensitive to pests and diseases. Increased visitor numbers in hot weather may add to local pressures.	*Management*: these are intensively managed sites so there is capacity for intervention to support adaptation. However, a lot of their value is in the particular design, form of trees and layout which may reduce adaptive capacity. Some areas of parkland may have 10 year management plans as part of HLS.	More vulnerable	English Heritage, 2008	Review frequency of bracken removal and scrub management. Consider climate change in succession planning in historic landscapes. Monitor pests and diseases. Increase frequency of historic building surveys. Monitoring and recording of sites designated for their historic knowledge.

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Historic routeways Found in moorland fringe, valley floodplain, undulating lowland farmland with wooded brooks landscape character areas. Supports sense of place and knowledge services.	Drier summers Wetter winters	Sensitive to drought and erosion of routeway surfaces.	*Environmental:* adaptive capacity depends on the type of surface.	Moderately vulnerable		Monitoring and recording of sites designated for their historic knowledge.

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Dry stone walls and boundary walls Found throughout the AONB but particularly in enclosed moorland hills, moorland fringe, undulating lowland farmland, undulating lowland farmland with settlement and industry and rolling upland farmland landscape character areas. Supports food production and sense of place	Drier summers Wetter winters	Sensitive to drought and increased rates of erosion. Sensitive to flooding. Sensitive to ground subsidence caused by drying and cracking of soils. Sensitive to changes in agricultural practice in response to climate change. May see a reduction in walls if farming intensifies.	*Environmental:* may depend on current condition of dry stone walls. Most are in relatively good condition but there are some in a poor state of repair. Capped walls may have higher adaptive capacity. Adaptive capacity influenced by soil type and type of building material e.g. shale may have lower adaptive capacity.	Moderately vulnerable		More frequent maintenance of dry stone walls.

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
			Management: some walls covered by HLS, therefore higher management capacity. Greater allocation for fell walls than lowland walls so they may have greater management capacity. Management may depend on whether walls are currently used for stock.			

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Farm buildings and barns Found throughout the AONB. Supports food production, sense of place	Hotter summers Drier summers Wetter winters Intense rainfall events	Sensitive to repeated cycles of wetting and drying leading to increased weathering, splitting, cracking, flaking and dusting of surfaces. Sensitive to increased moisture content in building fabric and increased variability of water table. Could lead to decay of stonework or timber. Rainwater goods may be unable to cope with intense rainfall. Also sensitive to rising damp. Sensitive to ground subsidence caused by drying and cracking of soils.	*Environmental*: adaptive capacity will depend on the type of building materials, the age of the structure and the current condition. Limestone buildings may be less resistant to erosion than those made from gritstone. Abandoned buildings likely to have lower adaptive capacity. *Management*: many buildings are still in use therefore have high management capacity although used for storing machinery rather than hay or stock. Some barns covered by HLS, greater management capacity.	Moderately vulnerable	English Heritage, 2008	Increase frequency of vegetation management at important historic sites. Increase frequency of historic building surveys. Monitoring and recording of sites designated for their historic knowledge.

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Domestic buildings Found throughout the AONB but particularly in moorland fringe and undulating lowland farmland landscape character areas. Supports sense of place	Hotter summers Drier summers Wetter winters Intense rainfall events	Sensitive to repeated cycles of wetting and drying leading to increased weathering, crystallisation and dissolution of salts, splitting, cracking, flaking and dusting of surfaces. Sensitive to increased moisture content in building fabric and increased variability of water table. Could lead to decay of stonework or timber. Rainwater goods may be unable to cope with intense rainfall. Also sensitive to rising damp.	*Environmental*: adaptive capacity will depend on the type of building materials, the age of the structure and the current condition. Limestone buildings may be less resistant to erosion than those made from gritstone. Abandoned buildings likely to have lower adaptive capacity. *Management*: many buildings are still in use therefore have high management capacity.	Moderately vulnerable	English Heritage, 2008	Increase frequency of vegetation management at important historic sites. Increase frequency of historic building surveys . Monitoring and recording of sites designated for their historic knowledge.

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
		Sensitive to ground subsidence caused by drying and cracking of soils. Internal surfaces and fabrics sensitive to increased pest attacks, moulds and fungi.				

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Parkland structures Metal railings, ha has, and follies associated with designed landscapes e.g. Quernmore Park Hall, Cow Ark, Browsholme Hall, Abbeystead and Stonyhurst College. Supports sense of place, recreation and knowledge services	Drier summers Hotter summers Wetter winters	Sensitive to soils drying out and cracking, damaging foundations. Also sensitive to splitting, cracking, flaking and dusting of surfaces as a result of drought. Sensitive to increased vegetation growth due to a longer growing season which could obscure the features. Sensitive to corrosion of metals caused by higher temperatures and wetter conditions.	*Environmental:* adaptive capacity depends on age, fragility of materials and pre-existing damage. *Management:* these features are likely to be managed already so there is scope to manage to increase resilience to climate change. Potential management techniques may have significant adverse impact on aesthetics.	Moderately vulnerable	English Heritage, 2008	Review frequency of bracken removal and scrub management. Increase frequency of vegetation management. Increase frequency of historic building surveys. Monitoring and recording of sites designated for their historic knowledge.

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Vaccaries Found in unenclosed moorland hills and moorland fringe landscape character areas. Supports sense of place, knowledge and food production services	Hotter summers Drier summers Wetter winters	Walls and boundary features are sensitive to repeated cycles of wetting and drying leading to increased weathering. Sensitive to ground subsidence caused by drying and cracking of soils.	*Environmental:* adaptive capacity will depend on the type of building materials, the age of the structure and the current condition. Limestone buildings may be less resistant to erosion than those made from gritstone. Abandoned structures likely to have lower adaptive capacity.	Moderately vulnerable		More frequent maintenance of dry stone walls. Monitoring and recording of sites designated for their historic knowledge.
Quarries Abandoned quarries found in unenclosed moorland hills (e.g. gritstone quarries at Clougha, Wolf Fell and Saddle Fell) and moorland fringe landscape character areas. Supports minerals and knowledge services	Drier summers Hotter summers Wetter winters	Sensitive to an increase in erosion leading to loss of exposed surfaces. Also sensitive to increased vegetation growth which can obscure features.		Moderately vulnerable		Increase frequency of vegetation management. Monitoring and recording of sites designated for their historic knowledge.

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Field patterns Found in enclosed moorland hills, undulating lowland farmland (ridge and furrow), valley floodplains and drumlin fields landscape character types. Support knowledge and sense of place	Drier summers Hotter summers Wetter winters	Sensitive to an increase in soil erosion caused by drying out of soil or flooding. Also sensitive to increased vegetation growth which can obscure field patterns.	*Environmental:* adaptive capacity may depend on the soil type where the historic field pattern is found.	Moderately vulnerable		Review soil management plans. Increase frequency of vegetation management. Monitoring and recording of sites designated for their historic knowledge.

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Kilns Found in undulating lowland farmland landscape character area e.g. Roman kilns at Quernmore and others in the Hodder valley. Supports knowledge and sense of place	Hotter summers Drier summers Wetter winters Intense rainfall events	Sensitive to repeated cycles of wetting and drying leading to increased weathering, crystallisation, dissolution of salts, splitting, cracking, flaking and dusting of surfaces. Sensitive to increased moisture content in building fabric and increased variability of water table. Could lead to decay of stonework or timber. Sensitive to ground subsidence caused by drying and cracking of soils.	*Environmental*: adaptive capacity will depend on the type of building materials, the age of the structure and the current condition.	Moderately vulnerable		Increase frequency of vegetation management at important historic sites. Increase frequency of historic building surveys. Monitoring and recording of sites designated for their historic knowledge.

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Water powered industrial features Found in wooded rural valleys landscape character area (e.g. mill lodges and historic mill sites, including mill ponds, races, sluices and weirs) and undulating farmland with wooded brooks landscape character type (e.g. mills at Calder Vale, Caton and Sabden) Supports sense of place and recreation services	Wetter winters Intense rainfall events	Sensitive to flooding and increased flows which could damage historic structures.	*Management*: if the structure is still is use it is likely to be managed thus has higher adaptive capacity.	Moderately vulnerable		Increase frequency of historic building surveys. Monitoring and recording of sites designated for their historic knowledge.

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Motte and bailey castles Found in valley floodplain landscape character area (e.g. the Castle Stead near Hornby, Sawley Abbey) and Norman castle at Clitheroe. Supports sense of place, knowledge and recreation services	Drier summers Hotter summers Wetter winters	Sensitive to drought and soil erosion which could result in loss of the feature. Also sensitive to increased vegetation growth which may obscure the feature.	*Environmental:* adaptive capacity may depend on soil type.	Moderately vulnerable		Increase frequency of vegetation management at important historic sites. Monitoring and recording of sites designated for their historic knowledge.

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Churches Found in moorland fringe, undulating lowland farmland, wooded rural valleys (e.g. deserted church at Littledale), forestry and reservoir (e.g. church at Stocks Reservoir) landscape character areas. Support sense of place	Hotter summers Drier summers Wetter winters Intense rainfall events	Sensitive to repeated cycles of wetting and drying leading to increased weathering, crystallisation, dissolution of salts, splitting, cracking, flaking and dusting of surfaces. Sensitive to increased moisture content in building fabric and increased variability of water table. Could lead to decay of stonework or timber. Rainwater goods may be unable to cope with intense rainfall. Also sensitive to rising damp.	*Environmental:* adaptive capacity will depend on the type of building materials, the age of the structure and the current condition. Limestone buildings may be less resistant to erosion than those made from gritstone. Abandoned buildings likely to have lower adaptive capacity. *Management:* many buildings are still in use therefore have high management capacity.	Moderately vulnerable	English Heritage, 2008	Increase frequency of historic building surveys. Monitoring and recording of sites designated for their historic knowledge.

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
		Sensitive to ground subsidence caused by drying and cracking of soils. Internal surfaces and fabrics sensitive to increased pest attacks, moulds and fungi.				

Table 3.4 - Vulnerability of natural resources in the Forest of Bowland

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Fisheries Rivers Ribble, Hodder, Wyre and Lune used for fishing (salmon, sea trout and brown trout) Reservoirs – Stocks reservoir is one of the top 5 largest trout fisheries in the UK Supports food production and recreation services	Drier summers Hotter summers Wetter winters	Sensitive to low flows and higher water temperatures which can reduce water quality. Fish may migrate in response. Water quality and chemistry (e.g. pH) can also deteriorate as a result of pollutants and sediment washed into water bodies during floods.	*Environmental:* adaptive capacity depends on characteristics of the water body e.g. size, depth *Management:* managed fisheries are likely to have greater scope for management, assuming habitat is in good condition. . Fish stocks in the River Hodder which are not managed may have lower adaptive capacity.	More vulnerable	Work done by Ribble Conservation Trust (and other Trusts)	Enclosure of livestock to protect sensitive habitats. Review reservoir operations to take account of climate change. Look for flood storage opportunities.

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
In-bye pastures Found throughout the lowland farmland landscape character areas. Supports food production, fresh water, flood alleviation and sense of place	Hotter summers Drier summers Wetter winters Intense rainfall events	Grassland is sensitive to drying out during summer, reducing available pasture. Sensitive to flooding and waterlogging.	*Environmental*: adaptive capacity may depend on species present and underlying soil type which affects drainage. *Management:* land is currently managed so has some adaptive capacity. May depend on stocking level.	Moderately vulnerable		Encourage appropriate levels, cycles and types of stocking. Review soil management plans.
Surface water intakes Surface water resources - intakes on major rivers inc. Lune, Hodder, Wyre, Roeburn, Ribble and Hindburn Supports fresh water service	Drier summers	Sensitive to low water levels in summer – pressure on water resources during time of higher demand. Potential increase in water availability in winter.	*Environmental*: adaptive capacity may be reduced due to present levels of abstraction, although abstraction rates have been reduced in some places e.g. River Brennand. Flows are likely to be protected, increasing adaptive capacity. *Management:* there may be some adaptive capacity due to transfer schemes set up to alleviate low flows.	Moderately vulnerable		

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Boreholes On-farm boreholes, particularly dairy farms	Drier summers	Sensitive to drying out in summer. Sensitive to changes in agricultural practice – potential increase in boreholes as farmers wish to have greater control of water resources.	Environmental: adaptive capacity depends on underlying geology	Moderately vulnerable		Adopt management practices to increase and stabilise ground water levels
Areas of managed planting and coppicing Coniferous forest plantation woodland at Gisburn Forest, Brennand valley and Longridge Fell. Supports timber, energy, fresh water, water quality, recreation and flood alleviation services	Hotter summers Drier summers	Trees are particularly sensitive to drought which leads to stress and exacerbates the risk of pests and diseases.	Environmental: older trees are likely to have lower adaptive capacity. Coppices likely to be uniform age which could reduce adaptive capacity. Management: species composition is managed so adaptive capacity is likely to be high.	Moderately vulnerable		Plant new woodlands, extend and connect existing woodlands. Increase genotypic variation in woodlands. Monitor pests and diseases. Review forest management plans. Woodland creation and management linked to wood-fuel production.

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Quarries Quarries and cement works found in the area to the east of Clitheroe. Support minerals and knowledge services	Hotter summers Wetter winters	Sensitive to vegetation growth during longer growing seasons which obscures the rock exposure. Sensitive to increased rates of weathering and erosion during hotter drier summers and also due to flood events.	*Management*: active quarries are intensively managed therefore have higher adaptive capacity	Less vulnerable	Prosser *et al.,* 2006. Dickson *et al*., 2007	Review quarry management plans to take account of climate change.
Reservoirs Stocks, Barley and Barnacre reservoirs. Supports fresh water, recreation and flood alleviation services	Hotter summers Drier summers Wetter winters Intense rainfall events	Sensitive to lower water levels in summer leading to increased pressure on water resources. Low water levels reduce water quality and expose dam and reservoir structures to higher temperatures. Sensitive to increase in water levels and flooding. Increase in sedimentation and reduction in water quality. Fish stocks in reservoirs sensitive to changes in water quality due to droughts or flooding.	*Environmental*: capacity may depend on age and construction materials of reservoirs. The safety margins built into these structures are considerable: they are designed to cope with 1 in 1000 year events. *Management:* reservoirs are highly managed systems so should have capacity to manage for climate change.	Less vulnerable		Review frequency of bracken removal and scrub management. Review reservoir operations to take account of climate change.

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Reservoir 'furniture' e.g. stone walls, roads and slipways and buildings Associated with Stocks, Barley and Barnacre reservoirs. Also Haweswater and other aqueducts have overground 'furniture' e.g. gates, inspection chambers and pipes over rivers. Supports fresh water service	Hotter summers Drier summers Wetter winters Intense rainfall events	Sensitive to drying out and cracking during dry summers. Also sensitive to flooding and high flows which exceed capacity.	*Environmental:* The safety margins built into these structures are considerable: they are designed to cope with 1 in 1000 year events. *Management:* reservoirs are highly managed systems so should have capacity to manage for climate change.	Less vulnerable		Review reservoir operations to take account of climate change.

Table 3.5 - Vulnerability of other landscape features in the Forest of Bowland AONB

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Footpaths and bridle paths Found throughout the AONB – lower density in the uplands, a denser network in the fringe areas. Long distance paths include Ribble Way, Pennine Way and Pendle Way, Wyre Way, Lunesdale Walk, Lune Valley Ramble, Journey through the Centre of the Kingdom. Support recreation service	Hotter summers Drier summers Wetter winters Higher annual average temperatures	Surfaces sensitive to drying out and erosion during droughts. More sensitive to erosion during flood events (already seeing damage during wet winters). Sensitive to becoming obscured by vegetation due to longer growing seasons. Potential for changes in demand and different usage patterns – possible increase in visitor numbers and demand for paths. Greater demand for mountain biking and fell running. Could become more congested and suffer erosion.	*Environmental:* adaptive capacity depends on soil type; paths on waterlogged soil are most sensitive to erosion by flooding whereas paths on drier soils may be more susceptible to erosion during summer *Management:* diverse nature of footpaths, bridleways etc. may reduce vulnerability of the network as a whole although density in the uplands is low. Paths which are already well managed likely to have higher adaptive capacity.	More vulnerable		Develop new rights of way. Increase maintenance on the rights of way network. Prepare a visitor fire risk plan for heathland and peatland areas.

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Sheep folds Found in moorland plateaux, enclosed moorland hills landscape character areas. Support food production and sense of place	Hotter summers Wetter winters	Sensitive to increased rates of weathering and erosion. Also sensitive to vegetation growth during longer growing seasons which obscures the feature. Also sensitive to ground subsidence caused by drying and cracking of soils.	*Management:* sheep folds are no longer used therefore unlikely to be managed.	Moderately vulnerable	Prosser *et al.,* 2006. Dickson *et al*., 2007	More frequent maintenance of dry stone walls.
Small scale industrial buildings e.g. cheese making Found in undulating lowland farmland and valley floodplains landscape character areas. E.g. Leagram, Dewlay. Supports food production.	Hotter summers Drier summers Wetter winters Intense rainfall events	Buildings are sensitive to repeated cycles of wetting and drying leading to increased weathering. Buildings and industrial uses are sensitive to flooding. Also sensitive to ground subsidence caused by drying and cracking of soils.	*Environmental*: often small scale industry is housed in historic buildings - adaptive capacity will depend on the type of building materials, the age of the structure and the current condition. *Management*: buildings are in use therefore have high management capacity.	Moderately vulnerable	English Heritage, 2008	Increase frequency of historic building surveys.

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Large scale industrial buildings Found in undulating lowland farmland with settlement and industry landscape character areas. Industry including tarmac works, cement works and industrial estates. Supports sense of place and minerals services	Hotter summers Drier summers Wetter winters Intense rainfall events	Buildings are sensitive to repeated cycles of wetting and drying leading to increased weathering. Also sensitive to ground subsidence caused by drying and cracking of soils. Buildings and industrial uses are sensitive to flooding.	*Environmental*: adaptive capacity will depend on the type of building materials, the age of the structure and the current condition. *Management*: buildings are in use therefore have high management capacity.	Moderately vulnerable		Increase frequency of historic building surveys.
Fords Found in wooded rural valleys landscape character areas.	Wetter winters Intense rainfall events	Sensitive to flooding in winter or during extreme rainfall events which prevent the ford being used.		Moderately vulnerable		Increase maintenance on the rights of way network.

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Visitor centres E.g. Beacon Fell Supports recreation function	Hotter summers Drier summers Wetter winters Intense rainfall events	Buildings are sensitive to repeated cycles of wetting and drying leading to increased weathering. Buildings and contents uses are sensitive to flooding. Also sensitive to ground subsidence caused by drying and cracking of soils. Potential for increase in visitors to the area as a result of warmer, drier summers – increase in demand for visitor centres.	*Environmental*: often visitor centres are housed in historic buildings - adaptive capacity will depend on the type of building materials, the age of the structure and the current condition. *Management*: buildings are in use therefore have high management capacity.	Moderately vulnerable	English Heritage, 2008	Increase frequency of historic building surveys. Develop visitor management plans at most popular sites. Change education and interpretation practice to reflect landscape change and promote understanding of climate change.

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Grouse butts Found in moorland plateaux, unenclosed moorland hills, enclosed moorland hills landscape character areas. Support recreation and food production (game shooting) services.	Hotter summers Wetter winters Intense rainfall events	Sensitive to increased rate of vegetation growth which may obscure the butt. Sensitive to flooding and erosion caused by high overland flows.	*Management:* relatively easy to build new grouse butts.	Less vulnerable		Increase frequency of vegetation management.
Cairns and stone towers Found in moorland plateaux landscape character areas. Support sense of place.	Hotter summers Wetter winters	Sensitive to increased rates of weathering and erosion. Also sensitive to vegetation growth during longer growing seasons which obscures the feature. Also sensitive to ground subsidence caused by drying and cracking of soils.	*Environmental:* adaptive capacity depends on rock type used to build cairns. For example, gritstone is more resistant to weathering than limestone and has higher adaptive capacity. *Management:* relatively easy to build new cairns although historic significance may be lost.	Less vulnerable	Prosser *et al.,* 2006. Dickson *et al*., 2007	Increase frequency of vegetation management.

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Shooting tracks and sheep tracks Found in moorland plateaux, unenclosed moorland hills, enclosed moorland hills landscape character areas. Support recreation and food production (game shooting) services.	Drier summers Wetter winters Intense rainfall events	Surface sensitive to drying out and loss through erosion. Also sensitive to erosion during flood events. Increase in summer temperatures may increase visitor numbers leading to more usage of tracks.	*Environmental:* adaptive capacity depends on soil type; paths on waterlogged soil are most sensitive to erosion by flooding whereas paths on drier soils may be more susceptible to erosion during summer. Shooting tracks do not currently experience high usage so have higher adaptive capacity.	Less vulnerable		Increase maintenance on the rights of way network. Prepare a visitor fire risk plan for heathland and peatland areas.
Network of minor roads and lanes Found in undulating farmland with wooded brooks landscape character areas. Support sense of place and recreation	Hotter summers Drier summers Wetter winters Higher annual average temperatures	Surfaces sensitive to cracking and heaving during droughts. Also sensitive to erosion during flood events. Sensitive to increased vegetation growth encroaching on the right of way. Potential for changes in demand and different usage patterns – possible increase in visitor numbers. Could become more congested.	*Environmental:* the extent of the network may reduce vulnerability of the network as a whole as alternative routes may be available. The route of roads and lanes is unlikely to be affected by climate change event if surfaces are sensitive. *Management:* Roads are likely to be managed at present so capacity to manage impacts of climate change.	Less vulnerable		Develop new rights of way. Increase maintenance on the rights of way network. Encourage use of public transport.

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Settlements Found throughout the lowland areas of the AONB below the moorland fringe but particularly in undulating lowland farmland with settlement and industry landscape character areas. Support sense of place and recreation	Hotter summers Drier summers Wetter winters Intense rainfall events	Settlements as a feature are unlikely to be sensitive to climate change and are likely to remain in their present locations. However, individual buildings may be sensitive (see 'domestic buildings' in the historic environment section).		Less vulnerable		Increase frequency of historic building surveys.
Post and wire fences Found in undulating lowland farmland with settlement and industry and valley floodplains landscape character areas. Supports food production	Hotter summers Drier summers Wetter winters Intense rainfall events	Fences may be sensitive to cracking and subsidence of soils during droughts. Also sensitive to erosion at the base of posts during flood events.	*Management:* relatively easy to re-construct a post and wire fence therefore high adaptive capacity.	Less vulnerable		

Asset	Exposure	Sensitivity	Adaptive capacity	Relative vulnerability rating	References	Adaptation actions
Modern farm buildings Found in undulating lowland farmland landscape character areas. Supports food production service	Hotter summers Drier summers Wetter winters Intense rainfall events	Buildings are sensitive to repeated cycles of wetting and drying leading to increased weathering. Also sensitive to ground subsidence caused by drying and cracking of soils. Buildings and contents are sensitive to flooding. Changes in agricultural practice – could see more modern farm buildings.	*Management*: buildings are in use therefore have high management capacity.	Less vulnerable		

Table 3.6 - Adaptation actions for landscape character types and ecosystem services

Adaptation action	Landscape Character Types														Ecosystem Services											
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	Soil	Food	Timber	Energy	Water	Minerals	C store	Flood	Pollination	SoP	Recreation	Knowledge
Return semi-improved rough pasture and grass moorland to upland heath communities, where appropriate	✓	✓	✓																✓			✓	✓	✓		
Adopt management practices to increase and stabilise ground water levels	✓	✓	✓							✓	✓	✓			✓				✓		✓					✓
Restore upland mire communities and bog-mosses	✓	✓	✓												✓				✓		✓			✓		✓
Restore areas of eroded and exposed peat	✓	✓	✓								✓	✓			✓				✓		✓					✓
Encourage appropriate levels, cycles and types of stocking	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓			✓	✓	✓			✓							
Review frequency of bracken removal	✓	✓	✓	✓			✓																			

Adaptation action	Landscape Character Types														Ecosystem Services											
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	Soil	Food	Timber	Energy	Water	Minerals	C store	Flood	Pollination	SoP	Recreation	Knowledge
Provide advice about the frequency and methods of vegetation maintenance on steep scarps, crags and rock screes	✓																							✓		
Review heather burning plans	✓	✓	✓																				✓		✓	
Monitor peat depth	✓	✓	✓								✓				✓						✓					
Plant new woodlands and extend and connect existing woodlands		✓	✓		✓	✓	✓		✓	✓			✓				✓	✓			✓			✓		
Increase genotypic variation in woodlands by planting a range of genotypes		✓	✓		✓	✓	✓		✓	✓			✓				✓	✓			✓					
Upland hay meadow creation				✓								✓											✓	✓		
More frequent maintenance of dry stone walls			✓	✓	✓		✓	✓				✓		✓		✓								✓		
Review soil management plans			✓		✓		✓					✓		✓	✓	✓			✓		✓	✓				✓

Adaptation action	Landscape Character Types														Ecosystem Services											
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	Soil	Food	Timber	Energy	Water	Minerals	C store	Flood	Pollination	SoP	Recreation	Knowledge
Promote the return of semi-improved grasslands to species-rich grassland				✓	✓		✓			✓		✓											✓	✓		
Review and adapt vegetation management on roadside verges and at important historic and geological sites		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓													✓	✓	✓
Review hedgerow management			✓	✓	✓	✓	✓	✓				✓			✓	✓						✓				
Consider climate change in succession planning in historic landscapes					✓		✓			✓														✓	✓	
Restoration and re-creation of wet grassland and wet woodland				✓		✓				✓									✓			✓		✓		
Monitor pests and diseases						✓							✓			✓	✓									
Increase frequency of historic building surveys							✓	✓																✓	✓	✓
Adapt the management of hay meadows										✓		✓											✓			

Adaptation action	Landscape Character Types														Ecosystem Services											
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	Soil	Food	Timber	Energy	Water	Minerals	C store	Flood	Pollination	SoP	Recreation	Knowledge
Monitoring and recording of buried archaeology in floodplains										✓																✓
Provide shelter for livestock in summer					✓	✓	✓									✓										
Provide information to farmers about diversification into previously un-farmed areas		✓	✓	✓												✓										
Enclosure of livestock to protect sensitive habitats		✓	✓	✓					✓	✓						✓			✓							
Review forest management plans													✓				✓	✓			✓					
Woodland creation and management linked to wood-fuel production		✓	✓		✓	✓			✓		✓	✓	✓				✓	✓			✓					
Increase area and connectivity of semi-natural habitats	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				✓		✓	✓	✓	✓	✓	✓

Adaptation action	Landscape Character Types														Ecosystem Services											
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	Soil	Food	Timber	Energy	Water	Minerals	C store	Flood	Pollination	SoP	Recreation	Knowledge
Review reservoir operations to take account of climate change													✓						✓			✓			✓	
Review quarry management plans to take account of climate change								✓												✓						
Identify the amount of carbon stored in blanket bog	✓	✓	✓																		✓					
Look for flood storage opportunities						✓				✓												✓				
Late cutting of road verges and grassy margins around pasture																							✓			
Change education and interpretation practice to reflect landscape change																								✓	✓	✓
Develop new rights of way																								✓	✓	
Develop visitor management plans at most popular sites																								✓	✓	

Adaptation action	Landscape Character Types														Ecosystem Services											
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	Soil	Food	Timber	Energy	Water	Minerals	C store	Flood	Pollination	SoP	Recreation	Knowledge
Review reservoir operations to take account of climate change													✓						✓			✓			✓	
Review quarry management plans to take account of climate change								✓												✓						
Identify the amount of carbon stored in blanket bog	✓	✓	✓																		✓					
Look for flood storage opportunities						✓				✓												✓				
Late cutting of road verges and grassy margins around pasture																							✓			
Change education and interpretation practice to reflect landscape change																								✓	✓	✓
Develop new rights of way																								✓	✓	

Adaptation action	Landscape Character Types														Ecosystem Services											
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	Soil	Food	Timber	Energy	Water	Minerals	C store	Flood	Pollination	SoP	Recreation	Knowledge
Develop visitor management plans at most popular sites																								✓	✓	
Encourage use of public transport																								✓	✓	
Increase maintenance on rights of way network and amenity areas	✓	✓	✓							✓															✓	
Prepare a visitor fire risk plan for heathland and peatland areas	✓	✓	✓																						✓	
Monitor and record sites designated for historic or geological knowledge	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓										✓		✓

3.4 Description of specific adaptation actions

Specific adaptation actions are described below. These are grouped under the headings of actions which address vulnerability of upland areas, ie most of the Bowland Fells NCA; those which address vulnerability in lowland areas, ie mostly the Bowland Fringe NCA (see figs 1.1 and 1.2); and those which address the vulnerability of ecosystem services.

Upland landscape character types include:

- Moorland plateaux;
- Unenclosed moorland hills;
- Enclosed moorland hill;
- Moorland fringe;
- Rolling upland farmland and farmed ridges.

Lowland landscape character types include:

- Undulating lowland farmland;
- Undulating lowland farmland with wooded brooks;
- Undulating lowland farmland with parkland;
- Undulating lowland farmland with settlement and industry;
- Wooded rural valleys;
- Valley floodplain;
- Drumlin fields; and
- Forestry and reservoir.

3.4.1 Upland actions

Return semi-improved rough pasture and grass moorland to upland heath communities, where appropriate

Landowners are only likely to undertake this action if it is incentivised, for example through Higher HLS.

Adopt management practices to increase and stabilise water levels

Reversing historic drainage by grip blocking enhances the moisture content of blanket bog soils. It also contributes to the preservation of buried archaeology. A considerable amount of work has already been undertaken in the Forest of Bowland, mainly through SCaMP and HLS agreements. For example, work has already taken place at Whitray and Greenbank and is soon to start at Bleasdale. A priority area for further work is Abbeystead.

Restore upland mire communities and bog-mosses

Where possible, work to restore sphagnum in upland areas should be undertaken. However, the potential to establish active blanket bog may be limited as it is difficult to retain water on slopes. Examples of successful re-establishment of sphagnum exist in the Peak District and it may be useful to see what lessons can be learnt from this experience.

Restore areas of eroded and exposed peat

This involves re-profiling and re-vegetating gully edges as well as re-vegetating peat areas. Through SCaMP, 450ha of bare peat have been re-vegetated, for example at Langdon Head and Brown Syke. There is still work to be done at Wolf Fen, Bleasdale and Abbeystead. This could be delivered through HLS.

Encourage appropriate levels, cycles and types of stocking

There is uncertainty over the impact of climate change on vegetation growth so it is important that landowners and managers regularly review stocking arrangements to take account of change. It may be necessary to adapt the type (e.g. cattle as well as sheep), levels and timing of stocking according to changes in vegetation and land managers should be encouraged to do this, possibly through HLS agreements. This is an example of adaptive management.

Review frequency of bracken removal

Climate change may increase the rate of bracken growth and more frequent removal may be required, particularly during warmer summers. Land managers should review the need to remove bracken on a regular basis.

Review advice to landowners and managers about vegetation maintenance to support conservation of steep scarps, crags and rock screes

The AONB management plan already includes an action to provide advice to landowners and managers about vegetation maintenance. This advice should be reviewed to take account of climate change: more frequent vegetation maintenance is likely to be required if vegetation growth becomes more vigorous during longer growing seasons.

Review heather burning plans

Heather burning plans should be reviewed to ensure they consider the impacts of climate change. For example, there may need to be a change in the timing of burning in response to changes in phenology caused by climate change. Burning plans can be part of HLS agreements (see Figure 3.1) and on SSSIs plans are reviewed every 6 years. This is an example of an adaptive management response and the frequency of review may need to increase in order to respond to changes in vegetation due to climate change.

Figure 3.1 – Controlled heather burning on moorland hills ©Graham Cooper

Monitor peat depth

It is important to monitor the peat depth in order to understand the impact of climate change but also to evaluate the results of management.

Plant new woodlands and extend and connect existing woodlands

Tree planting in upland areas has already been undertaken in parts of the Forest of Bowland through SCaMP and HLS. More than 200ha have been planted through SCaMP in the past 5 years. There could be opportunities to join up existing patches of valley woodlands by focusing planting in cloughs. Future areas for woodland planting through HLS include Whitray and Botton Head.

The natural regeneration of existing woodlands should also be supported, particularly in the small areas of ancient semi-natural woodland which exist in the Forest of Bowland. This may require fencing to allow trees to regenerate, as has been done at Littledale through an HLS agreement. However, this can conflict with landscape objectives and should only be undertaken in appropriate areas following an assessment of the potential impacts.

Increase genotypic variation in woodlands by planting a range of genotypes

Genotypic variations are caused by differences in number or structure of chromosomes or by differences in the genes carried by the chromosomes and is an important factor in determining the adaptive capacity of habitats. Communities with a high degree of genotypic variation are likely to have a higher degree of adaptive capacity as not all trees will be

affected to the same extent. It is therefore important that new woodland planting includes a range of genotypes. The increase in occurrence of drought conditions may favour drought resistant genotypes. Woodland creation schemes planting should therefore consider planting more drought resistant genotypes in order to adapt to climate change.

Upland hay meadow creation

It may be possible to extend the area of upland hay meadow habitat through seed collection and spreading. This could be incentivised through HLS.

Monitor key species

As noted under strategic actions, monitoring is important to identify how habitats and species are responding to climate change. It is also central to adaptive management approaches. Key species to monitor in upland areas of the Forest of Bowland include: ring ouzel, hen harrier. Manchester treble bar, cloudberry, sphagnum, chickweed wintergreen and pale forget-me-not.

More frequent maintenance of dry stone walls

More frequent maintenance is likely to be required in response to wetter winters and drier summers. There is currently a greater allocation for fell walls under HLS, therefore many walls are likely to be managed already. Further walls could be included as part of HLS agreements in future.

Review soil management plans

Land management practices which reduce negative impacts on soil structure are important for many reasons but can increase the resilience of the natural environment to climate change. Existing soil management plans and risk assessments are carried out as part of HLS agreements. These plans should be reviewed to take account of climate change and to ensure opportunities to increase the resilience of soils are maximised.

3.4.2 Lowland actions

Promote the return of semi-improved grasslands to species-rich grassland

Landowners are only likely to undertake this action if it is incentivised, for example through HLS agreements. Where this is undertaken there are likely to be opportunities to provide habitat for wading birds.

Encourage appropriate levels, cycles and types of stocking

This action, as described above for upland areas, is also important in lowland areas. Ensuring stocking levels are appropriate and flexible to changing vegetation conditions will be important for the management of grassland habitats. This action can be delivered through HLS, for example at Cobble Hey cutting times and stocking rates are currently managed to benefit wading birds.

Review frequency of bracken removal and scrub management

This action, as described above for upland areas, is also important in lowland areas. Bracken removal is likely to be particularly important in riparian areas and reservoir edges in order to maintain habitat for birds and invertebrates. Scrub management should also be focused on historic sites, for example, around parkland structures and at riparian margins to maintain grassland, fen and swamp habitats.

Monitor key species

Key species to monitor in lowland areas of the Forest of Bowland include: lapwing (see Figure 3.2), curlew, snipe and redshank.

Figure 3.2 – Lapwing ©Andy Hay RSPB-images.com

More frequent maintenance of dry stone walls

This action, as described above for upland areas, is also important in lowland areas. Walls in the lowlands currently have a lower allocation of funds under HLS than fell walls. Maintaining dry stone walls in lowland area therefore needs to be a priority and may require changes to HLS agreements.

Review and adapt vegetation management on roadside verges and at important historic and geological sites

Longer growing seasons may increase the rate of growth of vegetation, changing maintenance requirements. Roadside verges need to be managed appropriately for the species found there and management should be reviewed and adapted to take account of changing conditions. At sites of historic and geological interest, more frequent vegetation management may be required during summer to prevent historic features and geological exposures from becoming obscured. More frequent pruning and cutting may also be required in managed parks and gardens.

Review hedgerow management

The frequency and timing of hedgerow maintenance needs to be reviewed to take account of phonological changes as a result of climate change. The hedge laying season has already been shortened and now starts in November rather than October due to warmer autumns.

Review soil management plans

This action, as described above for upland areas, is also important in lowland areas. Land management practices that reduce negative impacts on soil structure are particularly important on soils with a high proportion of clay which are vulnerable to compaction and puddling. Soil moisture conservation measures will be particularly important in areas with shallow lime rich soils which are likely to be more drought prone.

Consider climate change in succession planning in historic landscapes

Current 10-year succession plans for historic landscapes should consider the impact of climate change and develop appropriate adaptation responses. For example, where there is a programme of planting trees next to veteran tress, drought resistant genotypes could be favoured. It may also be necessary to undertake crown works on veteran trees to reduce the root to crown ratio. Individual veteran trees which are historically significant may need to be stabilised.

Restoration and re-creation of wet grassland and wet woodland

Wet grassland and wet woodland habitat patches are highly fragmented in the lowland areas of the Forest of Bowland and there are opportunities to increase connectivity through habitat creation. The Environment Agency is looking into

the feasibility of suitable sites in the Lower Ribble area for habitat creation[19]. HLS could also be a suitable mechanism for delivering this action.

Monitor pests and diseases

Whilst this may be done at a national scale by organisations such as Defra, there could be benefit in setting up a local system for monitoring and sharing information on pests and diseases between land owners and managers.

Increase frequency of historic building surveys

Historic buildings and structures should be surveyed frequently to identify any structural problems or damage caused by wetting and drying. This should allow remedial actions to be taken if necessary including more frequent maintenance of roofs, guttering and mortar joints. Larger and more efficient rainwater goods may be required but they should be sympathetic to the historic character of the building.

Adapt the management of hay meadows

The management of hay meadows should be reviewed and adapted if necessary to take account of climate change and to ensure conservation of characteristic species. For example it may be necessary to change the number of hay cuts and the intensity of grazing to take account of changes in seasonal temperature and phenology. Increased wetness may lead to an increased rate of soil acidification through leaching and need for more liming.

Monitoring and recording of buried archaeology in floodplains

Monitoring and recording is particularly important if loss of an asset appears inevitable.

3.4.3 Ecosystem services actions

Review soil management plans

This action, as described above, is important for reducing the vulnerability of ecosystem services such as soil formation, food production and water resources. Soil moisture conservation measures are likely to be particularly important in farmed, lowland areas with shallow lime rich soils and measures to reduce impacts on soil structure should be focused in areas with clay soils.

Review hedgerow management

This action, as described above, is important for reducing the vulnerability of ecosystem services such as soil formation and food production. Creating shelterbelts and other field boundary habitats may have benefits for biodiversity but also soil conservation.

Provide shelter for livestock in summer

Hotter summers may increase the need for livestock shelter in summer. This could be provided by structures or through tree planting which could have benefits for biodiversity.

Provide information to farmers about diversification into previously un-farmed areas

Climate change may make previously marginal areas suitable for agriculture. Information should be provided to farmers about the natural environment implications of moving into new areas as part of an overall approach to encourage sustainable farming. However, this advice needs to be informed by an impact assessment as there are possible conflicts with biodiversity, landscape and historic environment.

Monitor pests and diseases

This action, as described above, is important for reducing the vulnerability of ecosystem services such as food production and timber. Farmers and forest managers are well placed to spot pests and diseases early. A local system for sharing information on pests and diseases could benefit farmers in the area.

Enclosure of livestock to protect sensitive habitats

Livestock may need to be kept away from sensitive habitats in order that they do not exacerbate vulnerabilities caused by climate change or to ensure the success of other adaptation actions. For example, livestock may need to be kept

[19] *See the Ribble Catchment Flood Management Plan (CFMP)*

away from newly planted areas. However, there are possible conflicts with landscape objectives and biodiversity and fencing should only be used in appropriate areas, in consultation with conservation organisations.

Increase genotypic variation in plantation woodlands

This action, as described above, is important for reducing the vulnerability of timber production. The Forestry Commission have carried out research into this area[20] and recommend that 'conservative' forestry is practised. This involves choosing species which are well matched to their current climate but which are capable of adapting to some change. For example, trees already at the dry end of their suitable range should not be favoured for future planting.

Review forest management plans

Forest management plans should be regularly reviewed to take account of the potential threats and opportunities as a result of climate change.

Woodland creation and management linked to wood-fuel production

The AONB management plan already contains an action to link woodland creation and management to wood-fuel production. However, wood-fuel production is currently constrained by small size of woodlands and poor access. There may be opportunities to link woodland creation and other management actions (see 'upland actions' above) to provision of wood-fuel. There may be opportunities to extend current wood chip production at Downham Estate. Woodland creation could have benefits for carbon storage as well as timber production.

Increase area and connectivity of semi-natural habitats

Semi-natural habitat has many benefits in terms of ecosystem services including water resources and quality, carbon storage and flood alleviation. Through HLS and SCaMP, a significant amount of work has been undertaken to restore and extend upland habitats in the Forest of Bowland (see 'upland actions' above). Priority areas for further work include Abbeystead where grip blocking work is required, woodland planting in cloughs, and connecting lowland grassland and wetland habitats. The Environment Agency is examining the feasibility of suitable sites in the Lower Ribble area for habitat creation and there are potential opportunities for wet woodland habitat creation on flood storage land.

Review reservoir operations to take account of climate change

Reservoir operations should be reviewed to take account of the impacts of climate change and adaptation action taken if necessary. For example, operating curves may need to be altered to take account of flooding. Defra Guidance on adaptation of reservoirs and dams to the impacts of climate change is forthcoming.

Increase frequency of vegetation management at important historic and geological sites

This action, as described above, is important for reducing the vulnerability of ecosystem services such as knowledge, sense of place and recreation.

Review quarry management plans to take account of climate change

Active quarry management plans should be reviewed to take account of the impacts of climate change. For example, additional measures may need to be put in place to manage dust in summer.

Identify the amount of carbon stored in blanket bog

In order to monitor the success of actions aimed at increasing carbon storage in the Forest of Bowland, it is important to have baseline information about current peat storage. It may be possible to carry out this baseline work through the Lancashire Peat Partnership.

Look for flood storage opportunities

The Environment Agency is investigating flood storage opportunities including setting back of existing embankments and land management changes in the Upper Wyre (Wyre CFMP). There is likely to be scope for flood storage within the Forest of Bowland as rivers are generally unconstrained, for example in the Loud, Hodder and Lune catchments.

Late cutting of road verges and grassy margins around pasture

Late cutting of road verges and field margins will increase habitat for invertebrates, supporting the pollination service. However, this may conflict with landscape and safety objectives and should only be done where appropriate.

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[20] *Broadmeadow and Ray, 2005; Ray et al., 2010*

Adapt the management of hay meadows

This action, as described above, is important for reducing the vulnerability of ecosystem services such as food production and pollination. It may be possible to extend the area of pollen-rich fields in lowland parts of the AONB which can be managed for the production of hay, haylage and silage. Land owners and managers should be encouraged to review the timing of cutting in relation to the phenology of invertebrates. This may be deliverable through entry level stewardship (ELS).

Monitor key species

Key species to monitor in terms of ecosystem services are pollinator populations.

Change education and interpretation practice to reflect landscape change and promote understanding of climate change

At sites where education is a key function, for example at visitor centres, people can be made aware of the vulnerabilities of the AONB to climate change and the importance of adaptation actions. In areas where habitat restoration and creation is ongoing, people should be informed of the purpose and importance of fencing.

Develop new rights of way

Developing new rights of way may take pressure off the most popular routes and spread visitors across the Forest of Bowland. The network of rights of way is particularly sparse in the uplands although care should be taken to ensure that any new rights of way do not conflict with biodiversity. This action should be informed by an environmental impact assessment in order to identify and mitigate potential conflicts.

Develop visitor management plans at most popular sites

In response to a possible increase in visitors, visitor management plans should be developed at popular sites. These include Gisburn Forest, Slaidburn, Dunsop and Downham, the Trough of Bowland and Beacon Fell. Plans should consider how the possible impacts of an increase in visitors on the natural environment could be mitigated.

Encourage use of public transport

An increase in visitors could result in an increase in cars in the Forest of Bowland, affecting the tranquillity of the area. There is already a public transport network which operates within the Forest of Bowland and it may be necessary to expand services such as the Bowland Transit and the Lune Villager to accommodate higher visitor numbers.

Increase maintenance on the rights of way network and amenity areas

A number of recent improvements have been made to rights of way in the Forest of Bowland (see Figure 3.3) including stone pitching on paths at Pendle Hill and stone flags at Fiensdale Head. However, it is likely that climate change will increase the need for footpath maintenance work including improvements to surfaces, drainage and vegetation removal. Associated infrastructure such as footbridges and stiles may also need more frequent maintenance. Priority routes for action include those on blanket bog and in river valleys, for example the Ribble Valley Way.

Figure 3.3 – Flagstone path over blanket bog ©Graham Cooper

Maintenance at amenity areas is also likely to increase as the growing season lengthens, with more frequent grass cutting and vegetation removal required. When planting new amenity areas, consideration should be given to the choice of planting and drought resistant genotypes used where appropriate.

Prepare a visitor fire risk plan for heathland and peatland areas

It may be necessary to keep people away from upland areas if there is a high risk of fire. Plans should be put in place to manage visitors in this situation. Humans are also a major cause of wildfires and it is important that visitors and residents are educated about fire risk and mitigation measures. Closure of open access areas due to high fire risk is already an option within the CRoW Act.

Monitoring and recording of sites designated for their historic or geological knowledge

If the loss of geological or buried archaeological assets appears inevitable ensure final recording and rescue of key materials.

4. Discussion

4.1 Introduction

This study has assessed the vulnerability of natural environment assets in the Forest of Bowland AONB to the impacts of climate change. Strategic and specific adaptation actions aimed at reducing the vulnerability and increasing the resilience of the AONB to climate change have then been identified. In this section the adaptation actions are discussed further and the limitations of this study are highlighted.

4.2 Adaptation actions

In Chapter 3, strategic and specific adaptation actions aimed at reducing the vulnerability of the Forest of Bowland AONB to the impacts of climate change are presented. The strategic actions are high-level, overarching actions which apply across the whole AONB area whereas the specific actions apply to particular assets, landscape character types and ecosystem services.

It is noticeable that many of the suggested actions are not new ideas but are drawn from current understanding of good conservation practice. For example, the idea that we need more semi-natural habitat in good condition and well connected is the central message of the Lawton review of England's wildlife sites and ecological network . These principles are also central to the England Biodiversity Strategy Climate Change Adaptation Principles . The England Biodiversity Strategy recognises that these principles already underpin existing policy and practice in nature conservation but highlight that climate change increases the need to understand and work with the dynamics of natural systems. In order to be resilient to the impacts of climate change and continue to deliver ecosystem services, the natural environment needs to be healthy now and in the future. It is thus unsurprising that many suggested adaptation actions are drawn from good conservation practice.

Much work has already been undertaken in the Forest of Bowland to manage semi-natural habitats and improve their health. Work has been particularly focused in upland areas where large areas have been re-wetted and replanted through HLS and SCaMP. This work should contribute to the resilience of these areas to the impacts of climate change and it should continue where necessary. To date, less management has been undertaken in the fringe and lowland areas of the Forest of Bowland and these areas should be a focus for future activity. Restoring, re-creating and re-connecting clough woodland, grassland and wet woodland could reduce the vulnerability of fringe and lowland areas to the impacts of climate change, increasing the overall resilience of the AONB.

Many of the actions identified in Chapter 3 involve reviewing and adapting existing management plans and practices. Given that adaptation involves delivering good conservation practice, it is important that it is embedded into existing plans and agreements. It will be necessary to regularly review plans and agreements to ensure they take account of the impacts of climate change and maximise opportunities to deliver adaptation. Monitoring, reviewing and updating of actions are central to an adaptive management approach. It is important that plans and agreements are flexible and can respond to changing conditions.

The majority of the specific actions have multiple benefits in terms of reducing vulnerabilities across a range of landscape character types and ecosystem services. These 'win-win' actions can be easily identified from Table 3.6. Specific actions which appear to deliver the most benefit in terms of reducing vulnerability across the AONB include:

- Encouraging appropriate levels, cycles and types of stocking;
- Planting new woodlands and connecting existing woodlands;
- Increasing genotypic variation;
- Reviewing soil management plans; and
- Reviewing and adapting vegetation management on roadside verges, historic sites and geological features.

In order to be sustainable it is important that adaptation actions do not have unintended negative impacts on the natural environment and that potential conflicts are recognised early. Consultation with stakeholders identified some areas of potential conflict between adaptation actions and where possible they were modified to reduce negative impacts. However, there are some actions which could conflict with objectives for other aspects of the natural environment. These potential conflicts are highlighted in the description of the actions but it is recommended that before undertaking any of the suggested actions, an assessment of potential environmental impact is made and measures taken to mitigate potential negative impacts.

Landscapes are dynamic: the assets that contribute to the current landscape character and ecosystem services in the Forest of Bowland have changed over many years and will continue to change. The vulnerability assessment carried out in this study indicates that the Forest of Bowland AONB may change as a result of climate change and that these changes could occur over relatively short timescales. However, accepting change can be challenging, particularly in designated landscapes where certain characteristics are valued. This report proposes a range of adaptation actions to enhance the resilience of landscape character and ecosystem services in the Forest of Bowland but it may be necessary to accept some change. Education and awareness raising awareness may be required to facilitate this acceptance.

4.3 Limitations of the study

This study makes a high-level assessment of the relative vulnerability of the landscape characteristics, biodiversity and ecosystem services of the Forest of Bowland AONB to the impacts of climate change and identifies potential adaptation responses. A number of limitations to the methodology and findings of the study should be recognised including:

- Scale of the study area;
- Limited consideration of indirect impacts of climate change and other drivers of change; and
- Subjective nature of the vulnerability assessment.

Landscape character types (identified from the Forest of Bowland AONB landscape character assessment) and ecosystem services were used as the units of assessment to enable the project to take a whole system approach and examine all the components which make up the landscape of the AONB. However, vulnerabilities are also likely to exist at smaller and larger scales than those identified in this study. For example, vulnerabilities will vary at the habitat-scale, up to the scale of wider habitat networks and catchments. Adaptation actions may also need to be focused at different scales. Further work could be undertaken to explore vulnerabilities and adaptation actions at smaller or larger scales. The six-step methodology followed in this study should be applicable to a range of scales.

This project has mainly considered the vulnerability of the natural environment to direct impacts of climate change. However, many assets are likely to be vulnerable to indirect impacts of climate change which may result from the response of other sectors. The main source of indirect impacts is likely to be changes in agricultural practice as a result of climate change. Changes in farming types and intensity in response to changing temperature and precipitation could have significant implications for the landscape character and ecosystem services of the Forest of Bowland.

Climate change (direct and indirect impacts) will not be the only driver of change within the Forest of Bowland AONB. Socio-economic changes may have greater implications for landscape character and ecosystem services than climate change. Agricultural practice (which strongly influences landscape character and delivery of ecosystem services) is largely influenced by economic and political factors such as changing crop prices and consumer demand. Population change and increasing development pressure can also influence landscapes: even in designated landscapes where development is restricted, increase in visitor numbers can affect landscape character and ecosystem services.

Uncertainty over the nature of climate change and the response of the natural environment makes it difficult to undertake an objective assessment. This study therefore took a subjective approach, identifying relative vulnerability of assets by considering sensitivity, exposure and adaptive capacity through literature review and consulting stakeholders. However, the results of this study are not definitive and other assessments of relative vulnerability may differ.

Not withstanding these limitations, the findings of this study provide a useful starting point to focus adaptation action in the Forest of Bowland AONB.

4.4 Further research

Through undertaking the research required to produce the Forest of Bowland AONB Climate Change Adaptation Plan, a number of areas for further research have been identified.

Prioritising actions

The list of potential adaptation actions in Chapter 3 is long. Whilst the discussion above recognises some potential 'win-win' actions, further work is required to develop a list of priority actions. The next step in developing an implementation plan for adaptation could be to assess the long list of actions against a set criteria designed to identify priority actions. Principles of good adaptation are available from the United Kingdom Climate Impacts Programme (UKCIP) and could be used to develop criteria. Criteria could include:

- Actions which reduce the vulnerability of 'more vulnerable' assets in the vulnerability assessment;
- Actions which deliver multiple benefits in terms of reducing vulnerability ('win-win' actions);
- Low regrets actions i.e. actions which deliver benefits regardless of climate change; and
- Timing of actions i.e. short, medium and long term actions.

Consultation on the vulnerability of the natural environment to the indirect impacts of climate change

This study has focused on addressing the vulnerability of the natural environment to the direct impacts of climate change but it will also be vulnerable to indirect impacts, for example, changing agricultural practice, recreation demand or the management of shooting estates. A similar approach to that used in this study could be used to identify the vulnerability of assets to indirect impacts of climate change and identify appropriate adaptation actions. This work should include consultation with farmers and land managers. The findings of work focusing on indirect impacts could be used alongside the actions presented in this report to provide a more comprehensive adaptation plan.

Establishment of monitoring projects

Monitoring is required to measure the impact of climate change and the success of adaptation actions. Species monitoring should focus on those species at the edge of their range in the Forest of Bowland, for example hen harrier and black grouse. Monitoring of non-biodiversity assets could also be beneficial, for example monitoring peat soil depth can be used to measure carbon loss and gauge the success of adaptation actions designed to increase the resilience of peat areas. This monitoring could be undertaken in partnership with the Lancashire Peat Partnership. Threatened historic assets may also need monitoring and should be preserved through recording if their loss appears inevitable.

Monitoring can also be used to measure the effectiveness of adaptation actions. Adaptation will not be a one-off action; it is a process which requires regular review. The outcomes of monitoring can be used to refine adaptation actions and should be used as part of an adaptive management approach.

Identify opportunities for conserving peat soils on steep slopes

A number of specific actions aimed at improving and conserving peat habitats and soils have been identified in Chapter 3, including stabilising water levels and restoring upland mire communities and bog-mosses. Methods for restoring raised mires in the UK have been developed by Wheeler and Shaw (1995) and generally assume a high and stable water table as an essential precondition. This may be secured by initial landscaping work (Carroll et al. 2009). However, conserving peat soils and habitats on the highest land in the Forest of Bowland may be difficult due to steep slopes and difficulty in retaining water. Lessons from other areas of the UK, for example the Moors for the Future Partnership work in the Peak District and South Pennines, should be identified and applied to the Forest of Bowland where appropriate. This work may involve literature review and consultation with land managers and members of the Moors for the Future Partnership. There may be an opportunity to undertake this work in partnership with the Lancashire Peat Project.

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