An assessment of the impact of climate change on the natural environment of the Tees Valley

Tees Valley Climate Change Resilience Group

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Foreword

Climate change is one of the biggest challenges facing the economy, society and the environment. The government has stated that tackling climate change is a top priority. While action and direction is clearly needed at international and national levels, there is also much that can be done at a more local level to prepare for the potential impacts of climate change.

However before thinking about the type of action to take, it is important to understand what climate change is likely to mean for the local environment, people, communities and businesses.

This report considers what the potential impacts of climate change could be on key landscape characteristics and habitats in the Tees Valley, and provides some pointers to the type of policies and actions that could be considered as part of climate change adaptation and mitigation measures.

The assessment has followed a methodology piloted by Natural England, and this report has been produced as part of the remit of the Tees Valley Climate Change Resilience Project. The Resilience Project was set up to identify and prioritise options to improve our resilience to current and future climate impacts, and to ensure that the resources needed to respond to climate hazards are targeted as effectively as possible.

The Resilience Project has been supported by:

Industry Nature Conservation Association

Darlington Borough Council

Hartlepool Borough Council

Middlesbrough Council

Redcar & Cleveland Borough Council

Stockton-on-Tees Borough Council

Tees Valley Unlimited

Cleveland Emergency Planning Unit

Durham and Darlington Civil Contingencies Unit

Environment Agency

Natural England

Groundwork North East

Climate North East

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1. Introduction

1.1 Reducing global greenhouse gas emissions is essential to reduce the effects of climate change. However due to current and historical emissions, some impacts of climate change are now unavoidable. The natural environment is likely to be vulnerable to these impacts and it is important to ensure that it has the capacity to adapt. Without such adaptive capacity, not only are landscapes, ecosystems and wildlife put at risk but opportunities to increase the resilience of the economy may be lost.

1.2 The publication in 2011 of the Natural Environment White Paper[1] has helped to raise the profile of the natural environment and bring it more into the forefront of Government thinking. Helping the natural environment to adapt to climate change is a theme that runs throughout the White Paper. However a healthy natural environment can offer natural services to help society cope with the impacts of unavoidable climate change. Tree planting can naturally cool the temperature in urban areas, and in some situations can help to manage increased flood risk. However the White Paper rightly points out that some tough choices will need to be made about how to protect and enhance nature while at the same time dealing with other pressures caused by climate change on for example water and food production.

1.3 Also published during 2011 the UK National Ecosystem Assessment (UK NEA)[2] provides a comprehensive overview of the state of the natural environment and shows how natural resources have been largely under-valued in the past. Climate change will have implications for agriculture, flood control and many other eco-system services.

1.4 Natural England is looking to secure the future of the natural environment. Its Character Area Climate Change Project examines the implications of climate change on individual Natural Character Areas (NCAs) and identifies the vulnerability of environmental assets and features to the effects of climate change and the appropriate adaptation responses. Using Character Area as the unit of assessment enables the study to take a whole system approach and examine the components which make up an individual landscape. Natural England piloted this approach in 5 areas, including South East Northumberland.

1.5 Natural England supported Tees Valley Unlimited in applying the methodology to assess climate change risks to the natural environment in the Tees Valley as part of a wider Tees Valley Climate Change Resilience project. The process of applying the Natural England methodology has several benefits, including access to specialist

[1] The Natural Choice: securing the value of nature; HM Government, June 2011

[2] The UK National Ecosystem Assessment (2011): Synthesis of the Key Findings, UNEP-WCMC, Cambridge

expertise and latest research. It also provides the opportunity to contribute information to the work of organisations in the Tees Valley whose principal objectives are to conserve and protect species, habitats, and the wider environment, and to organisations that recognise and promote the benefits that engaging with the environment can have in terms of health, cohesion, education, the economy and sense of worth.

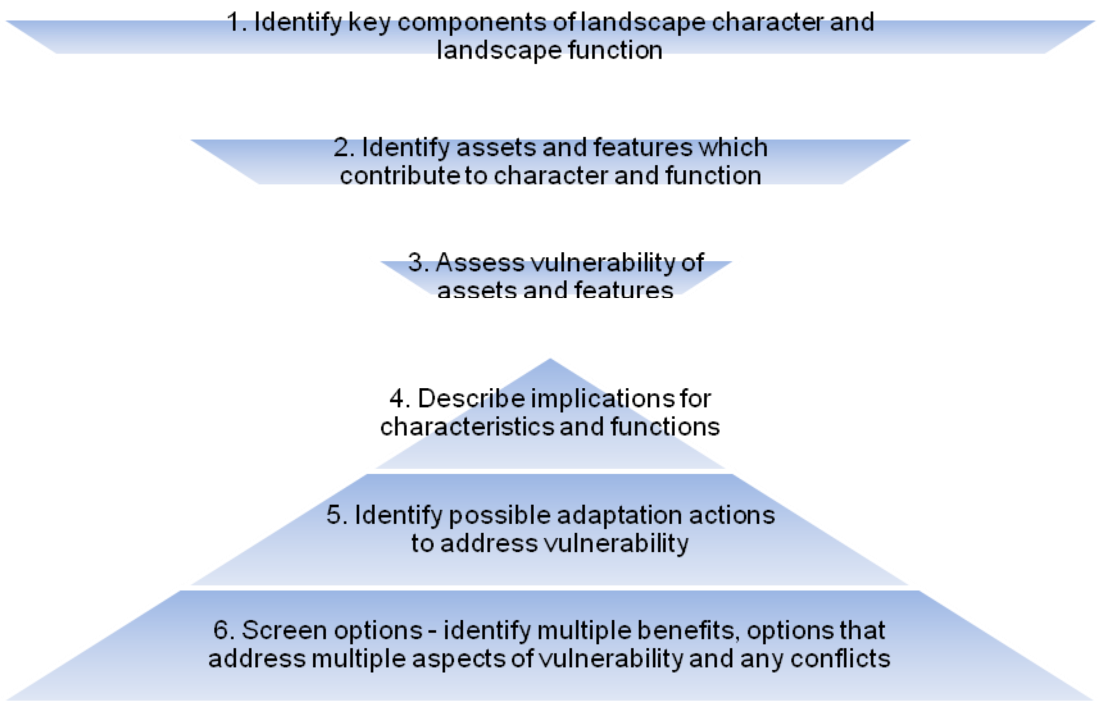
1.6 The multifunctional benefits of the natural environment are well documented, for example in increasing property values, improving physical and mental health, and increasingly, helping to adapt to climate change. However, without any understanding of how climate change may affect the natural environment, it will be more difficult to clearly identify opportunities to increase the resilience of the Tees Valley, and understand where climate change impacts on the natural environment may have an impact on economic regeneration.

1.7 This report will help inform future policy decisions on the implications and impact of climate change in the Tees Valley. It is suggested that the results of this project should contribute towards a common objective of “achieving sustainability of natural assets” – no net loss or ability of future generations to have at least the same natural environment benefits that we enjoy today.

2. Methodology

2.1 Natural England’s method for assessing vulnerability and considering adaptation options follows a framework consisting of six steps (figure 1). The starting point is to identify the most important aspects of landscape character and landscape function. The physical features that make the most important contribution to those aspects of character and function are then identified. The vulnerability of those physical features is then assessed, and from this the possible implications for landscape character and function can be identified together with potential adaptation actions to reduce vulnerability to climate change. These are then screened to identify actions that would have multiple benefits, and any potential conflicts between adaptation objectives.

Figure 1: Steps undertaken to assess the implications of climate change on the natural environment



Step 1 – Identification of landscape characteristics and functions

2.2 The landscape characteristics and functions of the Tees Valley area were identified through a review of the current National Character Area (NCA) descriptions. Urban areas are not considered in any detail, but urban green space is a key focus of the Tees Valley Green Infrastructure Strategy.

2.3 Natural England defines **'landscape character'** as "a distinct, recognisable and consistent pattern of elements that occur in a particular type of landscape. Combinations of geology, landform, soils, vegetation, land use, field patterns and human settlement create character. Character makes each part of the landscape distinct, and gives each its particular sense of place". England has been classified into National Character Areas, areas that have similar landscape character. The Tees Valley includes all of the Lower Tees National Character Area (NCA 23) as well as parts of the Durham Magnesian Limestone Plateau (NCA 15) and the North York Moors and Cleveland Hills (NCA 25).

2.4 **Landscape function** is defined as the goods and services that the landscape as a whole, or key features within it, provides to society. These can be recognised goods like food, or services such as flood attenuation, or they can be less tangible such as 'a sense of place'.

2.5 The elements contributing to the landscape character of an area, or which contribute to the functions it provides are made up of the component parts of that landscape, referred to as '**assets'** in this study. These assets can include key habitats such as woodland, or particular soil types or historic features. A combination of assets taken together can contribute to an element of landscape character, and may enable it to deliver a function. A simple example of this might be that trees and hedgerows can combine to give a landscape a well wooded feel (an element of landscape character) and may also combine to enable the landscape to deliver one or more functions, for instance absorbing carbon emissions (called carbon sequestration).

Step 2 – Identification of assets and features which contribute to landscape character and function

2.6 The assets and features which contribute to the landscape character and function within the Tees Valley were identified under the following headings:

Biodiversity

2.7 Biodiversity assets have been identified at the habitat scale. It is impractical to undertake the vulnerability and adaptation assessment at a species scale due to gaps in scientific evidence regarding the impacts of climate change. The vulnerability of biodiversity assets will be influenced by the overall extent of habitat, the exposure of the habitat to the impacts of climate change; the opportunities for the habitat to adapt to the impacts of climate change; the overall condition of the habitat; and non-climate related pressures such as agriculture, access and recreation.

Geodiversity

2.8 Geodiversity refers to the variety of rocks, fossils, minerals, natural processes, landforms and soils that underlie, and determine the character of our landscape and environment. Geodiversity assets include a number of vital ecosystem services such as soil and mineral production, as well as educating about past and future climate.

Historic environment

2.9 Historic environment assets contribute to the character of the Tees Valley and tell the story of its development. Among the most significant factors determining the character of historic environment in the Tees Valley is its coastal location, port activities, and commercial and industrial heritage including the development of railways, and the steel and chemicals sectors.

Access and recreation

2.10 Access and recreation assets make it possible to enjoy a range of activities. Where possible, data regarding the extent of the assets (e.g. length of paths and cycleways, area of open access land etc) have been included.

2.11 These assets all contribute to landscape character and function. They were identified through reviewing the NCA descriptions as well as consultation with regional specialists. The majority of the assets and features are available in GIS format and can be used to support mapping of key climate change impacts in the Tees Valley. The impacts of climate change mitigation on the more urbanised parts of Tees Valley are not included within the scope of this report except for the ability of the natural environment to sequester carbon.

Step 3 – Assess vulnerability of assets and features

Vulnerability assessment combining expert opinion with stakeholder analysis

2.12 The vulnerability of natural assets to the impacts of climate change was initially assessed using a series of templates developed by Natural England. The templates provide robust and nationally comparable guidance on both the direct and indirect impacts that climate change may have on the natural environment. Direct climate change impacts include hotter, drier summers and wetter winters, whereas indirect climate change impacts include actions or events that occur as a response to the changing climate. For example, if cropping regimes alter as a result of climate change, the altered regime could result in impacts on surrounding habitats or catchments that are *indirectly* as a result of climate change. Of course in reality, society changes to a variety of pressures and opportunities simultaneously, so it is also important to identify win-win and low-regrets opportunities that can improve our resilience to climate change as well as range of other pressures such as structural economic changes. Win-win and low regrets options are explained in more detail under Step 5.

2.13 The climate change impacts were taken from the headline scenarios for the North East, produced by the UK Climate Impacts Programme:

Climate Change Projections

In June 2009 the United Kingdom Climate Impacts Programme (UKCIP) released a new set of climate scenarios for the United Kingdom. The UKCP09 projections are the fifth and most sophisticated generation of climate projections for the UK. UKCP09 provides probabilistic projections of climate change, assimilated from an ensemble of models and presents three emissions scenarios (Low, Medium and High). The projections are presented for 25 x 25 km grid squares across the UK and for seven over-lapping 30-year time slices, moving forward in decadal steps (2010-2039, 2020-2049, until 2070-2099). The summary below gives an indication of predicted climate change parameters for the UK and North East.

Key headline findings from UKCP09 at a national and regional scale (2080s, medium emissions scenario)

UK wide

- All areas of the UK get warmer, and the warming is greater in summer than in winter.
- There is little change in the amount of precipitation that falls annually, but it is likely that more of it will fall in winter, with drier summers, for much of the UK.
- Sea levels rise, and are greater in the south of the UK than the north.

North East

- The central estimate of increase in **winter mean temperature** is 2.6ºC; it is very unlikely to be less than 1.4ºC and is very unlikely to be more than 4.1ºC.
- The central estimate of increase in **summer mean temperature** is 3.7ºC; it is very unlikely to be less than 2ºC and is very unlikely to be more than 5.8ºC. The central estimate of change in winter mean precipitation is 14%; it is very unlikely to be less

than 2% and is very unlikely to be more than 32%.

- The central estimate of change in **summer mean precipitation** is –17%; it is very unlikely to be less than –35% and is very unlikely to be more than 1%.

2.14 The rationale behind using regional headline summaries from the UKCP09 climate projections was to allow the consideration of responses that could be valid for a broad range of possible future climate scenarios as the actual climate change experienced will be influenced by future emissions pathways that are still under negotiation. Climate change will also increase the risk of extreme weather events such as heat waves and severe storms and these can have major impacts from which the natural environment can take a long time to recover.

2.15 Local experts, including RSPB, Tees Valley Wildlife Trust, Industry Nature Conservation Association (INCA), the Environment Agency, Groundwork North East, and Natural England, have provided comments on the vulnerability of the identified assets.

Step 4 – Description of the implications of climate change for landscape characteristics and functionality.

2.16 Having identified the assets that make the most important contribution to landscape character and function in the Tees Valley an initial assessment of the vulnerability of those assets to climate change and the potential implications of climate change for the landscape character and function was identified. Natural England have reported under the 'Adaptation Reporting Power' created by the Climate Change Act 2008. As part of their reporting process, a high level analysis of the climate change implications for landscape characteristics and functions in each Natural Character Areas will be used to triangulate the initial assessment.

Step 5 – Identification of potential adaptation actions

2.17 Potential adaptation actions needed to address the vulnerability of the assets and features of the Tees Valley, as well as potential opportunities to support economic regeneration. The aim is to identify responses to climate change which are valid for a broad range of climate variables suggested by the UKCP09 scenarios (for instance, increase in frequency of extreme rainfall events and extreme temperature events such as heat-wave).

2.18 A number of principles will be followed when deciding which adaptation actions are most appropriate:

Win-win adaptation response – A 'win-win' adaptation response has wider social or economic benefits than an action that solely has climate change benefits. A win-win response will also tend to reduce the vulnerability of more than one asset, characteristic or function of the natural environment such as improving wildlife corridors and promoting active travel, or improving biodiversity while reducing flood risk.

Low regrets adaptation response – A 'low regrets' adaptation is a response to climate change that is beneficial to the natural environment regardless of whether the projected climate change impact occurs, such as improved conservation or water quality outcomes.

Avoiding conflict between adaptation responses – It is important to avoid a situation where implementing an adaptation response compromises the ability to carry out other adaptation responses. This is a central tenet of the concept of sustainable adaptation, alongside the principle that adaptation responses should not increase climate change[3].

2.19 To ensure that adaptation actions are as consistent as possible with these principles a matrix has been used to help assess whether there are any potential conflicts between potential adaptation actions for specific natural assets, and to check that 'win-win' and 'low regrets' actions are, wherever possible, pursued. See appendix 1.

Step 6 – Screen options

2.20 As outlined above, it is important that suggested adaptation actions do not have unintended negative impacts on the natural environment and sustainable economic regeneration of the Tees Valley, and that potential conflicts and synergies are recognised. All the potential adaptation actions identified in step 5 have been screened to identify whether individual actions had a positive, negative or neutral effect on the key landscape character and function categories (appendix 1). This should enable the identification of actions that would have multiple benefits and those that might have negative side effects. Where negative or uncertain effects of an adaptation action are noted, it will be important to develop a management approach that avoids or at least minimises the possibility of negative effects.

2.21 Actions that could support adaptation across multiple assets or functions can also be identified.

[3] A good definition of sustainable adaptation can be found at http://www.naturalengland.org.uk/ourwork/climateandenergy/climatechange/adaptation/sustainable.aspx

3. Summary of Tees Valley Landscape Character and its functions

Tees Valley Natural Character Areas

3.1 The Tees Valley encompasses three Natural Character Areas, including part of the Durham Magnesian Limestone Plateau, the Tees Lowlands and part of the North York Moors and Cleveland Hills.

Key landscape characteristics

3.2 The key landscape characteristics of the Tees Lowlands include:

- A broad low lying plain of gently undulating, predominantly arable, farmland with wide views to distant hills.
- Meandering, slow-moving River Tees flows through the heart of the area dividing the lowlands to north and south.
- Contrast of quiet rural areas with extensive urban and industrial development concentrated along the lower reaches of the Tees, the estuary and coast.
- Large-scale chemical and oil refining works, dock facilities and other heavy plants along the Tees estuary form a distinctive skyline by day and night.
- Overhead transmission lines and pylons, motorway corridors, railway lines and other infrastructure elements are widespread features.
- Woodland cover is generally sparse but with local pockets such as along parts of the middle reaches of the Tees and the River Leven, as well as parkland and managed estates.
- Extensive areas of mud flats, saltmarsh, wetlands and dunes at mouth of the River Tees which support valuable wildlife habitats.
- Minor valleys and linear strips of open land extend as ‘green corridors’ from rural farmland into the heart of the Teesside conurbation.
- A legacy from the industrial era of planned public parks which now form an important part of the area’s green infrastructure

3.3 The key characteristics of the Durham Magnesian Limestone Plateau and the North York Moors and Cleveland Hills within the Tees Valley area include:

- Varied coastal scenery of low cliffs, bays and headlands, rich in wildlife
- A19 corridor, railway lines and other infrastructure elements.
- Distinctive and dramatic coastal landscapes with high cliffs, small coves and bays, coastal towns and fishing villages.
- Upland landscape dissected by a number of steep-sided, often well-wooded river valleys

Key landscape functions

3.4 The landscape of the Tees Valley delivers a range of services that contribute to economy and well being, including attracting investment and supporting healthy lifestyles. The following list defines some of the principal functions of the landscape. These functions in many cases support what are known as ‘ecosystems services’. Ecosystems services are the goods and services delivered by the natural environment, often for free, that have direct and indirect value to people[4]. However, landscape functions are sometimes broader than ecosystems services, and for key functions such as sense of place, may be derived as much from cultural development as the landscape itself.

Ecosystem Services
The Millennium Ecosystem Assessment has provided a comprehensive assessment of the state of the global environment, and has helpfully classified ecosystem services as;

- Supporting Services – necessary for the production of all other ecosystem services including soil formation, photosynthesis and water cycling
- Provisioning services – products obtained form ecosystems including food, fuel, pharmaceuticals, and fresh water
- Regulating services – benefits obtained from the regulation of ecosystem processes including air quality, climate regulation, water purification, and pollination
- Cultural services – non-material benefits people obtain from ecosystems through for example, recreation, spiritual enrichment, and aesthetic experiences

Food and biomass production

3.5 Despite its reputation as an industrial centre, about 55% of the Tees Valley is agricultural land. According to the 2007 Agricultural and Horticultural Survey, approximately 43,000 ha are farmed, the majority of which is identified as grade 3 in the Agricultural Land Classification. The main cereal crops grown are wheat and winter barley, and the main livestock are cattle, pigs, sheep and poultry.

Description		**Approximate area (ha)**
Crops and bare fallow	Of which:	21500
	Total cereals (mainly wheat and winter barley)	15600
	Bare fallow	790
	Horticultural	45
Temporary grass		3300
Permanent grass		12100
Rough grazing		330
Woodland		1270
Set aside		2165
Other		870
Livestock	of which:	Number

[4] A good summary of the ecosystems services concept has been provided by the Parliamentary Office of Science and Technology in their 'Postnote Number 281' (2007) (www.parliament.uk/documents/post/postpn281.pdf)

Description		Approximate area (ha)
	Cattle	30475
	Pigs	43975
	Sheep	53260
	poultry	1014620

Source: Defra

3.6 Urban food production is becoming increasingly popular in the Tees Valley. For example, the “Darlington it’s Growing” initiative and the urban farming and ‘Growing Together’ initiatives in Middlesbrough aim to provide opportunities for local people to grow their own fruit and vegetables. . Industrial symbiosis is also an interesting and important source for local food production (Growhow provide CO_2 and waste heat to John Baarda tomato in Billingham) because it reduces the environmental impact of industry as well as reducing food miles.

Freshwater management and drainage

3.7 Most of the Tees Valley receives water from Northumbrian Water via the Kielder water management zone, which is capable of being supported directly, or by substituting river compensation flows, with water derived from Kielder Reservoir and distributed via the Tyne-Tees tunnel. In addition to the two water resource zones supplying potable water, a third, industrial water system, supplies raw water to Teesside industrial customers.

3.8 The Hartlepool area is supplied solely by the local Magnesian Limestone aquifer with all groundwater sources pumping to a single treated water storage reservoir where it is blended to maintain compliant water quality. The closure of coal mines in the area and the reduction in pumping to de-water mine workings has resulted in the migration of highly mineralised water into parts of the aquifer system. There is currently no risk to public water supplies, although the potential for this to affect the quality of groundwater in the Magnesian Limestone that is used for public water supply is being investigated with the Coal Authority and the Environment Agency.

3.9 The River Tees rises in the high moors of the North Pennines and continues over open moorland to Cow Green Reservoir. From the reservoir it flows through the farms and pastures of Teesdale towards Darlington. At this point the river widens and heads towards the heavily industrialised River Tees Estuary, with its large areas of land reclaimed from salt marshes and mudflats.

3.10 The Tees catchment has a high conservation value, with 42 Sites of Special Scientific Interest and many other officially recognised areas, such as the North Pennine Moors. There are two major waterfalls on the River Tees, at High Force and Cauldron Snout. No migratory fish can pass High Force. The lower section of the River Tees and its estuary are predominantly urban and industrial in character, dominated by chemical and steel making which both produce comparatively large quantities of industrial waste. Teesside’s industry is notably one of the biggest sources of hazardous waste in the country and the area has the greatest concentration of authorised installations under the Environmental Permitting Regulations in England.

3.11 Important groundwater units in the Tees Valley include:

- The Permian Magnesian Limestone and Yellow Sand is an important aquifer for Hartlepool and Darlington, and outflows from the aquifer are important in sustaining flows for the River Skerne and headwater wetlands
- Quaternary sands and gravels are locally important in relation to slope ability and groundwater-surface water interaction
- The Triassic Sherwood Sandstone aquifer supports numerous industrial abstractions around Billingham
- The Ravenscar group (Jurassic sandstone and limestone) support some isolated groundwater abstractions

Mine water discharges in Tees Valley are associated with former ironstone mines at Skinningrove, Saltburn Gill, Eston and New Marske.

3.12 There are numerous licensed abstractions and over 300 consented discharges into the River Tees and its tributaries[5]. In addition, there are five sewage treatment works, numerous other waste sites, landfills and storage sites for hazardous or dangerous substances. The industrial area is classed as a groundwater vulnerability zone and a significant proportion of the riverside comprises contaminated land.

3.13 RSPB Saltholme nature reserve is dependent on water received from SABIC as a by-product of their brine production[6].

Minerals

3.14 Historically, mineral extraction in the Tees Valley included iron ore, and alum in the East Cleveland area, coal extraction in adjacent areas of County Durham, and extraction of salt and anhydrite near Billingham. More recently, the principal extraction is primary aggregates, including sand, gravel, and crushed rock, though there are also significant quantities of secondary aggregates from the materials produced by steel making, and marine dredged sand and gravels. There is also a potash mine at Boulby that produces approximately half the UK's potash (and rock salt as a by-product).

3.15 Local production from the Tees Valley may be increased to meet regional apportionment figures for crushed rock, sand and gravel. It is likely that sand and gravel requirements will be met principally from existing licensed sites at North Gare and Stockton Quarry and rock from Hart Quarry sites[7]. North Gare is a self replenishing beach extraction site within the Teesmouth and Cleveland Coast Special Protection Area (SPA) and Ramsar sites.

Climate regulation

3.16 Soils and biomass can perform an important role both in storing carbon and in carbon sequestration to support climate change mitigation. All vegetation growth absorbs carbon from the atmosphere, and soils also store carbon to varying degrees[8]. Grassland and woodland ecosystems, for example are a significant carbon store, while certain agricultural practices, such as those that increase organic matter or

[5] http://www.grdp.org/static/documents/Research/pages_23_to_40_1002766.pdf

[6] http://news.bbc.co.uk/1/hi/england/tees/6720233.stm

[7] Entec. 2010. Report for the North East Region Aggregates Working Party Apportionment of North East Region Guidelines for Aggregates Provision

[8] Swift, 2001, Batjes, 1996

retain moisture in the soil, can also aid the absorption of carbon. Green infrastructure has an important role in regulating the local climate and the Green Infrastructure Strategy for the Tees Valley demonstrates opportunities to increase the capacity of vegetation to reduce high summer temperatures in urban areas, for example, increasing the number of street trees and open spaces which act to reduce the impact of the urban heat island effect[9].

Flood water storage

3.17 There are numerous areas within the flood plains of the main rivers and their tributaries which provide functions such as rainfall interception, increased soil infiltration, water uptake, water storage and delaying and decreasing peak flows which all ultimately decrease the volume of (flood) water that requires management. Maintaining high organic content (humus) provides optimal conditions for soil to perform this important function.

3.18 Wetlands perform similar functions and are an extremely important natural characteristic in the Tees Valley. Due to the potential for severe flood risk in the catchment, the opportunity to develop win-win adaptation options based on improved soil management and 'soft' engineering solutions that increase water storage to reduce flood risk, surface water pollution and enhance biodiversity should be maximised. Localised examples of this already exist in the Tees Valley - for example, Lustrum Beck Ponds wetland area acts as an overflow for the Lustrum Beck Tidal Defence system.[10] The potential to expand soft engineering principles that have multifunctional benefits at a catchment scale in the Tees Valley should be explored.

3.19 The natural processes of floodplains and flood storage areas (including wetlands) also perform a filtering function allowing sediment rich water carried in flood waters to be deposited, thus improving water quality. Deposition of substances on floodplains also acts to enrich the quality of land and estuarine areas.

Soils

3.20 Soils process water and nutrients for the food we eat, they decompose and recycle our waste, moderate flooding, absorb carbon and provide raw materials, substrate and an anchor for development of infrastructure. Soils are an integral part of any land-based ecosystem, and are the building blocks of landscapes and societies. It typically takes about 100 years to form 1cm of topsoil, so healthy soils are a precious and finite resource and priority should be given to their conservation. Soils rich in organic matter also store carbon, as well as having enhanced water retention qualities. Biochar is a solid charred and carbon-rich by-product of combustion and offers great potential for carbon sequestration. When applied to land, biochar sequesters carbon over a longer period than simply planting trees, and has benefits in terms of soil conditioning - improving soil water retention and increased nutrient efficiency. Both Teesside University and the Centre for Process Innovation have the capacity to develop closed loop industrial systems to maximise the potential to use biochar to improve soil quality in the Tees Valley linked to the extensive range of thermal processes present in the area.

[9] The Urban Heat Island Effect is phenomenon where built infrastructure such as buildings and roads in urban areas absorb and release heat during high summer temperatures with the consequence that greater heat impacts are felt in urban areas. In the Tees Valley, this may be exacerbated by the presence of industrial operations that also release heat to the atmosphere.

[10] http://www.teeswildlife.org/Tees%20Corridor%2012pg%20A4.pdf

Pollination

3.21 Pollination is a critical ecosystem service without which many plants, and the animals and humans that depend on them, would find it difficult, if not impossible, to survive. Although many plants are pollinated ‘abiotically’ (that is by non biological processes such as wind), the Food and Environment Research Agency has estimated that it would cost around £400 million to "hand pollinate" the UK's fruit and vegetable crops[11]. Many wild plants rely on invertebrate pollination to set seed.

Energy Production

3.22 The Tees Valley is home to the largest integrated chemical complex in the UK, the largest hydrogen network in Europe, the largest UK chemical handling deep water port, pipelines connecting the Tees Valley with the rest of the UK, and large advanced engineering companies. It is also home to Europe’s largest bio-ethanol plant, the UK’s largest hydrogen network, and the UK’s largest biomass station. A number of projects are under currently consideration, or at various stages of development to increase the capacity for biomass power.

3.23 The proximity of existing and planned major biomass power stations and biofuels plants in Tees Valley means that biomass crops grown in the sub-region could have a ready market, and there could also be potential to use biomass dredged from the Tees[12]. A North East biomass register is currently being developed, which will include a GIS of major producers and consumers of biomass in the North East. There are also major opportunities to utilise non-woody biomass (such as organic waste), and other secondary resources as energy or transport fuel, and these range in scale from relatively small scale anaerobic digestion units to industrial scale pyrolysis and gasification plants.

3.24 There has also been extensive research by Teesside University into developing reed canary grass into a biomass feedstock as it is can be grown on contaminated land[13]. Increasing demand for biomass for energy production may lead to the intensification of agriculture for biomass production in the Tees Valley.

Health and wellbeing

3.25 The Lancet reported in 2009 that the National Health Service in the UK spends over £3000 a minute on health problems that could be prevented by physical activity[14].There is considerable evidence that using the natural environment for recreation, including walking, can have both physical and mental health benefits[15].

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[11] http://news.bbc.co.uk/1/hi/programmes/politics_show/regions/yorkshire_and_lincolnshire/8828994.stm

[12] http://www.nebusiness.co.uk/business-news/latest-business-news/2009/09/21/river-tees-tree-debris-could-feed-tees-valley-biomass-industry-51140-24742519/

[13]

http://www.tees.ac.uk/sections/research/news_story.cfm?story_id=3311&this_issue_title=May%202009&this_issue=192

[14] Haines, et. al. 2009. Public health benefits of strategies to reduce greenhouse-gas emissions: overview and implications for policy makers. The Lancet, 25th November 2009, p5.
a figure of over $5000 a minute, which equates to over £3000 a minute at the exchange rate 0.61 as of December 2009.

[15] A team of researchers from the University of Bristol and East Anglia recently analysed the connection between green space and public health in the city of Bristol. The study, supported by Natural England, compared extensive data on quality of life against a detailed inventory of parks, urban woodlands, footpaths and other green sites in the city. The results showed that people living closer to green spaces were more physically active, and were less likely to be overweight or obese. These trends were apparently independent of people’s income or social group; the most significant findings showed that people who lived

Having access to the natural environment, particularly from population centres is very important. Levels of access to the countryside vary across the Tees Valley, but a key objective of the Tees Valley Green Infrastructure Strategy and local authority Green Infrastructure and Open Space strategies is to improve access to the natural environment.

3.26 It is not just accessibility to green space and the countryside that is important in enabling people to access health benefits. The quality of green space is just as important. In 2010/2011 there were 17 areas in the Tees Valley that received Green Flag Awards and 1 area received a Green Flag Community Award

Aesthetic Value

3.27 While it can be difficult to place an absolute monetary value on peoples aesthetic or cultural experience of the landscape, many areas in the Tees Valley are regularly enjoyed, for example, by walkers, cyclists and bird watchers. Cultural services provided by the natural environment include a sense of history, a sense of place, inspiration, relaxation, leisure, spirituality and escapism.

Built and Industrial Heritage

3.28 There are several historic settlements in Tees Valley, and the area has a strong industrial identity.   During the 19th Century, the Tees Valley was famous for its ports and heavy industry, and it was in the forefront of railway development.   ICI developed integrated chemical works during the 1920s, which manufactured plastics, ammonia and other fertilisers until it sold its businesses during the restructuring of the 1990s. Many of the company's former manufacturing plants are still in operation, run by other chemical companies.

3.29 The reclamation of the estuary for industrial development has left a lasting aesthetic and environmental legacy in the Tees Valley, as settlements grew up around the river. The contraction of traditional industries has left large swathes of vacant, undisturbed land which has provided valuable wildlife habitat.

farthest from public parks were 27 percent more likely to be overweight or obese: http://www.naturalengland.org.uk/Images/gi-confw1pt2_tcm6-20453.pdf

4. Assessment of impact on Landscape Character Assets

Biodiversity Assets

4.1 Tees Valley contains a variety of habitats supporting a wide range of species. These include habitats listed in the UK's Biodiversity Action Plan (BAP), internationally and nationally important sites, as well as protected species and local sites. The Tees Valley also includes a significant number of brownfield sites that have been left undisturbed for many years resulting in a rich mosaic of habitats.

4.2 Internationally important sites – include Teesmouth and Cleveland Coast designated a Special Protection Area under the EU Birds Directive, as well as a wetland of international importance recognised by the Ramsar convention. Part of the North York Moors National Park is designated as a Special Area of Conservation under the EU Habitats Directive.

4.3 Nationally important sites – there are 21 Sites of Special Scientific Interest (SSSI) in the Tees Valley Full details of these can be found on Natural England's website (www.naturalengland.org.uk) which can also provide information on the current condition of the SSSIs.

4.4 Locally important sites – there are a large number of Local Wildlife Sites (LWS) in Tees Valley that represent a range of habitats of local significance. The Tees Valley Biodiversity Partnership website (www.teesvalleybiodiversity.org.uk) gives full details of the selection guidelines and criteria for LWS designation, as well as information on priority species and habitats from the Tees Valley Biodiversity Action Plan. The suite of statutory and non-statutory sites should be regarded as the Tees Valley's critical natural/biodiversity capital which is a minimum level of resource that needs to be sustained to allow a functioning ecosystem.

4.5 Priority species – There are a number of species in the Tees Valley that are protected by national and European legislation. Other species are designated as priority species for conservation purposes and are the subject of a biodiversity action plan. A Biodiversity Action Plan (BAP) is an internationally recognised programme to address species and habitats. In the UK, the BAP includes terrestrial and marine species as well as migratory birds that depend on UK habitats. Tees Valley BAP species include: barn owl, bats, brown hare, corn bunting, dingy skipper, grayling, great crested newt, grey partridge, harbour seal, moths, otter, purple milk vetch, ringed plover, tree sparrow, and water vole.

4.6 Habitats - The key habitats in the NCA are discussed below:

Lowland Mixed Deciduous Woodland

4.7 Lowland mixed broadleaved woodland covers a very wide range of woodland types growing in lowland Britain on a wide range of soil conditions, from very acidic to base rich and includes most of the semi-natural woodland in the Tees Valley.

4.8 This habitat is vulnerable to hotter, drier summers which could result in greater susceptibility to disease, shifts in the regeneration patterns of trees or decline in woodland cover, shifts in the composition of vegetation types or balance of types which could have implications for site designation criteria. There could also be a change in abundance of rare species or increased competition from invasive species.

Increased threat of fire will be a risk on driest sites. There is also evidence to suggest that the drying out of woodland through land drainage schemes can lead to a decline in the numbers of woodland bird species (for example willow tit which is a UK BAP species) and on invertebrates that require humidity provided by mature woodland, and climate change could exacerbate this effect.

Hedgerows

4.9 A hedgerow is defined as a boundary line of trees or shrubs over 20m long and less than 5m wide at the base. Hedgerows can be an important habitat for a range of species, particularly in intensively farmed lowlands, as they may offer the only significant refuge for many farmland and woodland species which rely on them for food, shelter and dispersal. As wildlife corridors, they also link semi natural habitats and provide routes to support the movements of plants and animals throughout the countryside.

4.10 Increased annual average temperatures and a longer growing season could increase hedgerow growth and therefore management requirements. This could also result in increased shading of hedgerow herbaceous flora, and a changing composition of wildlife in hedgerows. Re-intensification of agriculture as a result of longer growing seasons could also threaten this habitat.

4.11` Drier summers, particularly drought could increase mortality / die-back of hedgerow trees in vulnerable locations, and increase susceptibility to pests and diseases. Warmer winters could result in less favourable temperatures for winter chill requirements for regeneration of berry species and bud development, which could affect bud / flower / fruit production and the availability of food resources for wildlife.

4.12 Reduction in annual average rainfall and soil moisture could reduce wet ditch / hedgerow edge habitat, which would potentially result in a loss of diversity of hedgerow flora and resources for wildlife and loss of connectivity of wet ditches and hedgerow networks. This could lead to further problems for already declining farmland birds. Increased winter rainfall, with impacts such as flooding, water logging of soils and erosion, could lead to mortality of woody species exposed to prolonged flooding in the growing season and increased die-back from damage to soil structure by wet soil conditions.

Traditional Orchards

4.13 Traditional orchards are a priority habitat in the UK Biodiversity Action Plan. They are a semi-natural habitat providing food and shelter for a wide diversity of wildlife – lichens and mosses; bees, beetles, moths and other invertebrates; birds and mammals.

4.14 Traditional orchards were once plentiful in the Tees Valley but few now remain. Impacts of climate change could include a longer growing season allowing a greater range of species and varieties to be grown.

4.15 Lower soil moisture due to reduced annual precipitation will reduce available moisture in the growing season for fruit production, while wetter winters could potentially lead to mortality / crop loss if orchards are exposed to prolonged flooding in growing season or waterlogged soils as well as damage to habitat for dependent/primary species.

Intertidal mudflats and saltmarsh

4.16 Coastal mudflats and saltmarsh are interrelated transitional habitats between marine and terrestrial habitats. Coastal mudflats are sedimentary intertidal habitats created by deposition in low energy coastal environments, particularly estuaries and other sheltered areas. Coastal saltmarshes form the vegetated upper portion of intertidal mudflats between the mean high water neap tides and mean high water spring tides. Saltmarshes develop along coasts with soft shallow shores which provide protection from strong wave action.

4.17 Tidal flooding, erosion and higher storm surge heights as a result of sea level rise could result in accelerated erosion of seaward marsh edges, and the morphology of estuaries is likely to alter substantially due to changes in sedimentary processes. This would lead to some mudflats being permanently submerged, while others would be exposed less regularly. The loss of the base of estuarine food webs, supplying large amounts of organic material to adjacent habitats, particularly to mudflats is also an issue. There could be changes to a sandier substrate due to more flushing of finer particles - this would affect bird food types and potentially vegetation types, and changes in community composition due to increased submergence. Regular surveying/monitoring of migratory bird populations around Teesmouth by organisations including INCA and Teesmouth Bird Club could identify where this may become an issue. Impacts on internal creek patterns could affect the rate of internal erosion and sediment transport within the saltmarsh.

4.18 Indirect impacts include increased pressure on coastal defence structures due to reduced wave attenuation by the saltmarsh, as well as 'coastal squeeze' where saltmarsh is trapped and ultimately lost as it is pressed between rising sea levels and fixed sea defences. There may be opportunities to identify areas where coastal habitats could be allowed to roll inland naturally, but this must take full account of wider land use planning, economic, social and environmental objectives. Climate change and sea level rise could result in more coastal defence structures being built which in turn could lead to loss of habitat. Milder winters may also lead to more visits to the coast at that time of year, possibly resulting in more disturbance to wildlife such as wintering waders. Warmer summers could result in more visitors to fragile coastal habitats – in Tees Valley this could for example put pressure on vulnerable breeding bird species such as the little tern which is a feature of the Teesmouth and Cleveland Coast SPA.

Sand Dunes

4.19 Sand dunes form on the coast where there is a sufficient supply of sand and a beach plain whose surface dries out between tides. Dry sand is blown landwards and deposited above the high water mark, where it is trapped by specialised dune building plants, which grow up through successive layers of deposited sand. A healthy dune system has clearly zoned successional habitats, ranging from embryo dunes to mobile and fixed dunes, dune grassland, slacks and heath.

4.20 Erosion due to sea level rise could lead to beach lowering, and changes in dune hydrology which will affect dune slacks. Changes in shoreline position and dune system area are likely to affect sand stability, dune mobility and groundwater levels, which in turn will affect ecological habitats. Species assemblages will change, affecting bird and mammal food sources, and there will be less wind-blown sand if beach plains are smaller or wetter.

4.21 A longer growing season due to increased annual average temperatures could make dune systems become more stable as warmer temperatures favour growth of dune grasses' exacerbated by nitrogen deposition. If dunes get drier as a result of drier summers, they may lose surface vegetation and dune slacks will dry out. This could affect shorebird breeding habitats. Dunes can also be susceptible to coastal squeeze where they lie in front of defences or other infrastructure.

4.22 Wetter winters will prevent beach plain from drying out - wetter sand does not move by wind-blow and this can affect dune processes and hence vegetation.

Maritime Cliffs and Slopes

4.23 Maritime cliffs and slopes are defined as sloping to vertical faces on the coastline where a break in slope may be formed by slippage and/or coastal erosion. Slopes can vary between 15 degrees to vertical.

4.24 Wetter winters will increase risk of erosion and more vertical slopes. Reactivation of old landslide complexes may be beneficial to cliff habitats and species. Increased cliff erosion and more frequent landslides are not necessarily an issue for cliff habitats, but more rapid changes could occur if cliff slopes become more vertical as they may support a less diverse range of species.

4.25 Increased erosion could result in changes in the extent of cliff-top habitat, which act as a source for the cliff slopes. There could be more rapid retreat of coastal soft cliffs, more toe erosion and more rainfall increasing groundwater levels. If the water balance is affected, this could in turn affect seepage for invertebrates. Species assemblages will change, affecting bird and mammal food sources.

4.26 A longer growing season due to increased annual temperatures could result in invasive plant species affecting the composition of cliff vegetation communities.

Saline Lagoons

4.27 Saline lagoons are among the UK's rarest habitats. They are bodies of saline water which are partially separated from the adjacent sea – in Tees Valley, all saline lagoons are man made, and managed. Such water bodies retain a proportion of their seawater at low tide and may develop as being brackish, full saline or hyper-saline.

4.28 Tidal flooding as a result of sea level rise could lead to increased sedimentation and barrier breach resulting in loss of lagoons, or indirect impacts such as coastal squeeze. Salinity levels may vary more dramatically due to extreme events, reducing the number of species able to thrive in saline lagoons. Saline lagoons can be valuable habitats for breeding birds, including avocet which has recently returned to Teesmouth as a breeding species, and common tern. Fluctuations in water levels can lead to loss of nests through flooding or exposure to land predators such as foxes due to falling water levels.

Running water

4.29 Rivers and streams are dynamic systems that provide a wide variety of habitats to support a diverse range of plants and animals. A variety of water depths and flow types support a wide range of aquatic species, including invertebrates, fish and plants. Exposed shingle is particularly important for a range of invertebrate species whilst bank side vegetation supports an array of wildflowers and animals. Rivers and streams form important habitat corridors that provide safe routes for species and links to other wildlife sites. They also provide a recreational resource to a variety of users including fishing and canoeing.

4.30 Wetter winters and increased frequency of storms could lead to higher volumes of land run-off and increased flooding. Higher land run-off volumes will lead to enhanced nutrient and sediment delivery to rivers and increased hydraulic scour in rivers, increased wash-off of fine sediment and nutrients to watercourses, resulting in increased eutrophication and siltation effects such as high algal growth and standing crop, reduced spawning success of salmonid fish and other species using riverine gravels. There could also be flashier flow regimes that destabilise existing riverine sediments and river banks. Indirect impacts associated with increased flooding and land run off include the loss of physical habitat complexity from any works to stabilise river channels and improve their flood conveyance capacity.

4.31 Low flows during drier summers could result in downstream migration of perennial heads of streams. Lower water levels could mean ephemeral sections will become increasingly dry, whilst perennial sections will become ephemeral – resulting in an overall loss of riverine habitat volume or area. Low flow could also reduce water quality in terms of dissolved oxygen levels, and poorer flushing of contaminants leading to ecological stress.

4.32 Increasing annual average temperatures may create thermal stress particularly for those species near the southern limit of their temperature range. This will be most acute where species cannot migrate upstream to higher altitudes and cooler waters, due to other environmental factors (e.g. flow regime, bed sediment composition), access difficulties (e.g. in-channel structures), or the lowland nature of the whole catchment. Higher temperatures may also be more conducive for alien invasive species.

Ponds, Lakes and Reservoirs

4.33 A pond is defined as being a small body of water, between $1m^2$ and 2ha that holds water for at least 4 months of the year. Ponds provide rich and complex habitats for wildlife supporting a vast array of freshwater plants and animals.

4.34 Lakes and reservoirs include both natural and man-made water bodies, such as lakes, reservoirs, flooded quarries and gravel pits that are over 2ha in size. The plant and animal communities depend on the nutrient status of the water, which can range from nutrient poor (oligotrophic) through to nutrient rich (eutrophic).

4.35 For shallow lakes, ponds and ditch systems, higher water temperatures, a longer growing season, increased primary productivity and higher evapo-transpiration rates during warmer summers leads to increased likelihood of eutrophication symptoms where nutrient loads are high. There could also be a greater frequency and duration of (toxic) algal blooms or a ‘forward switch’ to a turbid algal dominated state, and lower dissolved oxygen levels. Higher water temperatures could be more conducive for invasive plants and allow recruitment for introduced and problematic fish species e.g. carp.

4.36 Drier summers (drought) could lead to increased concentration, and therefore toxicity of substances, decreased flushing/longer retention times (interaction with water quality pressures) and loss of connection with other freshwater habitat (rivers, ditch systems). Another consequence could be the exposure of littoral (shore) communities and loss of fish spawning habitat.

4.37 More frequent storms and higher intensity of rainfall could increase run off, sediment and nutrient delivery, with fluctuation and erosion of marginal features. There could also be potential loss of submerged plant communities. Extreme fluctuations in water levels may reduce overall biodiversity as only certain species will be resistant.

Reedbeds

4.38 Reedbeds are wetlands dominated by stands of common reed (*Phragmites australis*) and are found in areas where the water table is at or above ground level for most of the year. Anecdotal evidence suggests that the number and size of reedbeds in the Tees Valley, particularly around the estuary, has increased over the last 20 years or so. Milder winters may have increased the rate of (*phragmites*) seed germination allowing reeds to spread more quickly.

4.39 An increase in frequency of storms with higher intensity rainfall could lead to possible loss of habitat through flooding though reedbeds should survive inundation. Drier summers could lead to drying out of reedbeds in summer, and a reduction in water quality due to less dilution of pollutants which could constrain ecosystem functioning. Low water levels due to drought will lead to encroachment of scrub into reedbeds, reducing their ecological value. Sea level rise could lead to loss of reedbeds through coastal realignment and flooding. Reeds are tolerant to saline conditions to some extent, but some of the ecological communities they support, such as freshwater fish, are not.

Fens, and coastal and floodplain grazing marsh and swamp

4.40 Fens and swamps encompass a range of habitat types including vegetation that is fed by ground water or frequently inundated occurring on peat, peaty or mineral soils. In swamps, the water levels are above or at the surface of the vegetation for most of the year. These habitats are dynamic and management is necessary to maintain them and associated species, and prevent natural succession to scrub and woodland.

4.41 Wet woodland occurs on poorly drained or seasonally waterlogged soils, often on floodplains around the margins of other wetland habitats, and is usually dominated by alder, birch and willow, though in Tees Valley wet woodlands also include Black Poplar (one of Britain's rarest trees) in Darlington and Middlesbrough. This habitat is very scarce and fragmented.

4.42 Warmer summers, higher water temperatures and higher evapotranspiration could lead to species change. Drier summers, and especially drought, could lead to the drying out of fens in summer with a subsequent loss of individual species, and shift in community composition. This could also lead to the drying and oxidation of peat, followed by release of nutrients, further shifting community composition.

4.43 Wetter winters and higher intensity rainfall during storms will increase the risk of polluted run-off and unpredictable inundation of floodplain fen. Indirect impacts include increased silt loading when inundation occurs. Saline intrusion and flooding due to sea level rise may also cause the loss of some fen habitats.

4.44 Coastal and flood plain grazing marsh are grasslands found in low-lying coastal areas or within the flood plains of rivers that are periodically inundated with water. They usually have high water levels, which are maintained by ditches containing brackish or fresh water. These areas are traditionally managed by grazing animals or cut mechanically for hay or silage.

4.45 Higher water temperatures and higher evapotranspiration rates during hotter summers could lead to changes in species composition, and a loss of breeding habitat for wetland birds. Drier summers could lead to marshland and particularly wet grassland drying out and a loss of habitat. Declining summer rainfall means that there is a critical need to identify ways of ensuring continuity of water suppy. This could involve water storage through specially created wetlands which can act as ‘reservoirs’ to supply water to grassland and other habitats at critical times.

4.46 Flooding and higher rainfall intensity during storms and wetter winters could lead to unpredictable inundation of floodplain grazing marsh, increased silt loading when inundation occurs and a loss of breeding habitat for wetland birds. In particular, sudden rises in water levels due to spring flooding can result in the loss of nests of breeding wetland birds.

4.47 Saline intrusion and flooding due to sea level rise could lead to a loss of freshwater marsh species, including some wading birds. A possible solution is to create freshwater wetlands further away from saline intrusion to compensate for the loss of those which become saline habitats.

Lowland Meadow

4.48 Lowland meadows, as defined by the UK BAP, are species rich grasslands on neutral soils, usually below 250m in altitude. They are characterised by low nutrient inputs and are usually managed either as hay meadows or grazed as permanent pasture. Most are found in rural farmed landscapes but the definition also encompasses fragmented unimproved species rich grassland in non-agricultural settings such as churchyards and roadside verges.

4.49 Hotter summers and a longer growing season may cause the phenology of this habitat to change significantly due to earlier flowering/setting seed. Drier summers will favour stress tolerant (e.g. deep-rooted species) and ruderal species but retard competitors/stress-tolerant competitors which will again have consequences on designated sites

Lowland Heath

4.50 Lowland heath is a broad term that refers to a mosaic of wet, damp and dry habitats, characterised by ericaceous dwarf-shrubs such as bell heather and ling, with associated areas of freshwater pools and bogs, scattered trees and shrubs, bare ground and acid grasslands. They are generally found on poor acidic soils below an altitude of 300m.

4.51 Hotter summers and a longer growing season may accelerate spring growth and increase above ground biomass which could lead to a loss of species depending on bare ground and open areas. There is likely to be increased damage from heather beetle attacks. There may be slight increased flowering, though litter fall tends to decrease which subsequent changes in soil chemistry with possible impacts on soil fauna, and changes in community composition. Impacts on designated sites include the loss of/declining condition in parts of the SSSI/SAC designations and continuing unfavourable conservation status for Annex 1 habitat.

4.52 Drier summers and drought conditions will decrease *Calluna* flowering and lower plant replacement rate, decrease growth, net primary productivity, litter fall and seedbank for *Calluna* but will increase the risk of wild fires. The impacts on designated sites mentioned above may also apply. Wetter winters may increase run off and leaching.

Purple moor grass and rush pasture

4.53 This habitat typically includes a number of different species-rich fen meadow and rush pasture types, with plants such as purple moor grass and sharp-flowered rush usually abundant. This habitat may however no longer occur in Tees Valley.

4.54 Drier summers and a lower water table may lead to scrub invasion, woodland succession and a loss of species whereas prolonged inundation due to a higher water table in wetter winters may shift them towards true fen or swamp communities.

Brownfield sites

4.55 Due to the mosaic nature of brownfield site habitats it is not possible to comprehensively assess the range of potential vulnerabilities to climate change impact. However, because of potential development pressures on some of the brownfield sites in Tees Valley, it is important that ecosystem functions such as winter water storage as well as valuable wildlife sites are valued in regeneration schemes in order to prevent consequences such as increasing flood risk. The most important brownfield sites have already been identified as part of the local wildlife site designation process and can be taken into account in the planning and design of development.

Conclusion

4.56 Most of the key habitats and species in the Tees Valley are vulnerable to a range of stresses which are likely to be exacerbated by future climate change. In some cases, the changing physical or biological composition of a habitat as a result of direct or indirect climate change could affect the statutory designation of some sites. In some cases, increasing resilience to climate change offers real opportunities for biodiversity benefits e.g. wetland creation. Along with reducing the sources of harm not linked to climate change, increasing the connectivity of sites is crucial to allow species to adapt as fully as possible, so it is important to minimise the potential for unintended consequences such as the spread of alien invasive species through coherent messages and public awareness.

Geodiversity Assets

Quarries and pits

4.57 Hotter, drier summers could lead to increased vegetation growth obscuring exposure. Changing cycles of wetting and drying of faces could lead to increased slumping and obscuring of exposure, and failures of quarry faces may mean that exposures of the interest features end up beyond the boundaries of statutory sites.

4.58 Flooding and increased weathering and erosion rate as a result of increased frequency of storms will cause flooding, slumping and changes in vegetation in softer rock lowland areas, and reduced access to exposure.

4.59 Indirect impacts on quarries and pits include obscured exposure due to the stabilisation of faces in form of grading, battering, geotextiles, drainage, or vegetation, or other potential loss of exposure of interest features due to response strategies in other sectors. There could also be generation of other nature conservation interests (since such sites may also function as refuges for displaced taxa and habitats).

Coastal cliffs and foreshore

4.60 Intense rainfall and high wind speeds associated with increased frequency of storms could lead to accelerated erosion of softer rock coastlines. Sea level rise and tidal flooding will also increase erosion. Pressure to increasingly defend such coasts through a variety of engineering techniques, particularly where properties and high land values are involved could lead to a loss of exposure and impairment of natural processes. Accelerated foreshore lowering and disruption of sediment supply.

4.61 Drier summers and drought could lead to accelerated mass movement in susceptible cliffs, and usually temporary loss of exposure of interest features. Indirect impacts could result from schemes to stabilise through grading, battering, toe revetments, drainage etc. There are also indirect impacts likely to be associated with other coastal defence schemes.

Water bodies (rivers and streams)

4.62 Intense rainfall, flooding, high winds and increased rates of erosion associated with the increased frequency of storms could have direct impacts such as silt run-off into waterbodies, channel abandonment and burial, and migration of channel systems. Additionally, higher average annual temperatures and longer growing seasons could result in greater in channel vegetation growth with resultant sediment trapping.

4.63 Indirect impacts on water bodies could result from engineering schemes related to flood and erosion management as well as water storage. These could lead to permanent loss of exposure of interest features and impairment of processes.

Underground mines and tunnels

4.64 Intense rainfall and flooding associated with the increased frequency of storms and wetter winters could increase the discharge of pollutants, and impact on water quality. There could be flooding of mines and loss of access to interest features. However, in some cases there may be potential for water storage. There could be indirect impacts on water quality and schemes, as well as impacts associated with remedial engineering works, and potential to use mines and underground tunnels for floodwater storage or treat discharge that could impact on extent and access to interest features.

4.65 Hotter summers and longer growing season will lead to increased rates of weathering, and increase rates of failure and erosion. There is also likely to be vegetation change and increased growth rate which could exacerbate changes to specially adapted plants associated with mine dumps.

4.66 Wetter winters, increased intensity of rainfall, and flooding could lead to increased slumping and erosion, as well as change the chemistry of leachates. Floodwater storage could restrict access, and flooding could also increase the discharge of mine pollutants.

Extensive buried interest

4.67 Drier summers and drought conditions may lower the water tables leading to oxidation of peats etc. Indirect impacts could include potential changes in land use that could impact on access to and condition of interest features.

4.68 Milder wetter winters could increase vegetation encroachment and vegetation change. There could also be impacts on accessibility and potential damage to features through root penetration and disturbance. There could also be indirect impacts from engineering schemes related to flood management.

Road and rail cuttings

4.69 Longer growing seasons and hotter summers could increase vegetation growth obscuring exposure and create impacts on visibility and accessibility with potential damage to features through root penetration and disturbance.

4.70 Wetter winters could increase slump/slope failure, and failure of cutting faces may mean that exposures of the interest features end up beyond the boundaries of statutory sites. Indirect impacts from remedial engineering, e.g. in the form of netting, soil nailing, battering, grouting could obscure interest features and render them physically inaccessible.

Geomorphological (Static and active)

4.71 The increased intensity of rainfall, high winds, flooding and erosion resulting from increased frequency of storms may lead to a high risk of mass movements and slumping, and accelerated rates of weathering may occur. Longer growing seasons and wetter winters could increase vegetation growth leading to obscuring exposure.

4.72 Indirect impacts associated with remedial engineering could impact on interest features and impair geomorphological processes.

4.73 Sea level rise may increase the risk of mass movements as well as accelerate coastal erosion.

Inland outcrops

4.74 A longer growing season and wetter winters will increase rates of weathering and likelihood of vegetation growth obscuring features.

Soils

4.75 The vast majority of soils in the Tees Valley are vulnerable to increased winter rainfall and increased intensity of rainfall. Impacts on slowly permeable seasonally wet slightly acid but base-rich loamy and clayey soils, slightly acid loamy and clayey soils with impeded drainage, and slowly permeable seasonally wet acid loamy and clayey soils could result in fewer work days for arable cultivation and increased risk of soil compaction due to mechanised operations, stock grazing or recreational use in wetter conditions. Clay soils with a high shrink swell potential will be more difficult to manage and in some cases there could be disturbance to building foundations. Newcastle City Council is commissioning a geotechnical report on soils in Newcastle and their susceptibility to movement which may provide further evidence in relation to potential impacts[16].

4.76 Climate change impacts on freely draining floodplain soils could also result in similar impacts, but additionally, these soils may be unstable and prone to erosion, where they are cultivated/bare (e.g. arable land, recently reseeded grassland, footpaths) and organic matter contents are low. Sediment deposition may impact on soil quality depending on source. Buffer strips along field boundaries and water courses can help to reduce this impact.

4.77 Increased water run-off due to higher rainfall intensity may increase diffuse pollution (e.g. from applied manures, very fine sediment) or increased local flooding on slowly permeable seasonally wet acid loamy and clayey soils.

4.78 Increased temperatures could result in the loss of peat stock/carbon stores from slowly permeable wet very acid upland soils with a peaty surface but this will depend upon the balance between increased plant growth and organic matter decomposition. Increased intensity could increase the risk of gullying or hagging on these soils.

4.79 Reduced summer rainfall could impact on land uses/habitats and may require changes in agricultural practice on freely draining very acid sandy and loamy soils, and these soils may also be increasingly vulnerable to erosion through increased rainfall intensity where bare soil is exposed or is cultivated. Increased leaching is also possible.

4.80 Loamy and clayey soils of coastal flats with naturally high groundwater and sand dune soils are vulnerable to salinisation as a result of sea level rise that could potentially result in the loss of these assets.

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16 http://www.newcastle.gov.uk/wwwfileroot/ns/environment/DRAFTforPublicConsultationClimateChangeStrategyActionPlanJune2010.pdf p33

Historic environment assets[17]

4.81 The human components and historic environment tell an important story about the development of industry in particular, but also society more widely. The Tees Valley contains over 8000 recorded archaeological sites, 120 scheduled archaeological sites, as well as a number of parks and gardens that are of historic interest, together with over 1400 listed buildings and conservation areas

<u>Examples of key historical knowledge assets</u>

- Head of Steam Railway Museum in Darlington, a restored 1842 passenger station on the original route of the Stockton and Darlington railway
- Piercebridge roman fort which dates back to AD270
- The Hartlepool Maritime experience which is a recreation of an 18th Century seaport and includes the HMS Trimcomlea that was built in 1817
- The 5000 year old Hartlepool Submerged Forest in Hartlepool Bay – shelves of ancient peat with the roots of half-fossilised pine trees embedded in it.
- Heugh Gun Battery
- Stewart Park and the Captain Cook Birthplace Museum
- Transporter Bridge and visitor centre
- Cleveland Ironstone Mining Museum
- Guisborough Priory
- RNLI Zetland Lifeboat Museum containing the oldest surviving lifeboat in the world
- Saltburn Pier and Inclined Tramway
- Preston Hall Museum and Park

The Impact of climate change on below ground historic features

Many archaeological features survive as buried remains, often on agricultural land. These are often visible as cropmarks on aerial photographs. Where there are buried ditches the soil holds more moisture meaning that crops grow taller, ripen later and will stay green for longer. Where there are buried walls and hard surfaces there is less moisture meaning crops will become stunted and ripen earlier, appearing as parch marks. Cropmarks are particularly visible in dry summers. As many of these sites are only known from their cropmarks their importance, condition and the impact of climate change is difficult to estimate. Desiccation of archaeological features might lead to damage to fragile organic deposits which are only preserved in waterlogged anaerobic deposits. Further work is needed to assess the impact of climate change on these types of deposits. Over 100 of these types of sites are currently recorded in the Tees Valley.

Marks in the ripening crop at Barnaby Side, near Guisborough, show a sub-rectangular Iron Age Enclosure (on the boundary between the sandy brown field and ripening green/brown field). A less distinct circular enclosure is visible to its right with a linear feature cutting across the field to a former Bronze Age mound.

4.82 Sea level rise and flooding could directly lead to the loss of historical assets, and direct and indirect climate change impacts such as drier summers and changing vegetation patterns may also create the need for increased management of historic assets.

4.83 Depending on their location and degree of exposure, knowledge assets such as archaeological sites, listed buildings, and historic parks can be extremely vulnerable to climate change, particularly where the only available option is to fully record the

[17] All case studies in this section are courtesy of Tees Archaeology

asset and then accept the loss. In exceptional cases it may be possible to rescue and relocate certain assets.

Below ground historic features

4.84 Drier summers, drought and lower soil moisture could increase erosion and change soil chemistry. Soil pH change may affect buried archaeology, erosion may expose buried features, drying out and cracking/heaving may lead to exposure of buried features and loss of stratigraphic integrity. There could also be a loss of features preserved in waterlogged conditions.

4.85 Wetter winters and increased flooding could cause the crystallisation and dissolution of salts caused by wetting and drying that may damage archaeology as well as affect soil chemistry.

Flooding at the Scheduled Monument of Stainsby Deserted Medieval village.

Stainsby Deserted Medieval village now lies to the west of the A19 on the outskirts of Middlesbrough. The area has been developed for equestrian purposes and includes a designated landscape representing former medieval buildings, boundaries, ponds and field systems.

The site was subject to flooding in 2004 following heavy rainfall. This required emergency works to alleviate threat to property. The exact impact of this sort of short term flooding on upstanding archaeological remains has not been properly assessed.

Both construction of new flood defences and breaching of existing defences could have a negative impact of historic assets.

Flood waters at Stainsby Medieval Village in 2004. Damage might be caused during remedial works, changes in the burial environment and trampling and rutting from traffic on previously dry areas.

Indirect impacts include cropping changes that may affect buried archaeology through ground preparation, root penetration, de-watering and harvesting.

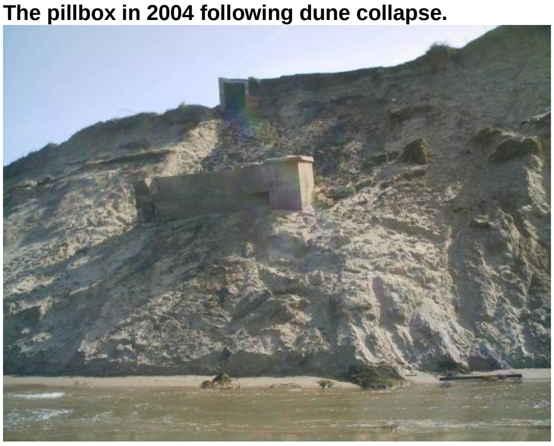
Large scale archaeological features may experience similar impacts to below ground features, though there could be additional impacts from increased vegetation growth obscuring features.

Relic boundaries may face pressures from increased vegetation growth as well as indirectly through changes to cropping regimes or land use.

The Impact of coastal erosion on Non-domestic Buildings
The Teesside coastline was heavily defended against invasion in World War II. The remains of these defences survive in a number of locations including Hart Warren, Greatham Creek and South Gare. The remains consist of anti-tank obstacles, pillboxes, section posts and gun emplacements. The majority would have been constructed in 1941. In January 2004 a well preserved V-shaped pillbox was destroyed at Hart Warren when the dune system beneath it collapsed. Approximately 50% of the structure slid down the dune with the remainder cleared by the local authority for safety reasons. Approximately 700 archaeological sites lie within 1km of the coast and might be threatened by coastal erosion.

The pillbox in 1986.

The pillbox in 2004 following dune collapse.



Historic wetlands could dry out and be lost during drier summers, with a consequent loss of features preserved in water logged conditions. Longer growing seasons could lead to vegetation succession leads to scrub encroachment on historic wetlands, whereas indirectly this could lead to intensification of agriculture onto previously marginal areas. Repeated cycles of flood and drought result in loss of wetland plants, and increased flooding due to wetter winters could increase in nutrient loading leading to eutrophication of historic wetlands.

Built water features could dry out, erode or crack during hotter drier summers, and be overwhelmed by floods and intense rainfall.

Domestic and non-domestic buildings could broadly experience similar impacts. Drier summers could increase erosion, subsistence and decrease soil moisture. Drying out could leads to damage to historic material, crystallisation and dissolution of salts caused by wetting and drying could damage structures and decorated surfaces, and drying out and cracking of soils leading to subsidence and damage to foundations. Hotter summers could lead to increased biological attack from insects e.g. termites.

Wetter winters could increase damage to structures from flooding, drainage may be unable to cope with higher intensity rainfall, rising damp damages buildings and increases risk of biological attack from moulds and fungi. Corrosion of metals may also occur. High winds could increase damage to external structures and facades.

4.86 For non-domestic buildings, indirect impacts of hotter summers could include the need to use farm buildings to house stock in summer to prevent heatstroke, and they may also be required to house stock that currently over-winter outside or stocking levels may have to be reduced to avoid erosion of wet land by animals and equipment during wetter winters.

Severe weather and coastal archaeology

Peat deposits which outcrop on the beach at Seaton Carew represent a wetland environment of archaeological interest at risk from climate change. The peat deposits encode information on past environments, sea level and climate as well as acting as an excellent medium for the preservation of organic material that would not otherwise survive. Savage storms in 2009 led to large chunks of peat being torn up and any archaeological information destroyed.

One of many large chunks of peat torn from the submerged forest during November storms in 2008.

Monitoring of the protected wreck site of a collier brig at Seaton Carew shows how sand movement can preserve or expose fragile archaeological remains of national importance.

The upper ribs of the wreck emerge during a sandstorm

Heavy sand loss exposes all but the very base of the wreck making it extremely vulnerable.

Access and recreation assets

4.87 The natural environment and open spaces represent a valuable resource for recreation and leisure. Accessible, good quality green spaces, along with the extensive network of footpaths, bridleways and cycle paths play an essential role in encouraging healthy lifestyles. Low levels of car ownership and high deprivation levels in parts of the Tees Valley mean that it is important to have areas of accessible green space close to where people live.

4.88 Key recreational assets in the Tees Valley include:

- A National Nature Reserve around the Tees Estuary and a number of local nature reserves
- RSPB Saltholme Wildlife Reserve and Discovery Centre
- Several major footpath and cycle routes of national as well as local importance
- Tees Barrage, including barge lock, fish pass and white water course
- Proposed North Tees Natural Network with a key objective of improving access to areas with no or limited access at present

4.89 Climate change will have a range of both positive and negative impacts on access and recreation assets throughout the Tees Valley, including:

Urban green space

4.90 Warmer drier summers will increase the popularity of visits to parks, gardens and nature trails, resulting in increased recreational pressure and potential impact such as footpath erosion. There may also be increased irrigation and management requirements.

Waterbodies

4.91 Hotter summers and reduced summer rainfall could lead to a reduction in water quality due to higher concentration of pollutants, as well as health impacts due to low water quality e.g. blue green algae and increasing vector borne diseases and pests. A general reduction in water levels will create more pressure on remaining resources for recreation, while indirectly creating more demand for outdoor recreation.

4.92 Increased winter rainfall and frequency of storms could increase hazards e.g. unstable banks, and reduce demand for water based recreation in the winter.

Forests and woodlands

4.93 Hotter drier summers could increase demand for woodland recreation due to the shade it can provide, but increase fire risk and the presence of ticks and potential for tick borne diseases. Drought and increased wind speeds could also increase hazards from falling branches.

Conclusion

4.94 Generally, warmer summers as a result of climate change will increase the value of the natural environment for recreational purposes. This could have a range of positive and negative impacts, from improved physical fitness, greater wellbeing, and an increased sense of appreciation and connection to the natural environment to negative impact on species and habitats, increased footpath erosion and disturbance of sensitive sites, wildfire risk, and increased incidence of health impacts (such as sun-stroke) and anti-social behaviour.

Summary of climate change impacts on landscape character and function in the Tees Valley

Key landscape characteristics	Climate change impacts	Potential vulnerability
A broad low lying plain of gently undulating, predominantly arable, farmland with wide views to distant hills.	The shape of the landscape is unlikely to change although the appearance may alter as land use responds to the impacts of climate change.	
Meandering, slow-moving river Tees flows through the heart of the area dividing the lowlands to north and south.	The impacts of wetter winters and drier summers could gradually change the character of the Tees and its tributaries. Changes in nutrient and sediment loads through increased run off and flooding, and flood defence measures could also potentially change parts of the river. There is also potential for increased erosion during storm surge/peak flow events	
Contrast of quiet rural areas with extensive urban and industrial development concentrated along the lower reaches of the Tees, the estuary and coast.	Settlement patterns are likely to change, and while there is a focus on increasing housing development around the five core urban centres in Tees Valley. Carbon neutral developments/zero carbon housing, sustainable drainage schemes etc could help to mitigate potential impacts from future built development.	
Large-scale chemical and oil refining works, dock facilities and other heavy plants along the Tees estuary form a distinctive skyline by day and night.	Though there may be changes in the location and composition of industrial and major operations, it is unlikely that this characteristic of the landscape will fundamentally change. However there is likely to be a need for new or improved sea and flood defences to ensure these assets are protected.	
Overhead transmission lines and pylons, motorway corridors, railway lines and other infrastructure elements are widespread features.	This is unlikely to change although there may be a need in the future to relocate or protect critical infrastructure due to climate change impacts.	
Woodland cover is generally sparse but with local variation such as, on steep banks of the middle reaches of the Tees, and to parkland and managed estates.	Climate change impacts may alter the structure and composition of woodland cover. Also, tree cover could increase in a number of locations due to the implementation of the Green Infrastructure Strategy, increased planting of trees to reduce urban heat island effects and surface flooding, and potentially as a result of increased biomass demand for energy production.	
Distinctive areas of peaty fenland flatts and carrs within the Skerne lowlands.	Hotter drier summers could lead to drying out or eutrophication and unpredictable flooding associated with increased winter rainfall and rainfall intensity could change the composition and extent of fens in the Tees Valley.	
Extensive areas of mud flats, saltmarsh wetlands and dunes at mouth of the river Tees which support valuable wildlife habitats.	Saltmarsh is vulnerable to coastal squeeze in Tees Valley although the compensatory habitat is being developed as a mitigation measure. Saltmarsh and mudflats are also vulnerable to potential changes to sedimentary processes resulting from climate change which could alter the morphology as well as estuarine food webs. Drying out of marshland and wet grassland could affect landscape character through increased amounts of woodland and scrub cover	
Minor valleys and linear strips of open land extend as 'green corridors' from rural farmland into the heart of the Teesside conurbation.	The role, function and quality of such land may change due to the implementation of the Green Infrastructure Strategy and fragmentation may be addressed through the creation of new and enhanced green space.	
Varied coastal scenery of low cliffs, bays and headlands, rich in wildlife, although despoiled in places by former extensive dumping of colliery waste on beaches and foreshores.	The shape of the coastline may change due to accelerated erosion and development of sea defences. The impact on wildlife is not clear due to uncertainties in the pace and specific impacts of climate change individually and cumulatively on species, particularly migratory birds. Increased number of visitors could increase pressure on certain habitats and species.	

Key:

Likely to be more resilient to climate change impacts or for which climate change impacts may be beneficial.	
Likely to require careful management and monitoring to support its adaptive capacity.	
Impacts could significantly change the character or nature of the asset, or destroy the asset	

5. Summary of climate change impacts on key functions of the natural environment

Food and biomass production

5.1 Climate change is likely to directly and indirectly affect food production in the Tees Valley. People and services could be displaced from low lying parts of the UK, and indeed from parts of the world that become inhabitable as a result of climate change and sea level rise, resulting in pressure on land in areas such as Tees Valley. Direct impacts could include intensification of agriculture, changing the geographical extent of crops that are economically favourable to grow, the timing of planting, and the need to alter land management practises to accommodate impacts of increased rainfall on clayey soils. Indirectly, increasing demand for biomass for power generation and biofuels could influence the landscape of the area.

5.2 As world population increases pressures for agricultural expansion and intensification are also likely to increase. Coupled with rising energy costs and as other parts of the world become agriculturally unproductive as a result of climate change then pressure to use areas of potential high productivity but which are also important for wildlife could increase. In the Tees Valley this could include rich alluvial land along the River Tees corridor.

5.3 Approximately three quarters of the carbon footprint of growing wheat results from the application of nitrogen based fertilisers, and there are several options to increase yields for ethanol production. One option is to apply fertiliser earlier, but this can be a problem as there is a higher risk of losing the application through increased run-off. An alternative option would be to grow triticale instead of wheat for bioethanol, as this requires 30-40% less nitrogen and can be grown on impoverished soils (including contaminated land since it would not be intended to enter the food chain). This could create indirect impacts on brownfield habitats.

5.4 Local urban food production is likely to increase as existing initiatives become more popular and widespread.

Freshwater provision and drainage

5.5 Freshwater supply for potable and industrial raw water is unlikely to be reduced in the short term (2010-2035) as a result of climate change, as there is ample natural resource in the North East, and Northumbrian Water have no immediate plans to export water to neighbouring water companies[18]. Increased seasonality of rainfall in the North East - less in summer and more in winter – will almost certainly affect freshwater provision and drainage and have impacts on the natural and built environment of the Tees Valley. Further research into the impact that reduced river flows during drier summers may have on permitting discharge consents in the Tees catchment may be useful.

5.6 Higher land run-off volumes will enhance nutrient and sediment delivery to rivers and increased hydraulic scour in rivers, increased wash-off of fine sediment and nutrients to watercourses, leading to further eutrophication and siltation effects. Migration of channel systems with increased erosion could lead to unpredictable flooding and loss

[18] http://www.nwl.co.uk/NW_Statement_of_Response_to_Consultation.pdf

of riverine/wetland habitat. This could be countered to some extent through the restoration of floodplain functions by, for example, wetland creation to provide additional flood storage and restore natural processes.

5.7 Increased temperatures could be more conducive to invasive species, and drier summers may negatively affect water quality. Cumulative impacts could contribute to changes in species composition and the life cycles of plants and animals. Sea level rise could impact on fresh water habitats, and there will be a need to plan for coastal habitats to ‘roll back’ inland to ensure a full suite of intertidal/floodplain habitats remain in place.

5.8 Changing freshwater habitats and drainage systems may damage the historic environment and geodiversity assets directly, or indirectly as a consequence of engineering schemes relating to flood and erosion management.

Minerals

5.9 In the Tees Valley, sand is obtained from the self-replenishing beach extraction site at North Gare (Hartlepool), therefore changes to the North East coastal systems and sand replenishment as a result of climate change may have a direct impact in the future. There may also be indirect impacts on sand extraction associated with a need to expand buffers around the habitat or change the management of the North Gare dunes as a result of climate change.

Climate regulation

5.10 Implementation of the green infrastructure projects provide opportunities to strengthen this function in the Tees Valley, in terms of reducing urban heat island effects, and potentially through flood mitigation. The ability of soils to sequester carbon is dependent upon changing land management practises, and although there is a small proportion of upland peat soils that may oxidise (and release carbon emissions), there may also be potential to develop peaty areas through increasing wetland habitat.

5.11 Climate change is likely to severe impacts on infrastructure. For example flash flooding on hard surfaces and roads could cause damage to sewerage system which in turn could have a damaging effect on wildlife habitats, especially wetlands and streams.

Flood water storage

5.12 Parts of the Tees Valley are currently vulnerable to flood risk so this is likely to be exacerbated as a result of climate change. There are a number of options available to increase the amount of water stored as a result of increased rainfall due to climate change[19]. Where possible, improving soil organic content (humus) increases the biological, chemical, and physical structure of the soil, increasing water infiltration rates and therefore reducing run-off, as well as minimising the leaching of nutrients from the soil.

5.13 Research by the University of Manchester on the role of green infrastructure on alleviating flood risk shows[20]:

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[19] http://www.rspb.org.uk/Images/naturalfloodmanagementinactionposter_tcm9-196387.pdf

[20] http://www.cabe.org.uk/sustainable-places/advice/green-infrastructure-and-flood-risk

- increasing the green space cover in urban areas by 10 per cent reduces surface run-off by almost 5 per cent
- increasing tree cover in urban areas by 10 per cent reduces surface water run-off by almost 6 per cent
- adding green roofs to all the buildings in town centres can reduce surface water run-off by almost 20 per cent

5.14 Wetlands also often perform important flood storage and mitigation functions and there appears high potential in Tees Valley to explore how improved flood mitigation could support the creation of wetland habitat or vice versa[21]. The Tees Valley contains a significant area of floodplain as well as intertidal mudflats and saltmarsh which reduce flood risk by dissipating wave energy.

Soil Formation

5.15 The existing quality of the soils in Tees Valley will influence their vulnerability to direct climate change impacts. Terrestrial soils with low organic content will be highly vulnerable to direct climate change impacts such as increased erosion, leaching, and run off as a result of increased frequency and intensity of rainfall. Soil formation on sand dune and coastal soils will also be highly vulnerable to erosion as well as salinisation. Warmer, drier summers may exacerbate erosion which will negatively affect soil formation. There may also be indirect impacts from changing sedimentary processes that influence soil formation.

Pollination

5.16 The impacts of climate change on pollination are intrinsically linked to the direct and indirect impacts of climate change on biodiversity and agricultural production.

Health and wellbeing

5.17 There are a range of positive physical and mental health and wellbeing benefits that will result from climate change and increasing physical activity through recreation outdoors. Additionally, some significant negative impacts on health and wellbeing such as increased risks of heat stress can be reduced through increasing green infrastructure, particularly in urban areas.

Sense of place and aesthetic value

5.18 Key landscape features such as peaty fenland flats and carrs in the Skerne lowlands, and the extensive areas of mudflats, saltmarsh wetland and dunes are vulnerable to direct and indirect climate change impacts. These, alongside impacts on the historic environment, could negatively affect the sense of place and cultural services provided by the landscape in the Tees Valley. However, there are also opportunities to develop new positive connections with the landscape of the Tees Valley, particularly around increased recreation and association with the natural environment.

5.19 A longer growing season, and earlier spring flowering, together with opportunities to develop multifunctional wetland habitats may all influence the aesthetic value of the landscape. Country parks and nature reserves may be harder and more expensive to manage as, for example, paths become overgrown more quickly.

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[21] http://www.defra.gov.uk/environment/flooding/documents/manage/jointstment.pdf

6. Conclusions and Future Actions

6.1 Unless greenhouse gas concentrations in the atmosphere can be reduced it will be difficult to avoid major, even catastrophic, impacts on the natural environment. Clearly, reducing greenhouse gas emissions requires coordinated action at international and national levels. Even if emissions can be reduced the effects of climate change will continue to be felt for many years to come. Therefore there is an urgent need to develop strategies to manage and reduce the effects of climate change on the natural environment.

6.2 Central government and many public and private bodies, including local authorities, have a range of policies, programmes and initiatives in place to help with the challenges of climate change, including a move to a low carbon economy. The Royal Town Planning Institute, in its 'Seven Commitments to Climate Change', has suggested that action to adapt existing places is likely to be more important and valuable than action to secure sustainability in new development. The same probably applies to the natural environment, where it is best to help existing habitats and landscape characteristics adapt to and manage the effects of climate change rather than focussing too much on the creation of new habitats.

6.3 In general terms this report has shown that the impacts of climate change on the natural environment will include:

- Changes in plant and animal species that can survive in particular habitats
- New species moving into certain areas and habitats while others may be lost if they are unable to adapt to changing conditions
- Changes in the timing of seasonal events such as flowering, fruit production, breeding and migration patterns
- Increased risk of soil erosion and flooding during intensive rainfall
- More frequent occurrences of extreme weather which may result in some habitats not being able to recover to the same extent as they may have done in the past

6.4 Responses to the climate change impacts highlighted in this report will need to be taken up by a variety of different bodies and organisations. In many cases further work and research will be needed to allow all options and implications to be considered and a detailed response to be made. There are however a number of practical steps that can be taken to safeguard the natural environment, including:

- Seeking to improve the condition of existing habitats to help species cope better with climate change
- Expand existing habitats and create new areas for wildlife
- Create and enhance natural corridors and 'stepping stones' to help species move between areas of high value

- Restore lost and degraded habitats
- Work closely with the farming community on practical ways of helping the natural environment to become more resilient, for example by encouraging buffer strips for wildlife around fields

6.5 The impact of climate change on the natural environment will also require a policy response such as:

- Using the planning system to ensure the natural environment is accommodated
- Making full and appropriate use of green infrastructure strategies and projects
- Demonstrating the economic benefits of a healthy natural environment

6.6 The proposal in the government's recent white paper on the natural environment for the establishment of Local Nature Partnerships (LNP) offers an opportunity to consider further the implications of climate change on the natural environment. A key objective of LNP's is to work strategically to conserve biodiversity and improve the range of socio-economic benefits and services provided by a healthy natural environment. A key role of a Tees Valley LNP could be to ensure that potential impacts of climate change are understood by the wide range of partners and stakeholders tasked with conserving and enhancing the natural environment.

Appendix: Adaptation Assessment Matrix

Actions	Win-win	Low regrets	Landscape	Ecosystem services	Geology and soils	Biodiversity	Historic Environment	Access and recreation
Priority actions								
Use a landscape approach to managing and creating habitat e.g. Through green infrastructure strategy	+	+	+	+	+ / +	+	-/+	-/+
Develop catchment level adaptation	+	+	+	+	+ / +	+	-/+	+
Develop multifunctional wetlands (including sustainable urban drainage systems) e.g. To reduce flood risk and support biodiversity and recreation	+	+	+	+	+ / +	+	-/+	+
Ensure climate change is coherently built into spatial planning across Tees Valley	+	+	+	+	+ / +	+	+	+
Develop coherent and consistent messages to raise public awareness and promote responsible access and recreation	+	+	+	+	+ / +	+	+	+
Periodically review available evidence and adjust management of asset as appropriate	-/+	-/+	-/+	-/+	-/+ / -/+	+	+	+
Record assets where loss is inevitable	+	+	+	+	+ / +	+	+	+
Monitoring	+	+	+	+	+ / +	+	+	+
Adaptation Actions identified for key assets of the Tees Valley								
Woodland - lowland mixed deciduous woodland								
Maintain existing habitat	+	+	+	+	-/+ / -/+	+	-/+	+
Increase size of small woods in intensive agricultural /urban areas	+	+	+	+	-/+ / -/+	+	-/+	+
Increase connectivity	+	+	+	+	-/+ / -/+	+	-/+	+
Address other threats e.g. deer, new pests and diseases	+	+	+	+	-/+ / -/+	+	0	+
Build in flexibility in conservation objectives to accommodate vegetation shifts.	+	+	+	+	-/+ / -/+	-/+	-/+	+

Develop consistent and coherent approach to where invasive might be accepted as part of future natural woodland	+	+	+	+	-/+ / -/+	-/+	-/+	+
-								
Hedgerows								
Maintain range of hedgerow structures through appropriate management, from hedgerows on floristically rich banks, hedgerows with and without trees and range in sizes of hedgerows.	+	+	+	+	0 / +	+	+	+
Ensure adequate replacement population of hedgerow trees, already there are too few young trees and more are needed.	+	+	+	+	0 / +	+	+	+
Consider alternative species / provenances if climatic conditions likely to be unsuitable for planting same species as that lost	+	+	+	+	0 / +	-/+	+	+
Adjust and apply Environmental Stewardship prescriptions to improve protection of hedgerow trees e.g. adjacent undisturbed 6m field margins	+	+	+	+	0 / +	+	+	+
Breeding birds: keep cross-compliance and Environmental Stewardship requirements for permitted hedge-trimming periods under review	+	+	+	+	0 / 0	+	+	+
Ensure that hedge-trimming prescriptions through Environmental; Stewardship allows fruit resource to be maximized (i.e. not removed through poorly timed management	+	+	+	+	0 / +	+	+	+
Maintain diversity and connectivity of wet ditches & hedgerows as far as possible through e.g. location of new hedgerows, re-wetting of grasslands, assessing impacts of proposals for improved drainage / irrigation	+	+	+	+	0 / -/+	+	+	+
Retain and expand hedgerow network in vulnerable erosion areas	+	+	+	+	0 / +	+	+	+
Traditional orchards								
Fruit crops; Consider other fruit varieties or species to maintain sustainable economic use and thus habitat conservation	+	+	+	+	0 / +	-/+	-/+	0
Ensure grazing or scrub management restored	+	+	+	+	0 / +	+	-/+	0
Urgent review of EIA (Agriculture) Regulations 2006, currently orchards < 2 ha are excluded, most orchards are smaller than 2 ha.	+	+	+	+	0 / 0	+	0	0
Keep incentive payments / budget in HLS under close review	+	+	+	+	0 / 0	+	0	0
Target traditional orchards for HLS	+	+	+	+	0 / 0	+	0	0
Ensure habitat network for movement of invertebrates northward developed as far as possible by traditional orchard habitat creation and conservation	+	+	+	+	0 / 0	-/+	0	0
Ensure adequate replacement population of orchard trees, already most of trees are old and there are too few young orchards.	+	+	+	+	0 / +	-/+	-/+	0

Ensure habitat continuity and connectivity	+	+	+	+	0 / 0	-/+	0	0
Encourage sustainable mistletoe harvesting for vulnerable trees	+	+	+	+	0 / 0	+	0	0
Saltmarsh and mudflats								
Creation of new habitats provided that coastal realignment is not prevented by hard sea-defences.	+	+	+	+	-/+ / 0	-/+	-/+	-/+
Allow for realignment of shorelines and adequate space and sediment for shoreline adjustment through strategic coastal planning.	+	+	+	+	-/+ / 0	-/+	-/+	-/+
Adaptive measures to relocate human assets in flood or erosion risk areas.	-/+	-/+	-/+	-/+	-/+ / 0	-/+	-/+	-/+
Adjust designated site boundaries (i.e. generally need to make larger functional sites) and interest features as coasts evolve	+	+	+	+	-/+ / 0	-/+	-/+	-/+
Management plans for coastal nature conservation assets to respond to predicted changes across the whole coastal cell, not in isolation.	+	+	+	+	-/+ / 0	-/+	-/+	-/+
Sand dunes								
Creating space to allow dune systems to migrate landwards	+	+	+	+	+ / 0	+	-/+	-/+
Allow for realignment of shorelines and adequate space and sediment for shoreline adjustment through strategic coastal planning.	+	+	+	+	+ / 0	+	-/+	-/+
Adaptive measures to relocate human assets in flood or erosion risk areas.	+	+	+	+	+ / 0	-/+	-/+	-/+
Adjust designated site boundaries(i.e. generally need to make larger functional sites) and interest features as coasts evolve	+	+	+	+	+ / 0	+	-/+	-/+
Management plans for coastal nature conservation assets to respond to predicted changes across the whole coastal cell, not in isolation.	+	+	+	+	+ / 0	+	-/+	-/+
Manage dunes to maintain the full range of successional stages, avoiding build up of organic soil layers and development of coarse grassland and scrub	+	+	+	+	+ / 0	+	-/+	-/+
Ensure hydrological conditions are fully conserved – reduce abstraction pressures and ensure maximum recharge of dune water table by reducing impacts of scrub/trees	+	+	+	+	+ / -/+	+	+	0
Maritime cliff and slope								
Site boundaries (i.e. generally need to make larger functional sites) and interest features need to be adjusted to allow for future recession	+	+	+	+	+ / 0	+	-/+	-/+
Greater awareness of unavoidable risk to human assets required and adaptation options need developing-linked to erosion risk mapping.	+	+	+	+	0 / 0	+	0	-/+

Manage non-natural run-off e.g. from roads and buildings/hard surfaces.	+	+	+	+	+ / +	+	-/+	0
Provision of wide, semi-natural cliff top habitats that allow migration of species from cliff tops to slopes as recession occurs.	+	+	+	+	-/+ / 0	+	-/+	-/+
Allow for realignment of shorelines and adequate space and sediment for shoreline adjustment through strategic coastal planning.	+	+	+	+	-/+ / 0	+	-/+	-/+
Adaptive measures to relocate human assets in flood or erosion risk areas.	+	+	+	+	0 / 0	-/+	-/+	-/+
Management plans for coastal nature conservation assets to respond to predicted changes across the whole coastal cell, not in isolation.	+	+	+	+	+ / 0	+	-/+	-/+
Saline lagoons								
Site boundaries (i.e. generally need to make larger functional sites) and interest features need to be adjusted to allow for future recession	+	+	+	+	0 / -/+	+	-/+	-/+
Identification of saline lagoon habitat within planned managed realignment projects	+	+	+	+	0 / -/+	+	-/+	-/+
Management plans for coastal nature conservation assets to respond to predicted changes across the whole coastal cell, not in isolation.	+	+	+	+	0 / -/+	+	-/+	-/+
Running water								
Increase the ability of catchments to retain rainfall and reduce artificially enhanced surface run-off - increase soil organic matter, reduce soil compaction, re-creation of semi-natural habitats, SUDS).	+	+	+	+	0 / +	-/+	-/+	+
Selective restoration of natural physical form and function of river channels and floodplains to relieve peak flows in suitable areas of the catchment.	+	+	+	+	0 / -/+	+	+	+
Reduce nutrient and sediment delivery by reducing agricultural nutrient usage and soil erosion, and enhancing treatment of domestic and industrial effluents.	+	+	+	+	0 / +	+	+	+
Promotion of above through CFMPs and RBMPs and the philosophy of integrated catchment management.	+	+	+	+	0 / +	+	0	0
Restoration of natural physical form and function of river channel to restore low-flow habitat niches and maximise the resilience of riverine biota to drought.	+	+	+	+	+ / 0	+	-/+	+
Increased consideration of the health of the hyporheic zone which can help to sustain riverine species during times of drought, reducing biological recovery times	+	+	+	+	0 / 0	+	0	+
Water resources policies and engineering works to improve the capture of peak river flows in floodplains in a way that can be stored and used for water supply at times of peak demand (periods of low rainfall).	+	+	+	+	0 / -/+	+	-/+	+
Removal of in-channel structures where possible.	+	+	+	+	0 / 0	+	0	-/+
Restoration of riparian shading by trees to an extent appropriate to river type.	+	+	+	+	-/+ / 0	-/+	0	+
Monitoring of high risk species liable to complete elimination and selective seeding of colonists into new watersheds as the climate space of species changes	+	+	+	+	0 / 0	-/+	0	-/+

shallow lakes								
Increase ecosystem resilience by reducing other pressures:	+	+	+	+	0/0	+	0	+
1. Reduce nutrient and sediment loads	+	+	+	+	0/+	+	0	+
2. Limit introduction of non-native plant and animal species	+	+	+	+	0/0	+	0	-/+
3. Increase water retention capacity within catchment	+	+	+	+	0/+	+	-/+	+
4. Restore hydrological connectivity between open waters and wetlands.	+	+	+	+	0/0	-/+	-/+	+
Ensure water resources policies and processes deal with 'unsustainable' abstractions.	+	+	+	+	0/0	+	0	+
Consider impact of artificial water level control structures	+	+	+	+	0/0	+	0	-/+
Restore lake habitat to enhance structural diversity	+	+	+	+	0/0	+	0	+
Restore lake marginal habitat and emergent structure to provide areas protected from wave action.	+	+	+	+	0/0	+	0	+
Ensure coastal management options and scenarios consider freshwater assets.	+	+	+	+	0/0	+	0	0
Consider scope for landward migration, recreation or possible 'soft' protection (i.e. low standard of protection and consistent with natural functioning coast) for freshwater habitats.	+	+	+	+	0/0	+	-/+	+
ponds and ditches								
Increase ecosystem resilience by reducing other pressures:	+	+	+	+	0/0	+	0	+
1. Reduce nutrient and sediment loads	+	+	+	+	0/+	+	0	+
2. Limit introduction of non-native plant and animal species	+	+	+	+	0/0	+	0	-/+
3. Increase water retention capacity within catchment	+	+	+	+	0/+	+	-/+	+
4. Restore hydrological connectivity between open waters and wetlands.	+	+	+	+	0/0	+	-/+	+
Consider impact of artificial water level control structures	+	+	+	+	0/0	+	0	+
Restore lake habitat to enhance structural diversity	+	+	+	+	0/0	+	0	+

Create networks of small water bodies to provide refugia for aquatic flora and fauna	+	+	+	+	0 / 0	- /+	0	0
Restore marginal habitat and emergent structure.	+	+	+	+	0 / 0	+	0	+
Ensure coastal management options and scenarios consider freshwater assets.	+	+	+	+	0 / 0	+	0	0
Consider scope for landward migration, recreation or possible ‘soft’ protection (i.e. low standard of protection and consistent with natural functioning coast) for freshwater habitats.	+	+	+	+	0 / 0	+	- /+	+
reedbeds								
Increase resilience of existing habitats, and enabling adaptation through habitat creation/re-creation.	+	+	+	+	0 / 0	+	0	+
Reduce existing pressures on habitat to increase resilience to climate change impacts, and especially to interactions between climate change and other pressures	+	+	+	+	0 / 0	+	0	+
Better management of river levels.	+	+	+	+	0 / 0	+	0	+
Opportunities for replacement or recreation of reedbed/fen will need to be sought from flood management schemes	+	+	+	+	0 / 0	+	- /+	+
Storage and use of winter rainfall	+	+	+	+	0 / 0	+	- /+	+
Tackle poor water quality where this is constraining ecosystem function	+	+	+	+	0 / +	+	0	+
fens								
Opportunities for replacement of fen will need to be sought from flood management schemes	+	+	+	+	0 / 0	+	- /+	+
Increase resilience of existing habitats, and enabling adaptation through habitat creation/re-creation.	+	+	+	+	0 / 0	+	0	+
Increase connectivity with floodplain, but needs caution if groundwater fed or other low nutrient fens exist in floodplain, and might suffer eutrophication through increased inundation from sediment-laden river floodwaters	+	+	+	+	0 / 0	+	- /+	+
Improved soil management within fen catchments.	+	+	+	+	0 / +	+	0	0
Coastal and floodplain grazing marsh								
Increase resilience of existing habitats, and enabling adaptation through habitat creation/re-creation.	+	+	+	+	0 / 0	+	0	+

Reduce existing pressures on habitat to increase resilience to climate change impacts, and especially to interactions between climate change and other pressures	+	+	+	+	0/0	+	0	+
Better storage of winter rainfall	+	+	+	+	0/0	+	-/+	+
HLS funding to enable management of water levels within grazing marsh , and in adjacent farmed areas where there is hydrological continuity	+	+	+	+	0/0	+	-/+	+
Improved management of rivers and floodplain and flood risk	+	+	+	+	0/0	+	-/+	+
For CFGM, the maintain extent target under the Wetland HAP specifically addresses loss to sea-level rise in terms of quality and quantity of compensatory habitat. This is implicit in the three other wetland habitat targets.	+	+	+	+	0/0	+	0	+
Lowland meadows								
Ensure existing sites continue to be managed according to best practice guidelines.	+	+	+	+	0/+	+	0	0
A more flexible approach to site management, for example varying the timing of the hay cut or the timing/duration of aftermath grazing.	+	+	+	+	0/-/+	+	0	0
Expand the resource across its range through restoration of semi-improved grasslands and re-creation on improved grassland/arable land. Target this to ensure expansion and linkage of existing sites. Ensure build in environmental heterogeneity.	+	+	+	+	0/+	+	0	0
Maintenance and restoration of existing drainage channels	+	+	+	+	0/0	+	0	0
Removal of flood defence structures to re-instate more natural flooding regimes.	+	+	+	+	0/-/+	+	-/+	0
Lowland heath								
Increase the rate of management (higher grazing pressure, shorter burning/cutting cycle)	+	+	+	+	0/-/+	+	0	0
Manage stand to keep heather young and healthy	+	+	+	+	0/-/+	+	0	0
Reflect potential for changes in conservation objectives and condition assessment	+	+	+	+	0/-/+	+	0	0
Purple moor grass and rush pastures								
Maintenance of a high summer water table or periodic flushing of soils	+	+	0	+	0/+	+	0	0

Ensure best practice management of existing stands	+	+	0	+	0 / +	+	0	0
Eliminate water abstraction pressures from sensitive catchments	+	+	0	+	0 / +	+	0	0
Increase area of existing habitat through targeted re-creation and restoration effort around existing patches.	+	+	0	+	0 / +	+	0	0
Reflect potential for changes in species composition in conservation objectives and condition assessment.	+	+	0	+	0 / -/+	+	0	0
Promote assisted colonisation for species known to be losing climate space through grazing management and via transfer of green hay	+	+	0	+	0 / 0	+	0	0
Promote adaptive grazing management of sites	+	+	0	+	0 / -/+	+	-/+	0
Informal greenspace								
Provide shady areas - increase deliberate planting	+	+	+	+	0 / 0	+	0	+
Heat health info/awareness campaigning	+	+	+	+	0 / 0	0	0	+
Provide easily accessible and up to date information about local recreation opportunities and responsible recreation	+	+	0	+	0 / 0	+	+	+
Replant green space with drought tolerant species	+	+	+	+	0 / 0	-/+	0	+
Promote circular walks and cycle rides from settlements to reduce need for car travel.	+	+	0	+	0 / 0	-/+	0	+
Promote water efficiency in green space management	+	+	0	+	0 / +	0	0	+
Linear route maintenance	+	+	0	+	0 / +	0	0	+
Direction of people away from most sensitive areas	+	+	0	+	0 / +	+	0	+
Promote use of public transport to visit inspiring landscapes and long distance cycling to reduce need for car travel.	+	+	+	+	0 / 0	+	0	+
Develop fire prevention strategy for woodland	+	+	0	+	0 / 0	+	0	+
Historic environment								
Record all known buried archaeology/routeways/features/structures	+	+	0	+	0 / 0	0	+	+
Vegetation management	0	0	0	-/+	0 / 0	-/+	+	+

Reduce other sources of nutrients to mimise impacts of increased winter flooding on historic wetlands e.g. agriculture, sewage treatment	+	+	+	+	0/0	+	+	+
HE domestic and non-domestic buildings								
Install larger and more efficient rainwater goods	0	0	0	0	0/0	0	+	+
More frequent maintenance of guttering and mortar joints	0	0	0	0	0/0	0	+	+
Use temporary flood guards and boards to prevent water entering	0	0	0	0	0/0	0	+	+
Install emergency drainage sumps	0	0	0	0	0/0	0	+	+
Identify artefacts likely to be severely damaged by flooding and remove them from the building after receiving a flood warning	+	+	0	0	0/0	0	+	+
Insurance	0	0	0	0	0/0	0	+	+
Dry buildings gently and slowly	0	0	0	0	0/0	0	+	+
Designed landscapes								
Trial planting of more drought resistant species	0	+	0	-/+	0/0	-/+	-/+	0
Increased management requirements e.g. more frequent grass cutting, pruning etc	0	+	0	0	0/0	-/+	0	0
Quarries and pits								
Ensure that the maintenance of interest features form part of regular management and is taken account of in mineral planning including restoration plans as well as development plans that address the afteruse of the site (e.g. as a disused quarry).	+	+	0	-/+	+/0	-/+	-/+	0
Ensure that conservation objectives and management plans are appropriate to interest.	+	+	0	+	+/0	+	-/+	0
Review of site boundaries in order to identify where boundary changes are appropriate for the management of the interest features.	+	+	0	+	+/0	0	-/+	0
Management agreements with the extractive industry to clear exposures and pump water from key areas from site. Where these are impractical/ineffective or likely to be out-weighed by other considerations – consider final recording and rescue of key/representative material.	+	+	0	0	+/0	-/+	-/+	-/+
Coastal cliffs and foreshore								
Shoreline Management Plans should be influenced so that they better support the development of naturally evolving coastlines	+	+	+	+	+/0	+	0	-/+

Natural England to develop a robust position on the benefit of sustainable management of the coast.	+	+	+	+	+/0	+	0	-/+
Consider promoting the need for some form of compensation for property loss as part of a longer term solution.	0	-/+	0	0	0/0	0	0	-/+
Influence national and regional planning policy and guidance in relation to coastal development and management.	+	+	+	+	+/0	+	0	-/+
Water bodies (rivers and streams)								
Influence in order to modify flood defence schemes that deleteriously interfere with natural river / stream processes	+	+	+	+	+/0	+	0	0
Discourage floodplain development and educate about flood plain issues.	+	+	+	+	0/0	+	0	0
Influence national and regional planning policy and guidance in relation to flood plain developments.	+	+	+	+	0/0	+	0	0
Underground mines and tunnels								
Develop mine management schemes water level and pollution issues in sympathy with the interest features.	+	+	0	+	+/0	+	-/+	-/+
Where loss of the interest features appears inevitable – final recording and rescue of key materials (e.g. mineral specimens).	+	+	0	+	+/0	0	-/+	-/+
Extensive buried interest								
Address through management agreements and planning system to ensure that land use changes do not impact on ability to access features and do not damage access features.	+	+	0	+	+/0	-/+	-/+	-/+
Manage development proposals to minimise impacts on interest features or otherwise oppose them.	+	+	0	+	+/0	-/+	-/+	-/+
Take full account of need to avoid flooding designated areas in designing flood management schemes	+	+	0	+	+/0	-/+	-/+	-/+
Where loss of the interest features appears inevitable – final recording and rescue of key materials.	0	+	0	+	+/0	0	+	-/+
Road, rail and canal cuttings								
Address vegetation growth through management agreements	+	+	0	+	+/0	-/+	0	0
Manage engineering schemes to minimise these impacts	+	+	0	+	+/0	0	0	0

Review site boundaries in order to identify where boundary changes are appropriate for the management of the interest features – this may help create the space for remedial engineering that does not have such a deleterious impact	+	+	0	+	+ / 0	+	0	0
Raise awareness influence Network Rail, Highways Agency etc.	+	+	0	+	+ / 0	0	0	0
Geomorphological (Static and active)								
Review site boundaries in order to identify where boundary changes are appropriate for the management of the interest features – this may help create the space for remedial engineering that does not have such a deleterious impact	+	+	0	+	+ / 0	+	0	-/+
Influence shoreline Management Plans to support maintenance of natural evolving coastlines.	+	+	+	+	+ / 0	+	0	-/+
Natural England to develop a robust position on the benefit of sustainable management of the coast.	+	+	+	+	+ / 0	+	0	0
Advocate compensation of property lost to natural erosion.	0	+	+	+	+ / 0	+	-/+	-/+
Oppose coastal protection and develop well communicated social arguments for doing so.	+	+	+	+	+ / 0	+	-/+	-/+
Address issues such as vegetation through management agreements. (also for inland outcrops)	+	+	0	+	+ / 0	-/+	0	0
Mines/ underground tunnels								
Consider rescue digs in extreme cases to place interest features in museums.	+	+	0	+	+ / 0	0	-/+	-/+
Research to understand likely changes	+	+	0	+	+ / 0	0	-/+	+
Increased effort to develop mine management schemes to work as best as possible with changes in water tables and to manage pollution issues.	+	+	0	+	+ / 0	0	-/+	0

Key

+	Action will have a positive effect on the column category
0	Action will not affect the category
-	Action will have a negative effect on the column category
+/-	The action's effect could be positive or negative, depending on the way it is executed