Assessment of Heritage at Risk from Environmental Threat

KEY MESSAGES REPORT

in Partnership with English Heritage

05 November 2013

ENGLISH HERITAGE

CONTENTS

▪ THE PROJECT

1. THE PROJECT

PROJECT RATIONALE & THE NATIONAL HERITAGE PROTECTION PLAN

The National Heritage Protection Plan (NHPP) sets out English Heritage's priorities for the safeguarding of England's heritage from 2011-2015. The NHPP identifies eight measures with supporting actions around which to build the necessary research and protective actions to ensure adequate preservation and understanding of the historic environment. The intention is that these measures will be delivered by English Heritage in partnership with other organisations from across the heritage sector.

Measure 2 of the NHPP, Strategic Threat Assessment and Response, pushes for action and 'wider support' in order to counter, offset, mitigate or adapt in ways that reduce the loss of our most important heritage. It calls for focussed responses towards 'winnable battles'.

Section 2C lays out the need to identify natural and environmental threats to the historic environment, assess their potential to contribute to significant heritage asset loss and identify any particular asset types especially prone to those threats.

2C: Natural and Environmental Threats

2C1 Major Environmental Threats: While uncertainty remains over trends, currently we recognise flooding events and erosion as threats whose severity may be increasing in certain areas as a result of climatic changes. Apparent reduction in precipitation may increase fire risks in moorland or woodland areas. Related directly to such threats, national and international directives and legally binding measures (for example for water management and water quality) may have a significant impact on heritage assets. Action will focus on partnership working to establish risk mapping and strategies for prioritising tactical responses. The artificial distinction between threats/impacts covered here and some under 2C2 is recognised.

2C2 Attritional Environmental Threats: A wide range of environmental processes threaten the preservation of heritage assets, whether built, buried or submerged, interior or exterior. These can be characterised as physical (e.g. severe precipitation, wind, changes in relative temperature or humidity, compression, dewatering), chemical (pollutants, acidification, corrosion etc.), or biological (microbial, invasive plants, insects and invertebrates, larger, burrowing and roosting animals). Climate change is accelerating many of these impacts (and probably retarding others). Action should focus on the need to understand the likely impacts on our most significant heritage and to develop priority responses.

This project has been commissioned in response to NHPP Section 2C1 Major Environmental Threats, to aid English Heritage in prioritising and informing the direction of its tactical response to major natural and environmental threats through:

- The identification of types of sudden and catastrophic threat that affect the historic environment;
- An assessment of their likelihood to contribute to significant historic environment asset loss; and,
- The identification of heritage asset and landscape types that may be particularly vulnerable to those threats.

The overarching aim of this project is to determine those threats that are most significant, understand the scale of the threat and what is at risk, and what the vulnerabilities within the sector are, in order to inform the direction of future work in this area. The project is not a primary research project and is instead a synthetic piece of work that draws together existing expertise from within English Heritage and external bodies i.e. other agencies, research organisations and institutions. One of the project's aims is to identify key areas for future research.

The project addresses all forms of historic environment assets but with a focus on those most threatened by non-attritional change. However, in recognition of the artificial distinction, the project has aimed to identify where there is anticipation of a 'tipping-point' beyond which an attritional threat may become catastrophic.

PROJECT ACTIVITIES

Overview of Project

This project combines elements of two projects identified in 2C1:

- **2C1.101:** Project 1. Assessment of Natural and Environmental Threats – Rapid assessment of types of natural and environmental threats which impact on the historic environment and their likelihood in contributing to substantial loss of heritage assets.
- **2C1.201:** Project 2. Characterisation of Heritage Assets Most at Risk from Natural and Environments Threats – Rapid characterisation projects to identify assets and landscapes that may be particularly vulnerable to certain risks, e.g. where likelihood of Boscastle/Lynmouth/Cockermouth type floods or Fylingdales fire are greatest.

A full project design has been prepared in accordance with English Heritage's MoRPHE guidance, this will be appended to the final project report.

The project design sets out three primary stages of work:

- **Stage 1:** Developing understanding and agreement
- **Stage 2:** Identifying and analysing the "What and Where" of major threats
- **Stage 3:** Reporting

This Key Messages report marks the end of Stage 1. It should be noted however that the scope and content of this report exceeds that envisaged in the original Project Design; this change reflects emerging project requirements and will be reflected in the Updated Project Design.

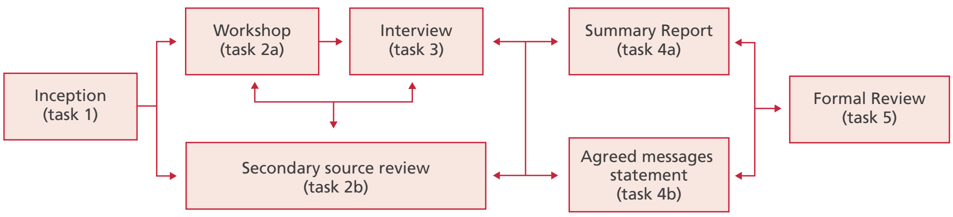
Work to Date

Stage 1 of the project leading up to this report has comprised three key tasks:

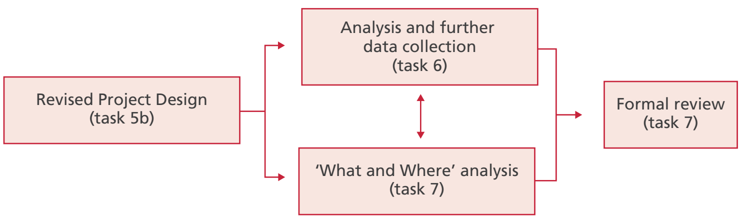
- Background research;
- One-on-one interviews with key members of English Heritage's Climate Change Adaptation Network as well as external representatives of other organisations involved in related work; and
- A workshop with selected English Heritage staff external representatives.

The workshop, and interviews, component of this project equates to 2C1.101 and will form the basis of the second report, which equates directly to 2C1.201. As detailed in the Project Design, they have therefore been combined as a single project.

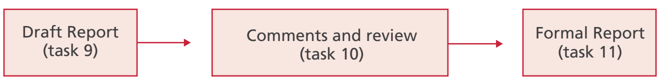
Stage 1



Stage 2



Stage 3



Background research
The following sources of information have been considered in the production of this report[1]:

- UKCIP climate change projections.
- Existing work on climate change and the historic environment, particularly Climate Change and the Historic Environment (Cassar, M., 2005, Centre for Sustainable Heritage, University College London, London); and Climate Change and the Historic Environment Scoping Study Report (Cassar, M and Pender, R., 2003, for English Heritage Archaeology Commissions PNUM 3167. Centre for Sustainable Heritage, University College London).
- Reports from other heritage agencies including: A Strategic Approach for Assessing and Addressing the Potential Impact of Climate Change on the Historic Environment of Wales;[2] Climate Change, Heritage and Tourism: Implications for Ireland's Coast and Inland Waterways;[3] and work by Historic Scotland leading up to its Climate Change Action Plan 2012 – 2017.
- The EU Noah's Ark Project on furthering understanding of the effects of climate change on heritage, including Guidelines on the Adaptation to Climate Change (Noah's Ark 2007) and Vulnerability of Cultural Heritage to Climate Change (2008). [4]
- UK Government agency policy and research on adaptation and resilience; as well as strategies from other agencies such as Natural England, the Forestry Commission and Environment Agency. English Heritage's own work in this area, or work undertaken in conjunction with English Heritage has also been researched.

Interviews
One-on-one interviews have taken place with key representatives from English Heritage as well as outside bodies. These have focused on establishing the nature and extent of environmental threat now and in the near future. Representatives with remits/authority in the following areas have been interviewed:

- Historic buildings
- Ancient monuments and archaeological remains
- Collections
- Materials science
- Coastal processes
- Rural and environmental affairs
- Environmental threat

Representatives from Natural England, the Environment Agency, Society for the Protection of Ancient Buildings (SPAB), and Historic Scotland have also been interviewed.

Workshop
A workshop was held on July 24th at English Heritage's offices in York. In attendance were several members of English Heritage's Climate Change Adaptation Network and representatives from the Environment Agency, Natural England, Historic Scotland, York Council, and Atkins.

Next Steps

This report therefore puts forward a broad understanding of the key environmental threats facing the historic environment developed from the background research, interviews and workshop, the messages from those that have taken part and from the evidence that they have presented. The next step is to present this evidence in an accessible and ready format at a broad level. Rapid risk assessment using available data will be put together to show the whats and wheres that have emerged from Stage 1 of the project. Part of this research will be to marry historic environment data with climate change and environmental threat data held by other agencies in order to establish in a more conveniently understood way, the parameters of the threat.

This report sets out the Key Messages identified through background research, interviews and workshop then agreed with the project team. It is not the final project report but it does provide a clear indication of the key areas for further consideration in the next stage of work.

This report identifies six Key Themes i.e. the six major potentially catastrophic environmental threats facing the historic environment. The themes have been set out as broad groups encompassing particular categories of threat resulting from related environmental events or trends. Each 'category' (theme) is treated in a pro forma manner. For each Theme this report:

- Sets out the nature and scope of the problem;
- Identifies potential risk multipliers;
- Assesses the vulnerability of the assets;
- Summarises the evidence base; and
- Highlights the key areas for further research.

[1] Work undertaken in particular areas that has influenced this report is listed in the Evidence Base section of each Threat Assessment (Section 2).
[2] 2012. Produced for The Historic Environment Group – Climate Change Subgroup by the Countryside and Community Research Institute, the Dyfed Archaeological Trust, and the Centre for Environmental Change and Quaternary Research.
[3] 2009. Irish Heritage Council and Fáilte Ireland.
[4] Sabbioni, C., Cassar, M., Brimblecombe, P., Lefevre, R.A. 2008. Vulnerability of cultural heritage to climate change. Report prepared for the Council of Europe (EUR-OPA: European and Mediterranean Major Hazards Agreement).

A key concern that arose during Stage 1 of the project was the potential threat caused by 'risk multipliers' i.e. cumulative factors that could exacerbate the impact of an environmental threat. These potential risk multipliers are discussed within each of the key themes and predominantly relate to the effects of climate change; and human actions. In some cases, it is these risk multipliers that present the most extreme and pressing threats.

The report is summarised in the final comments, which presents a succinct distillation of key problems, common themes and highlights urgent priorities which should be addressed by English Heritage.

Other activities in the NHPP intersect with this project and recommendations for further work made here may crossover with current or proposed projects. Where possible, work currently being undertaken, or completed, as part of NHPP 2C1 is noted in each section.

▪ INTRODUCTION TO KEY THEMES

2. INTRODUCTION TO THE KEY THEMES

KEY THEMES

The Key Themes addressed here have emerged from the research and engagement work undertaken so far. They represent groupings of those threats considered by heritage practitioners to present the most serious and potentially sudden and catastrophic effects on the historic environment.

The threats considered here are categorized by type as follows (in approximate order of the severity of threat as it is currently understood).[5]

RISK MULTIPLIERS

In addition, the following risk multipliers have been identified in significant exacerbating factors:

- Climate change
- Human actions

Circumstances that increase the possible severity of the impact of environmental events can overlay each other. Although such a combination of circumstances (e.g. dry summers and freezing winters; or changes to management practices and extreme weather events) may not be new, the frequency with which they are occurring has increased.

By recognising, highlighting, and proactively trying to identify risk multipliers and cumulative factors, and by disseminating lessons learnt from such environmental impacts where they occur, counter-disaster planning in these circumstances will be more effective. Throughout the Key Themes section of this report, it should be noted that the greatest environmental impact will occur when threats accumulate, or where existing circumstances exacerbate the potential damage from environmental threats.

Climate change

Many environmental threats are not new, and catastrophic one-off events have always occurred. In this sense, climate change becomes a risk multiplier, exacerbating pre-existing conditions, or enabling the tipping point which pushes a contained or understood threat into something more devastating. As Cassar's 2005 report stated, climate change often highlights long-standing preservation issues rather than creating new problems.[6] Climate change is therefore considered against each Key Theme.

Cumulative threat

Many of the most disastrous recent environmental events have been caused by an overlayering of different threats. In this sense, it is not so much the gradual changes that climate change is bringing, but the cumulative change: heavy rain followed by freezing temperatures; dry winters followed by hot summers.

Key Theme	Nature of Threat / Impact
Coastal Processes	Erosion, in the form of shoreline retreat, cliff erosion and collapse (surface erosion caused by weathering and erosion caused by wave action), saltmarsh migration, and dune migration; flooding; marine issues
Inland water inundation	Fluvial/flash-flooding of rivers and other water courses, causing major flood; high water velocity and high water level river flow; pluvial/surface water and groundwater saturation; repeated low-energy inundation/rainwater ingress
Extremes of wetting and drying	Changes to soil hydrology and pedology caused by drying/dewatering or saturation of certain soil types, landscapes (e.g. peat/clay), or water sources
Fire	Heathland or moorland landscape scale fires
Pests and diseases	Species-specific and material-specific disease and pest outbreaks; increased activity and presence of pests and diseases
Urban Heat Islands	Higher temperatures in specific urban areas caused by historic emissions

[5] As the Key Themes embrace a number of sub-themes, the level of severity is variable.
[6] Cassar, M. 2005. Climate Change and the Historic Environment. UCL and English Heritage.

Thresholds
Material properties, chemical balances, biological behaviours can all alter when environmental conditions change. Here, a temperature change of a couple of degrees can alter the properties of salt content within stone, or the breeding habits of insects, pushing them over a threshold from attritional threats to catastrophic.

Climate Change Projections
The Intergovernmental Panel on Climate Change (IPCC) is the foremost international body charged with the assessment of and dissemination of data and reports on climate change. The IPCC operates under the auspices of the United Nations and was established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO). The IPCC's chief remit is to provide regular assessment reports on the current state of knowledge of climate change. The 2007 Fourth Assessment (Synthesis) Report is the most current main report, though the 2014 (Fifth Assessment) report is due to be published soon, with parts of it already in circulation in draft. The 2013 Summary for Policymakers[7]outlines headline findings from the 2014 assessment. The Summary states that:
Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased.[8]

Further statements address recent trends and their percentage probability. (Climate change predictions are based on observational data collected over several decades and present data run through increasingly sophisticated computer simulations to replicate climate behaviours.) Although a number of uncertainty factors are at work in climate change predictions, climate change scientists agree that we are facing certain changes which are likely, very likely, or certain to have significant effects on the climate in the short, medium and long term. And although some projections may have dramatic effects on us directly, the implications for how we adapt to both the threat and the circumstances may be even more dramatic.

Climate Change Projections in the UK
UKCIP was founded by the government in 1997 as the UK Climate Impacts Programme, and is based at the Environmental Change Institute at Oxford University. UKCIP acts to bring together scientific research, policy making, and adaptation practice. It has published reports on UK climate projections at intervals in 1998 (UKCP98), 2002 (UKCP02) and 2009 (UKCP09), issuing synthesised understanding of climate change projections to the public domain. The data is based on methodology run by the Met Office Hadley Centre Climate Programme funded by the Department of Energy and Climate Change. It also uses the data collected by the IPCC.

Climate change projections are usually based on the UKCIP's 2009 projections, and those of other organisations[9] that contributed to Adapting to Climate Change: UK Climate Projections June 2009 published by DeFRA. However, it should be acknowledged that there is some consensus that UKCIP 09 underestimated the extent of change, and faster changes should be anticipated.

Human actions

The impact of an environmental threat on the historic environment can be increased by human action, or inaction, either before an event occurs or in the aftermath of an event. For example the absence of upland management regimes can increase fuel load on moorlands exacerbating the impact of fire; or the mismanagement of woodlands and designed landscapes can increase the impacts of storm events. Human action during or post disaster can also be influential on outcomes for the historic environment e.g. the actions of agencies fighting fires or resolving flood events. Further, capital schemes and adaptive responses across the built environment, agriculture, infrastructure etc. which are designed to alleviate environmental threat to other sectors (e.g. ecology) can have a direct, potentially negative, effect on the historic environment. These schemes are often driven by government policy and can be enacted at national agency level, local authority level, or at individual landowner level.

The Water Framework Directive (an EU framework designed to improve water quality, implemented by several agencies in the UK) and Catchment Sensitive Farming (designed to prevent agricultural pollution of river catchments, funded by DeFRA, run by the Environment Agency and Natural England) initiatives for example, have considerable consequences for archaeology within England. The institution of fish passes in weirs while beneficial for the aquatic environment and fish stocks can have a significant visual impact on the historic weirs themselves. Similarly, the impacts on historic mines of the Mine Waste Directive is leading to significant loss, alteration and damage to heritage assets that may be as yet poorly understood.

The actions of governmental and non-governmental agencies and third sector organisations in response to perceived risks and threats can therefore be as problematic as the risks and threats themselves. Although the historic environment is sometimes accounted for at a high level in these organisations, the needs of heritage is often seen as secondary and does not always feature in the high level decision making process. This project has identified this as a significant threat in itself, and it is threaded throughout all the Key Themes as a risk in and of itself, and a risk multiplier in terms of the added layer of threat that it can contribute to solely environmental issues.

[7] Intergovernmental Policy on Climate Change Twelfth Session of Working Group I: Approved Summary for Policymakers. 2013. The report summarises the Physical Science Basis report. Both are available at: http://www.ipcc.ch/
[8] Section B of the Approved Summary for Policy Makers.
[9] The Met Office Hadley Centre; UK Climate Impacts Programme; British Atmospheric Data Centre; Newcastle University; University of East Anglia; Environment Agency; Proudman Oceanographic Laboratory; Tyndall Centre; Marine Climate Change Impacts Partnership.

KEY THEMES

COASTAL PROCESSES

Benacre Broad, Suffolk:
The freshwater Broad is now separated from the North Sea only by a low shingle spit, which will soon be overtopped. Trees are being killed by saline groundwater and peat on the foreshore is eroding. It is thought that a dug-out boat found floating offshore derived from this.
© Peter Murphy

3. KEY THEMES

COASTAL PROCESSES

Nature and Scope of the Problem

The coastal zone has always been subject to environmental change. The diversity of the coast has meant that some areas have historically been more at risk than others and this continues to be the case due to a number of factors such as the nature of geology or isostatic rebound (the sinking of land in the south east and rising in the north west in response to ice unloading at the end of the last ice age). Efforts to protect the coast also have a long precedent and historic flood defences have played their own part in shaping the coastline and estuarine areas.

Erosion

Wave and tidal action, storm surges and heavy and repeated rain events cause erosion. Erosion affects different coastal areas in different ways. For the historic environment (inclusive of all heritage assets located in the coastal zone), the principal issues identified by this study are:

- Shoreline retreat – causing the inundation and erosion of the coastal zone resulting in the loss of heritage assets and areas of historic landscape through shoreline erosion or beach lowering. This can affect extensive areas (also see Risk Multipliers below);
- Cliff erosion – tends to be fairly localised but can result in catastrophic loss of, or harm to, assets as well as exposure of currently in-situ remains. Coastal erosion describes the process (or any part thereof) of destabilisation of cliffs; the transportation of cliff material through the cliff system; its deposition on the foreshore; its removal by waves. Coastal (cliff) erosion differs in nature according to cliff systems and wave patterns, but here is used to reference cliff recession or erosion (landward retreat from cliff base to top) and landslides (where destabilised sections of the cliff fall). Cliff systems are also undermined by rainwater or groundwater seepage, surface erosion, and general weathering, made worse during heavy inundation, all of which can also induce landslides.
- Saltmarsh migration – geographically restricted but loss of existing saltmarsh and its migration inland can result in loss of assets and areas of historic landscape. Saltmarsh migration occurs where saltmarshes are forced to retreat/migrate in land due to sea-level rise.
- Dune migration – very restricted in extent nationally, but locally significant. Dune migration occurs where dune systems are forced to retreat/migrate in land due to sea-level rise.

In general, low-lying soft sediment shorelines are most at risk, particularly East Yorkshire, East Anglia and the Thames Estuary, In other areas risk varies, with other factors such as geological change (e.g. natural synclines such as the Hampshire basin) contributing to change. Longshore drift – where prevailing winds in particular drive sediment and influence erosion at an angle to the shoreline – also plays its part, and historic flood defences can mean that areas down drift are particularly at risk.

Although low-lying zones are particularly at risk, wave attack at the base of cliffs contributes to cliff collapse. Issues of erosion and problems stemming from past land reclamation schemes threaten most estuarine areas around England i.e. the locations of saltmarshes and known concentrations of historic environment assets. Given the length of England's shoreline (c. 5,500km) and the value of the historic environment that lies along it and within its intertidal zone, the scale of potential threat from coastal processes is very significant and probably represents the single largest environmental threat identified by this study.

The marine zone is beyond the scope of this report, however, it should be noted that as a consequence of erosion, and the deposition and dissolution of material in the water, there will be two principle effects on underwater heritage: firstly, the profile of the seabed is likely to be altered by deposited materials; and secondly, pH levels will alter due to ocean acidification. The effects of this are not entirely clear, though certain species will be affected, with probable knock-on effects to marine archaeology; and there is likely to be a direct effect on metals underwater.[10]

[10] Dunkley, M., 2013, The potential effects of oceanic climate change on the management and curation of underwater archaeological remains, The Archaeologist, Autumn 2013, Number 89, p.60-62.

Flooding
The development of coastal areas, particularly development within ports and harbours has knock on effects for flood risks. To a large extent, these risks are being dealt with through the Rapid Coastal Zone Assessment Surveys (RCZAS) and follow up work in NHPP Activity 4A3.2. However, it is important to note the nature of the flood risk in coastal areas from the sea, rivers, groundwater and surface water saturation, and acknowledge that most coastal settlements are low-lying, situated on rivers as they meet the sea, and often at the confluence of two or more rivers. Coastal flooding, as seen for example at several Cornish coastal towns in winter 2012, where surface and fluvial flood waters inundated towns and devastating cliff collapse occurred (as at Polperro and Looe respectively), can have a significant impact on heritage assets, both buried and built, through flood damage and erosion/destabilisation.

Risk Multipliers

Climate change
Change in continuous processes such as sea level rise and temperature rise have been included in the most recent climate change projections.[11] More recent evidence suggests however, that the likely median change in sea-level will be higher than current projections.[12] It is more difficult to predict the effect of environmental change on the frequency of episodic or occasional events such as storm surge[13] (where there is a short-lived increase in water level above tide level) and flood events, but the catastrophic nature of recent flood events demonstrates their potential severity, and the frequency of such events is unlikely to decrease.

Climate change on its own is therefore expected to accelerate existing environmental threats such as erosion and flooding, as described above. In particular, as a cumulative factor, rising sea levels on top of storm surges even at current levels would considerably accelerate erosion. Further, the increasing trend in heavy inundation rainfall events is destabilizing for cliff systems. This is exacerbated by the surface erosion and weathering caused by hot summers and cold winters (although UKCP09 projects warmer winters). Landslides in particular are likely to increase in frequency under these circumstances.

It may also introduce new ‘risks’ such as species colonization. Possibly as a result of rising sea temperatures and shipping, new species have begun to colonize in British waters. Some of these species flourish in ways that are detrimental to the marine historic environment (which although beyond the scope of this report should be acknowledged), and also to historic assets in the intertidal zone. So far, these issues have been identified in the warmer waters of the south-east. In particular, the blacktip shipworm Lyrodus pedicellatus has been observed in waters off Cornwall and in the Solent. Sea temperature rise will mean in increase in the spread of these and other possibly destructive species.[14]

Human action
Humans have long adapted the coast to suit their needs for habitation, industry and agriculture. Many of England’s major cities and historic towns also lie in the coastal zone. As a consequence, much of England’s coastline has been adapted by human action, generally in the form of coastal defences to ameliorate flood risk or local erosion, or to protect settled sites. Whilst these defences may protect and safeguard many heritage assets e.g. historic settlements or archaeological sites, they also squeeze the coastal zone leading to the loss of other heritage assets.

The management of existing flood defences, the enhancement of flood defences and the development of new defences in the face of climate change is a multi-agency activity. These activities, coupled with climate change related increases in sea level, will result in the increased loss of assets and landscapes of the seaward side of defences, as well as loss of assets and landscapes in areas where inundation is permitted in place of defences (sometimes referred to as managed retreat or managed realignment).
Unintended consequences for heritage can also occur where sea defences in one area create pressures elsewhere along the coast.

Vulnerability Assessment

Assessing the vulnerability of the historic environment at risk from coastal processes requires an understanding of what the resource is within the coastal zone, and what the projections show for e.g. shoreline retreat, along the coastal fringe. Existing work by English Heritage in this area has taken place, especially regarding properties administered by English Heritage. Shoreline Management Plans informed by Rapid Coastal Zone Assessment Surveys have gone further in some areas to identify the wider resource at risk. The further categorisation of assets at risk can be made through assessments of significance.

---

[11] The UKCP09 projection for sea-level rise between 2020 and 2030 (high emissions scenario, medium probability) stands at 11.5 – 16cm for London (increase from 1990 level) http://ukclimateprojections.defra.gov.uk/21729.

[12] See for example, Lowe, J. Met Office Hadley Centre 2010 A meta analysis of existing sea-level rise projections.

[13] The extremes of high and low water recorded at Newlyn seem to be increasing in line with sea-level rise (Jenkins, G.J., Perry, M.C., and Prior, M.J. 2008. The climate of the United Kingdom and recent trends. Met Office Hadley Centre, Exeter, p19.)

[14] UKCP09 states that since the 1980s the temperature of the seas around the UK have risen at a rate of about 0.2–0.6 ºC (http://ukclimateprojections.defra.gov.uk/22841). The 2013 IPCC Summary for Policymakers states that it is virtually certain that sea temperatures have risen since 1971 (SPM-4); and that sea level rise has accelerated (SPM-6).

Threat	Effect	Area	Assets at risk	Potential outcome
Cliff erosion	Collapse of cliffs and shorelines. Added sediment to intertidal zone. Ocean acidification.	All areas with cliffs and within the projected margins of shoreline retreat	All heritage assets within the coastal zone: historic buildings, historic landscapes, archaeological sites	Potential total loss of assets of local – international significance
Saltmarsh migration/ destruction	Drying out or total inundation of salt marshes, caused principally by erosion; also by past reclamation schemes and current flood defence schemes.	All estuarine areas	All heritage assets within saltmarsh: archaeological sites, wrecksites, historic landscapes	Potential total loss of assets of local – national significance
Dune migration	Dunes migrating back as sea level rise causes encroachment.	All dune areas	All heritage assets with the dunes: archaeological sites, some historic buildings	Potential total loss of assets of local – regional significance (some national)
Flooding	Coastal flooding. Failures or consequences of flood alleviation schemes.	Coastal zone; estuarine areas	All heritage assets – buildings and archaeology – in the affected area	Potential damage to or loss of assets of local – international significance
Coastal squeeze	Inundation / encroachment of inter-tidal or coastal zone as retreat becomes in possible due to hard coastal defences	Coastal zone; estuarine areas	All assets within the coastal zone	Potential damage to or loss of assets of local – international significance
Managed retreat/ managed realignment	Deliberate realignment or retreat of shoreline	Inter-tidal zone; coastal zone	All heritage assets – buildings and archaeology – in the affected area	Potential total loss of assets of local – international significance
Species colonization	Warmer seas increase spread and activity of recent non-native arrivals, eg. blacktip shipworm Lyrodus pedicellatus	Marine and possibly intertidal zone	Heritage assets made of timber	Potential total loss of assets of unknown significance
Ocean acidification	Increased carbon dioxide dissolution in seawater increases acidification	Marine	Underwater heritage assets, particularly metals and timbers	Potential damage – loss of assets of known and unknown significance

Evidence Base

Significant evidence for the effects and patterns of coastal processes exists. The potential effects of climate change are also subject to continuing and extensive research at a high level. However, there remains uncertainty as to the climate change projections of how climate change will exacerbate processes. In terms of the historic environment, work is being undertaken to exploit data sources to understand the effects of these processes.

Erosion and flood risk

A risk assessment of English Heritage's coastal estate (English Heritage Coastal Estate Risk Assessment[15]) identified 54 properties within the estate that were at risk (within 200m of the coastal zone, and without existing flood defences). Environment Agency data on coastal erosion and flood risk areas (projecting the 2025, 2050 and 2105 coastlines) were collated in a GIS with English Heritage data on the coastal estate. Of the 54 identified properties, 48 were identified to be at risk of flooding, two at high risk. 38 of the properties were at risk from coastal erosion, with four at high risk.

The potential damage to the historic environment beyond English Heritage's estate includes the effects of coastal processes on designated and non-designated assets, and also on the unknown archaeological resource. Shoreline Management Plans produced by local authorities and the Environment Agency, with Defra, set the framework for managing the risk in 'Coastal Policy Units'.[16] Each unit's management strategy is based on one of four options:

1. Hold the line;
2. Advance the line;
3. Managed realignment;
4. No active intervention.[17]

English Heritage commissioned Rapid Coastal Zone Assessment Surveys (RCZAS), which informed the heritage aspect of the SMPs based on desk-based assessment of historic maps, aerial photographs etc, and rapid field survey. This enables the identification of areas of known, and previously unknown (as far as possible) archaeological interest that are at risk. Both the Coastal Estate Risk Assessment and RCZAS that are currently extant for the North East, North West, Yorkshire and the

[15] Hunt, A. 2011. Research Department Report Series no. 68-2011

[16] Coastal Policy Units are 'a discrete definable length of coast' – a few kilometres in most cases.

[17] Murphy, P., Thackray, D., and Wilson, E. (EH, NT, EA). 2009. Coastal Heritage and Climate Change in England: Assessing Threats and Priorities. Conservation and Management of Archaeological Sites, Vol. 11 No. 1, March, 2009, 9–15.

Severn contain risk tables which assign heritage assets with high, medium or low 'at risk' status according to the data sets.

Invasive species colonization
Evidence for invasive species colonization is primarily observation-based, with records held by the Non-native Species Secretariat (NNSS). So far, these issues have been identified in the warmer waters of the south-east. English Heritage plans to commission a geographical survey of marine attritional threats to heritage assets in English waters which will include baseline data on species, from which to develop mitigation strategies with the NNSS.

Ocean acidification
Increased acidity levels in water are an observable phenomenon that has been the subject of monitoring and research by the UK Ocean Acidification Research Programme. Its effect on materials has been studied elsewhere, and plans are in place to institute collaborative research with English Heritage and the UK Ocean Acidification Research Programme.[18]

Key Areas for Further Research

The National Heritage Protection Plan (NHPP) contains a number of actions appropriate to this theme, including directly: 2C1.3 Flood/erosion risk assessments and accompanying measures to reduce impact on heritage assets project - Methodology to extend the Coastal Estate Risk Assessment through a regional pilot study by integrating RCZAS data with Environment Agency flood and erosion mapping (outcome: Tested methodology for integrating results from 2C1.1 and 2C1.2 to provide consistent flood/erosion risk assessment for loss of significance to heritage assets.)

In addition to the above and the need to complete and refine the RCZASs around the coast (included in the National Heritage Protection Plan Measure 3A2), there are a number of other areas where further analysis and research would benefit our understanding of the threat and the nature of suitable responses. These include:
Mapping and identification of critical response areas e.g. areas with known concentrations of assets and landscapes, which are also areas requiring flood defence responses (parity with 2C1.3 Methodology 1: project to extend risk assessment methodology through regional pilot study). The next iteration of our report will include a broad-based modelling of the density and number of heritage assets in the flood and erosion risk zones, as available data permits. Beyond this, further detail, as per 2C1.3 will be required;

- Development of strategic assessment processes that can enable consideration of historic environment issues early in the SMP process;
- Review of strategies and directives on coastal processes at governmental or associated agency level to understand the position of heritage and identify potential unforeseen threat;
- Development of priorities for intervention and identification of areas / themes for research to accompany managed loss of assets / landscapes;
- Development of strategic approaches for land-owner / manager engagement through the communication of confident evidence-based understanding of the effects of threat on the historic environment. Existing models include the Climate Change Impact Report Cards.[19] These should be useful for policy advisors, ministers, local authorities and decision-makers at any level of society and in any organisation.
- Research into adaptation of historic buildings to flooding etc. possibly to be undertaken under NHPP Activity 2A2: Resolving impact on carbon challenge on the built environment.
- Better confidence in climate change modelling is necessary to progress next step approaches to scenario planning.

NHPP 2C1 Context

- 2C1.4 Measures to secure greater resilience of heritage assets to natural and environmental threats contains two project Methodologies appropriate to this theme. (Outcome: Greater resilience of heritage assets and places to impacts of acute or extreme environmental threats. Wider awareness of heritage dimension.) Particularly these methodologies relate to working with Natural England and the Environment Agency and on producing resilience guidance for land and asset managers. (2C1.4.1 and 2C1.4.3.)
- 2C1.5 Development of counter-disaster (post-event, asset recovery) responses to natural and environmental threats contains two project Methodologies appropriate to this theme. (Outcome: Improved cross-agency working: reduction of post-event impact on heritage assets.) Particularly, these methodologies relate to understanding 'lessons learnt' and to developing emergency planning guidance. (2C1.5.1 and 2C1.5.2.)
- 2C1.6 Reduction of negative impact on heritage assets arising out of the responses of others to natural and environmental threats contains four measures that are appropriate to this theme. (Outcome: Improved cross-agency working and heritage taken into account in partner implementation on environmental quality directives; reduction of negative impacts.) Particularly these methodologies relate to ensuring a more strategic positioning of heritage in multi-agency initiatives, and ensuring areas and asset at risks are identified.

---

[18] Dunkley, M., 2013, The potential effects of oceanic climate change on the management and curation of underwater archaeological remains, The Archaeologist, Autumn 2013, Number 89, p.60-62.
[19] The Climate Change Impact Report Cards pull together the latest evidence to provide a robust, reliable and up to date report on climate impacts. They are useful for policy advisors, ministers, local authorities and decision-makers at any level of society and in any organisation. Current cards exist for Terrestrial Biodiversity and Water (http://www.lwec.org.uk/resources/report-cards)

INLAND WATER INUNDATION

City of York:
York during the floods of 2012.

INLAND WATER INUNDATION

Nature and Scope of the Problem

Inland flooding (except in cases of infrastructural damage) is usually caused by intense rainfall events. For waterways (rivers and canals, drains and dykes), such events can increase water levels and water velocity, and cause bank breaches or overtopping. Run-off can exacerbate these effects.

- Inland water inundation issues can be extremely damaging for the historic environment. Inland water inundation threats can be broken up into the following event types:
- Fluvial / flash flooding (rivers or other watercourses breaking their banks causing major flood inundation);
- High water velocity and high water level river flow (higher than normal water levels or water power causing infrastructural/fabric stress);
- Pluvial / surface water and groundwater flooding (inundation where groundwater saturation occurs or infrastructure cannot cope with extreme water levels and drainage is limited);
- Repeated low-energy inundation (persistent rainwater ingress).

Major waterways therefore carry a strong flood risk, as do low-lying areas and areas that overlay underground water systems prone to groundwater issues; but increased development in the 20th century and hard surfacing has spread the risk through limitation of drainage through soils in built-up areas (areas of clay soils are particularly vulnerable as water doesn't infiltrate quickly). At risk areas are predominantly in river floodplains and catchment areas and in low-lying areas particularly in the east of England. However, pockets of high risk also exist in built-up inland areas.

The observed increased frequency of heavy rainfall [20] means that less dramatic events are also becoming more problematic with repeated heavy rainfalls causing material damage over a period of time.

Risk Multipliers

Climate change

Although the mean average rainfall has not changed dramatically,[21] the nature of rainfall appears to be changing, with heavy rainfall events becoming more common, causing more frequent occurrences of excess water inundation (see footnote 20).

The cumulative effects of climate change, such as seasonal extremes, can have a significant effect on worsening inland inundation events. Extremes of freezing or heat dry-out have exacerbated flood events in recent years by restricting drainage. These extremes are also having an impact on historic infrastructure, causing stress or fractures that can lead to failure.

Human action

A number of flood prevention initiatives – both historic and recent, involving both hard and soft engineering – exist in order to combat the threat of flooding. In some cases these can be beneficial to archaeology, such as in restrictions on development of flood plain areas. In others however, the knock-on effect for archaeology can be detrimental. For example, Catchment Sensitive Farming (CSF), a joint initiative between the Environment Agency and Natural England, funded by Defra and the Rural Development Programme for England, designed to prevent agricultural run-off into river catchments by reducing soil compaction has proved destructive to buried archaeology when practiced without understanding of the effects on the buried resource. Other flood alleviation issues include engineering responses including the creation and maintenance of (often through deepening and widening):

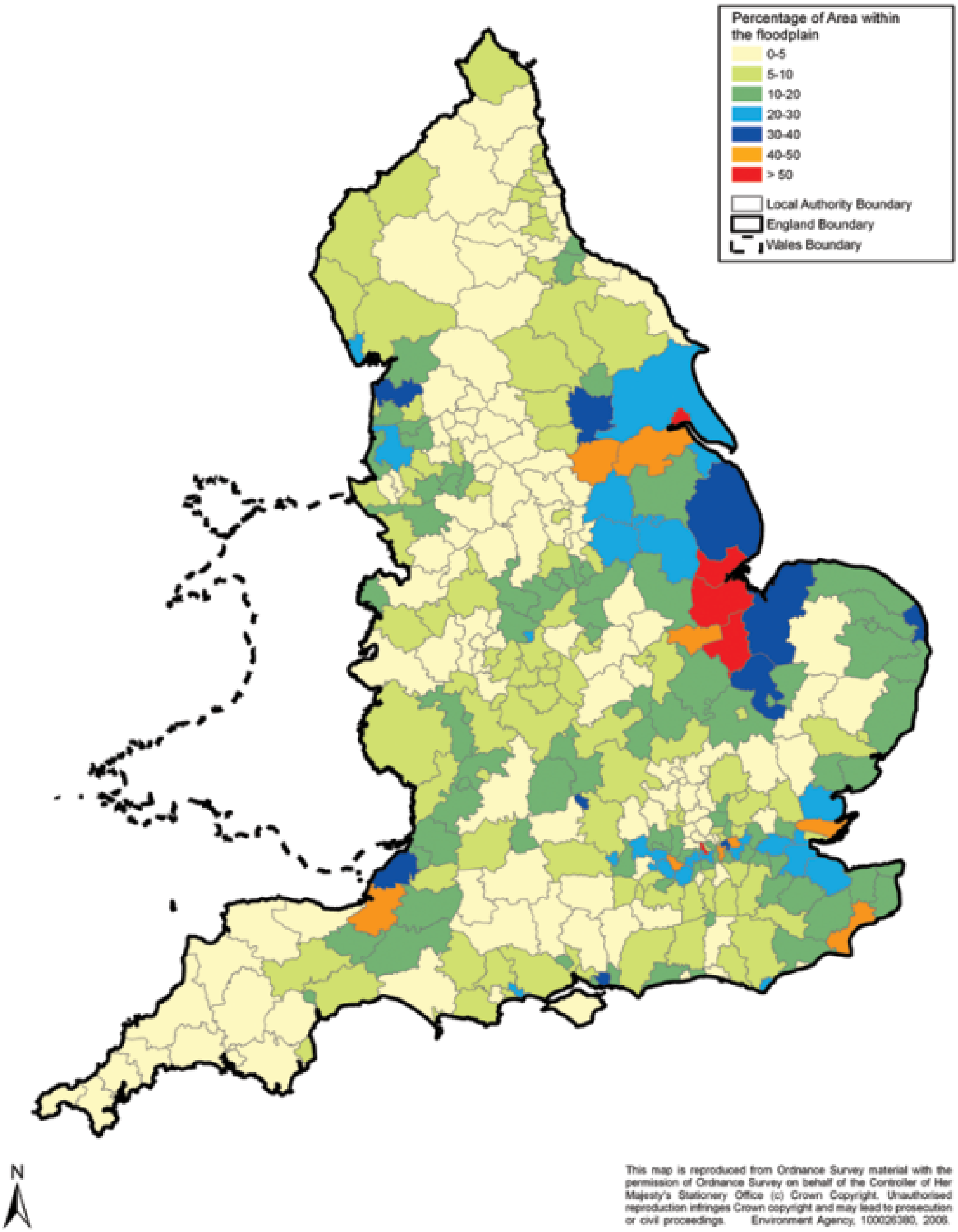
- Flood water storage reservoirs;
- Flood relief channels to bypass vulnerable stretches of river or channel;
- Confinement of high water levels with flood embankments or walls;
- Creation of new drainage/water disposal systems; and
- Managed realignment.

Further problems are caused by organisational – governmental, governmental agency, non-governmental, commercial and third-sector – responses which cause property owners to adapt properties in particular ways. In particular, insurance requirements to weatherproof houses can require property owners to adapt heritage assets within their care – particularly historic buildings – in ways that are at odds with heritage requirements, for example insurance companies can insist on PVC flood resistant doors. Conversely, restrictions on property alterations in place through heritage designation and local authority measures can stall property owners wishing to protect their properties from further harm.

[20] 2014. Summary for Policymakers. IPCC. SPM-4. The UKCP09 projected change (based on the high emissions scenario, medium probability, for the thirty-year period 2020s) in the percentage increase in average mean winter rainfall is between +4 and +7%; and in summer, between -6 and -8%, with an increase in both summer and winter of heavy rain days (>25mm) (http://ukclimateprojections.defra.gov.uk/21808).

[21] UKCP09 report The climate of the United Kingdom and recent trends states that annual mean precipitation over England and Wales has not changed significantly [...]. Seasonal rainfall is highly variable, but appears to have decreased in summer and increased in winter, although with little change in the latter over the last 50 years.

Figure 3.1 Percentage of land at risk of flooding by local authority area[22]



[22] Figure 3-1; from Environment Agency. 2009. Flooding in England: A National Assessment of Flood Risk

Vulnerability Assessment

All heritage assets in flood-prone areas are currently at risk, with increased frequency heavy rainfall or storm events broadening the magnitude of threat, especially where repeated low-energy water inundation is concerned. A further risk is carried by the potential ground destabilisation (see Section 2.4).

Fluvial / flash flooding

Recent floods have damaged some historic infrastructure sites and structures, as occurred in Cumbria during 2009. River flooding, sometimes exacerbated by other factors (such as lack of drainage capacity or other cumulative environmental factors) can affect historic landscapes that are within the flood plain catchment, or exposed to inundation. Cumulative factors can contribute to catastrophic events such as at Boscastle in 2004. As most historic towns and cities are built around the access and resource of rivers, a substantial part of urban England falls within flood risk areas.

High velocity and high water level river flow

High water levels and faster flows in waterways have the potential to affect heritage assets within the water, such as bridges and banks; archaeology within banks etc.

Pluvial / surface and groundwater flooding

The impact of heavy rainfall events is often exacerbated by cumulative factors relating to reduction in efficient drainage e.g. poorly designed or maintained storm water systems. These issues can cause sporadic damage to the historic environment, through surface water flooding where drainage capacity fails or is insufficient, and through groundwater saturation.

Repeated occurrences of both types of flooding, especially where heritage assets are not resilient, can lead to substantial damage through inundation of heritage assets, both archaeology and built heritage. Where the underlying water table becomes saturated due to issues of drainage or repeated heavy rainfall, the groundwater can itself prove damaging to heritage assets and can take time to recede. Repeated low-energy inundation can become as problematic as large-scale flooding. Groundwater flooding can also affect hydrogeology, and may be a particular issue in valleys on chalk lands or in areas where thick deposits of sands and gravels cover less permeable rocks.

Repeated low-energy inundation

Higher frequency heavy rainfall events can cause damage at a scale that is comparable to flood events. Historic rainwater goods, or sensitive materials, can allow rainwater ingress to harmful levels, leading to problems of extremes of wetting and drying (see section 2.4) but also to considerable water damage to materials.

All forms of flooding can affect materials. Timber can distort, and drying is problematic. Salt crystals that naturally occur in masonry and concrete dissolve in water and are brought closer to the surface. As they dry, they can cause spalling or exfoliation. This problem can be particularly problematic in exposed uncapped stonework, common in archaeological masonry structures. At Fountains Abbey, flood water from the Skell caused direct damage to stonework and underlying damage that is still not fully understood. Fluctuations in humidity within buildings after rainwater ingress on historic contents and collections (wallpaper, paintings, furniture etc.) can be damaging to such materials.

Threat	Effect	Area	Assets at risk	Potential outcome
Fluvial / flash-flooding	High volume flood	Flood plain; river catchment; downriver areas	Settlements; all heritage assets in the flood zone	Damage to or loss of assets/groups of assets of local – international significance through water damage or force of water
High velocity / high water flow	Rapid flow and / or high water	Water courses	Heritage assets within the water course: archaeology in the bank; built heritage	Damage to or loss of assets/groups of assets through scour or more substantial damage - of local – international significance through water damage, scour or force of water
Pluvial / surface/ groundwater flood	Saturation / drainage failure, low – high level flooding	Low-lying areas where groundwater level is high / or areas where drainage infrastructure is problematic	Settlements; all heritage assets in the flood zone	Damage to groups of assets of local to international significance through water damage, potentially leading to loss
Repeated low-energy inundation	Saturation over time; rainwater ingress	Everywhere	Particularly built heritage assets but also unknown consequences for buried archaeology	Damage to and possible eventual loss of assets of local – international significance
Flood management schemes / flood defences	Hard or soft engineering	Flood risk areas	Historic infrastructure; buried archaeology	Damage to and possible loss of assets of local – regional significance Potential setting issues
Catchment initiatives	Hard or soft engineering	River catchment areas	Buried archaeology	Damage to and possible loss of potentially unknown assets local – regional (possibly +) significance Potential setting issues

Evidence Base

Evidence for the effects of inland water inundation is increasingly understood through materials analysis, and as the effects of recent extreme flood events become fully known. In terms of data on flood occurrence, the Environment Agency holds flood data including the flood map,[23] which is publicly accessible and shows the extent of Floodzone 2 and 3 data, and the location of flood defences. English Heritage holds some historic flood data.

English Heritage expanded the methodology for the coastal risk assessment to its inland estate, plotting properties within its ownership against the river network and flood data from the Environment Agency (Inland Flooding Risk Assessment Pilot Study 6278). As a pilot study, this work took in only the estate – properties including offices – and not other archaeological or built heritage assets.

A further pilot study is in process (Flooding and Historic Bridges Impact Assessment 6189, due to be completed winter 2013) relating to the historic bridge stock on the Aire (commensurate with NHPP 2C1.4, assessing the risk of flood on river infrastructure). It has already provided a greater understanding of how high velocity and flood waters are affecting historic infrastructure, and has advanced possibilities for detailed risk assessment.

Both these projects used existing flood datasets held by the Environment Agency and local authorities, cross-referenced with historic data and English Heritage's own data sets. Both were also augmented by site visits.

Lessons learnt from floods, both historic and recent, are also building a knowledge base of observational data.

Further evidence is held by a number of organisations but is not necessarily publicly or easily accessible. Some organisations hold extensive historic rainfall data however. Insurance companies also possess extensive flood data of potential use in the understanding of non-fluvial flooding and flood risk.

Key Areas for Further Research

The NHPP's actions in 2C1.3 include an assessment of the inland flood risk and on infrastructure (see above) which have both been completed as pilot projects. Other more general topics in 2C1 are listed below. Further research in this area could include:

- Further development of existing pilot studies such as:
- The expansion of the English Heritage coastal flood risk assessment / inland flood assessment to account for heritage assets beyond the EH estate;
- Further development of the English Heritage bridge stock to provide a basis for a higher level methodology or carrying this form of assessment at the national level.
- Analysis and identification of key risk geographical areas through analysis of fluvial flood risk data and heritage asset data. It should be noted that the next iteration of this report will include a broad-based modelling of the density and number of assets on the National Heritage List in the flood risk zones (within confines of data permits). Beyond this, further detail, will be required to drill down into other datasets and to model risks at a regional and sub-regional level;
- Development of methodologies for assessing risk posed by non-fluvial flood events;
- Development of a greater understanding of the cumulative effects of the adaptive response as a risk multiplier. A survey of governmental, non-governmental, third-sector and other authority level initiatives to understand the position of heritage in flood prevention initiatives and how they will materially affect areas needs to be developed to identify potential unforeseen threat and to provide a further layer to the understanding of what is at risk;
- Development of strategic approaches for land-owner / manager engagement through the communication of confident evidence-based understanding of the effects of threat on the historic environment. Existing models include the Climate Change Impact Report Cards (see footnote 19). These should be useful for policy advisors, ministers, local authorities and decision-makers at any level of society and in any organisation;
- Clarity through the above measures will allow identification and classification of areas where mitigation of risk/or management of decline is the appropriate action. These understandings need to be disseminated and guidelines developed on management of decline; and
- Review of past destructive events to identify key lessons learnt regarding human action / inaction and the development of a 'lessons learned strategy' in which adaptive response consequences could be understood, key messages allowed to trickle down, and practical measures found to prevent further incidence in order to ensure its effectiveness; and
- Establish links with relevant services/ management interests (Local Authority risk planning teams / Environment Agency / fire service / English Heritage estates / National Trust / historic property owners etc) to develop coherent emergency response strategies and procedures to ensure that heritage values are clearly identified and appropriate mitigation embedded in responses to flood events.

[23] Environment Agency flood map: http://www.environment-agency.gov.uk/homeandleisure/37793.aspx

2C1 Context

2C1.3 Flood/erosion risk assessments and accompanying measures to reduce impact on heritage assets contains a project Methodology directly related to this Key Theme. (Outcome: Tested methodology for integrating results from 2C1.1 and 2C1.2 to provide consistent flood/erosion risk assessment for loss of significance to heritage assets.) This is a pilot project to extend the coastal assessment to the inland estate. This has been completed.

2C1.4 Measures to secure greater resilience of heritage assets to natural and environmental threats contains two project Methodologies appropriate to this theme. (Outcome: Greater resilience of heritage assets and places to impacts of acute or extreme environmental threats. Wider awareness of heritage dimension.) Particularly these methodologies relate to working with Natural England and the Environment Agency and on producing resilience guidance for land and asset managers. (2C1.4.1 and 2C1.4.3.) A pilot project (Methodology 2) assessing the impact of high velocity flood on river infrastructure has been completed.

2C1.5 Development of counter-disaster (post-event, asset recovery) responses to natural and environmental threats contains two project Methodologies appropriate to this theme. (Outcome: Improved cross-agency working: reduction of post-event impact on heritage assets.) Particularly, these methodologies relate to understanding 'lessons learnt' and to developing emergency planning guidance. (2C1.5.1 and 2C1.5.2)

2C1.6 Reduction of negative impact on heritage assets arising out of the responses of others to natural and environmental threats contains four measures that are appropriate to this theme. (Outcome: Improved cross-agency working and heritage taken into account in partner implementation on environmental quality directives; reduction of negative impacts.) Particularly these methodologies relate to ensuring a more strategic positioning of heritage in multi-agency initiatives, and ensuring areas and asset at risks are identified.

EXTREMES OF WETTING & DRYING

Yorkshire:

A feeder stream supplying a Yorkshire moorland reservoir is exposed as water levels fall

EXTREMES OF WETTING AND DRYING

Nature and Scope of the Problem

The trend towards extensive periods of dry weather, followed by saturating events means that some landscapes (particular soil types, former mining areas, etc) are particularly susceptible. The nature of the impact and resulting threat to the historic environment will also vary in terms of the time scales over which potential 'threats' will operate. For example, an extreme wetting event (heavy rain or storm event) may have direct and immediate consequences (e.g. flood damage to buildings and structures) to direct impact over protracted periods of time resulting from changing environmental conditions (e.g. changes to preservation conditions resulting from increased saturation or drying on archaeological contexts).

It is also likely that extremes in wetting and drying will act not only as individual sources of threat, but cumulatively with other factors, for example, an extreme wetting event is likely to be combined with intense rainfall, heavy winds and possible lightening strikes; and repeated drying out followed by intense saturation may create unstable ground conditions, and risk of erosion. These cumulative events may in turn take place following for example, a dry summer, where a parched ground condition can be a fire hazard, as occurred in 2003 at Fylingdales Moor. In that scenario, the depleted vegetation, fractured soils, and less permeable surfaces that followed the event also serve to prevent rapid absorption; so that the effect of an extreme wetting event in conditions resulted in significant erosion. These conditions could also lead to flash flooding .

Understanding the scale and potential extent of the threat from extremes of wetting and drying therefore may be seen as considerable and complex. Although the mechanics and degree of impact is difficult to determine in advance, the likely scenarios and possible impacts can be identified.

Increased rainfall events over relatively short periods accompanied by long drought periods have also caused problems for aquifers, leading to desiccation of waterlogged and wetland areas, and changes in hydrology and pedology (soil structure and chemistry). These extremes also lead to an increased risk of geological instability, with subsidence, slope failure and landslips becoming more common. Mining landscapes are also at risk of increased instability, with a further dimension of risk causing possible damage to underground water courses. The desiccation of clay soils can also lead to considerable problems relating to building foundations.

Risk Multipliers

Climate change

Current projections indicate that summers will be hotter and drier with increasingly intense episodes of heavy rainfall, while winters will be warmer and wetter: the latest IPCC figures state that the intensity of precipitation events has likely increased; and that there has been an increase in warm, dry days; while UKCP09 states that Central England Temperature has increased by one degree since the 1970s,[24] and projections suggest an increase of temperature between 1.2°-1.4° in winter; and 1.3°-1.5° in summer over the next 30 years.[25] It is also likely that extreme episodes of wetting and drying and freezing will take place with less predictability, introducing a further degree of difficulty in mitigating risk.

Climate change may also increase the risk of wetting and drying through changes in seasonality and the distribution, rate, intensity, duration and frequency of precipitation (rain and snow fall) levels, dryness and temperature. These changes could result in:

- Increased risk of high-energy flood events
- Increased risk of storm damage from intense rain / snow
- Increased risk of high-velocity and high water-level river flows
- Increased risk of fluvial and flash flooding
- Increased risk of surface and groundwater flooding
- Increased risk of repeated low-energy inundation
- Impact of associated environmental factors on the effects of wetting and drying. For example, higher temperatures cause more evaporation and evapotranspiration. This can lead to further drying out and shrinking of soils and increase risk of subsidence to historic assets.
- Increases or reduction in ground water and soil moisture/ temperature levels;
- Changes to soil structure and make up (organic content etc.) and
- Changing evaporation and evapotranspiration rates.

[24] 2013. Summary for Policy Makers. IPCC. SPM-4. UKCP09 The climate of the United Kingdom and recent trends, p3.
[25] Based on the high emissions scenario and the medium probability http://ukclimateprojections.defra.gov.uk/21730.

Human action

Historic human behaviours concerning problems of saturation have had significant knock-on effects, as can be seen on a large landscape-level scale with the drying of fenland areas, and on a smaller, but internationally significant scale at Star Carr where drainage schemes have caused desiccation and acidification.

The human response both to the threat of climate change, and more generally to other environmental contexts can therefore be as causative and problematic as 'natural threats for the historic environment. In particular:

- Changes to land management regimes resulting from changes to natural systems, including:
- increased levels of water in river catchments
- saturation of land and managed flood risk
- the need to maintain water quality
- the impact on agricultural production
- Changes in hydrological systems and management systems to increase capacity to cope with changing water-levels, or water quality such as:
- Changes to overland and sub-surface water storage and movement; e.g. through the Water Framework Directive or Mining Waste Directive.
- Changes to vegetation patterns and land use.
- Changes to drainage regimes

Vulnerability Assessment

Changes in farming regimes and practice (arable and pastoral) as a result of de-watering – particularly through the CSF scheme – or increased groundwater levels and water threats may also have consequences for the historic environment as farmers employ different planting and cropping methods, for example, planting deep-rooting crops (resulting in deeper root penetration); or introducing new nutrient regimes to mitigate for wetting / drying conditions on soil nutrition.

The Water Framework Directive and Mining Waste Directive may also have consequences in changes to hydrology that may affect the historic environment. The Mining Waste Directive directly affects historic mine assets that may not be fully understood through interventions in the historic infrastructure. Historic mines may also be hydrologically active, presenting potential future problems as interventions may cause unforeseen problems, e.g. by altering groundwater levels.

Mitigation of at-risk areas, such as mining landscapes which need to be made safe, or reservoir alteration requirements and removal and replacement of historic infrastructure has also increased.

Threat	Effect	Area	Assets at risk	Potential outcome
Extreme wetting	Saturation	Everywhere, although particularly low-lying areas or areas with restrictive topography	Assets in prone areas, particularly buried archaeology in low-lying land (fenland areas etc); sensitive historic landscapes	Damage to or loss of assets of unknown (potentially low – international) significance through alteration of soil composition
Extreme drying	Shrinkage; dessication destabilisation	Everywhere, although particular soil types, such as clays are more prone; and wetland or waterlogged environments	Assets in prone areas, particularly buried archaeology; all assets on land where destabilisation may occur; sensitive historic landscapes	Damage to or loss of assets of known and unknown potential (low- international) significance through drying out and potential collapse
Extreme wetting and drying	Saturation followed by shrinkage; destabilisation	Everywhere, although particular soil types, such as clays are more prone; and wetland or waterlogged environments	Assets in prone areas, particularly buried archaeology; all assets on land where destabilisation may occur; sensitive historic landscapes	Damage to or loss of assets of known and unknown potential (low- international) significance through stress and potential collapse
De-watering schemes; Water Framework Directive; Mining Waste Directive; other land management and agri-environment schemes	Changes to watertable; changes to hydrology; hard or soft engineering to prevent pollution to groundwater and river systems	Catchment zones	Principally buried archaeology; historic industrial and infrastructural sites; also setting issues	Damage to or loss of assets of known and unknown potential (low- international) through physical disturbance; changes to hydrology and pedology

The geological and geographical sensitivity across the historic environment to extremes of wetting and drying is variable. Particular landscape areas that are sensitive include:

- Archaeologically rich landscapes in contexts sensitive to extremes in wetting and drying, such as lowlying land (fenland areas etc.), moorland and heath, and inter-tidal zones;
- Seasonally or permanently waterlogged biodiverse environments such as mires, ponds, rivers and their floodplains, and estuaries where deposits may be organic (i.e. peat) or mineral (i.e. alluvium);
- Peat bogs (significant carbon sinks).

Particular asset types at risk from these extremes include:

- Historic settlements and assets associated with high risk rivers and flood plains or located in river valley bottoms with restrictive topography likely to result in increased risk of saturation;
- Historic assets including buildings located on soils prone to shrinkage or dessication and destabilising effects of drying / wetting such as clays in the south east;
- Sensitive historic landscape character areas and assets such historic woodlands and parks and gardens.

Evidence Base

The effects of wetting and drying and the climate change and human action risk multipliers that contribute to them are being observed by those in the field, principally at local government level. Projects to determine more fully how the historic environment is being affected are under way or have been completed. These include an identification of waterlogged areas most at risk. English Heritage's Strategy for Water and Wetland Heritage (December 2012) [26] sets out the research context and thematic strategy for water and wetland heritage, priorities and objectives.

Governmental/quango agency level dissemination of the water agenda is available from relevant organisations, such as Environment Agency and Defra.

Knowledge of historic mining areas is largely in the voluntary sector, with local and national interest groups undertaking studies and surveys of both subterranean and above-ground sites.

Key Areas for Further Research

Alignment with other agencies is advised through actions in NHPP 2C1, specifically through work with Natural England and the Environment Agency in developing resilience (2C1.4.1 and 3) and reducing the impact of other environmental interventions (2C1.6.1, 2, 3, 4). Various other NHPP actions, including those in 2C2 promote research into protective measures such as soft-capping, and as such are not included in this section. More general relevant 2C1 areas are listed below. The following projects are recommended:

- Identification and mapping of at risk areas and landscapes of high archaeological resource value that may be liable to risk from increased wetting, as from flooding, changes in long term environmental conditions for example: wetlands/peat moorlands, and increased wetting and drying on sensitive soils/ geologies associated with significant heritage assets;
- Identification of key at risk asset types and research into potential effects resulting from wetting and or drying on their heritage significance and value. Generic action plans for asset types at risk with overarching principles. There is a need for collaborative working and trust development especially with voluntary groups and national agencies;
- Development of strategic approaches for land-owner/ manager engagement through the communication of confident evidence-based understanding of the effects of threat on the historic environment;
- This is another area where a formalisation of 'emergency' retrospective assessment of destructive events into a 'lessons learned strategy' in which adaptive response consequences could be understood;
- Promote better and solid mechanisms for the drip-down of observational understanding of threat from local authority level;
- Review of strategies and directives on water management at governmental, non-governmental, third-sector and other authority level to understand the position of heritage and identify potential unforeseen threat;
- Research in to the connectivity of natural processes, how changing environmental conditions impact on one another and how those process effect the historic environment and archaeological resource;

[26] Heathcote, J. English Heritage Thematic Research Strategies.

- Since other agencies are promoting and carrying through a 'joining-up' approach to catchment and river basin areas, and other ecological systems, the effects of this on the historic environment need to be understood;
- Evaluation of sites of archaeological/heritage interest at risk in terms of types of archaeological/heritage materials that may be exposed to risk from flooding/ saturation and potential mitigation/management strategies;
- Predictive modelling of impacts of interventions in historic infrastructure through WFD or MWD works in order to improve understanding of such sites;
- A formalised approach to sophisticated risk assessment across the historic environment is needed to properly understand threat to heritage assets and will help to determine management (decline or mitigation) on the ground (see below);
- Clarity through the above measures will allow identification and classification of areas where mitigation of risk/or management of decline is the appropriate action. These understandings need to be disseminated and guidelines developed on management of decline. Pilot areas for assessing processes of managed decline could be set up.

2C1 Context

2C1.3 Flood/erosion risk assessments and accompanying measures to reduce impact on heritage assets contains a project Methodology directly related to this Key Theme. (Outcome: Tested methodology for integrating results from 2C1.1 and 2C1.2 to provide consistent flood/erosion risk assessment for loss of significance to heritage assets.) A pilot project to extend the coastal flood risk assessment to the inland estate has been completed.

2C1.4 Measures to secure greater resilience of heritage assets to natural and environmental threats contains two project Methodologies appropriate to this theme. (Outcome: Greater resilience of heritage assets and places to impacts of acute or extreme environmental threats. Wider awareness of heritage dimension.) Particularly these methodologies relate to working with Natural England and the Environment Agency and on producing resilience guidance for land and asset managers. (2C1.4.1 and 2C1.4.3.)

2C1.5 Development of counter-disaster (post-event, asset recovery) responses to natural and environmental threats contains two project Methodologies appropriate to this theme. (Outcome: Improved cross-agency working: reduction of post-event impact on heritage assets.) Particularly, these methodologies relate to understanding 'lessons learnt' and to developing emergency planning guidance. (2C1.5.1 and 2C1.5.2.)

2C1.6 Reduction of negative impact on heritage assets arising out of the responses of others to natural and environmental threats contains four measures that are appropriate to this theme. (Outcome: Improved cross-agency working and heritage taken into account in partner implementation on environmental quality directives; reduction of negative impacts.) Particularly these methodologies relate to ensuring a more strategic positioning of heritage in multi-agency initiatives, and ensuring areas and asset at risks are identified. Methodology 2 particularly concerns the analysis of the River Basin Management Plans.

FIRES

Flyingdales Moor, North Yorkshire:
Flyingdales Moor following the devastating fire and subsequent rains of 2003

FIRE

Nature and Scope of the Problem

Fire has always been a significant environmental threat. Its catastrophic effects on the historic environment have frequently been seen. For the purposes of this project, fires at a landscape level are considered a particular environmental threat (as opposed to the domestic fire threat at individual built asset or settlement level in urban areas). It is apparent that both natural and managed fires have the potential to affect archaeological assets and wider historic environment in different ways at different levels and scales of impact. For example, fire can, and has had, a direct influence on site formation process. It can also affect the interpretive integrity and preservation of archaeological materials and historic structures.

At present the scale of fire as an environmental threat is unclear. It is likely, however, that the threat may have both immediate and apparent consequences e.g. the loss of a historic building, to cumulative and less apparent impacts e.g. the impact of increased burning from wildfire and or ongoing fire management and regulated burning regimes on the integrity of the survival of sub-surface archaeological deposits. Large-scale fires such as that in Fylingdales Moor have shown the extent of damage that fire can inflict and also the potential for damage to be inflicted on an unknown archaeological resource.

Investigations have shown that fire can have a significant impact on the archaeological record. Impacts can range from negligible to severe depending on the type of fire and the type of archaeological asset. Less work appears to have been undertaken into the wider heritage resource and similar investigation on the potential effects of fire and mapping of most at risk areas / heritage assets have been little studied in the English context although the lessons learnt analysis undertaken following Fylingdales has been instructive.

Risk Multipliers

Climate change

Climate change projections suggest a potential increase in the risk of fire via two particular routes: [27]

- Changes in seasonality, increased temperatures and longer dry periods, increasing the combustibility of potential fuel loads and weakening natural fire barriers;
- Changes in precipitation levels, including the distribution, rate, intensity and frequency of rain and consequential impact on groundwater and soil moisture levels; the extent of drying out of soils and parching of vegetation cover, and increases to soil and air temperatures.

Human action

- Changes to land management resulting from a need to manage and control fire risk may themselves incur further risk, including:
- direct risk, in response to an increased frequency of fire through controlled burning, ground cover clearance; introduction of or changes to livestock stocking levels etc.;
- and indirect risk resulting from other climate change mitigation measures such as efforts to increase resilience to drought through reduced levels of cutting or leaving cuttings (grasses, stubble etc.) on the ground for longer periods (to increase moisture retention in the soil).
- Anthropogenic responses to fire risk, and its use in land management, can also have an impact on historic landscapes and their physical and visual make up, as well as the visibility of remains. A potential increased frequency and/or intensity of fire may also contribute to, or accelerate, other 'threat' mediums that may in turn have an impact on archaeological material (as at Fylingdales, where a fire leading to loss of ground cover led to destabilised land surfaces and erosion, which was compounded by heavy rainfall). This layering of harmful impacts on historic assets creates a cumulative effect.

Vulnerability Assessment

The vulnerability of the historic environment is variable, with a number of factors contributing to its susceptibility:

Landscape character and make up;

- The intensity and the duration of potential fires, fuel loading and extent of travel (how extensive the damage, how deep will it burn how far and how fast it might spread). This may have a direct relationship to potential for, and severity of, damage to the historic environment and heritage assets;
- Sensitivity of archaeological features and materials to heat, fire and smoke damage (i.e. material robustness – stone, flint, chert, wood, leather, porous ceramics, and bone);
- Changes in precipitation rates, frequency and timing and distribution may act as a risk multiplier as well as directly as threats and influence risk and vulnerability.

Particular areas of the historic environment that are more prone to risk can be categorised as follows:

[27] 2013. Summary for Policy Makers. IPCC. SPM-4; http://ukclimateprojections.defra.gov.uk/21730.

Fire sensitive archaeologically rich landscapes
Some landscapes are more prone to fire, such as moorland, heath, woodland and scrub or unmanaged sites, or sites where management changes have led to an increased risk of fire. Influenced by weather events such as dry spells, these landscapes provide plentiful fuel and few barriers to the spread of fire. Coppices and hedgerows within such landscapes are also at risk in dry weather. Recent patterns also suggest that such landscapes that are close to urban conurbations are particularly at risk.

These landscapes may also be archaeological rich due to high preservation conditions, and little development. They also risk being not well or fully understood. Fires have the potential to cause

- physical damage to sites resulting such as burning out of organic material, snags, trees falling etc;
- heat damage to monuments resulting in fracturing and spooling as at henges or rock art sites;
- thermal alteration to artefacts and archaeological material from fire such as flint scatters, ceramics etc;
- possible loss or corruption of organic dating evidence etc;
- a loss of ground cover and exposure of previously masked remains resulting in a change to the setting of monuments and their visual associations or landscape character;
- increased site and feature visibility from vegetation burn-off and consequently greater vulnerability to vandalism, exposure to and damage from greater physical access.

Fires may also result in the loss of ground cover resulting in increased erosion rates (especially on slopes or terraces) and loss and or redistribution of archaeological material; and an impact on sub-soil preservation conditions as a result of changes to soil chemistry or microbial activity; and loss of or changes to ground cover resulting in increased damage from rain, new drainage patterns or flooding.

Fire sensitive designed landscapes
A general increase in the likelihood of fires will lead to more incidences of fires at historic designed landscapes, potentially affecting built heritage and historic planting schemes, particularly hedgerows and veteran trees. These areas are particularly susceptible to visual change and alterations to landscape character, while buildings within them are at risk of damage or loss of materials and interiors.

Threat	Effect	Area	Assets at risk	Potential outcome
Fires at sensitive landscapes	Damage to underlying archaeology Destabilisation and erosion of land surfaces Greater sensitivity to other weather events	Heathlands Moorlands Woodlands	Buried archaeology Archaeological monuments Individual built heritage assets	Largescale damage through fire and exposure to poorly understood archaeologically rich landscapes Opening up of protected archaeology Changes to visual context
Fires at sensitive designed landscapes	Damage to historic buildings and settings	Historic landscapes	Historic planting schemes Built heritage	Loss or damage to historic buildings Loss of veteran trees
Fires at built assets or settlements	Damage to built heritage	Historic landscapes	Built heritage	Loss of historic buildings Damage to historic settlements
Land management adaptation	Proliferation of combustible materials Increased exposure to managed fires	Fire sensitive landscapes	Predominantly buried archaeology, archaeological monuments	Unrecorded prolonged damage to archaeological deposits Increased risk of unmanaged fires
Land management change in fire sensitive areas	Increase in fire threat in certain areas; introductions of fire breaks	Heathlands; moorlands woodland	Buried archaeology; some built heritage assets	Potential catastrophic wildfires damaging archaeological landscapes; damage to buried archaeology and visual setting
Reduction of fire service provision	Increase in fire damage in certain areas	Rural areas	Built heritage; historic interiors; historic settlements	Potential increase to the severity of fires in remote areas of traditional building
Increase in fire prevention strategies	Insensitive additions to historic buildings and interiors	Historic buildings	Built heritage; historic interiors	Insensitive change to built heritage interiors, potentially with unsuitable materials

Fire sensitive built assets
Built heritage located in or near fire sensitive areas, and historic settlements and individual assets where there is a high use of combustible materials are particularly sensitive. Where these are located in close proximity to one another, and where access by fire services may be restricted the risk of fire spreading is higher. Heat damage, fracturing and loss of stone work to monuments and buildings and loss of organic construction materials from fire are particular risks here. Historic interiors are also particularly susceptible.

Evidence Base

The current research into the effects of fire resulting directly from climate change in England is limited. There is a basic level of data on the potential increase in frequency of longer and drier summers that may result in higher frequency of fire, but little research into the effects of fire on historic environment assets. Devastating fires such as that at Fylingdales Moor were followed by extensive exercises in recording and studying the damaged archaeological remains, which led to an increased knowledge in how rocks in particular responded to the fire, and in management of the devastated area. Work was carried out by multi-agency teams including the Environment Agency and English Heritage.

A greater body of investigations into the effects of fire on archaeological remains has been undertaken in the USA.

Key Areas for Further Research
2C1 contains a number of general measures applicable to this theme, these are listed below. In addition or in conjunction, the following measures are suggested:

- Formalisation of 'emergency' retrospective assessment of destructive events into a 'lessons learned strategy' in which unforeseen management response consequences could be understood, key messages allowed to trickle down, and practical measures found to prevent further incidence would ensure its effectiveness.
- Identification and mapping of at risk areas and landscapes of high archaeological resource value that may be liable to increased risk of fire, for example: heathland and moorland, where risk of fire to peat (which can be hard to control) can be very damaging to organic deposits.
- Identification of key at risk asset types and research into potential effects resulting from fire on their heritage significance and value.
- Evaluation of sites of archaeological/ heritage interest at risk in terms of fuel loading, types of archaeological and heritage materials that may be exposed to fire and potential mitigation or management strategies.
- Establish links with relevant services and management interests (such as local authority risk planning teams, Environment Agency representatives, local fire and police services, EH estates and NT property owners and managers etc) to develop coherent emergency response strategies and procedures to ensure that heritage values are clearly identified and appropriate mitigation embedded in responses.

2C1 Context

2C1.4 Measures to secure greater resilience of heritage assets to natural and environmental threats contains two project Methodologies appropriate to this theme. (Outcome: Greater resilience of heritage assets and places to impacts of acute or extreme environmental threats. Wider awareness of heritage dimension.) Particularly these methodologies relate to working with Natural England and the Environment Agency and on producing resilience guidance for land and asset managers. (2C1.4.1 and 2C1.4.3.)

2C1.5 Development of counter-disaster (post-event, asset recovery) responses to natural and environmental threats contains two project Methodologies appropriate to this theme. (Outcome: Improved cross-agency working: reduction of post-event impact on heritage assets.) Particularly, these methodologies relate to understanding 'lessons learnt' and to developing emergency planning guidance. (2C1.5.1 and 2C1.5.2.)

2C1.6 Reduction of negative impact on heritage assets arising out of the responses of others to natural and environmental threats contains three measures that are appropriate to this theme. (Outcome: Improved cross-agency working and heritage taken into account in partner implementation on environmental quality directives; reduction of negative impacts.) Particularly these methodologies relate to ensuring a more strategic positioning of heritage in multi-agency initiatives, and ensuring areas and asset at risks are identified.

PESTS & DISEASE

Oak processionary moth:
The larvae, or caterpillars, of Oak processionary moth are a pest because they pose a threat to oak trees and to human and animal health.

PESTS AND DISEASES

Nature and Scope of the Problem

Non-native pests and diseases can – and have historically – cause catastrophic impacts on the historic environment of the UK. The virulent strain of Dutch elm disease which first appeared in Britain in 1967 for example wiped out most mature elms in England, and killed 25 million trees across the UK. Increased import traffic, particularly of unchecked timber imports, appears to have increased the incidence of new pests and diseases reaching Britain.

Containing outbreaks is extremely difficult. Although some species and diseases are well understood, primarily through research in countries where they are established, baseline knowledge of others is poor. Behaviours of pests and diseases may also vary in a new geographical setting so total reliance on background data from other countries can be problematic. Further, species and disease control can depend on an understanding of potential predators and viruses that attack the threatening species, and the behaviour of these in a new scenario is likely to be poorly understood in the UK, and indeed corresponding predators and viruses may not be present.

New pests and diseases have the potential to attack materials of various natures, and may threaten whole species, and therefore landscapes; and certain building materials and artefacts, and therefore historic buildings and collections.

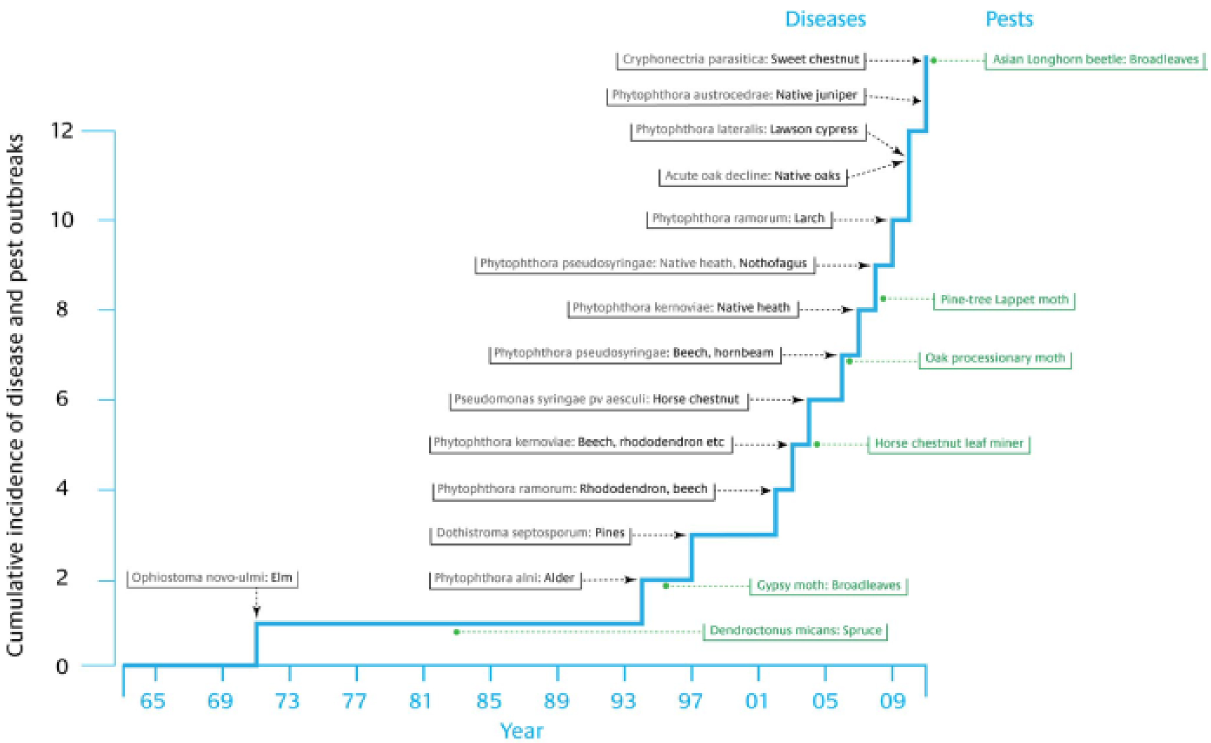
Most pests and diseases are considered an attritional threat. Those considered here are at risk of reaching a 'tipping point' or threshold, beyond which their effects may be considered catastrophic.

Threats considered here that may potentially reach a catastrophic tipping point are:

Diseases affecting trees or flora

Disease forms such as cankers or dieback have the potential to wipe out or severely threaten certain species of tree. Some threaten a number of species. The potential effect on historic landscapes increases in criticality if certain trees, such as oaks, which are strong features of historic parks and gardens, are threatened. New species can arrive via timber or plant imports, or possibly via air streams from continental Europe. Many tree diseases do not have curative treatments, leaving only containment options or preventative felling or pruning as viable treatments.

Figure 3.2 New tree disease and pest outbreaks in the UK [28]



[28] From: Independent Panel on Forestry. Final Report. 2012. Figure 9. Based on data supplied by the Forestry Commission.

Species affecting trees or flora
The increased spread of non-native species, potentially enabled by rising temperatures, or the increased virulence of native species has the same potential as some diseases in the effect on the historic environment. Further problems are posed by the possibility of indiscriminate harm caused by types of pest, such as timber-boring beetles. New pests are known to arrive in import packing materials (such as Asian longhorn beetle which also affects timber) or in timber and plant imports, such as oak processionary moth. Treatments can be problematic, as in the case of the oak processionary moth, in that they may not be discriminatory and can put other species at risk, and containment can be difficult.

Risk Multipliers

Climate change
Until recently the spread of some pests has been constricted by the cool and seasonal climate of the UK, particularly the north, but the current and projected temperature rise and increased mild weather will enable the spread of some pests previously restricted in their breeding habits and distribution. Higher temperatures may also provide conditions for other non-native species to become established that have hitherto been unable to survive in England.[29]

These conditions may also allow established species to spread. In particular, warmer prolonged periods may allow a third growth cycle for several species including webbing moths; and an increase in relative humidity promotes the chances of survival for eggs. A greater distribution of some species will occur as flight becomes enabled, and easier at higher temperatures.

Species affecting materials
The rise in temperatures, relative humidity and milder winters may increase the spread of species that cause damage to historic collections, such as moth damage to materials (wallpapers, furnishings, etc.). Although the threat of species to collections is widely considered to be an attritional threat as temperature change is slow, the recent boom in, for example, moth populations in London over the last decade, is not fully understood but is thought to be at least in part the result of milder year-round temperatures and relative humidity.[30]

Growth cycles and egg survival of several potentially harmful species have hitherto been manageably low, but the potential for increased growth cycles and/or increased mobility at thresholds over a certain temperature means that attritional threat may reach a tipping point at which infestation could become catastrophic for certain collections and historic properties.

Human action
Human management responses to potential catastrophic outbreaks of diseases and pests that may affect single or multiple tree or plant species can have significant impacts on the historic environment. Drastic measures such as preventative felling can alter landscape character, as can replacement planting with different species. Restrictions on imports of certain trees will have a less severe effect. Insecticides and other chemical treatments can often carry side-effects with either visual impacts, or impacts on other species which may in turn have consequences. Conversely, resourcing issues are likely to affect import controls with the possible consequence of increased importation of damaging species.

Conservation heating, where the temperature of historic properties is maintained at a certain level, has many benefits in reducing a number of environmental problems, and safeguarding delicate materials, but can also eliminate the natural seasonal cycles for outbreaks that occur within historic properties and potentially provide more favourable conditions for egg survival.

Vulnerability Assessment

Understanding what is at risk from pests and diseases requires an overview of current threats that exist within England, and the rate of increase and geographical reach of each threat. Further, understanding of possible imminent threats is required. There is a disparity between the effects that 'indoor' issues will have on heritage assets, and the implications of the increasing 'outdoor' threat. The above table indicates the rising occurrence of the risk of new pests and diseases to the UK.
Essentially, at risk are:

(1) Particular tree (or other plant) species from species-specific pests and diseases such as diebacks;
(2) Groups of species (such as broadleaved trees) from wood-boring pests such as Asian longhorn beetle; and
(3) Particular materials (such as timber), or fabrics, at risk of moth infestation.

(1) and (2) would potentially cause severe damage to designed landscapes as well as urban and rural settlement settings – the loss for example of veteran oaks to a Registered Park and Garden, or extensive damage or loss of London planes to London's cityscape would represent a dramatic alteration to the landscape.

The implications of the more generic problems represented by (3) potentially entail adaptation to a more dramatic baseline threat. The Asian longhorn beetle for example, should an infestation become established and more widespread, has the potential to affect healthy timber, and therefore both landscapes and historic buildings in prone areas. Current treatment of timber in historic buildings does not offer any protection to this kind of pest.

[29] 2013. Summary for Policy Makers. IPCC. SPM-4.
[30] Brimblecombe. P. & Lankester, P. 2012. Long-term changes in climate and insect damage in historic houses. Studies in Conservation 2012; p8.

Threat	Effect	Area	Assets at risk	Implications for the Historic Environment
Diseases affecting trees and flora	Loss or devastation of certain species	Across the UK	Designed historic landscapes; settlements; urban landscapes	Loss of or damage to particular historic or ornamental planted species throughout the UK
Species affecting trees and flora	Potentially indiscriminate loss or damage of trees/ flora	Across the UK	Designed historic landscapes; settlements; urban landscapes	Loss or damage to live trees/ flora across historic landscapes
Species affecting materials	Widespread damage to healthy and unhealthy timber and other at-risk materials	Across the UK	Historic buildings; historic collections	Damage to healthy timber in historic buildings; damage to historic collections
Preventative tree felling	Localised or largescale felling or removal of specific tree species to combat outbreaks	Historic environment	Designed historic landscapes; historic settlements;	Potentially drastic changes to the landscape, particularly in parks and gardens and in areas where certain tree species contribute to character.
Indoor climate control	Year-round interior heating	Historic buildings; collections	Built heritage assets; collections	Potential increase in pest outbreaks in historic interiors

There is very little regulation in the import of woods and other products in which it is known that new species have arrived; and no quarantine requirements within the UK despite its island advantages. For several species identified close by therefore, arrival is more a matter of when than if. Resourcing issues at borders may accelerate these problems.

The increase in moth and beetle infestations which are taking hold in historic properties, including those that house collections, is unlikely to abate and will instead require adjustments to prevention strategies to ensure their robustness and proper resourcing. While this is currently effective, pest and disease thresholds may mean that the volume of this work could increase beyond manageable levels.

Evidence Base

Much evidence for the spread and growth of pest populations and diseases is observational. Links across national agencies has allowed monitoring and logging of spread and growth.

The Forestry Commission maintains databases of threats to timber from pests and diseases, much of which is GIS based, and updated from field reporting. The Non-native Species Secretariat monitors invasive non-native species in Great Britain and coordinates the response strategy with input from governmental and non-governmental agencies, charities and universities.

English Heritage maintains links with outside groups and institutions that monitor disease and pest spread. It is also networked with European counterparts, allowing early warning of possible or imminent threats from the continent.

Indoor pests, diseases and related issues are better understood with significant research being undertaken, or already finished. A PhD thesis completed in 2013, The Impact of Climate Change on Historic Interiors, by Paul Lankester, aimed at determining the effect of climate change on interiors and collections. The method used damage functions to model future change – including relative humidity and temperature changes over seasons. English Heritage operates an existing Insect Pest Management Programme (IPM) with Objectives set out in the NHPP including the preparation of site reports from insect monitoring data (Objective IG).

It also has access to significant historical data on insect activity within certain historic properties. This can be used as a comparator with current activity in understanding the effects of environmental change. English Heritage has also recently commissioned further collection and studies of insect data in its historic estate to better analyse the situation and potential threat. This work is being undertaken by Professor Peter Brimblecombe and involves statistical analysis of historic and insect data of the EH estate. The work is due for completion in late 2014.

Key Areas for Further Research

Although many of these issues are considered attritional and are therefore addressed in 2C2, or in research analysis in other parts of the NHPP, a number of 2C1 measures are generally applicable – these are listed below. Partly due to their consideration as attritional affects however, and also to issues surrounding their applicability to the historic environment, there are significant gaps in knowledge concerning the what and where of this theme.

In order to more precisely determine what is at risk, identification of relevant datasets, particularly from the Forestry Commission is required, followed by their collation against relevant historic environment data, for example, the distribution of potentially at-risk timber-frame buildings against any projected outbreak data for timber pests. The next iteration of this report will contain a broadbrush case study for this kind of assessment and will explore the possibilities of this approach;

- The likelihood and imminence of the spread of some catastrophic problems may force English Heritage to take an increased lobbying role in the future. Measures should be sort to seek preventative influential discourse as early as possible;
- An understanding of behaviours of pests and their potential thresholds beyond which management solutions must change would enable better resourcing of prevention and adaptation strategies;
- Lankester's PhD used a simple transfer function to determine indoor temperatures, and was concentrated by necessity on a small number of historic properties. Extending this work to a greater number of properties, especially those considered particularly at risk from these issues, with more exact temperature modelling would enable a better understanding of issues;
- Perhaps due to a disjuncture between the public identification of the planted environment as 'heritage' and the heritage sector's own remit of a largely cultural estate, there is limited understanding of the effects of diseases and pests on the designed landscape;
- This is another area where a formalisation of 'emergency' retrospective assessment of destructive events into a 'lessons learned strategy' in which adaptive response consequences could be understood, key messages allowed to trickle down, and practical measures found to prevent further incidence in order to ensure its effectiveness.

2C1 Context

2C1.4 Measures to secure greater resilience of heritage assets to natural and environmental threats contains two project Methodologies appropriate to this theme. (Outcome: Greater resilience of heritage assets and places to impacts of acute or extreme environmental threats. Wider awareness of heritage dimension.) Particularly these methodologies relate to working with Natural England and the Environment Agency and on producing resilience guidance for land and asset managers. (2C1.4.1 and 2C1.4.3.)

2C1.5 Development of counter-disaster (post-event, asset recovery) responses to natural and environmental threats contains two project Methodologies appropriate to this theme. (Outcome: Improved cross-agency working: reduction of post-event impact on heritage assets.) Particularly, these methodologies relate to understanding 'lessons learnt' and to developing emergency planning guidance. (2C1.5.1 and 2C1.5.2.)

2C1.6 Reduction of negative impact on heritage assets arising out of the responses of others to natural and environmental threats contains three measures that are appropriate to this theme. (Outcome: Improved cross-agency working and heritage taken into account in partner implementation on environmental quality directives; reduction of negative impacts.) Particularly these methodologies relate to ensuring a more strategic positioning of heritage in multi-agency initiatives, and ensuring areas and asset at risks are identified.

URBAN HEAT ISLANDS

City of London:
The Church of St Margaret Pattens, overlooked by 20 Fenchurch Street, London.

URBAN HEAT ISLANDS

Nature and Scope of the Problem

The term Urban Heat Island (UHI) refers to the phenomenon of higher temperatures in urban areas compared to the 'normal' temperatures in outlying areas. The principal cause of the UHI effect is likely to be the increased heat retention of the built fabric of the urban realm, with the dense and often high-rise form of city plans also serving to retain heat. Temperature variances as a result of UHI vary widely according to the size and form of the urban area. Commonly UHI results in temperature variances of up to 7°C between urban and rural areas, and 9°C differences have been recorded between London and its rural surroundings.[31]

The rise in temperatures associated with the UHI phenomenon can have wider meteorological effects. Data from American cities has shown that UHI can lead to increased precipitation in urban areas: the anomalous warm of the city creates relatively low air pressure that causes cooler, rural air to converge on the urban centre, (i.e. convection), which at higher altitudes condensates and precipitates.[32] Studies carried out in several United States cities found that UHI's induced precipitation and thunderstorm events. The UHI effect has also been linked to heightened levels of atmospheric pollution; as the high temperatures and reduced wind speeds associated with UHI trap pollutants in the atmosphere above cities.[33]

Although the UHI phenomenon has been documented since the early 19th century, current projections of temperature variations and the associated heightened levels of precipitation and pollution could increase with overall rises in global temperature: cities are getting hotter faster than anywhere else – so much so that they're often excluded from calculations of average global warming as statistical outliers.[34] One of the longest-studied UHIs is in Central London where a 2009 paper showed that the development of the Central London UHI began before the early 20th century (and the temperature date-ranges covered), and temperature increase was occurring within similar ranges to rural areas, while outlaying areas, particularly as measured at Heathrow, were catching up[35]. In London therefore, the well-established UHI serves to alter the behaviour not only of weather systems, but also of how fabrics respond to higher temperatures.

In some senses, UHIs are a risk multiplier, with heat and associated weather events exacerbating or easing existing environmental threats. The UHI will mean that potential catastrophic thresholds will be reached earlier (for, for example, insect infestation, salt damage, pollution damage).

Other cities and highly-developed sub- and peri-urban areas also have UHIs.

Risk Multipliers

Climate change

The temperature rise effects of climate change[36] may serve to increase the temperatures within UHIs further, with the potential for damaging thresholds to be reached (for example, for drastic insect or mould population increases; so as to affect humidity levels; to exacerbate pollution effects).

These effects may also be positive: the combined effects of projected increased temperatures coupled with UHI could result in increases in winter temperatures, resulting in reductions in damage to stone and concrete masonry and decorative stonework as a result of freeze thaw weathering.

Human action

Measures to ease heat in cities can result in further temperature rise (e.g. through increased use of air conditioning). The pressure on 'green lungs' within cities will increase.

New measures aimed at mitigating the effects of UHI could create setting issues.

Urban Heat Island as risk multiplier

To some degree, the higher temperatures that the UHI phenomenon entails can itself be considered a risk multiplier, with thresholds for e.g. insect population increase, already being reached.

Vulnerability Assessment

The increased temperatures that result from UHI do not directly pose a critical threat to built heritage assets as, generally speaking, historic buildings are well suited to dealing with increased temperatures. Solid masonry construction is less sensitive to changes in atmospheric temperature and they are often well ventilated which helps to reduce interior temperatures. In addition there may be direct benefits to the historic built environment as a result of UHI (see above).

---

31 P.D. Jones and D.H. Lister. 2009. London and urban-related warming trends in Central London since 1900. Weather. December 2009, Vol. 64, No. 12

32 Baik, J.J., & Kim, Y.H. 2000. Dry and moist convection forced by an urban heat island. Journal of Applied Meteorology, 40(8): 1462-1475.

33 Greater London Authority. 2006. London's Urban Heat Island: A Summary for Decision Makers

34 Jones, T. 2013. How Can We Live With It? London Review of Books 35(10) 23rd May 2013

35 P.D. Jones and D.H. Lister. 2009.

36 2013. Summary for Policy Makers. IPCC. SPM-4.

The increased rainfall that may be associated with UHI poses greater risks to built heritage assets. Increased rainfall could result in accelerated stone decay, particularly of more friable sandstones, and accelerated mould growths in historic interiors. This impact could be partly mitigated by alterations to rainwater goods; though these alterations themselves may have detrimental effect on the appearance of historic buildings. In addition the increased levels of air pollution associated with UHI could lead to further degradation of historic masonry and carved stone detailing; as with increased levels of precipitation sandstones will be particularly vulnerable to this. Thresholds at which such problems may become catastrophic may be accelerated.

The adverse effects of UHI can be reduced or entirely eradicated by alterations to the form of urban places, though this itself has obvious implications for the historic built environment. The addition of lighter coloured roofing and paving materials can reduce ambient temperatures, as these lighter materials reflect rather than store solar energy, but these can fundamentally alter the appearance of historic buildings and areas. It has been suggested that more radical alteration of urban areas, creating denser cities with small footprints surrounded by thickly wooded gardens and large bodies of water, are needed to mitigate against the effects of UHI[37]. If such plans are put into effect they could have serious implications for historic urban areas.

In general designed landscapes are less susceptible to the effects of UHI, and tend to record lower temperatures than surrounding urban areas. But some substantial increases in temperature and decreases in soil moisture, as a result of climate change and exacerbated by UHI, may result in some historically significant schemes of planting becoming difficult to maintain. Similarly associated increases in ambient temperature may cause heat and pollution pressures on urban parks and gardens, which play important roles in environmental regulation in cities. At the least, parks could become less enjoyable places to be, but potential consequences could be catastrophic in the parching of ground and the effect this may have on vegetation; therefore spiralling the effects of the UHI.

Evidence Base

Most work on UHI occurs in meteorological circles and is aimed at determining temperature and other weather variations. There is a lack of focused study on the effects of UHI on the historic environment; particularly on archaeological remains. However, work is currently underway on raised pollution levels and other problems that may be exacerbated by UHIs as risk multiplier, such as salt degradation and some stonework.

Key Areas for Further Research

There is a lack of research into how UHI will affect the historic environment beyond materials analysis. More general actions in 2C1 (detailed below) are of relevance, however, specific work needs to be done in order to understand the threat.

- Research into the area and nature of London as a UHI has been undertaken. The next iteration of projects could aim to understand the nature of other UHIs within England;
- UHI will exacerbate other threats such as the incidence of pests and diseases, extremes of wetting and drying in green spaces etc. Potential project could explore datasets which will help to identify particularly imminent threats that may be accelerated by UHI conditions;
- As well as quantifying the effects of UHI on the historic environment further research will be needed on methods for reducing the effects of UHI without recourse to methods that destroy the distinctiveness of historic places;

2C1 Context

2C1.4 Measures to secure greater resilience of heritage assets to natural and environmental threats contains one project Methodology (3) appropriate to this theme. (Outcome: Greater resilience of heritage assets and places to impacts of acute or extreme environmental threats. Wider awareness of heritage dimension.) Production of appropriate resilience guidance for land and asset managers and owners of vulnerable landscapes.

2C1.5 Development of counter-disaster (post-event, asset recovery) responses to natural and environmental threats contains two project Methodologies appropriate to this theme. (Outcome: Improved cross-agency working: reduction of post-event impact on heritage assets.) Particularly, these methodologies relate to understanding ‘lessons learnt’ and to developing emergency planning guidance. (2C1.5.1 and 2C1.5.2.)

2C1.6 Reduction of negative impact on heritage assets arising out of the responses of others to natural and environmental threats contains three measures that are appropriate to this theme. (Outcome: Improved cross-agency working and heritage taken into account in partner implementation on environmental quality directives; reduction of negative impacts.) Particularly these methodologies relate to ensuring a more strategic positioning of heritage in multi-agency initiatives, and ensuring areas and asset at risks are identified.

[37] Jones, T. 2013. How Can We Live With It? London Review of Books 35(10) 23rd May 2013

4 COMMON THEMES

4. COMMON THEMES

The interviews undertaken as part of this project have supported the original provision of the Project Design of the twin threats of 'natural' environmental events and the human adaptive response.

In both those categories, water has been identified by this project as the most pressing environmental threat facing the historic environment in the short to medium term. Through coastal processes, fluvial, pluvial, ground and surfacewater inundation, wetting and drying, and other cumulative effects, it is the single biggest causational and contributing factor to the environmental threat facing heritage assets. Work being undertaken in order to alleviate water as a threat by other environmental disciplines is also part of this threat.

However, there are also significant gaps in knowledge that may mean the comprehension of other threats is not advanced enough to be able to downgrade their priority. This project has identified for instance, the potential catastrophic nature of the acceleration and increase in pests and diseases, while observing the lack of knowledge regarding a) the scope and spread of the threat and b) how it can be mitigated or managed.

However, the significant crossover between themes and what is 'missing' from understanding threat and its mitigation means that there is considerable scope for projects that will work across the Key Themes. The identification of the adaptive response as a risk multiplier across each theme for example, and the accompanying identification that it is the adaptive response of certain agencies that is most critical means that partnership and resilience projects as outlined in 2C1.4 and 6 should be prioritised.

The interviews have also highlighted a perception that English Heritage's reactive position with regards environmental threat has been problematic. Although it is clear that EH is driving preventative and other measures beyond 'response', i.e. proactive initiatives, there seems to be a requirement for a more confident approach. As most of the historic environment is in private hands, and indeed is at risk, there is a critical need for systems that will allow confident assessment, categorisation and guidance that can be as useful at government and other agency level as when trickled down to local management level. This should not be curtailed by a need to know the details of climate change. The scale of the threat also means that philosophies of conservation applied to the historic environment may need to be adapted. Where protection is impossible, challenges of how to manage decline need to be met, and landowners/managers aided in how best to meet the challenge.

The following further work therefore, is identified as crossing over several themes, and has emerged from perceived needs in the sector:

- Identification and mapping of at risk areas and landscapes of high resource value that are at risk;
- Development of strategic approaches for land-owner / manager engagement through the communication of confident evidence-based understanding of the effects of threat on the historic environment. Existing models include the Climate Change Impact Report Cards;
- Formalisation of 'emergency' retrospective assessment of destructive events into a 'lessons learned strategy' in which adaptive response consequences could be understood, key messages allowed to trickle down, and practical measures found to prevent further incidence in order to ensure its effectiveness;
- Promote better and solid mechanisms for the drip-down of observational understanding of threat from local authority level;
- Review of strategies and directives on environmental threat management at governmental, non-governmental agency, third-sector and other authority level to understand the position of heritage and identify potential unforeseen threat;
- A formalised approach to sophisticated risk assessment across the historic environment is needed to properly understand threat to heritage assets and will help to determine management (decline or mitigation) on the ground (see below);

Clarity through the above measures will allow identification and classification of areas where mitigation of risk/or management of decline is the appropriate action. These understandings need to be disseminated and guidelines developed on management of decline.

ATKINS

Andrew Croft
Atkins Heritage
The Axis
10 Holliday Street
Birmingham
B1 1TF

Email Andrew.Croft@atkinsglobal.com
Telephone +44 7803 25 8592
Direct telephone +44 7803 25 8592