UCL CENTRE FOR SUSTAINABLE HERITAGE

Climate Change and the Historic Environment

May Cassar

… the spring, the summer,
The chiding autumn, angry winter, change
Their wonted liveries, and the mazèd world
By their increase, now knows not which is which:
And this same progeny of evils comes
From our debate, from our dissension;
We are their parents and original.'

A Midsummer Night's Dream, Act II Scene I

Closing lines from the 'weather' speech by Titania in Act 2 Scene 1 of Shakespeare's *A Midsummer Night's Dream*. This speech is a slightly unnerving description of the effects of climate change. England was suffering a particularly meteorologically turbulent time when Shakespeare was writing his play, but the accounts of terrible floods and altered seasons ring true today.

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www.ucl.ac.uk/sustainableheritage/climatechange/climatechangeandthehistoricenvironment.pdf

Cover photograph © English Heritage: National Monuments Record.
Ringbrough Coastal Battery, Humberside
Coastal erosion presents a major threat to many sites of 20th century archaeology. Built between 1941–2, this Coastal Artillery Battery which includes cast concrete munitions trackways and ancillary buildings is now in immediate threat of complete destruction.

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Acknowledgements

In 2002, the Centre for Sustainable Heritage was commissioned by English Heritage to carry out a scoping study on climate change and the historic environment, including buried archaeology, historic buildings, parks and gardens (Archaeology Commissions PNUM 3167). The start of the study coincided with the publication of the current UKCIP02 climate change scenarios. The final report has been prepared by Professor May Cassar, while the original research was carried out by Dr Robyn Pender. However, such a report is never the product of one or two individuals. There were numerous other collaborators in the study including Professor Bill Bordass (William Bordass Associates), Jane Corcoran (Museum of London Archaeology Service), Professor Lord Julian Hunt (UCL), Taryn Nixon (Museum of London Archaeology Service), Professor Tadj Oreszczyn (UCL) and Professor Phil Steadman (UCL). English Heritage's interests were represented by Mike Corfield and latterly by Bill Martin. UKCIP through Dr.Richenda Connell provided scientific advice during the editing of the report. The study could never have been carried out without strong regional participation from heritage managers in the East of England and the North West of England as well as scientists and policy makers.

It is intended that this report will make a contribution to the debate on the impact of climate change on the historic environment. Its recommendations and the gaps in information and research that it has identified should be the focus of discussion and timely resolution.

31 August 2005

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1 Key recommendations

English Heritage in its annual report on the state of England's historic environment **Heritage Counts** [www.heritagecounts.org.uk] acknowledges that 'long-term climate change . . . threatens to impact upon all aspects of daily life, not least the survival of heritage assets' (**Heritage Counts** 2004, 5.5 Environmental Sustainability). This report provides essential background information necessary to address one of the key questions in the first State of the Historic Environment Review in 2002 namely, 'identifying ways of measuring the impact of climate change and the historic environment' (SHER02, Challenge 5).

Whether or not there is universal acceptance of the level of climate change impact described in this report, these recommendations deserve careful consideration because they are based on evidence of a fragile heritage which could be damaged by much less than a catastrophic event.

Recommendation 1: Sector leadership on climate change

English Heritage should maintain sector leadership on climate change it has established by commissioning this study, by leading on the development of climate change impact indicators, by disseminating information on climate change to historic environment stakeholders and by promoting the inclusion of climate change impact on the historic environment in wider agendas.

Recommendation 2: Monitoring, management and maintenance

Climate change often highlights long standing preservation issues, rather than discovering new problems. The issue that English Heritage needs to address is how to streamline current monitoring, management and maintenance practices to improve the stability of the historic environment, no matter how weak or strong is the impact of climate change.

It is important that English Heritage promotes and supports local decision-making in maintenance and emergency response. To do this effectively, local cross-disciplinary training programmes in basic maintenance procedures for its own staff and contractors should be considered. Good maintenance could also be promoted by shifting the emphasis from grants for repair to grants for maintenance.

Recommendation 3: Value and significance in managing climate change impacts

The 'save all' approach to the historic environment needs to be re-evaluated. It is not realistic to conserve anything forever or everything for any time at all. Conservation planning pioneered by English Heritage, stems from a consideration of value and significance of the historic environment. Value and significance have also been considered in the Designation Review which has looked at what is conserved and why, and the value of the commonplace. Value and significance must also be part of future planning of the historic environment faced by a changing and worsening climate. Both English Heritage and the National Trust are already facing up to difficult decisions on how to manage the coastal heritage in the face of sea level rise induced by climate change.

Recommendation 4: Participation in the planning of other agencies

English Heritage needs to raise its profile outside the heritage sector by participating and contributing fully to the measures being developed by agencies responsible for addressing climate change impacts in other sectors such as the Environment Agency and the Department for Environment, Food and Rural Affairs (Defra). English Heritage is in a strong position to do so because of its natural affinity with long-term planning.

Recommendation 5: Fully functional heritage information system

There is an urgent need to overcome the weaknesses of paper maps and disparate databases and to transform all existing information to a single standard. A fully functioning and fully integrated heritage information system should replace individual project mapping with a comprehensive digital map base that integrates currently separate data-sets and links them to images such as photographs and plans. It should also be able to capture, display and analyse heritage data in context with other geographic data and appropriate information from climate change models. It should have the capability of continuous upgrading and refinement and be available as an on-line facility.

Recommendation 6: Emergency preparedness

Strong interest has been expressed in a coordinated damage alleviation service for dealing with the effects of extreme rainfall and high winds on the historic environment. Queensland in Australia provides one model for such a body in the State Emergency Services [www.emergency.qld.gov.au/ses/]. Funded by all levels of

government, and staffed largely by trained volunteers, one of their key functions is the immediate protection of storm-damaged property to reduce the risk of further damage. With extreme weather being predicted for the UK, and with the major storms of 1990, 1998 and 2000 in the UK, costing the insurance industry in excess of £3 billion (data source: Ecclesiastical Insurance Group), English Heritage and other heritage organisations together with the Environment Agency should lead on the establishment of a similar service.

Recommendation 7: Adaptation strategies and guidelines for historic buildings, archaeology, parks and gardens

There is little published on conservation and directed adaptation of the historic environment in response to climate change. This is an important gap that English Heritage should aim to fill. This process can begin by integrating climate change impacts in the revision of English Heritage's 'Practical Conservation' series, making use of the results from recent research such as the Engineering and Physical Sciences Research Council (EPSRC)/United Kingdom Climate Impacts Programme (UKCIP) **Engineering Historic Futures** project [www.ucl.ac.uk/sustainableheritage/research/HistoricFutures/] and the EC project on **Global Climate Change Impact on Built Heritage and Cultural Landscapes (Noah's Ark)** (http://noahsark.isac. cnr.it/). An important focus of attention should be adaptation of drainage and rainwater goods, and the discreet provision of irrigation and water storage. The latter makes sense in any circumstances, as too much water is being drawn from aquifers and groundwater sources. Opportunities should be identified to roll out and integrate these issues into existing or planned projects in buildings, archaeology, parks and gardens.

Recommendation 8: Buried archaeology and prediction maps

The complexity and variability of the buried environment requires the development of a series of prediction maps that draw on a wide number of interrelated variables and not on single variables such as soil type. These maps which could emerge from staged studies characterising the heritage resource, field testing the characterisation and defining a management model for the site or landscape based on qualitative values and vulnerability to climate change, would be used by resource managers (landowners, statutory bodies, local authorities) to inform management or conservation plans for archaeological landscapes or sites.

2 Description of the English Heritage climate change scoping study

'Climate change is an acknowledged threat to both the natural and the historic environment. For example, changes in the intensity and frequency of storm events will pose a challenge to a wide spectrum of the historic environment from coastal sites to veteran trees. Can we measure the likely impact and cost the necessary mitigation?'

State of the Historic Environment Report, English Heritage, 2002.

English Heritage, recognising the need for information about the likely impact of climate change on the historic environment of the UK, commissioned University College London (Centre for Sustainable Heritage) to produce a scoping study designed to investigate likely risks and suitable strategies of mitigation and adaptation. This is the report of that study.

2.1 Context of the scoping study

Introduction

Climate change has been a much-debated issue for some years, but it is now widely accepted that well-established climate patterns are indeed changing. It is becoming a matter of urgency not only to mitigate the level of future change by reducing greenhouse gas emissions, but also to develop plans to adapt our societies and economies to cope with the climate changes that will occur.

The Third Assessment Report of the Intergovernmental Panel on Climate Change [IPCC] – the UN's scientific advisory committee on climate change effects – notes: 'Adaptation has the potential to reduce adverse effects of climate change and can often produce immediate ancillary benefits, but will not prevent all damages.' [p.12] They further observe that '…well-founded actions to adapt to… climate change are more effective, and in some circumstances may be cheaper, if taken earlier rather than later.' [p18] Even so, it has proved difficult to convince many planners of the need to incorporate climate change into their strategies. For this there appear to be two main reasons: firstly a time-scale much longer than most planning horizons, and thus seemingly less urgent, and secondly the uncertainty implicit in climate predictions.

'Global temperature has risen by about 0.6°C over the last 100 years, and 1998 was the single warmest year in the 142-year global instrumental record . . . The UK climate has also changed over the same period, and many of these changes are consistent with the warming of global climate. . . . Much of the change in climate over the next 30 to 40 years has already been determined by historic emissions and because of the inertia in the climate system. We are likely, therefore, to have to adapt to some degree of climate change however much future emissions are reduced.'

M. Hulme et. al, Climate Change Scenarios for the United Kingdom: The UKCIP02 Scientific Report, 2002

Predictions must incorporate not only the scientific uncertainties inherent in trying to model complex weather systems, but also the much less quantifiable uncertainties in future emissions, and so the temptation arises to 'wait until the situation is certain.'

There is, however, one sector that operates on long term planning, and for which the climate instability has particularly serious implications: the historic environment. Dealing day-to-day with the conservation of sites that may be thousands of years old makes heritage managers see problems 50 or 80 years hence (as given in the UK Climate Impact Programme (UKCIP)'s published climate change scenarios and in Table 1) as a current issue. They are well aware, too, of the complex interaction between their sites and the local climate, and concerned about any forces which may disrupt equilibrium conditions under which the sites have been preserved for so long.

It is therefore not surprising that heritage organisations in the UK have been active in trying to assess the impacts of climate change which will need to be integrated into their planning. The National Trust, for example, has been actively considering future policy in this light since the mid 1990s. English Heritage commissioned this broad-based scoping study to look at the impacts of climate change on the historic environment, and propose strategies for adapting to the new risks and problems, and it has also proposed a policy on climate change (March 2005).

Specification for the scoping study

Old buildings, archaeological sites, and historic parks and gardens are put at risk by the same dangers to the wider environment – flooding, coastal erosion, subsidence and possibly increased storminess – which have already been identified by other climate change studies. However, they present in addition a number of complexities that suggest they may be especially imperiled.

Changes in rainfall patterns and temperatures, even where these may not be perceived as a major threat to modern buildings, are likely to have dramatic effects on

buried or exposed archaeological sites. Parks, gardens and historic landscapes will be faced not only with changed climates, but very possibly with shortages of water and other resources that could make maintenance increasingly troublesome. It may become difficult to propagate even endemic species. For old buildings and their preserved contents the problems are also likely to prove acute; it has long been understood that fluctuations in the local microclimate present the main danger to continued survival. Historic building materials are extremely permeable to the environment of air and soil; changes in moisture content can occur rapidly, and these can activate damaging cycles of salt crystallisation. Old rainwater goods may be unable to cope with changed patterns of rainfall, and acute events such as flooding have much worse and longer-term effects on historic than on modern buildings.

Expensive protection and adaptation strategies may be necessary to cope with these greatly increased dangers, and these will therefore require careful planning based on a controlled assessment of risk.

Methodology

In response to English Heritage's brief for scoping the likely impacts of climate change on the historic environment, the Centre for Sustainable Heritage at University College London has used a diverse range of information sources. Climate change and adaptation literature together with expert views from climate and heritage specialists were reviewed and assessed. A detailed questionnaire gathered responses from managers and advisers in organisations including English Heritage and the National Trust, as well as from field officers, and from local authority officers responsible for archaeology and listed properties. Current views, future plans and possible conflicts of interest between different aspects of the historic environment were elaborated during regional meetings which focussed on prioritising issues as well as gathering expert views. Information was also gathered from local managers and field officers during a number of site visits. Finally a workshop for policy makers was presented with the results. This meeting successfully distilled a

'Climate change decision making is essentially a sequential process under general uncertainty. Decision making has to deal with uncertainties including the risk of nonlinear and/or irreversible changes, entails balancing the risks of either insufficient or excessive action, and involves careful consideration of the consequences (both environmental and economic), their likelihood, and society's attitude towards risk.'
R. T. Watson and the IPCC Core Writing Team, Climate Change 2001 Synthesis Report: Contribution of Working Groups I, II, and III to the Third Assessment Report of the IPCC, 2001

Table 1: Projections from the UKCIP02 climate change scenarios showing relative confidence levels (H = high; M = medium; L = low)

Key Predictions	Confidence level
Temperature	
Annual warming by the 2080s of 1–5^{0}C, depending on region	High
Greater summer warming in the southeast than the northwest of England	High
Variability – years as warm as 1999 becoming very common	High
Greater warming in summer and autumn than in winter and spring	Low
Greater day-time than night-time warming in summer	Low
Summer and autumn temperatures become more variable	Low
Precipitation	
Generally wetter winters for the whole United Kingdom	High
Greater contrast between summer (drier) and winter (wetter) seasons	High
Snowfalls decrease significantly everywhere	High
Substantially drier summers for the whole United Kingdom	Medium
Variability – summers as dry as 1995 become very common	Medium
Winter and spring precipitation becomes more variable	Low
Storminess	
Winter depressions become more frequent, including the deepest ones	Low
Humidity	
Specific humidity increases throughout the year	High
Relative humidity decreases in summer	Medium
Soil moisture levels	
Decrease in summer and autumn in southeast England	High
Increase in winter and spring in northwest England	Medium
Sea level rise	
Continuation of historic trends in vertical land movements introduces significant regional differences in relative sea level rises around the United Kingdom	High
Storm surge – for some coastal locations and some scenarios, return periods will reduce an order of magnitude by the 2080s	Medium
Changes in storminess, sea level and land movement mean that storm surge heights will increase by the greatest amount off southeast England	Low
Solar radiation	
Reduction in summer and autumn cloud, especially in the south, and increase in radiation	Low

number of important recommendations, as well as producing some general directions for adapting the historic environment to a changing climate.

This integrated and broad methodology was made feasible by concentrating the study on the risks to cultural heritage in two English regions: the East of England and North West of England. These were chosen to coincide with the areas already studied by Cranfield University's 'Regional Climate Change Impact Response Studies in East of England and North West England' (RegIS) project (from which information is already available) and to provide contrasts in crucial factors such as flood risk, accessibility and urbanisation, climate, and type of buildings, archaeology, and gardens.

The study tried to scope useful ways of assessing and adapting to possibly unpredictable climate change risks. This report details these suggestions and supporting information. It includes a number of demonstration risk maps for the East of England and the North West, which are presented to compare the susceptibility of local heritage sites to the patterns of climate change projected by Regional Climate Models for the UK. The report also clearly identifies future areas of research and the policy implications to meet the needs of cultural heritage in a changing climate.

2.2 Climate change prediction and policy

Modelling future climates

Climate predictions are based on climate models, which in turn are constructed from studies of the current climate system, and the factors which influence it. The UK Meteorological Office [Met Office] defines the climate system as shown below.

A climate model is a mathematical formulation of the effects of all the key processes operating in the climate system. Various different climate models can be constructed; the effectiveness of any particular model is assessed by seeing how well it reproduces past climate behaviour. Numerous uncertainties exist, since knowledge of how the climate system operates is by no means complete. But the greatest problem for prediction remains the estimation of future socioeconomic patterns (patterns of land use, for example, as well as emissions). Additionally, extrapolating the models to future climates implies the assumption that the broad operation of the climate system will remain constant even under high emissions scenarios and not undergo dramatic shifts.

Britain's Met Office is a world leader in climate modelling. Met Office projections are taken from the Hadley Centre's coupled atmosphere-ocean general circulation [AOGCM] models HadCM2 AOGCM, developed in 1994, and its 1998 successor HadCM3 AOGCM. Such advanced global models typically have a rather coarse resolution (a few hundred kilometres, for which computing time is the main factor responsible), but they capture well the main processes controlling the earth's climate. They also take into account emissions: 'Greenhouse-gas experiments with AOGCMs have usually been driven by specifying atmospheric concentrations of the gases, but if a carbon cycle model is included, the AOGCM can predict changes in carbon dioxide concentration, given the emissions of carbon dioxide into the atmosphere. At the Hadley Centre, this was first done in 1999. Similarly, an AOGCM coupled to an atmospheric chemistry model is able to predict the changes in concentration of other atmospheric constituents in response to climate change and to the changing emissions of various gases.' [The Hadley Centre website is www.metoffice.gov.uk/research/hadleycentre/].

The coarse resolution of global models does not allow for useful local climate change projections: local weather is heavily influenced by local features such as topography and land use. This is overcome by constructing more detailed models for limited areas and shorter time periods, taking input from the global AOGCMs at the area boundaries and for sea-surface conditions. The Hadley Centre has a number of

such Regional Climate Models (RCMs). The projections on which this Scoping Study is based are taken from the output of HadRM3, available through the Climate Impacts LINK Project [www.cru.uea.ac.uk/link/] and published by UK Climate Impacts Programme [UKCIP] [www.ukcip.org.uk/]. Resolution for the projections released in 2002 is 50 km over Europe, with the model run over the periods 1961-90 and 2070-99 for a range of emissions scenarios. Refinement of global models is ongoing and the next set of UKCIP scenarios will be published in 2007/08.

Using climate models to plan ahead

Having such a state-of-the-art tool as the 2002 regional predictions from HadRM3 allows initial responses to the threat of climate change to take place, and set in motion long-term adaptation processes. It is not only important for heritage managers to decide their own response: statutory bodies such as the Environment Agency are also using these new tools to plan ahead, and – since plans such as flood defences crucially impact on the historic environment – it is important that a considered heritage response is developed and communicated across public decision-making as an integrated response will be ultimately more effective at safeguarding against damage.

The willingness of heritage managers to plan ahead could see them emerge as leaders: they have direct access to the general public through their work, and could help to articulate concerns over loss to what is historically significant from climate change. Knowledge of past climatic variations and their impacts on the environment and on human activities may help to guide planning of responses to future climate changes. The following is an assessment of the issues of particular concern to the historic environment which arise out of climate change. Many potential problems have been identified, and indeed there are few aspects of conservation and preservation practices that will not be affected by future changes. This Scoping Study also questions our attitude to the historic environment and our approach to its conservation and preservation and the priority that should be given to climate change adaptation.

'. . . well-founded actions to adapt to climate change are more effective, and in some circumstances may be cheaper, if taken earlier rather than later.'
R. T. Watson and the IPCC Core Writing Team, Climate Change 2001 Synthesis Report: Contribution of Working Groups I, II, and III to the Third Assessment Report of the IPCC, 2001

3 Sources of climate change information, advice and research

There is an overwhelming amount of information available: in print, in electronic format, and as advice from different organisations. Some is frequently updated, so it is almost impossible to dip into the information and obtain a quick snapshot of developments. Consequently in sourcing information for this report, rather than attempting to be comprehensive, the aim has been to clearly identify the key sources of information and advice, and to create a guide to the most generally important and useful information.

3.1 Advice and research

The organisations undertaking these activities can be conveniently grouped under two headings: global and UK-focused.

The single most important global organisation is the Intergovernmental Panel on Climate Change [IPCC], 'established by the World Meteorological Organization [WMO] and the United Nations Environment Programme [UNEP] to assess scientific, technical and socioeconomic information relevant for the understanding of climate change, its potential impacts and options for adaptation and mitigation'.

On a national level, the UK is fortunate in hosting a number of the world's leading research organisations investigating climate change. The Met Office supports the Hadley Centre for Climate Prediction and Research which 'provides a focus in the United Kingdom for the scientific issues associated with climate change'. The University of Oxford houses the Environmental Change Institute [ECI], founded 'with the aim of informing issue-driven policy-relevant research for the management of environmental change'. The flagship programme of the ECI is the UK Climate Impacts Programme [UKCIP], set up by the UK Government in April 1997 and currently funded by Defra. UKCIP's stated aims are 'to coordinate and integrate an assessment of the impacts of climate change at a regional and national level that is led by stakeholders'. Stakeholders or partners 'commission the research and determine the research agenda, ensuring that it meets their needs. UKCIP provides support and guidance throughout the process to both stakeholders and the researchers, so providing a bridge between researchers and the decision-makers in government organisations and business'. The University of East Anglia has both the Climate Research Unit [CRU], which aims 'to improve scientific understanding in three areas: past climate history and

its impact on humanity; the course and causes of climate change during the present century and prospects for the future', and the Tyndall Centre for Climate Change Research which intends 'to develop sustainable responses to climate change through trans-disciplinary research and dialogue on both a national and international level'.

3.2 Critical bibliography

The following is a guide to some of the most useful literature and other information sources currently available. It includes web-based guidance and data as well as publications, as much of use appears in this form. This literature can be roughly divided into three categories, which are: Climate Systems, Approaches to Mitigation, and Impact/Adaptation Studies. Most literature considers all three, but as a rule tends to emphasise one theme, with the other categories being given secondary consideration. In the following discussion, literature is classed by its category of main reference, and within this it is grouped by whether the primary scope of the study is global/international, UK, sectoral, or regional/local.

Climate Systems

These include studies that address the evidence for and mechanics of climate change, the climate and social models (scenarios) that underlie predictions of future climate, and studies presenting the predictions generated by such models. Since climate systems are studied at a global / international and national levels, and not at a sectoral or regional / local level, the literature originates from these sources.

Global/International Reports

The IPCC assesses, and then publishes under its own banner, much of the vast amount of scientific research on climate change carried out all over the world. Its Third Assessment Report, published in 2001 under the title 'Climate Change 2001', consists of four large volumes: The Scientific Basis; Impacts, Adaptation and Vulnerability; Mitigation; and a Synthesis Report. The Synthesis Report is highly recommended for the following reasons:

- It presents in a straightforward and easy-to-consult manner the background to climate change prediction.
- It provides an excellent summary of the meaning and development of futures scenarios and the global view of chance, mitigation, and adaptation.
- It discusses the assumptions and boundary conditions of the various climate models.
- It compares the results of different models.

This publication can be consulted online at [www.ipcc.ch/pub/SYRspm.pdf] (Policy-Makers Summary). The four volumes are available at [www.ipcc.ch/pub/SYRtechsum.pdf].

The IPCC regularly publishes proceedings of workshops on the latest developments in climate science [www.ipcc.ch/pub/pub.htm]. For example, a workshop in 2002 discussed the best approaches to predicting extreme weather events [www.ipcc.ch/pub/extremes.pdf]. The proceedings note that small-scale climate events have associated high costs: 'In one important example, land subsidence losses from two droughts during the 1990s in France resulted in losses of US$2.5 billion – a cost on a par with large hurricanes. Subsidence losses have been observed to triple during drought years in the UK, with a cost approaching $1 billion annually.' The IPCC Fourth Assessment Report is due for publication in 2007.

There are a number of internationally recognised climate modelling centres and the results of their work can be obtained through the IPCC Data Distribution Centre [http://ipcc-ddc.cru.uea.ac.uk/].

National Reports

At a national level, the most important tool for future planning in the UK is the UKCIP02 climate change scenarios presented in 'Climate Change Scenarios for the United Kingdom: The UKCIP02 Scientific Report' [UKCIP02] [www.ukcip.org.uk/]. This report provides some of the data generated by the Hadley Centre's Regional Climate Model, HadRM3, as 26 parameters of monthly data on a 50km grid. The full set of data can be obtained directly from UKCIP.

UKCIP02 uses four different emissions scenarios for three future time periods (the 2020s, 2050s and the 2080s). Most of the information is presented as maps showing changes in temperature and rainfall with extensive explanatory text. The actual values

of future temperature and rainfall can be calculated by adding these changes to the UKCIP02 baseline dataset. UKCIP02 includes details of seasonal average changes and some information on changes in extreme events though this is less robust. This report gives the 'best guesses' for future UK climate predictions in an accessible way.

Approaches to climate change mitigation

In climate change science, 'mitigation' is given a very precise meaning: the limiting of the scale of future climate change by addressing greenhouse gas emissions (this strict meaning is used throughout this report, to prevent confusion). Mitigation lies largely within the political/industrial sphere, as it deals with preventive measures on a geopolitical level. The purpose of this study was to scope the current and future impact on the historic environment of the climate change which is already taking place. The topic of climate change mitigation lies therefore outside this study and is not covered in this report.

Impact/Adaptation Studies

This category includes both literature that addresses the implications of climate change, and that which discusses the economic, social and practical measures that will be needed in response.

The study addressed the predictions for climate change in the UK and how specifically management of the historic environment needs to be adapted in response; this report therefore does not discuss detailed measures. Nevertheless, it is perhaps useful to note that much information can be found throughout the recommended impact/adaptation reading material.

Global/International Reports

On a global level, the IPCC's Third Assessment Report is again the central source for global impact assessment. A recent report by the European Environment Agency, 'Impacts of Europe's changing climate' [EEA Report No 2/2004] provides an overall assessment of impacts across the European Union [http://reports.eea.eu.int/climate_report_2_2004/en].

'We believe that further research on climate change impacts is needed but that work on adaptation should not wait until such research is complete, given that many of the options will have a positive impact regardless of climate considerations and are worth doing anyway.'

Select Committee on International Development Third Report, 2002

National Reports

Nationally, Defra is the UK Government Department responsible for the official UK response to its climate change treaty commitments. It regularly publishes 'National Communications' the latest being 'The UK's Third National Communication under the Framework Convention on Climate Change' [www.defra.gov.uk/environment/climatechange/3nc/pdf/climate_3nc. pdf].

Defra has also published 'The Impacts of Climate Change: Implications for Defra' [www.defra.gov.uk/environment/climatechange/impacts2/index.htm] which sets out the policy challenges the department faces in response to climate change.

For a useful synopses of all the research conducted under the umbrella of the UKCIP see 'Measuring progress: Preparing for climate change through the UK Climate Impacts Programme' [www.ukcip.org.uk/].

The publication by Defra's predecessor, MAFF of 'Flood and Coastal Defence Project Appraisal Guidance', addresses coastal flooding and loss and the likelihood of adaptation strategies endangering the historic environment [www.defra.gov.uk/environ/fcd/pubs/pagn/fcdpag1.pdf]. This makes it a critical reference document for English Heritage's input into the crucial area of coastal planning. More recently the Government's Foresight Programme has published the 'Future Flooding' report which assesses the change in flood risk caused by climate change and socio-economic change over the 21st century [http://www.foresight.gov.uk/previous_projects/flood_and_coastal_defence/ index.html].

The Environment Agency's publications are usually published online. The Agency has devised a programme of research aimed at incorporating climate change considerations within policy, processes and regulations. Jointly with Defra, it runs a research programme focusing on flood management [www.defra.gov.uk/environ/fcd/research/].

UKCIP's 'Climate Change and Local Communities – How prepared are you?' [www.ukcip.org.uk/] and the Environment Agency's 'The climate is changing: time to get ready' [www.environment-agency.gov.uk/] though useful, are less strategically important than the above.

Sectoral Reports

A number of published sectoral reports are useful to highlight for different reasons: some provide useful information in their own right; others will provide English Heritage with useful examples of how other sectors are responding to climate change impacts. The reports most worthy of note are discussed in some detail below.

The EPSRC and UKCIP are supporting a portfolio of projects, which will produce reports under the banner 'Building knowledge for a changing climate' (BKCC). The projects which include **Engineering Historic Futures** (page 3) and **Betwixt** (page 45) are investigating the impacts of climate change on the built environment, transport and utilities, including historic buildings, urban planning, urban drainage and slope stability [www.ukcip.org.uk].

The Construction Research and Innovation Strategy Panel (CRISP) has produced a report 'CRISP Consultancy Commission 01/04, A Review of Recent and Current Initiatives on Climate Change and its Impact on the Built Environment: Impact, Effectiveness and Recommendations' containing a very useful critical review of various climate change initiatives and programmes.

The Foundation for the Built Environment published a report 'Potential Implications of Climate Change in the Built Environment' (Graves H M and Phillipson M C, 2000, ISBN 1 86081 447 6) which contains technical assessments of potential impacts and adaptation strategies based on the UKCIP98 scenarios. Though these have been superseded by the UKCIP02 scenarios the results still stand.

The Construction Industry Research and Information Association (CIRIA) has published a review of the implications of climate change and practical guidance on assessing and managing the associated risks, such as ground movement, rain penetration and wind loading. 'Climate change risks in building – an introduction (C638)' can be obtained from CIRIA [http://www.ciria.org/acatalog/C638.html].

The Chartered Institution of Building Services Engineers (CIBSE) has published 'Climate Change and the Indoor Environment: Impacts and Adaptation' (CIBSE TM36: 2005) which provides building simulation case studies including one on a 19th century semi-detached house with suggested adaptation to avoid overheating.

A report funded by the Office of the Deputy Prime Minister has reviewed the adequacy of current national planning policy in the UK in responding to climate change. The report, 'The Planning Response to Climate Change: Advice on Better Practice' can be obtained from [www.planningportal.gov.uk/england/professionals/en/1112201229106.html].

The RegIS report was the basis for selecting the East of England and the North West for detailed regional examination in this study [www.ukcip.org.uk/]. It provides an integrated assessment of climate impacts on agriculture, biodiversity, water resources and the coastal zone.

The MONARCH report 'Climate Change and Nature Conservation in Britain and Ireland: Modelling natural resource responses to climate change (the MONARCH project)' focuses on biodiversity impacts [www.ukcip.org.uk/].

The National Trust has taken the lead on climate change impacts in a number of areas. The web-based 'National Trust Climate Change: A Paper presented by the Head of Nature Conservation and the Environmental Practices Adviser on behalf of the Chief Agent' is the Trust's foundation document on its response to Climate Change [www.nationaltrust.org.uk/environment/html/env_iss/papers/envissu2.htm]. 'The National Trust Soil Policy' was the first of its kind; it presents the National Trust's approach to climate change issues and as such is an important publication [www.nationaltrust.org.uk/environment/html/env_iss/pdf/soil01.pdf]. The 'National Trust PPS14: Climate Change' is the National Trust's relevant Planning Position Statement [www.nationaltrust.org.uk/environment/html/land_use/pdf/pps14.pdf]. The National Trust has recently undertaken a coastal risk assessment for the next 100 years [http://www.nationaltrust.org.uk/coastline/save/coastal_policy.html].

The National Trust was also the major contributor to a study by Reading University, published recently by UKCIP titled 'Gardening in the Global Greenhouse: The Impacts of Climate Change on Gardens in the UK' [www.ukcip.org.uk/].

English Heritage's technical advice note on 'Flooding and Historic Buildings' [www.english-heritage.org.uk/filestore/conserving/advice/flooding%20tan.pdf] provides the most up-to-date advice on adaptation measures in response to flood events. The periodic reports on the 'State of the Historic Environment' are important for statistics relating to the role and responsibilities of the organisation [www.english-heritage.org.uk/Default.asp?WCI=Node&WCE=7005]. Although as this report will show, archaeologists are extremely concerned about the implications of climate change, the volume 'The Heritage Management of Wetlands in Europe EAC Occasional Paper No.1 WARP Occasional Paper No.16' has only one paper dealing with climate change, which is an issue of particular importance for wetland preservation. This is Gill Walters' paper 'Threats and pressures on wetland environments in England and Wales and the response of the Environment Agency.'

[Eds. B. Coles and A. Olivier, EAC 2001]. The proceedings of the two national conferences on Preserving Archaeological Remains in Situ (1996, 2001) – jointly organised by English Heritage and the Museum of London Archaeology Service [MoLAS] – are noteworthy. [MoLAS, 1998 (ISBN 1-901992-02-0) and MoLAS, 2004 (ISBN 1-901992-36-5)] These conferences sought to identify strategies for understanding the physical, chemical, and biological environment of buried archaeology. This is the necessary foundation for comprehending the potential impacts of climate change.

The Country Land & Business Association's 'Climate Change and the Rural Economy' published in 2001 is a very focused report, with a useful Executive Summary [www.cla.org.uk].

Reports from the English regions and devolved governments of the UK

All the English regions as well as Scotland, Wales and Northern Ireland (Table 2) have carried out scoping studies and published reports on the impact of climate change. These can be found on the UKCIP website at www.ukcip.org.uk.

Table 2 Summaries of scoping study reports produced by the English regions and devolved governments of the United Kingdom

Location	Scoping study report
South West	Warming to the idea: Meeting the challenge of climate change in the South West
South East	Rising to the challenge: The impacts of climate change in the South East
London	London's warming. The impacts of climate change on London
East of England	Living with climate change in the East of England
East Midlands	The potential impacts of climate change in the East Midlands
West Midlands	The potential impacts of climate change in the West Midlands
North West	Changing by degrees – The impacts of climate change in the North West
Yorkshire & Humber	Warming up the region: The impacts of climate change in the Yorkshire and Humber Region
North East	And the weather today is ...
Scotland	Climate change: Scottish implications scoping study
Northern Ireland	Implications of climate change for Northern Ireland: informing strategy development
Wales	Wales: Changing climate, challenging choices: the impacts of climate change in Wales from 2000 to 2080

3.3 Available information: conclusions

Excellent information is now available on the background to climate change, especially through IPCC and UKCIP. A good range of policy-makers' advice exists on general issues, but there are very few guidelines on directed adaptation.

There is little published on preservation of the historic environment and climate change impact. This is a task in which English Heritage could lead. Climate change often highlights long standing preservation issues rather than creating new problems. The fundamental issue that needs to be addressed by everyone is how to streamline current management and maintenance practices, which will improve the historic environment whether or not the impact of climate change proves as severe as predicted under the worst case scenarios.

'The Trust is presently concerned with many aspects of environmental change, such as land use, agriculture, transport and water resources. The Trust will need to understand the short and long term interrelationships between these issues and climate change issues; and may have to adjust conservation practices to account for different types and rates of change than have previously been experienced.'
Climate Change: A Paper presented by the Head of Nature Conservation and the Environmental Practices Adviser on behalf of the Chief Agent, The National Trust,1998

4 Determining heritage susceptibility to climate change

Of the many predicted changes to the UK climate, which are likely to be of greatest importance to preserving the historic environment? To determine this central question of the Scoping Study, the methodology described below was devised:

- **Establish climate-related factors of concern** – In consultation with the project team, the widest possible list of likely climate-related problems for the preservation of the historic environment was drawn up.
- **Establish impact of climate change on these factors** – The 2080s predictions of UKCIP02 and other sources were used to establish the likely climate change effects on these problematic factors, for the study areas of the East of England and the North West.
- **Design questionnaire** – This information was refined into text form, and incorporated into a questionnaire. This was then disseminated to a wide cross-section of heritage professionals – including local council officers – again concentrating on (though not restricted to) the areas of the East of England and the North West.
- **Site visits** – Buildings, archaeological sites, and parks and gardens were visited and area managers, advisers, and field officers asked to comment on the climate change predictions.
- **Regional workshops** – The results of the questionnaire and site visits were compiled and presented at a Regional Workshop in each of the study areas.
- **List of factors of concern refined** – On the basis of the questionnaire results and the discussions held at the Regional Workshops, the original list of climate-related problems was refined to five issues central to the historic environment.
- **Policy-makers' workshop** – These issues were presented at a Policy-Makers' Workshop for detailed discussion and prioritisation.
- **Report to English Heritage**

Each of these steps is discussed in detail in the following sections.

4.1 Questionnaire

A central part of the scoping study was a questionnaire designed to determine the level of concern felt about climate change by heritage managers (managers, field workers, local council advisers, and researchers). It was recognised, however, that questionnaires can easily lose focus, or become too difficult for busy respondents to complete satisfactorily; for this reason both the approach and the format of the questionnaire were designed in a very different way to, for example, those disseminated for the CRISP and National Trust Gardens studies.

In the report 'The Impact of Climate Change: Implications for the DETR' carried out by In-House Policy Consulting, Thomson noted a gap between climate change prediction, and its translation into practical guidance to help shape policy development and operational management. Talking with heritage managers during the design of the questionnaire, it became clear that this gap persists despite the efforts of UKCIP in publishing the recent scenarios. While this raises a side issue of how to attract media attention to important releases of information such as the UKCIP02 projections, the central problem remains that the exact data needed by individual planners is often difficult to extract from published data without considerable time and effort. This may be a result of publications being designed to appeal to a broad audience: there can be no single clear message.

It was clear that this questionnaire could be designed to serve also as an information document for heritage workers, thereby encouraging more focused and less generalised responses.

Accordingly, the questionnaire was built around 18 central questions, one for each issue of concern identified with the project team. Each question gave a text synopsis of the climate change impact projected for that issue, taking predictions from UKCIP02 and a number of other sources such as RegIS for the East of England and the North West, and comparing the projections for 2080s with the baseline years of 1961–90 as well as recent years noted for extremes of climate (such as very hot summers). As decided during the design stages of the study, the extreme values of change for the High Scenarios were used to allow planning within safe margins. It should be noted that these values are still smaller than those gained by extracting the tail of the data generated by the climate model rather than the mean values.

The questionnaire, the list of respondents and the results can be found in Annex 1. The following is a synopsis of the responses.

Questionnaire results

Respondents were given a wide choice of planning time frames for future protection of the historic environment from which to select, from 0–5 years to greater than 100 years. Most ticked this latter option (Figure 1), even if they also noted that their budget horizons were much shorter. Repeatedly, respondents commented on the obligation to preserve for future generations.

Buildings and Contents

Rainfall

The greatest concern for respondents from the buildings sector was the predicted increases in heavy rainfall. 'This is a huge concern as much damage is already due to faulty or inadequate water disposal systems, and many of the historic rainwater goods are not capable of handling heavy rains, and are often difficult to access, maintain, and adjust.' It was noted that, although often rainwater goods have been over-designed, close monitoring would be needed to ensure that they were successfully coping with the changing climate.

This raises the problem of how rainwater disposal systems might be adjusted on listed buildings. 'It may be difficult to increase the number or diameter of down pipes in order to cope with increased or heavier rainfall, because of the effect on the appearance of the buildings. Some buildings already have inadequate rain-water disposal systems, and we will have to look at unobtrusive ways of improving them.' 'Since dispersed water drainage systems in most rural historic buildings are very badly designed and poorly understood by their specifiers, a rush to redesign them could be harmful both to the buildings and the archaeology.'

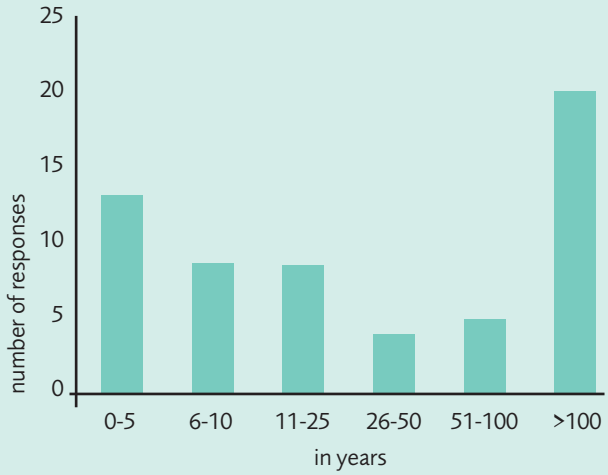


Figure 1: Heritage managers' questionnaire responses on planning time-scales

Almost every respondent flagged the need

for thorough maintenance: 'Our experience is that most water ingress is due to lack of maintenance (for example blocked gullies and downpipes) rather than failure of materials.'

Flooding and soil moisture content

Fluvial flooding was identified as a major problem, requiring directed repairs and upgrading to drainage (it was noted that this has important implications for any surrounding archaeology). It was felt to be of great importance that disaster plans were reassessed and upgraded to cope with flood risks. Post-flood drying is critical, with buildings and excavated archaeology at great risk from subsidence.

Ground heave and subsidence as water recedes were identified as the major issues arising from projected changes in the water table height.

Coastal flooding and storm surge were also identified as extremely worrying, at least for sites in high-risk areas. 'Storm surges are likely to have same effect as overall sea level rise, i.e. inexorable.'

It was in the context of the irrevocable and dramatic loss of coastal sites that one particular conservation theme raised by this study first arose: 'We'll never save everything, so hard decisions are needed as to which to "let go"'. Coastal loss also raised the issue of heritage input into broader planning: …I presume that major sea level rises will be a non-heritage issue (i.e. of such wider concern that it will be dealt with by other authorities).'

Extreme weather

The level of anxiety expressed over high winds by building respondents is the only case where the questionnaire results proved quite different from those arising from other aspects of the study, such as the site visits and the regional meetings, with only 17% expressing 'great concern'. By contrast, direct discussions flagged this as a climate change issue of major importance, with wider ramifications for general emergency planning. Problem areas noted by questionnaire respondents include windows as well as roofs, awnings and verandas, and large trees close to buildings. Ruined buildings and excavated archaeology in particular would be in great danger of wind throw, indicating that more careful thought may have to be given to the stabilisation of such sites.

As with extreme rainfall, it was noted that increases in high winds will rapidly

reveal any problems with maintenance: 'Increased frequency of building inspections and attention to repair of defects in roof coverings will be increasingly essential.'

Temperature and relative humidity

The projected temperature changes were felt to be of most importance for visitor comfort; although winter heating would decrease, it was expected that there would be a corresponding push to install air-conditioning and cooling systems in summer. This should encourage further research into the environmental behaviour of traditional constructions and the design of passive systems including natural ventilation systems.

Rising temperature was also observed to be a risk for deterioration of materials and contents, since it would increase the rate of chemical reactions.

The outcome of changes in relative humidity was felt to be unpredictable, and therefore requiring of close monitoring. 'The size and rate of fluctuations in relative humidity are at least as important as the mean levels, and it is hard to know how these may be affected. Since climate change is a gradual process, it is hoped that vulnerable materials will accommodate to these changes.' 'Broadly, this may be an improvement... However, the issue is the transition from current to future values and the re-equilibration of the porous materials. I think it would be folly to try to reproduce 'past' conditions by humidification etc. Rather, undertake the necessary monitoring and remedial interventions to make the [object] safe under the new prevailing conditions.' However, it should be noted that 'if the wet gets wetter and the dry drier, then both the absolute levels and the fluctuations could be more damaging,' Humidity may rise problematically after intense rainfalls. As one correspondent noted that for efficient monitoring it will be necessary to establish clear standards and protocols for measuring and recording, and a set of baseline values.

Pests and diseases

Humidity and temperature have synergistic effects on pests and diseases: 'Changes to relative humidity could result in new sorts of insect pests attacking collections.' Current management regimes are probably adequate. However, mapping should enable monitoring and training to be reviewed and adjusted to new risks as they arise. Maintenance was raised again as an important issue.

'Climate control will be very problematic, as there is often a great rift between the needs of the occupant and the best interest of the fabric. Also, historic systems may have been compromised, and options for the introduction of new systems extremely limited.'

Human comfort, health and safety

Human comfort, health and safety issues would have implications for climate control: 'We would resist the introduction of intrusive climate control equipment, preferring if possible to use passive or minimally intrusive methods.' Meticulous maintenance was again flagged as obligatory, to prevent dangers such as falling masonry.

Water table chemistry

If changes in water table chemistry result from a fall in water table height, or from sea-water incursion, certain areas may see a change in the pattern of damage from rising damp. Monitoring was felt to be a necessity, especially for sites already known to suffer from rising damp problems.

Solar radiation

Some concern was expressed for the impact of increased solar radiation on contents (rather than on the buildings themselves). It was however generally believed that current practices should be sufficient to cope, with relatively few refinements. 'We are already investigating neutral density window films for light control, and introducing shutters and blinds even where there is no historical precedent.' One correspondent noted that the introduction of filters does require an increased commitment to maintenance. 'Sometimes excessive damp (e.g. from driving rain) followed by solar radiation can drive moisture and salts to the inside of walls. The incidence of this type of thing could be increased in climates which are warmer, damper and/or windier.'

Lightning

Lightning risk was another area where respondents felt current practice was probably adequate: 'Efficient lightning conductors and fire precautions are already a priority.'

Plant physiology and distribution

Changes in plant physiology and distribution were of limited concern, except where plant roots may cause damage to foundations leading to subsidence of the whole

structure. However, one correspondent noted that 'the use of vegetation as a means of addressing the other conditions (such as wind or sunlight exposure) could be an interesting new consideration.'

Buried Archaeology

Soil chemistry and moisture content

Unanimously, archaeologists expressed their great concern for soil moisture and due chemistry due to the projected changes in equilibrium conditions which have preserved the sites until now.

For wetlands sites, archaeologists are expecting 'a very serious loss of certain data types which are only preserved in waterlogged/anaerobic/anoxic conditions.' 'Archaeology presently preserved close to the ground surface (i.e. especially in rural areas, or post-medieval archaeology in more urban situations) is likely to be destroyed before it is excavated and recorded.'

Drying of the soil has indirect effects on the archaeological record as well: 'Sites will lose stratigraphic integrity if they crack and heave due to changes in sediment moisture.' 'Strong changes between water levels for summers and winters will have a tremendous effect on those sites which are situated in the area of dry-wet cycles.'

Repeatedly, respondents noted a significant gap in knowledge: the exact effects of chemical changes on preservation are poorly understood. 'We do not know much about how chemicals affect artefacts in the plough soil which is a matter of great interest to those who identify and record portable antiquities.' 'Eutrophication could accelerate microbial decomposition of organics, and might also influence corrosion of metals.' 'We have little data on nitrates and artefact corrosion… further research is required.'

Flooding

Many sites will be endangered by sea level rise and storm surge: '600 to 1800 good sites are vulnerable to coastal erosion.' Although this threat is already recognised – and, indeed, already active in many places – management practices do not yet take sufficient account of the problem: 'Flood protection/ managed retreat plans tend to consider only scheduled ancient

'The as yet 'unknown' heritage will be likely to degrade and disappear, without ever having been recorded. The heritage we think is being preserved in situ may not remain so . . . '

monuments, although we are trying to change this attitude to include other archaeological sites, including those below the current low tide level…' Inevitable loss will probably require approaches to rapid investigation and recording.

Here too, the issues of chemical disturbance were of concern: 'Coastal floods will introduce intermittently large masses of 'strange' water to the site, which may disturb the metastable equilibrium between artefacts and soil.' Not all sites will be endangered as a matter of course: 'Some Fenland rivers are already under tidal influence. Many prehistoric and Roman fenland sites were built and decayed in salt-rich environments.'

Some of the effects on archaeology are likely to be indirect. Buried archaeology may be at risk not only from flooding but also from ill-considered flood risk alleviation schemes.

'Conservation management plans should address significance of the entire site – built/ archaeological/ landscape and define management policies to protect these interests. Site management should not lead to scenarios where plants are out of control and damaging other fabric.'

The predicted changes in rainfall are also likely to cause flooding, and associated erosion. Again, it was felt that many sites would inevitably be lost: 'River side/intertidal archaeology will have to be recorded – this sort of thing cannot be protected in such large tracts of land/river.' Erosion could be slowed down, it was noted, by appropriate planting.

Plant physiology and distribution

Plant physiology and distribution changes were also a cause for concern. 'Changes in vegetation cover will greatly affect the survival of buried sediments and artefacts and ecofacts. Deep root penetration is very damaging to structures and sediment boundaries.' There is also the problem of dewatering by transpiration, and loss of vegetation cover through drought could also exacerbate erosion. Here the issue of mitigation came up briefly: 'New energy crops (e.g. short-cycle coppice and Miscanthus) may be planted over sites.'

Human comfort, health and safety

Of the three heritage categories, it was archaeologists who expressed the greatest concerns over the possible health and safety issues raised by climate change. 'Archaeological excavation and survey is often very arduous. More extreme conditions would only make them more so for fieldworkers.' The actual conditions for

excavation were unlikely to be improved: 'harder, drier ground, increased sun, heat and insects will all make the job more difficult, uncomfortable and risky.' 'Piped water will be required to make excavation/recording of archaeological sites possible.'

Temperature

Fears were expressed that increased temperatures will exacerbate deterioration. However, as one respondent noted, 'seasonal changes in deposit temperatures are detectable. This must have some effect on bio-activity, but is probably not a limiting factor for decomposition.' One respondent noted a possible advantage: an increase in crop marks.

Wind

The effects of high wind on buried archaeology were generally felt to be restricted to barrows, and sites in very dry or sandy subsoil conditions with the exception that tree throw could cause damage to archaeological sites in woodland or plantations. One correspondent noted that wind was another factor increasing the risk and expense of excavation.

Pests and diseases

Increased pests and diseases could disturb wetland sites in particular, 'and we are very ignorant about long term effects.'

Other factors

Little concern was expressed for other climate changes. Increased solar radiation was felt unlikely to cause problems for buried material, although exposed material – especially painted surfaces – could be at risk. Solar radiation could certainly help desiccate uncovered soil.

Parks, Gardens and Landscapes

Wind

Respondents from those responsible for parks and gardens heritage listed their primary concern as wind despite the fact that the questionnaire pointed out the uncertainty in predictions of future wind conditions. Mature important specimens are particularly susceptible to wind damage: storms can quickly destroy landscape

designs, and the changes in climate may make replacement difficult or impossible. Since the gale of 1987, this has been an action issue for gardeners: 'Shelter belt redesign is being considered in places (though the land acquisition required to extend belts will give rise to costs).'

Temperature

The predicted changes in temperature may be of some advantage in protecting tender plants, but less favourable impacts will be seen on species needing frost to germinate or set seed (such as daffodils and apples). Greater choice of tender plants must be offset against the dilution of historic design interest and accuracy. Warmer temperatures will require changes to staff and visitor arrangements; they may also increase opportunities for revenue-raising outdoor events.

Plant physiology and distribution

The potential changes in plant physiology and distribution are already well recognised in this sector, with the emphasis being on active management: 'there are too many variables to plan ahead.'

Pests and diseases

Warmer conditions were recognised as greatly increasing the risks from pests and diseases: particularly for plant collections and structural planting. Historical integrity may prove difficult to maintain for this reason alone. Recent attempts at designing less-intrusive care regimes may have to be reconsidered: 'The National Trust is attempting to move away from use of chemicals, but this situation may force an increase.'

Rainfall

The projected changes in rainfall patterns are likely to give rise to many changes in parks and gardens. To cope with summer droughts some form of water storage is likely to prove necessary for many sites, particularly in the East of England; but this many be challenging to install invisibly. Drainage redesigned to cope with heavy autumn and winter rain may prove even more difficult to integrate with historic parks and gardens. The very planting able to cope successfully with dry summer conditions is likely to be at risk from waterlogged soils in winter. Waterlogging also destabilises trees, making them more susceptible to topple in increases in wind storms.

Soil moisture content

Future difficulties in maintaining soil moisture contents were felt to require improvements in soil and land husbandry practices.

Water table height and chemistry

Water table height and chemistry changes may also provoke 'problems with maintaining levels of ornamental lakes, and with the bore holes and water supplies from wells and springs on which gardens and water features depend.' Correspondents noted that regular soil analysis and testing will become vital, especially for historic plant collections.

Fluvial flooding

A likely outcome of heavy rain is a significant increase in fluvial flooding. This is not only directly damaging, but also of concern for erosion. Correspondents noted that runoff flooding has been exacerbated by changes in land cover such as the building of roads and hard stands for car parking replacing front gardens.

Coastal flooding

Coastal properties may also be at risk from flooding associated with sea level rise and storm surges. For these sites, the after effects of floods are exacerbated by the salinity of the flood water; all these problems are currently seen in the National Trust gardens at Westbury Court, and a number of other sites around the country such as Fountains Abbey and Alfriston. 'Wider catchment management is needed to minimise impact. The cost of flood protection/drainage channel diversions onto surrounding land is likely to be very high. We need to plan ahead financially for these situations, which we have not done so far.' As for buildings and archaeology, coastal loss was generally considered to be unavoidable: 'It is against National Trust policy to protect land from coastal erosion.'

Other factors

Rather less concern was felt about most other factors, such as relative humidity changes (except in as much as these increase pests and diseases), or solar radiation: 'We may need to adopt a different range of tree species to deliver shade in drier conditions: those from warmer climates?'. Lightning was not perceived to be a major

issue for parks and gardens: 'Other landscape features, such as heath and scrub or unmanaged sites, are much more likely to be a fire risk.'

In summary, correspondents noted that the opportunities for a more diverse choice of plants must be offset against losses of historical integrity, and likely increases in maintenance costs. 'English Heritage is unlikely to support reconstruction of a historic park and garden.'

General Issues raised by the Questionnaire Respondents

From the responses and the additional comments offered, it is clear that certain issues emerged as of prime importance.

Recognition and status of the historic environment:

- The historic environment has an ambiguous status within central, regional and local government and various other agencies.
- It is peripheral to the activities of both cultural and environmental sectors, instead of being properly integrated into both.
- A more integrated approach to the management of the historic environment is needed if the necessary measures to moderate the effects of climate change are to materialise.
- Governments do not take the longer-term view, and although climate change is crucial and critical, it is not a high priority.

Conflict between planning guidance and 'preservation in situ' of archaeological remains:

- Climate change could have serious implications for the current practice of archaeology and the planning process.
- Preservation by recording or additional monitoring/provision for maintenance of the subsurface buried soil environment will be needed as part of any adaptation strategy, to satisfy the archaeological conditions placed on any planning consent for building development. Sites preserved in situ should be monitored to assess the sustainability of the strategy. Both measures will add more costs to building development.

- Specific development proposals attract disproportionate resources to archaeological sites even when the quality of the site is not high.
- Coastal sites are under the very highest level of threat: there is no management strategy at present, and it is unrealistic to expect that development funding will be available for investigation and recording. Developers, unsurprisingly, are not willing to purchase land that is about to be eroded away by the sea. Without a developer to take responsibility for the demise of an archaeological site, there is no one to call upon presently to pay for recording prior to destruction.
- Sites are often of a type that is not seen anywhere else in the country (e.g. Mesolithic coastal sites), and so if they are not investigated before they are destroyed by climate change, they will be lost forever both in terms of physical reality and in terms of recorded archaeology.

Factors affecting the official response to the effects of longer-term change:

- Lack of understanding of longer-term change means that existing resources for management are expected to go further.
- There are insufficient incentives for land owners to manage the historic environment in a beneficial way, compared to land stewardship.
- Most pro-active conservation measures are more easily directed towards areas that are under least threat. It is, for example, easier to implement conservation schemes on dry earthwork sites of minimal quality, than to secure the beneficial management of vastly more valuable buried wet (or semi-wet) sites, which are also under much greater threat.
- Fenland archaeology poses particular problems: most survives in areas under cultivation which do not fall within areas of wider environmental protective designations.

Research and monitoring

- There is a lack of good data on the effects of natural and artificial environmental change. More fundamental data is needed regarding the effects of climate change, as well as synthesising existing data from the natural heritage.
- There has been no monitoring of representative samples of archaeological sites for a long enough period, since the 'preservation in situ' strategy is relatively recent.
- The understanding of the behaviour of the materials is poor; with climate goal posts being shifted, this will worsen.
- Resources need to be devoted to understanding how materials will respond to change in marine, coastal and terrestrial environments (and both above and below ground).

Management and funding issues:

- Changes are needed to prioritise and coordinate available funding.
- Grant-giving bodies need to make crucial adjustments to their approach to encourage an increase in regular, well-considered maintenance.
- There is a need for appropriate and feasible management/conservation plans for historic sites, and for these to address nationally standardised issues.
- Local government is effectively powerless in implementing positive change, preventative measures, or even rescue measures without extra funding. Furthermore, most of the issues appear to be the remit of central rather than local government.
- In terms of physical losses to archaeology (as distinct from buildings) in the East of England, arable agriculture has always been, and seems likely to continue to be, the major cause.
- Virtually no control over losses to agricultural destruction exist even in the case of Scheduled Ancient Monuments.
- Management agreements for Scheduled Ancient Monuments on agricultural land are needed. Climate change needs to be put into a wider perspective before priorities are drawn up.

Dilemmas facing those responsible for the historic environment:

- The biggest decision will probably be over which sites to 'let go'. There will never be the money to save everything. Decisions on the value and significance of a site may need to be made upfront before money is spent on short-term or no-real-hope projects.
- We should be planning for climate change and not trying to hold the cultural heritage in stasis, and this should be communicated to the public.
- If climate change means that deposits begin to deteriorate if not excavated (and thus preserved by recording), the current strategy of preserving in situ may lead to the destruction rather than the preservation of the archaeological heritage. If this is the case, then preservation by record should be favoured wherever possible.
- Increases in rainfall intensity are already causing gutters to overflow and drainage pipes to back up. Invisible or non-invasive fixes may not be possible. What aspects of heritage are we prepared to sacrifice in order to save the rest?

4.2 Site visits

From the outset it was clear that climate change will present unique local management and maintenance challenges. It was therefore important to obtain the views of staff actively engaged in the protection of historic houses and contents, archaeological sites and ruins, and parks and gardens. To get a clear sense of how climate change might impact on local stewardship decisions, a number of short site visits took place, with the aim of meeting those responsible to discuss problems in situ.

Sites in the East of England and the North West were chosen in consultation with English Heritage experts to cover as wide a range of issues as possible likely to arise from the impact of climate change on the historic environment. While most of these sites were the responsibility of English Heritage, sites cared for by other organisations were also visited. These were Sutton Hoo (National Trust), Flag Fen Bronze Age Site (Fenland Archaeological Trust), and Birkenhead Park on the Wirral (Metropolitan Borough of Wirral). A list of sites and site characteristics may be found in Annex 2.

Issues raised during site visits

The important issues arising from the site visits are summarised below.

Climate change effects are already being felt on all types of site

Almost all managers had already noted progressive changes in the climate patterns of sites, and associated increases in deterioration. Some of these were:

- increased erosion, especially associated with increased storminess (Sutton Hoo)
- problems with local flooding (Audley End)
- problems with sustaining turf (Birkenhead Park, Furness Abbey)
- changing patterns of pests and diseases (such as the year-round presence of Canada geese at Birkenhead Park)
- problems with rainwater disposal (Audley End, Beeston Castle).

Coastal loss

A visit to Dunwich in the East of England, where most of a large medieval town has been lost to the sea, illustrated that while loss has always been a critical issue for coastal sites, the situation is being made worse by climate change. It may be possible in certain circumstances to save some sites. However, the choice must include an assessment of the value and significance of not only the sites being targeted for protection, but also of neighbouring sites since localised defences disrupt natural coastal processes. Endangered sites of less than first importance – such as Languard Fort, near Folkestone – may have to be recorded and abandoned, despite the care and cost already spent on their conservation.

Competition with surrounding land use

This issue, already of crucial importance for many sites, is likely to be exacerbated by climate change. For example, Sutton Hoo is neighboured by turf farms that increase the risk of erosion. Summer water shortages, too, are likely to see sites competing with farming for limited resources (this would impact not only on parks and gardens, but critically on wetlands archaeology such as Flag Fen).

Presentation of ruins

The predictions for possible increased storminess and high winds may put exposed

ruins, such as those of Furness Abbey in Cumbria, at risk of wind throw, or increased erosion. Novel methods of protection should be considered: for example, using planting as shelter belts. This of course has implications for the buried archaeology of the site, raising again the issue: what aspects of heritage are we prepared to sacrifice in order to save the rest?

A side issue is the popular use of turf as a 'green carpet' around monuments. This cover acts also as a dust control measure, but if it is to be retained as a feature it will be necessary to find more robust grass species. Already lawns are becoming difficult and expensive to maintain, and many may prove to be unsustainable in the long term.

Maintenance

Meticulous maintenance and monitoring of condition, always central to successful preservation will become more critical as climate changes take effect. For example, drainage and rainwater disposal systems may prove unable to cope with extreme rainfalls: problems will have to be recognised and dealt with immediately, if they are not to become chronic. Historic buildings such as Audley End combine large expanses of roof with complex, often concealed rainwater goods. To date the approach has been to only make concealable changes to down pipes and guttering, but site managers and advisers felt that this approach might not be enough in the future.

Funding issues

There is insufficient funding for maintenance, despite its critical importance for preservation. Grants are given for capital works, but not for day-to-day management, and budgeting well in advance – crucial for forward planning – is almost impossible. For example, Birkenhead Park has been granted £11.4 million by the Heritage Lottery Fund and others to restore the park and install a visitor centre, yet it is difficult to find a source of funding that secures maintenance beyond the next ten years. It is clearly unsustainable to invest large sums in restoration schemes without including provision for long-term upkeep, especially in the light of a changing climate.

It is arguable, indeed, that the current funding structures may reward poor maintenance.

Lack of local input into planning

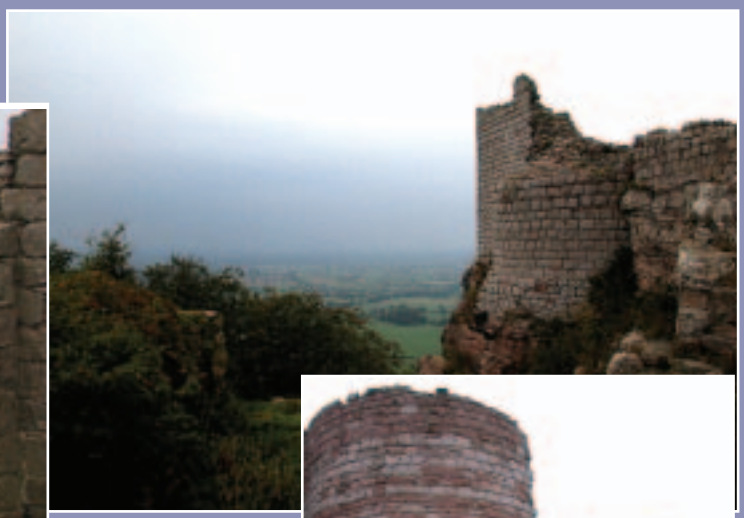
English Heritage has an enormous but largely overlooked resource in its local

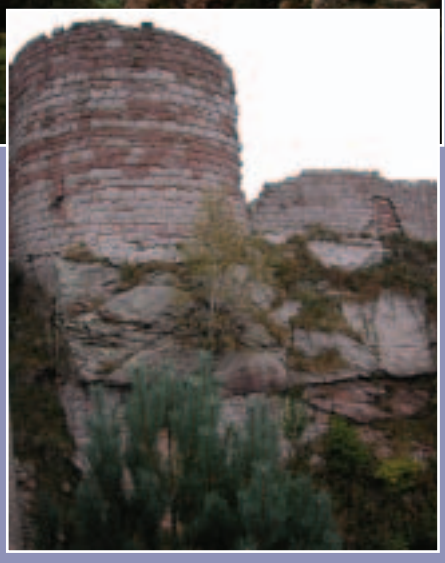
managers and maintenance staff. Decision-making needs to utilise staff with local knowledge of planning issues. Although consistent policies are crucial, they should not be implemented in a way that prevents routine maintenance or emergency decisions being made by local management.

Internal links

The English Heritage intranet was considered to be an under utilised resource. Its potential role as a central clearing-house for information and as a link between managers of remote sites and the centre and to each other was emphasised. Another example of how internal links might be improved is given in the case study of Beeston Castle.

Case Study:
Beeston Castle





Beeston Castle is an isolated site, and the most regular work there is undertaken by the gardeners, who trim turf and remove aggressive wall plants. The gaps in the mortar made by the removal of these plants remain however until maintenance staff can be called in to fill them with approved mortar. Here there would be not only a clear cost saving, but also a significant improvement in care, if the gardeners could be given pre-prepared mortar and taught to make the appropriate small repairs themselves.

Need to evaluate and prioritise preservation

Regional management was well-informed and greatly concerned about this issue, recognising that eventually sites would have to be prioritised for the level of protection they receive, even though individual managers were partial to the sites for which they were personally responsible. English Heritage is beginning to implement this approach in its survey of its historic collections in which value, significance, condition and risk are being integrated into the survey process that takes place every 10 years, and upon whose results resources for conservation will be allocated.

Landscape preservation

Characteristic English landscapes, such as those around Hadrian's Wall or the once coppiced woodland around Stott Park Bobbin Mill, are under grave threat from climate change. However, a landscape and its many and disparate component parts make it extremely difficult to preserve as a whole. Landscapes are likely to be among the most high-profile losses in the historic environment.

4.3 Regional workshops

Regional workshops held in Cambridge and Manchester were intended to provide a forum for concerned local area managers, advisers and field officers to discuss the conservation and management issues raised by climate change across the board. The structure of the meetings was designed to encourage specialists in different fields to argue through conflicts of interest, and establish common ground. Details of the meetings are given in Annex 3; the following is a synopsis of the most important findings.

General summary of regional workshops

Two break-out sessions were held at the workshops, one which focused on preservation issues raised by the climate change predictions, and a second which looked at overall management issues. In each session, participants were asked, both individually and as a group, to determine levels of importance (on a scale of 1 to 5) of a number of key concerns. The same issues were addressed separately for each of the

historic environment categories: buildings and contents, buried archaeology, and parks, gardens and landscapes.

Although the workshops were identical in structure, in the East of England discussion revolved around the predictions themselves and the preservation actions these would imply, while in the North West broader issues of management proved to be the focus. In both cases the cross-disciplinary nature of the discussion proved extremely useful, and was enthusiastically received.

General comments from the two break-out groups are presented below, under the headings 'Comments on Climate' and 'Comments on Management'. Comments are divided between the three heritage categories, but it should be emphasised that the concerns expressed are those of the group as a whole, derived as a consensus during each of the break-out sessions.

Comments on climate

Buildings and Contents

Of great concern

Coastal loss, fluvial flooding, storminess and extreme winds and rain were selected by both the East of England and the North West as the greatest threats to historic buildings and their contents from climate change. Flooding was rated as the most important general issue. Participants in both regions judged extreme weather to be of great importance to the fabric of buildings, noting that in many cases downpours were already exceeding the capacity of historic rainwater goods.

Of significant concern

Temperature was judged to be a factor of some importance, participants deciding that the most important issue was the speed of change, rather than its eventual level. Problems were likely to be felt by contents and collections. The North West was greatly concerned about pests and diseases, about which the East of England participants were much less worried. This difference may reflect the inclusion of a collections specialist in the Manchester group: it is for collections that potential pest problems appear most acute.

Of some concern

Some concern was expressed about changes in soil moisture content leading to subsidence and heave affecting buildings and ruins.

Other comments

It was noted that smaller collections and sites would suffer most from climate change impacts, because fewer resources could be devoted to them.

Buried Archaeology

Of great concern

In both regions, extreme concern was expressed about coastal loss, flooding and changes in the height of the water table. This last change was seen as more than a wetlands issue: it was pointed out that monitoring of the water table in York has shown seasonal fluctuations in the upper 2 metres, and any changes could have catastrophic results.

Of some concern

Some concern was expressed about the effects of heavy downpours of rain.

Of little concern

East of England participants were slightly more concerned than North West participants about pests and diseases, and health and safety.

Of no concern

Both regions felt that buried archeology was not likely to affected by the projected changes in temperature and humidity.

Parks, Gardens and Landscapes

Of greatest concern

Both meetings expressed strong concern about all climate changes; it was felt that historic parks and gardens would inevitably suffer badly. The interest in growing more exotic plants was discussed, and the concern raised that, far from increasing garden diversity, this might give rise to a type of 'monoculture' in future schemes.

It was pointed out that urban townscapes present particular issues. The question was raised: do we accept changes in landscape more readily? Adaptation will have

the greatest impact on townscapes, and these could be both positive and negative. In terms of necessary research, it was felt that wind tunnel effects may have to be investigated.

Comments about the management concerns

Buildings and Contents

Of great concern

Monitoring and maintenance were given the highest priority by both workshops. The problem of funding capital works rather than maintenance was discussed. It was noted that informed monitoring and maintenance were crucially dependent on directed research.

Of significant concern

Differences arose between the two meetings on the importance of the current decision-making structures. In the North West, the example of Malton's flood control was raised. This required intervention up on moors, and by the Environment Agency, not the local council. This raises issues of where decision- making should take place, and how the process might be made more inclusive.

Heritage input into broader issues, evaluation of priorities, education and traditional skills were all felt to be extremely important by the North West workshop, but were considered of less concern by the East of England participants.

Buried Archaeology

Of great concern

The absolute priority was given to directed research into deterioration mechanisms. Great importance was also placed on monitoring and maintenance, and heritage input into broader issues.

Of significant concern

The evaluation of priorities was felt to be very important for unexcavated archaeology.

Of some concern

Education and training were felt to be useful, but not of greatest importance.

Parks, Gardens and Landscapes

Of great concern

Monitoring and maintenance, evaluating priorities, and encouraging education and traditional skills were all felt to be greatly important for preserving parks and gardens and landscapes in the face of a changing climate.

Of significant concern

Research, evaluation of decision-making structures, and heritage input into broader planning issues were all considered important.

4.4 Key climate factors determined by the scoping study

A clear consensus about the climate change factors of greatest concern for the historic environment emerged from the questionnaire responses, the site visits, and the regional meetings: temperature, reduced spring/summer/autumn rainfall, extreme rainfall in winter and high winds, fluvial and runoff flooding and coastal flooding and loss.

Temperature

Clear outcomes for heritage, with likely increases in deterioration mechanisms. Much might depend on the rate of change.

RESPONSE: Monitor, research and be prepared to react if necessary.

Reduced spring/summer/autumn rainfall

This is a major problem looming in the East of England, though the North West may not be immune. Problems will arise from competition with agriculture for limited resources.

RESPONSES: Look at ways of storing winter rainfall.
Refine soil management, use of over planting etc.

Extreme rainfall in winter and high winds

Although extreme winds and storminess have the weakest predictability, they are of enormous concern for future planning. Local managers generally felt that more extremes were already being seen.

RESPONSES: Look at ways of improving site drainage and rainwater disposal. This may have to be more intrusive than in the past.
Look at new ways of stabilising/protecting ruins.
Push for the establishment of an emergency response service through central government.

Fluvial and runoff flooding

This will have a widespread effect, with Environment Agency responses likely to impact on historic sites.

RESPONSES: Need better local risk assessment.
Could some of the answer be found in site-specific defences, such as those tested by HR Wallingford?

Coastal loss and flooding

This would not of course affect every site, but those it does the result is likely to be devastating – and there are many coastal sites. Adaptation measures to protect one area of coast are likely to cause direct damage elsewhere, and further endanger yet other sites.

RESPONSES: English Heritage needs to play a significant part in the broader planning processes of the Environment Agency with priority given to recording rather than attempting to preserve many sites – but who will pay for this?

5 Demonstration maps of climate change vulnerability

Maps provide the best way of presenting complex risk data to the widest possible audience. Overlay maps of vulnerable heritage and risk factors are a simple and effective means of grasping the overall scale of the problems presented by climate change, as well as being a straightforward way of assessing risks to individual properties; a GIS [Geographical Information System] database could be used to incorporate data on climate change together with information about the historic environment, such as that held on the Countryside Agency's Character Map.

English Heritage considered adopting a standard GIS system in the 1990s, but opted instead to design a unique system with the cooperation of IBM under the Private Finance Initiative (PFI) scheme. The 'Heritage Spatial Information Service' (HSIS) is intended to store complex records of England's historic environment, from individual artifacts to sites, on a base of digital maps from the Ordnance Survey. It is

Table 3 Listing of historic environment assets as recorded in the English Heritage State of the Historic Environment Report 2002/Heritage Counts 2004 Report

	Number of records				
Record	**SE**	**NW**	**Total England**	**Date**	**Notes**
Sites and Monuments Record	129,787	78,604	1.43 million	2004	Algao estimates number of entries increases by 5% per annum
Scheduled Monuments	2, 665	1,328	19,837	2004	
Listed Buildings	75,685	25,315	371,971	2004	
Council 'Local Lists'	20,000	7,000	100,000		Estimated 218 per council; 44% of councils have Local Lists
Conservation Areas	1,986	808	9,140	2004	
Register of Parks and Gardens	359	129	1,584	2004	Estimated total
Battlefields Register	6	3	43	2002	
Protection of Wrecks Act	15	0	40		Estimated total
Military Remains Act					
National Parks (thousand hectares)	0	261	994	2004	
Areas of Outstanding Natural Beauty (thousand hectares)	641	157	2,040	2004	
Heritage Coast (km)	74	6	1,057	2004	

intended to integrate the current disparate records, as the examples in Table 3 indicate. This is an opportune moment to include climate change data and to fill this knowledge gap for English Heritage planners. Alternatively a standard GIS programme that integrates the sizable body of available information could be used.

GIS would allow climate data, such as that from UKCIP, to be processed statistically to map, for example, the tails of the model output distributions (and thus determine the extreme predictions of the climate models). Another advantage lies in integration with local council offices, which already carry a great deal of information in GIS format. English Heritage is the ideal clearing house for centralising this information on a widely-available database.

The feasibility of rapidly constructing such a database is demonstrated by the flood mapping carried out in a recent project by the Norwich Union, using Intermap radar data with a resolution of 1.25m and a vertical accuracy of 1m. [www.intermaptechnologies.com/nextmap/]. The same data could be used to map buildings, ruins, parks and gardens, and even landscapes. Mapping buried archaeology might pose a problem, but could be handled if favourable soil conditions for preservation could be mapped.

Soil maps indicating sensitivity of this vital resource to climate change deterioration would also be useful for determining impacts on key aspects of the historic environment.

In terms of the climate change data, certain gaps still exist, although a number are currently being addressed. **The Built EnvironmenT: Weather scenarios for investigation of Impacts and eXTremes (BETWIXT)** project (part of the BKCC portfolio mentioned in section 3.2 under Impact/Adaptation Studies Sectoral Reports on page 16) provides high resolution climate data of particular relevance to the built environment.

5.1 Demonstration maps

To illustrate the usefulness of overlay maps, and to underline the importance of the climate change impacts identified by this study, a number of demonstration maps have been constructed. These are indicative only as in all cases the information has been compiled from other sources, and therefore it is not advisable for the maps to be used for planning purposes.

The climate change factors mapped are those arising from the questionnaire responses, site visits, and regional meetings: temperature, reduced spring/summer/autumn rainfall, extreme rainfall and high winds, fluvial and runoff flooding, and coastal flooding and loss.

The following information sources were used in constructing the maps.

Heritage sites

Urban area maps are taken from Defra's England Rural Development Programme [www.defra.go.uk/erdp]. These allow known properties to be pinpointed. In addition, the sites visited during the study are clearly indicated.

Soil susceptibility

Agricultural land grading, as presented by Defra's England Rural Development Programme [www.defra.go.uk/erdp]. Grades 1 and 2 soil have been combined to give the category 'well-drained, fertile soils'. Grade 3 becomes 'some drainage problems', Grade 4 'poor drainage', and Grade 5 'heavy soils'. Please note that this glosses over the topographical aspects included in soil grading.

Climate change factors

Taken from UKCIP02, from the high emissions scenario for the 2080s.

- **Temperature**

The extreme temperatures are taken from the '90th percentile daily average threshold temperature increase' for summer.

- **Reduced spring/summer/autumn rainfall**

The drop in soil moisture is given by the 'percentage soil moisture content change' for autumn, the season projected to show the greatest changes.

The drop in seasonal rainfall is given by the 'change in average summer precipitation (%)' projected to become the driest season.

- **Extreme rainfall in winter and high winds**

Extreme rainfall is indicated by the 'percentage increase in 2-year return precipitation events' for winter, the season projected to have the strongest changes in rainfall pattern.

Extreme wind is given by the 'percentage increase in 2-year return wind events' in winter, again the season considered most likely to show increases in gales.

- **Coastal flooding and loss**

Coastal flooding and loss incorporates the maps for the projected '50-year storm surge'.

Flood risk

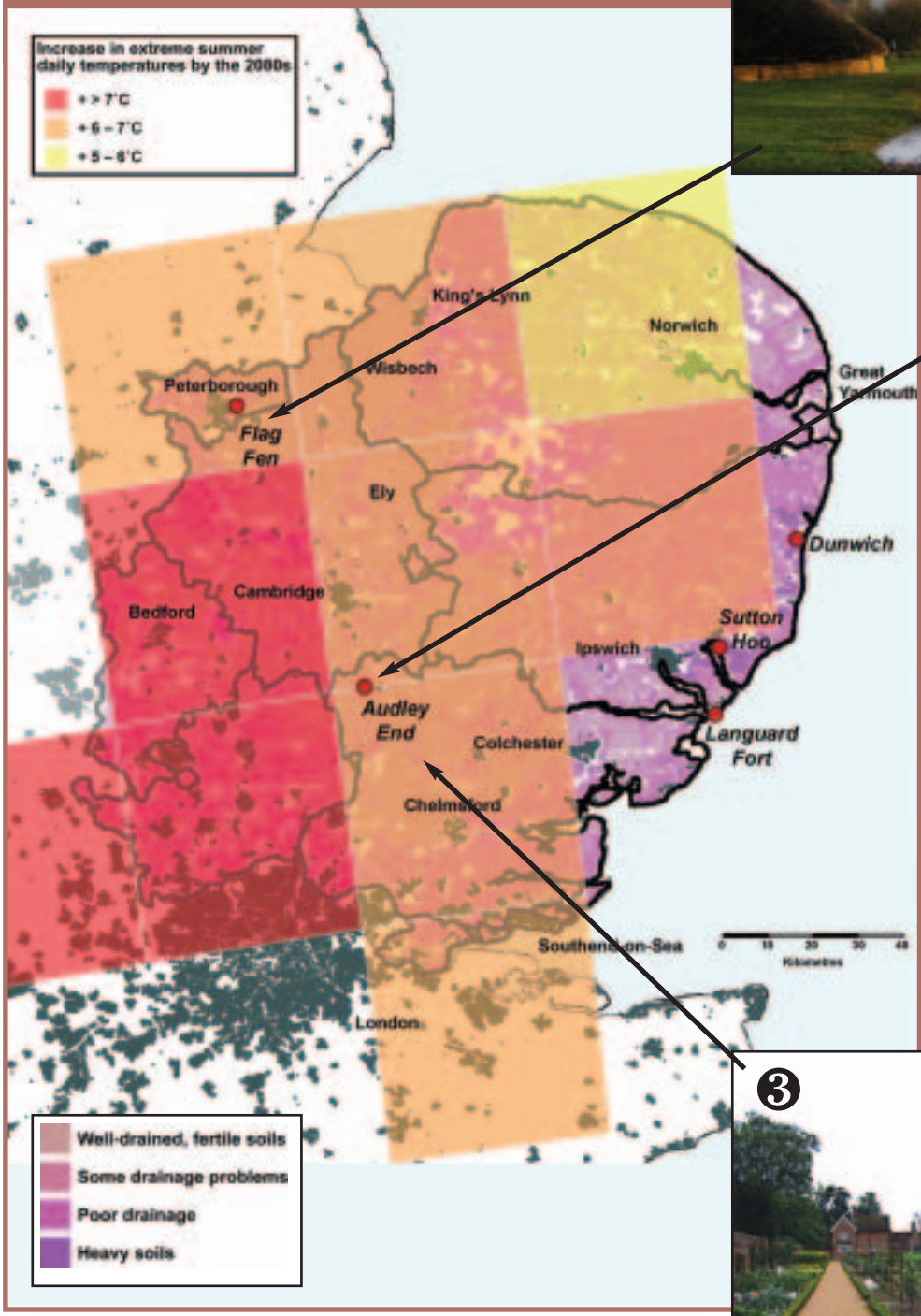
Flood risks are taken from the Environment Agency's 2000 Flood Risk Map [www.environment agency.gov.uk/subjects/flood/]. Note that these maps do not incorporate any projected changes to flood defences. Local councils will have access to newer flood risk maps that take account of flood defences. There could be order-of-magnitude reductions in flood return periods by the middle to the end of the 21st century because of climate change.

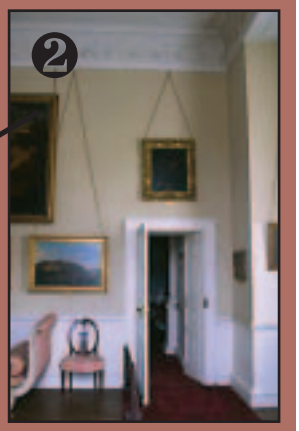
Temperature East of England

Maximum temperatures will rise markedly

The predicted rises in temperature are of concern largely because of our poor understanding of the exact processes of deterioration. How quickly can materials adapt to new average temperatures? Will higher temperatures accelerate decay? Of particular concern are the temperature extremes, which may make temperatures so far rarely experienced by the objects in our care common by the 2080s.

1. Temperature rises may exacerbate biodeterioration, with consequent problems for excavated and unexcavated archaeology.





2. Fragile contents may suffer if changes occur too rapidly for equilibrium. There will be an increased demand for comfort cooling.

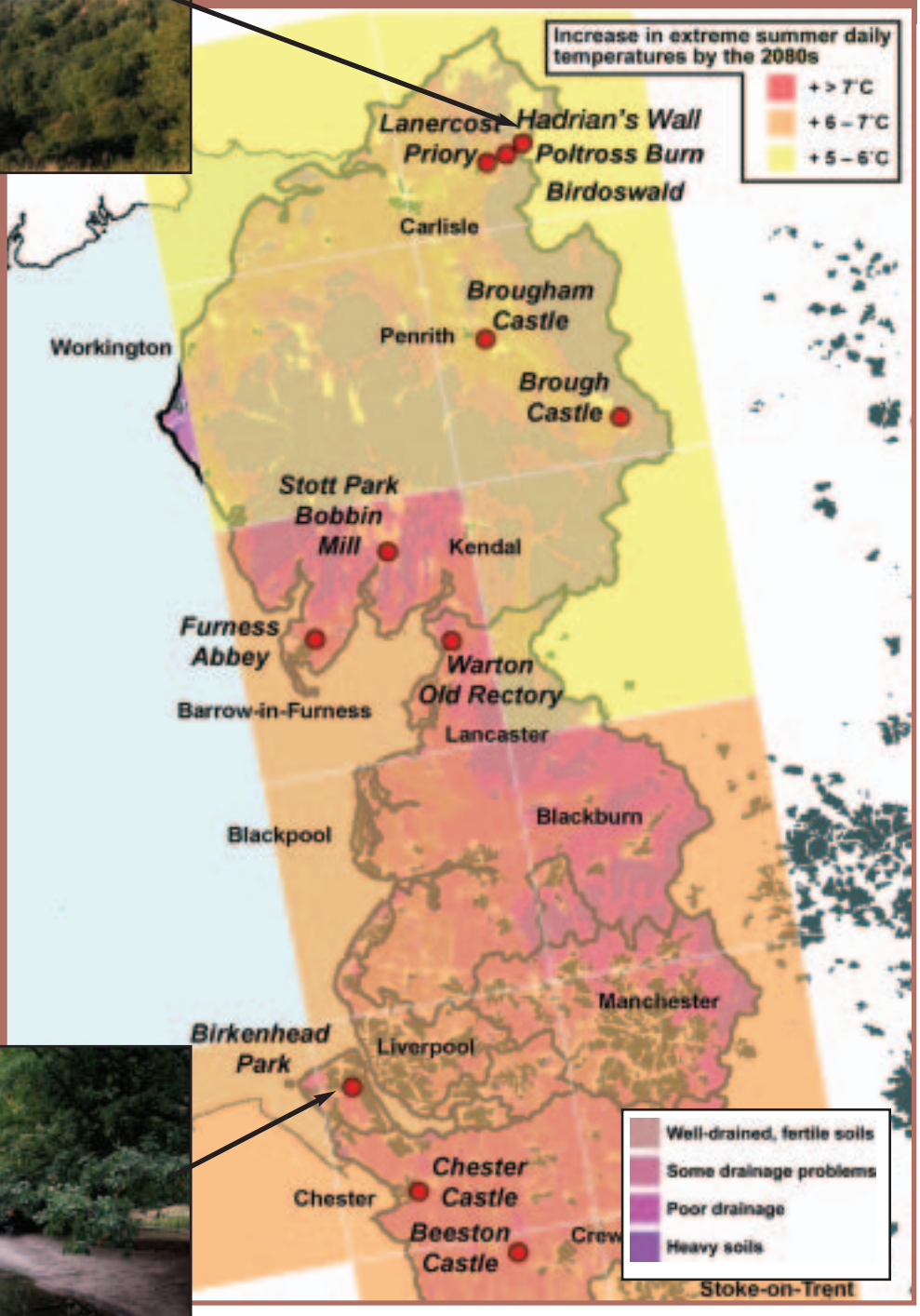
3. Plants which need frost to germinate or set seed may be difficult to grow successfully, even if – like the apples in the kitchen garden at Audley End House – they are currently a common species in the UK.

North West Temperature

Maximum temperatures will rise markedly

Cities such as Manchester and Liverpool will face very high summer temperatures, which will be exacerbated by the urban heat island effect.

1. The familiar English landscapes will change as the balance of species changes.



2. Pests and disease patterns are also likely to change: this damage on the lake shore at Birkenhead Park is due to Canada geese which have begun over wintering in the UK.

Reduced rainfall
Spring/Summer/Autumn

East of England

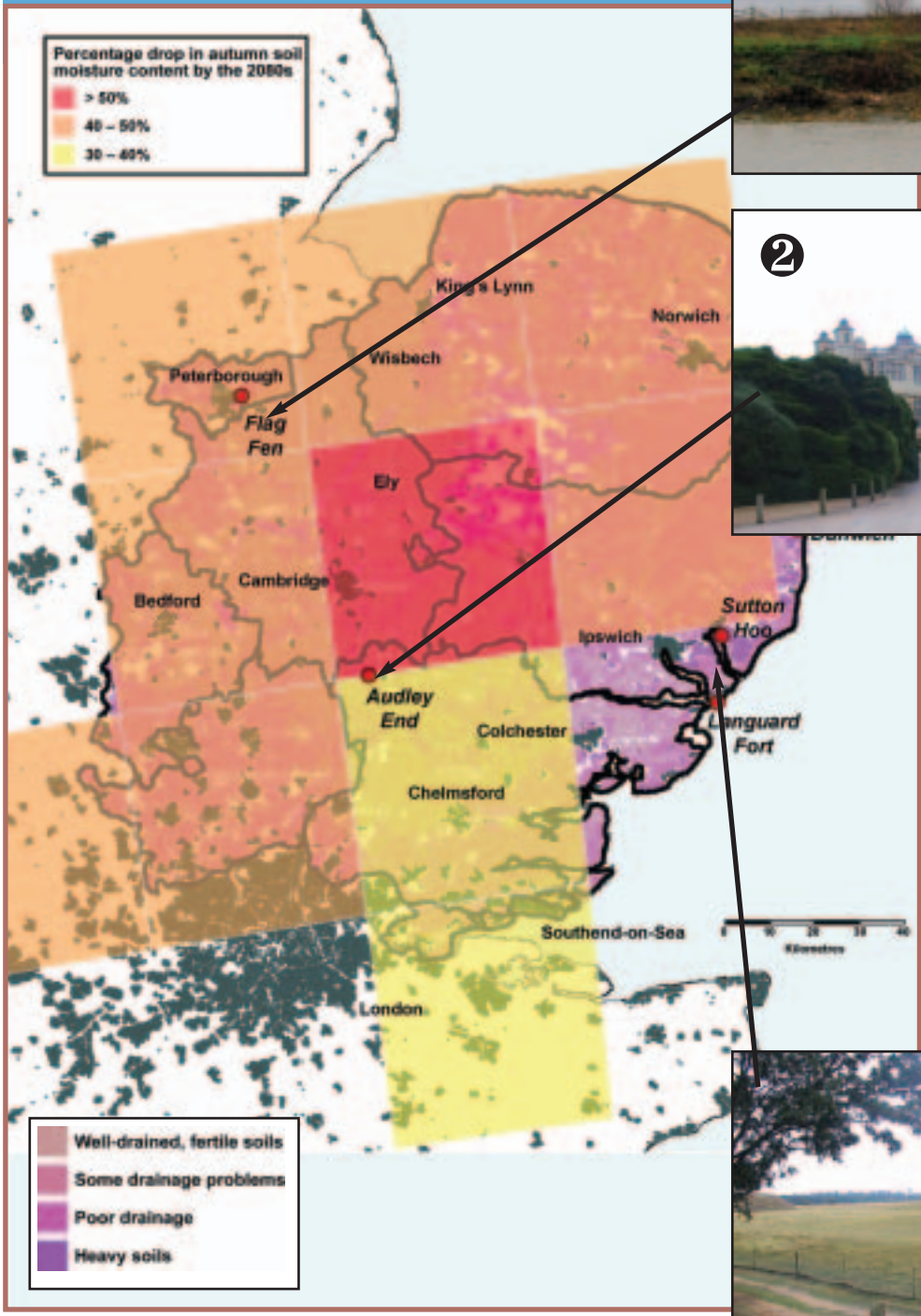
Soil moisture levels will drop markedly

UKCIP projects, for the 2080s, a drop in the annual average soil moisture content of up to 40%. Seasonal decreases are likely to be even greater. It is immediately clear that the wetlands areas of the East of England are greatly threatened, with implications for all areas of heritage.

1. Archaeological deposits will be endangered by decreasing soil moisture, especially in wetands.

2. Buildings will be at increased risk from subsidence.

3 Erosion problems may increase, as at Sutton Hoo.

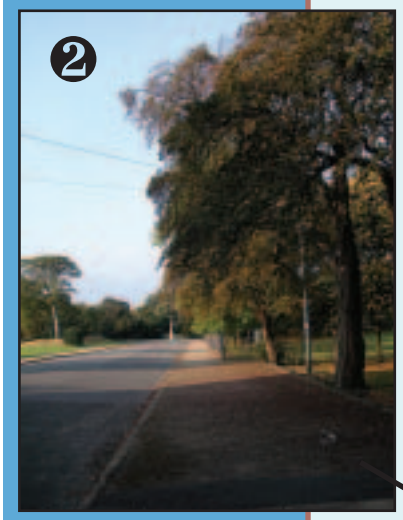


North West

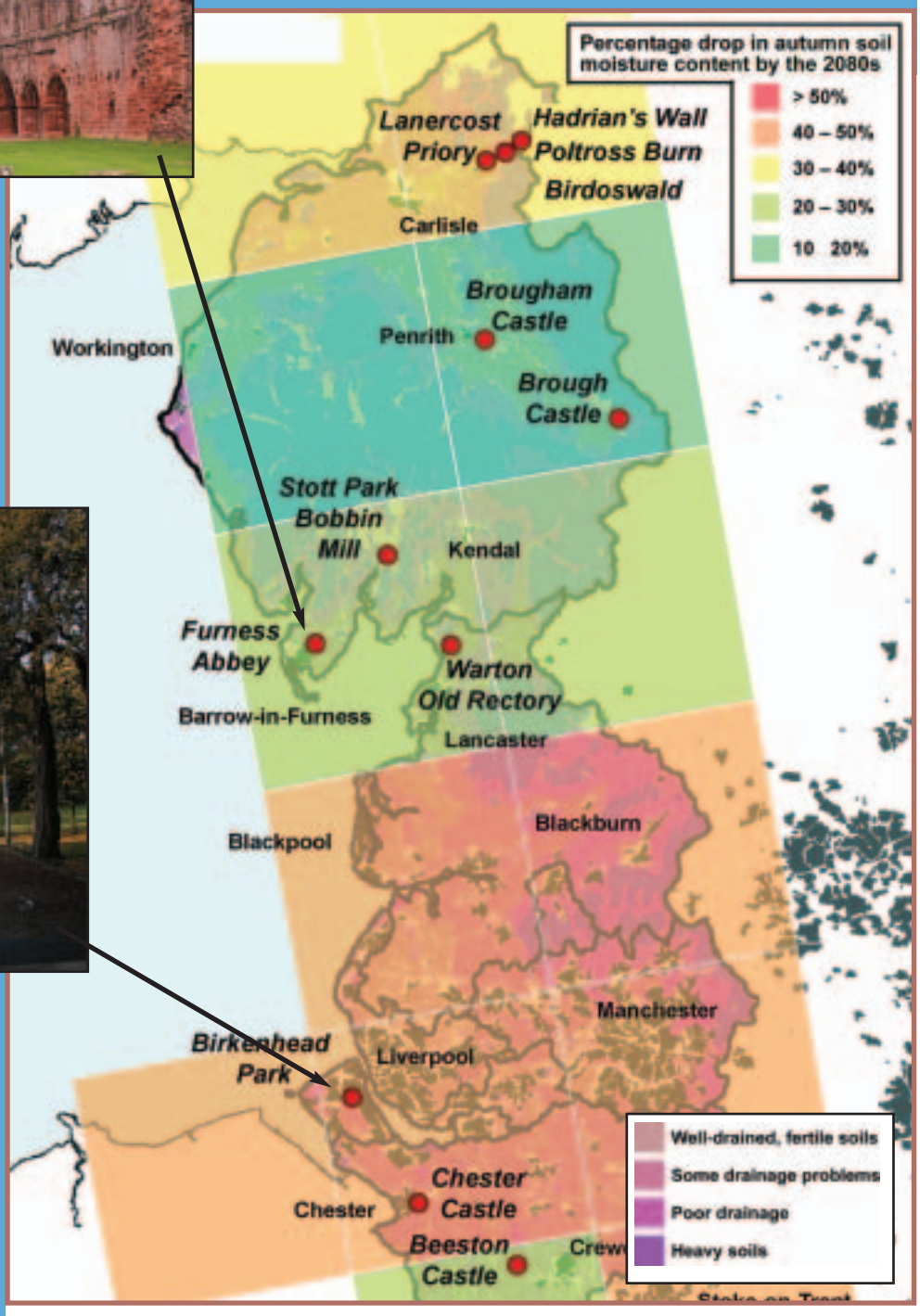
Reduced rainfall
Spring/Summer/Autumn

Soil moisture levels will drop markedly

1. Ruins will be at particular risk of major damage from subsidence.



2. Parks and gardens will have to adopt careful soil and water husbandry to remain sustainable.



Reduced rainfall
Summer

East of England

Summer drought, especially in the East of England

Average annual rainfall is projected to stay much the same for much of the UK, although a 50% fall by the 2080s is being predicted for the East of England. Seasonal patterns are likely to change dramatically, however, with summer (as shown here) expected to become much drier.

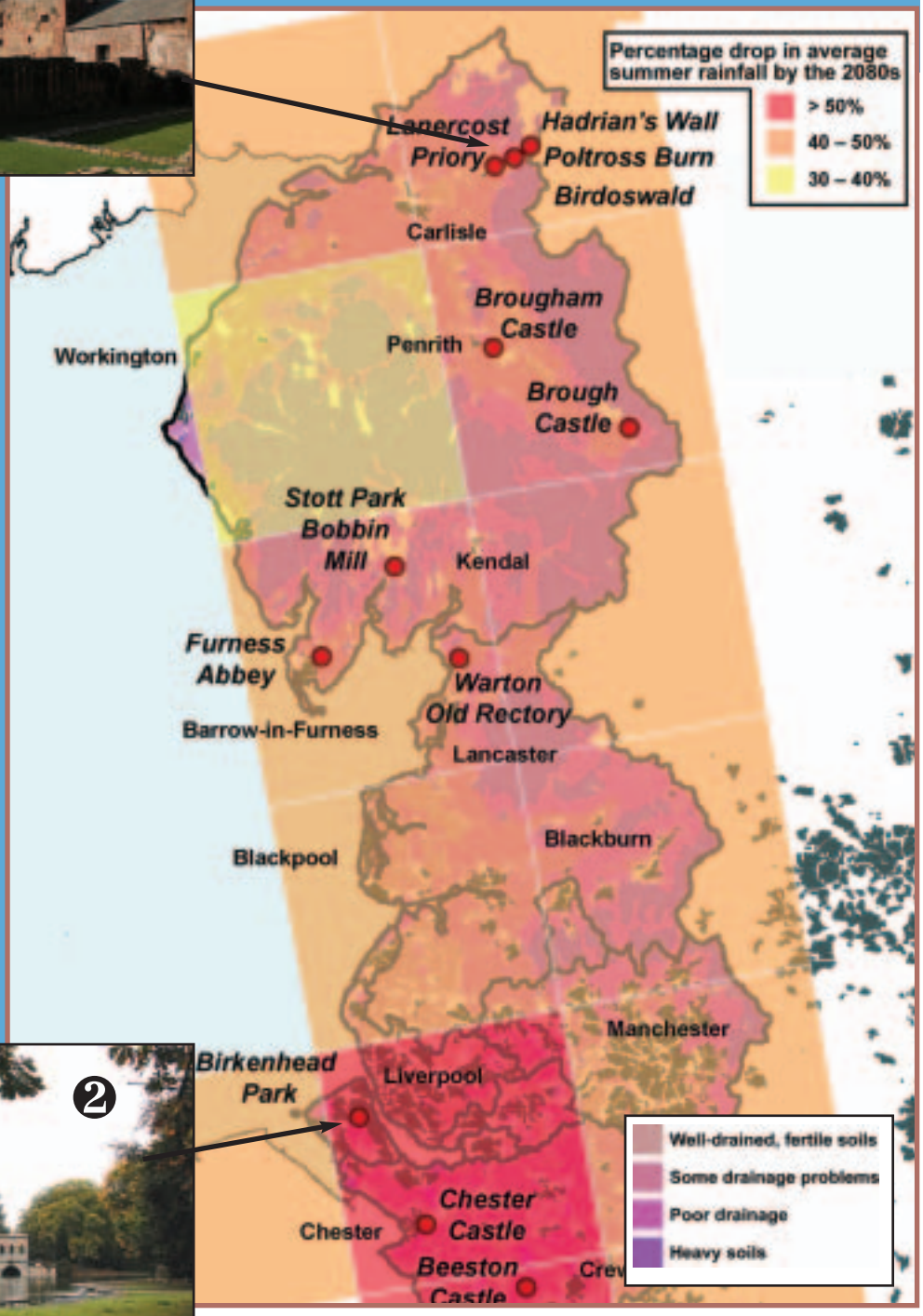
1. Competition with agriculture will exacerbate water shortages for the historic environment.

22 Historic water features may become difficult to sustain.

Summer drought in the North West

Summer drought has implications for parks and gardens and landscapes, especially if competition with agriculture for limited water supplies is factored in.

1. Green carpets of lawn, so much a part of current site presentation, may be unsustainable.



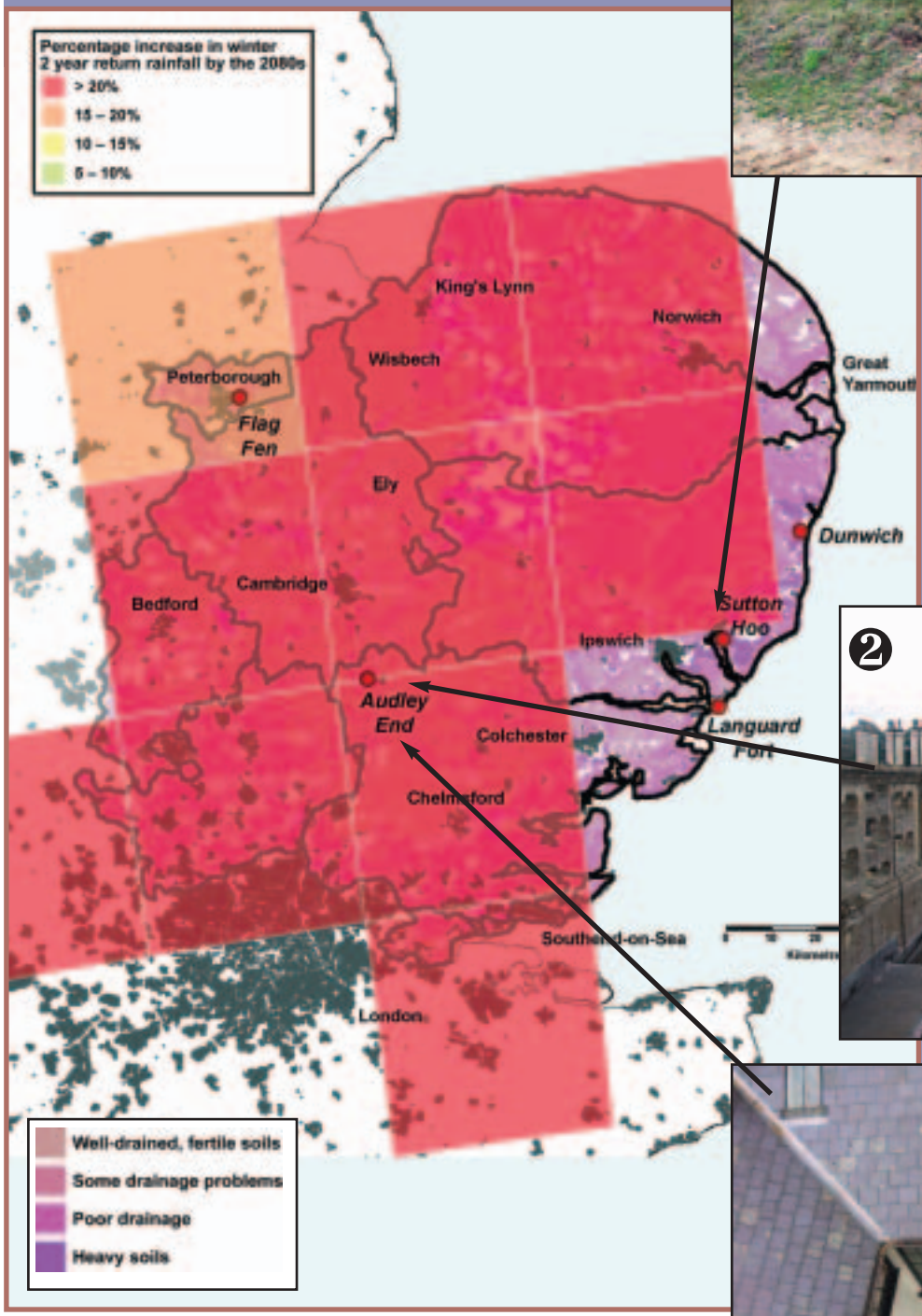
2. Historic water features could in many cases be adapted to incorporate seasonal water storage.

Extreme weather 1 East of England

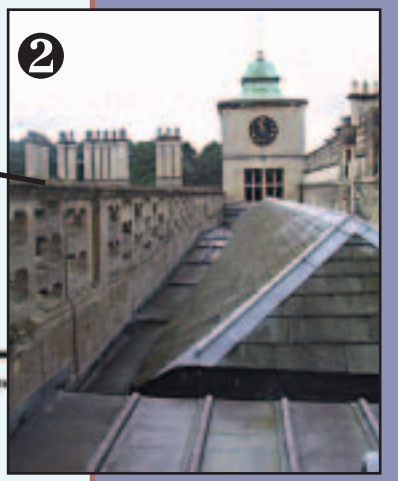
Torrential winter rainfall will be more common

Projections for extreme weather conditions have particular importance for heritage planning, which must be designed to cater for 'worst-case' scenarios. The UKCIP02 scenarios express high confidence in the predictions for increased extreme winter rainfall: rain is more likely to come in downpours than in the prolonged showers previously so characteristic of the UK climate.

1. Erosion can be a major problem for archaeology, as here at Sutton Hoo.



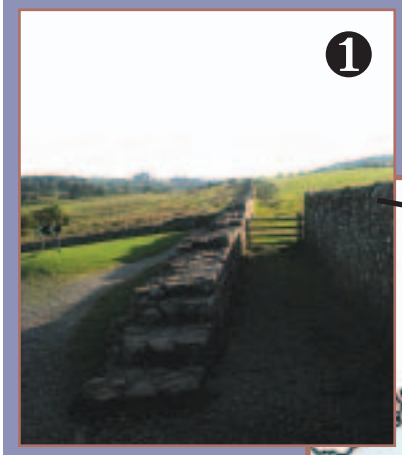
2/3. Historic houses such as Audley End House have complex roofs, guttering and drainage systems which make maintenance complex and may be unable to cope with torrential downpours.



North West Extreme weather 1

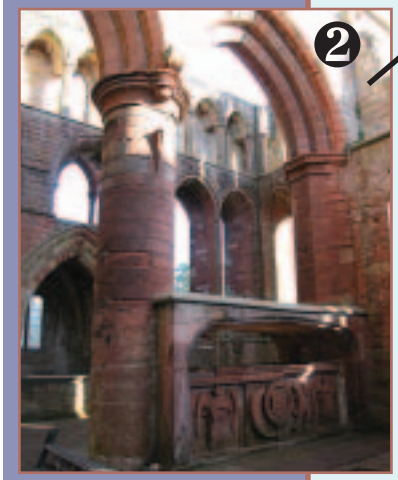
Torrential winter rainfall will be more common

The flooding implications of heavy rain are addressed in separate maps; downpours also cause erosion, and may push old drainage and rainwater goods beyond their limits.

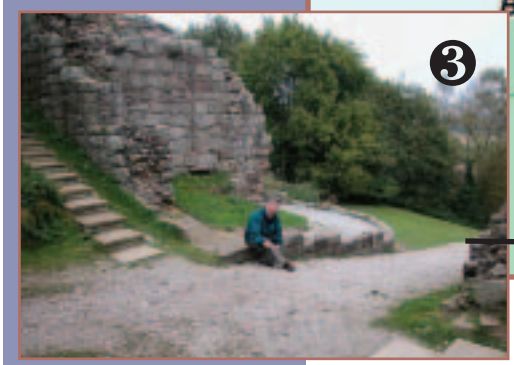


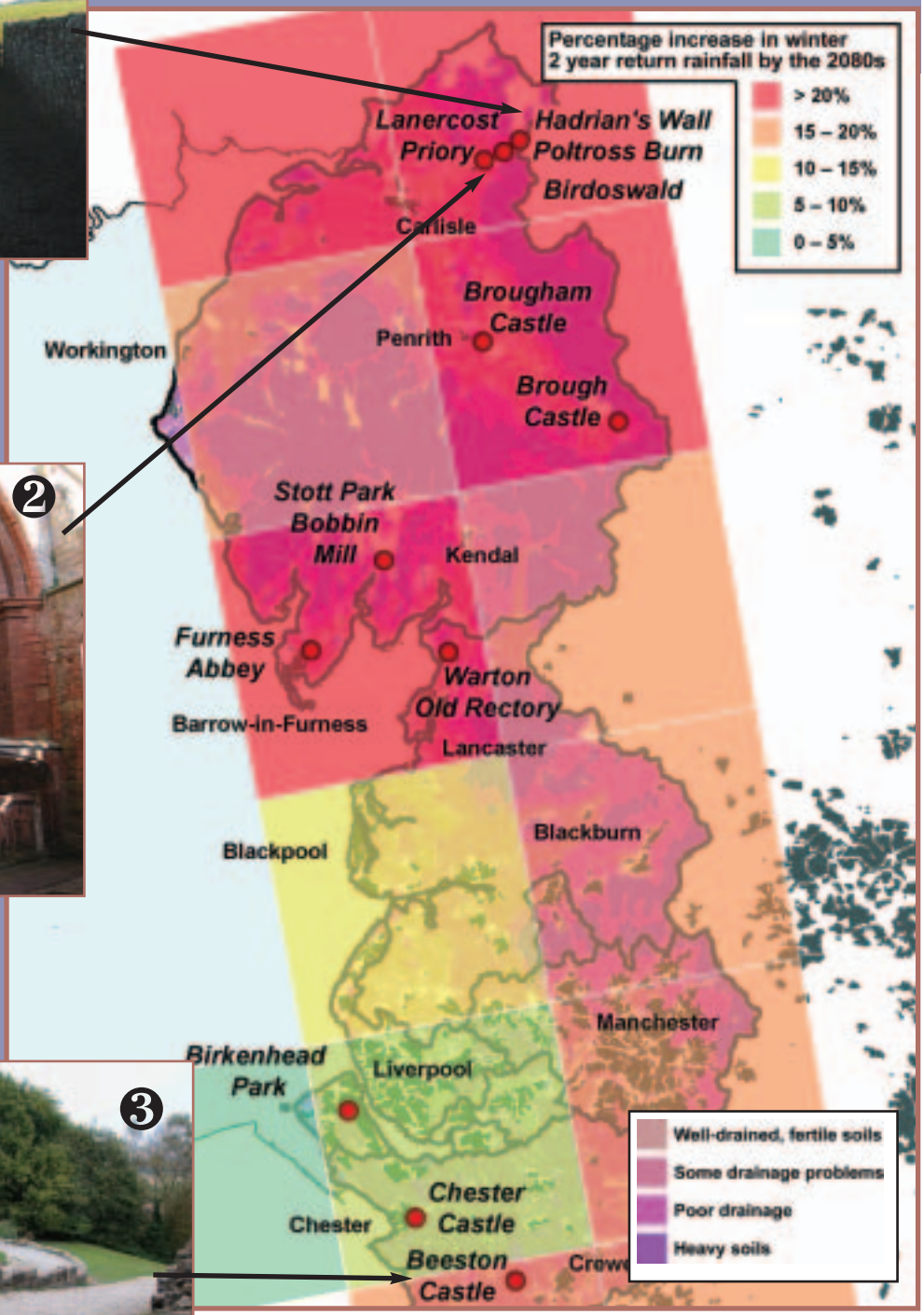
1. The sheer scale of sites such as Hadrian's wall can make maintenance difficult.

2. Roofless sites may need added protection as rainfall patterns change.



3. Site drainage will need to be reassessed.





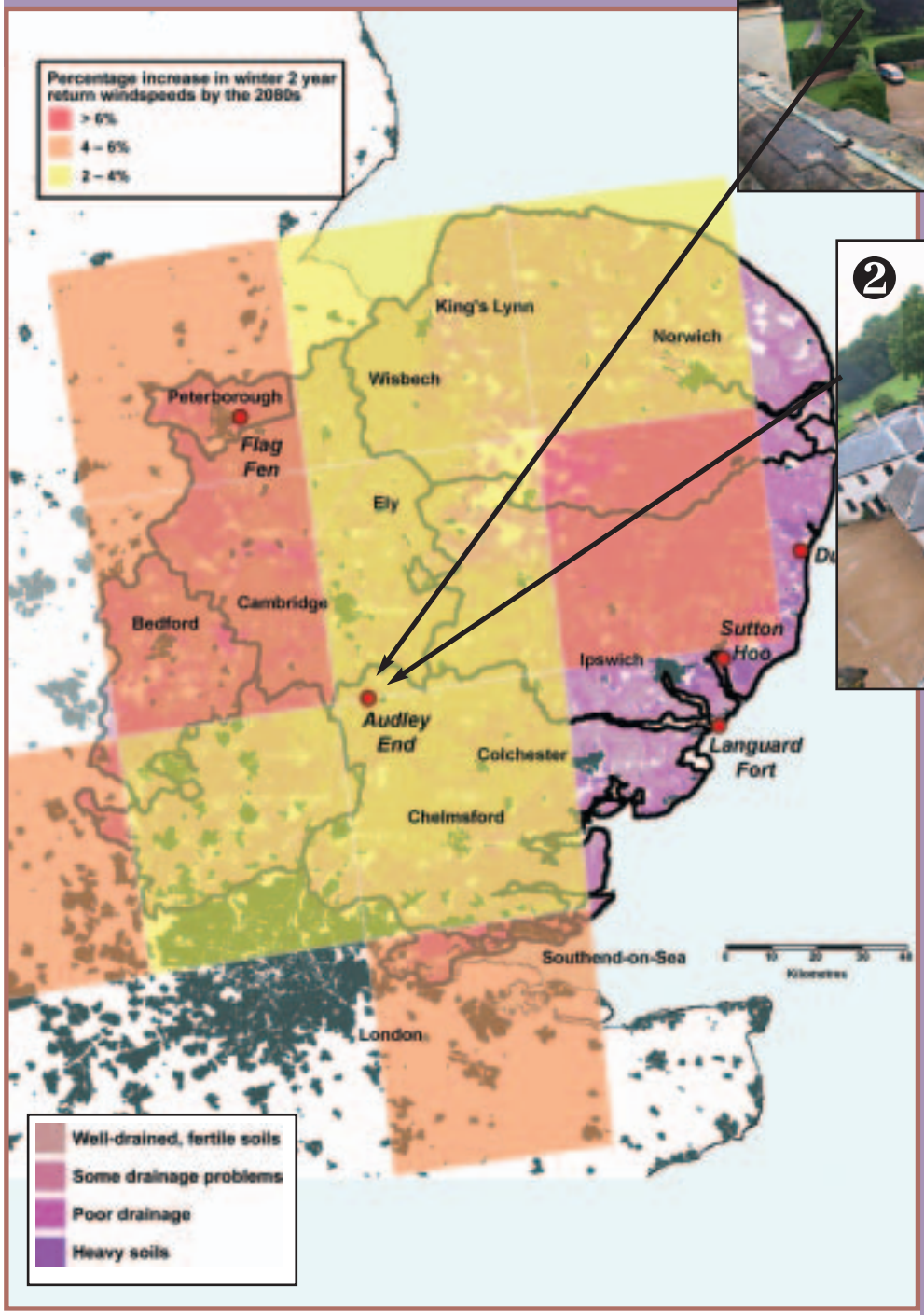
Extreme weather 2 East of England

Damaging windstorms may become more common

The projections for extreme wind have a much lower confidence rating than those for extreme rain, but the potential problem presented by high winds is such that ways of improving these predictions are being actively sought.

1. Mature trees will be at particular risk, and will be hard to replace as climate changes.

2. The complex roofs of historic houses make them especially vulnerable to wind damage. Damaged roofs and rainwater goods are followed by water ingress, causing severe long-term problems to the historic fabric and interiors.

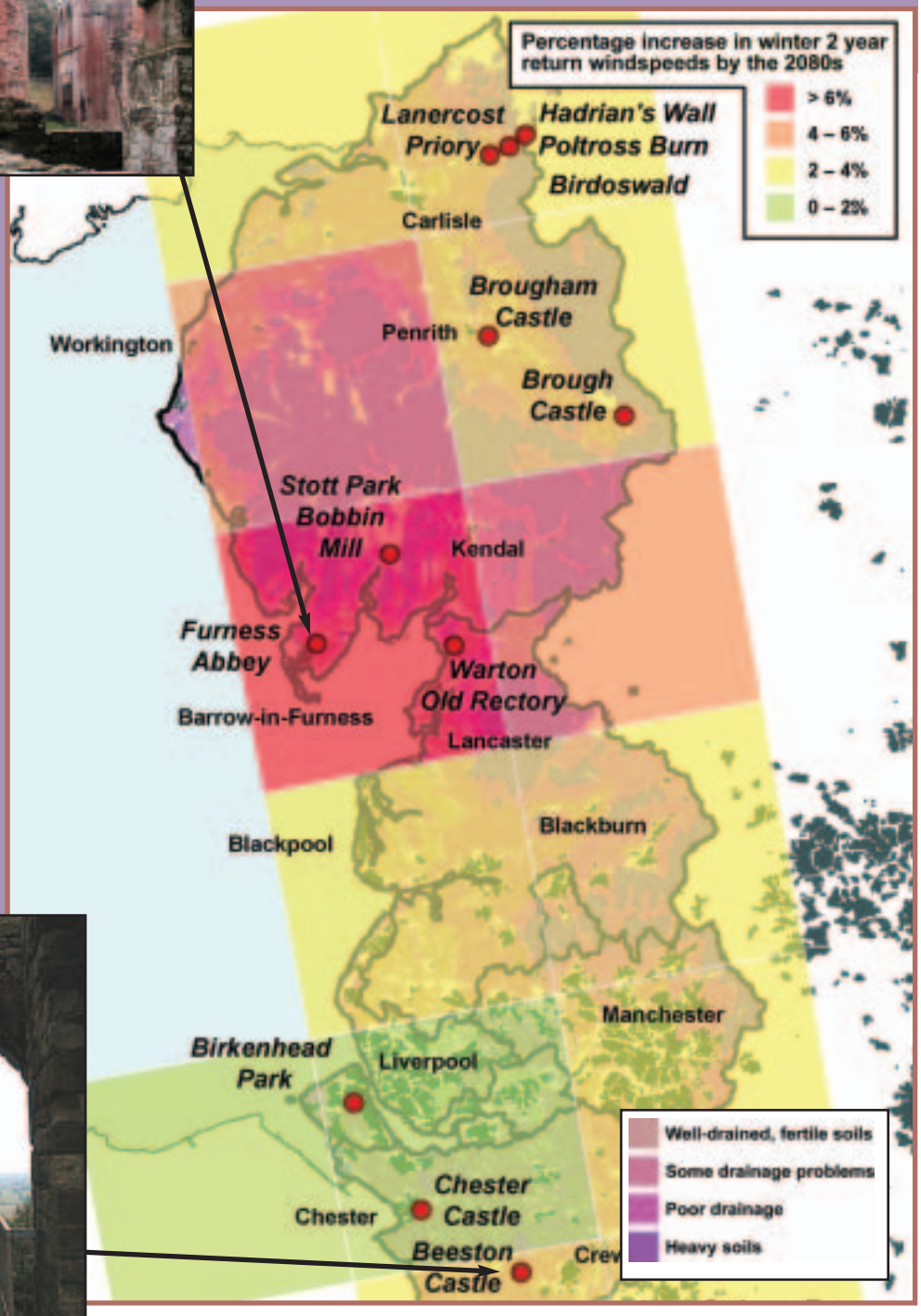


North West

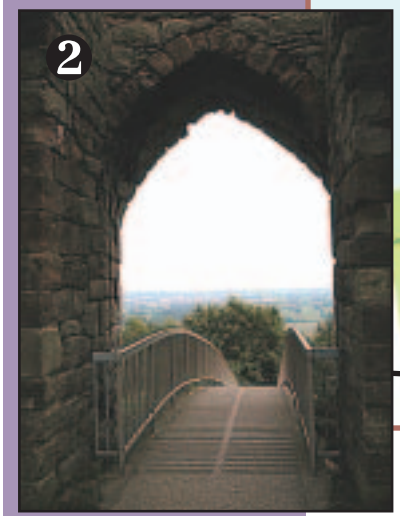
Extreme weather 2

Damaging windstorms may become more common

1. Ruins are particularly susceptible to wind throw.



2. High winds will also have safety implications.

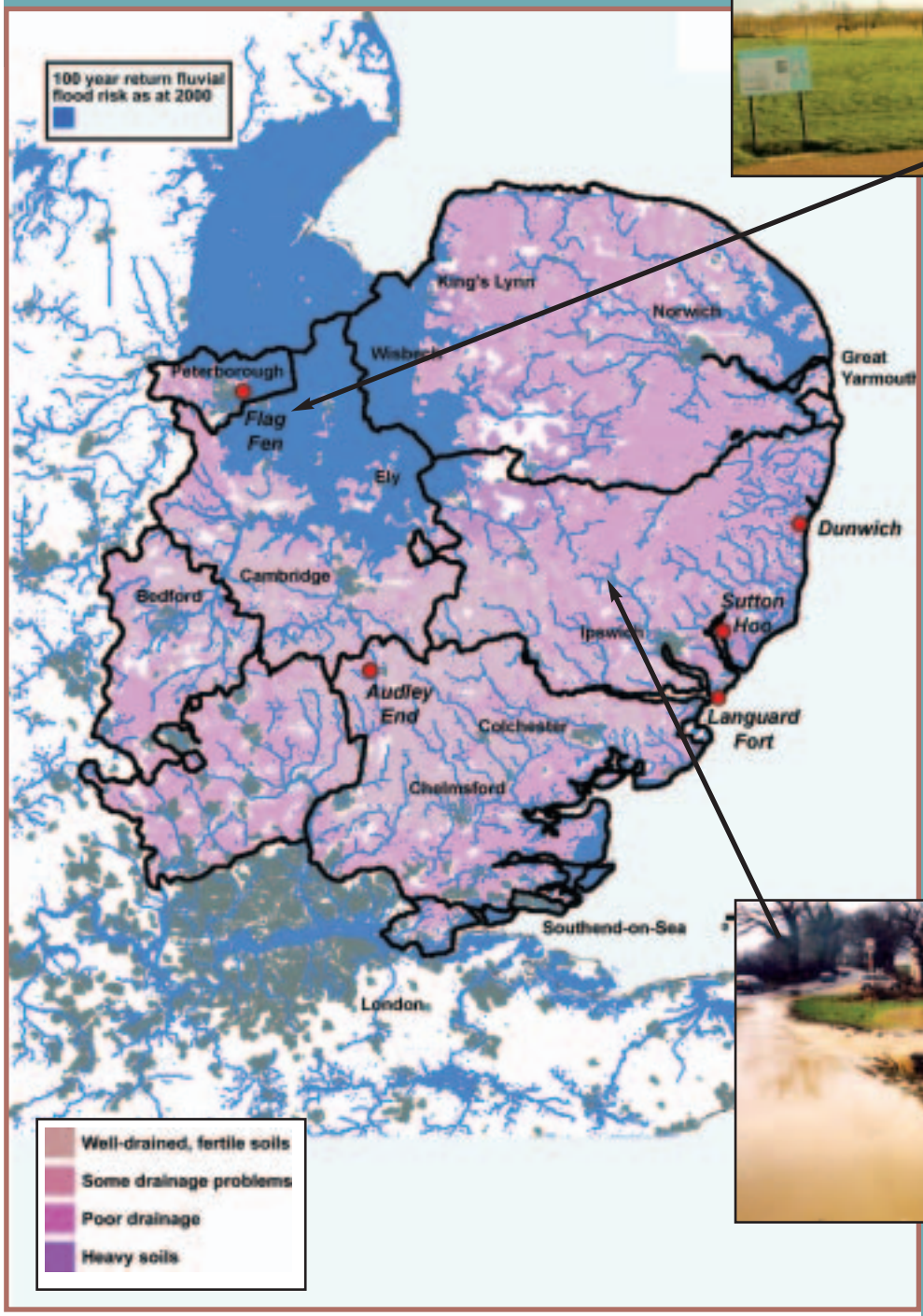


Fluvial flooding East of England

Floods will increase in frequency and severity

Environment Agency maps of 100-year return flooding as at 2000. Climate change will reduce this return period.

1. Flooding itself may not be a problem for wetland sites, but flood protection measures may be very damaging.



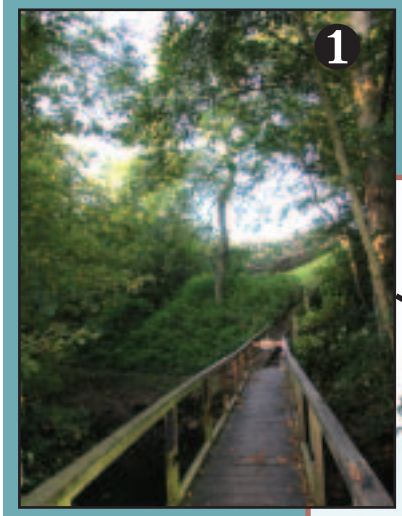
2. Run-off erosion can rapidly cause immense damage.

North West

Fluvial flooding

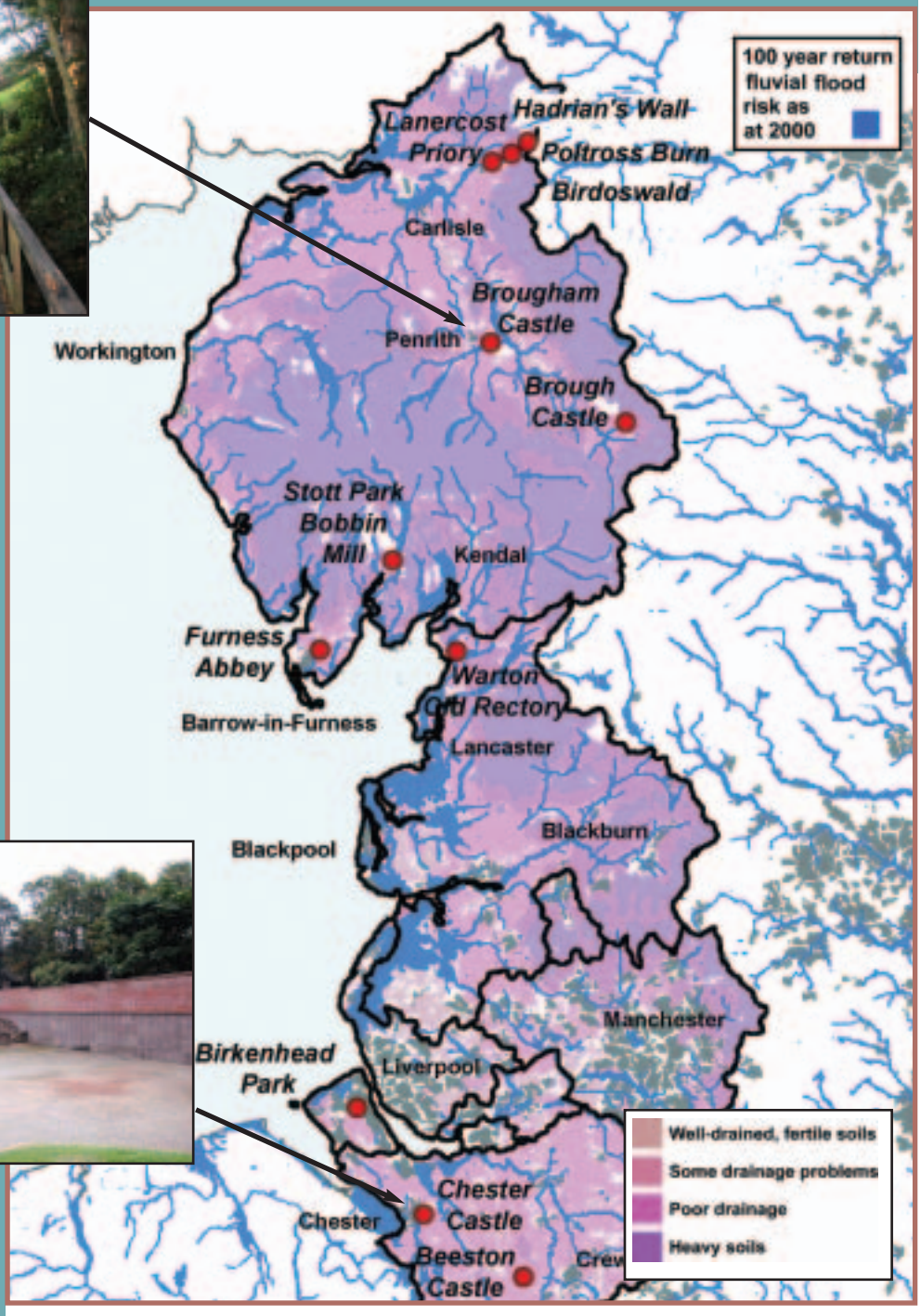
Floods will increase in frequency and severity

These maps do not incorporate flood protection strategies. Buried archaeology may be at risk not only from flooding but also from ill considered flood risk alleviation schemes.



1. Increased erosion of river banks leads to maintenance problems.

2. Excavated archaeology – such as Chester Roman amphitheatre – can be prone to regular flooding.

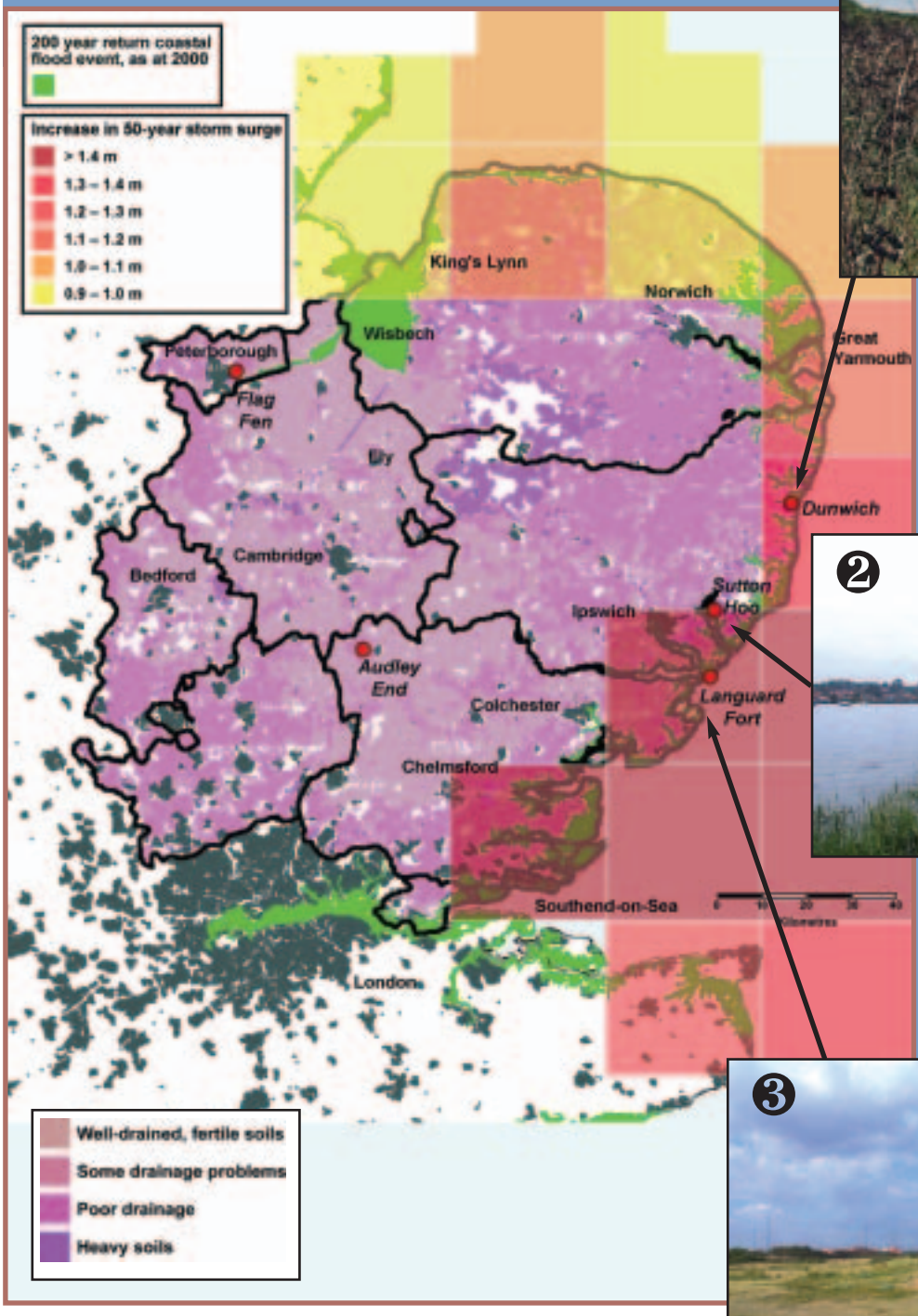


Coastal flooding East of England

Sea levels will rise, and storm surge will exacerbate coastal flooding and loss

The Environment Agency maps of 200-year return coastal flooding as at 2000 are overlaid with maps from the UKCIP report showing projected 50-year return storm surge heights for the 2080s.

1. As can be seen at Dunwich, coastal loss is inevitable.



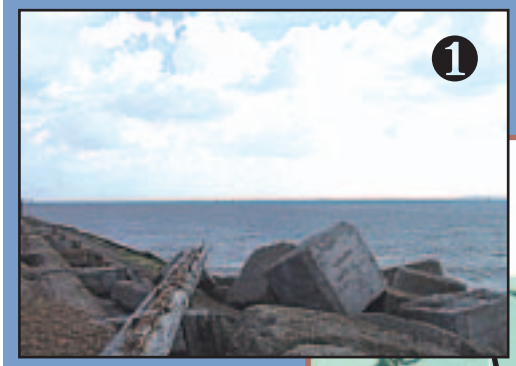
2. Potential loss of coastal sites (as here at Sutton Hoo) points towards a policy of active investigation and recording.

3. Sustainability of an endangered coastal site will have to depend on assessments of value and significance.

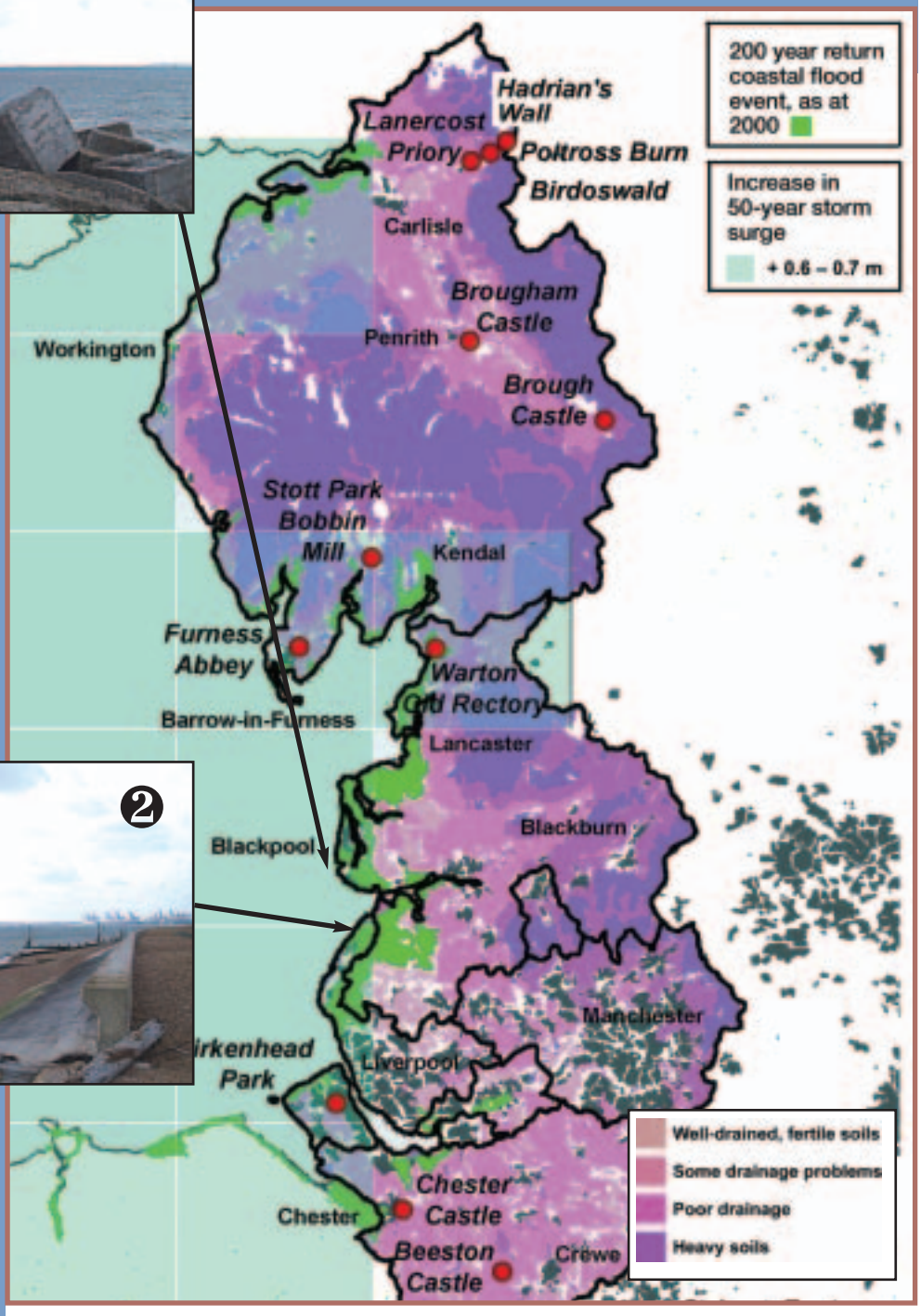
North West Coastal flooding

Sea levels will rise, and storm surge will exacerbate coastal flooding and loss

Again, these maps do not incorporate flood protection strategies, nor do they show the inevitable loss of areas of current coastline. As with fluvial flood defence defending an area of coastline will have strong implications for other areas, and will certainly impact on the historic environment.



1/2. Hard coastal defences are installed at the cost of the underlying archaeology, and will also change conditions in neighbouring areas of coastline.



6 Implications for policy

6.1 Policy-makers' workshop

The issues raised by the study were discussed and developed further by an invited group of scientists, senior heritage managers from all categories of the historic environment and policy makers at a one-day policy workshop held at the Royal Society. Details of the meeting can be found in Annex 4. The following are synopses of the key concerns and main conclusions.

Key concerns

A number of key concerns were identified and prioritised by those attending the policy workshop.

Topping the list was the need to raise awareness and to **educate the public** on the meaning for the historic environment of climate change, including loss and adaptation and the notion of abandonment in the face of extreme weather.

Next identified was **professional preparedness**, that is the need to make good use of science and to educate and train heritage managers with limited resources and within a climate of uncertainty. The need for **sector leadership** was highlighted by the workshop and this had to be demonstrated by joined-up thinking across the sector, regionally and nationally, and by involving others in debates to create stronger collaboration across different sectors.

The issue of the **investment** required to protect the historic environment, who will foot the bill and how the emphasis can be shifted in favour of maintenance rather than repair were also discussed, as was the use of contingent valuation techniques and cost-benefit analysis to evaluate the investments in adaptations.

Values of a different kind: the impact of conflicting societal values, changes in society and demographics and in people's behaviour were also considered in the workshop; and lastly, the effect of land use planning and the need for evolutionary planning in the face of climate change were also identified as priorities.

6.2 Conclusions

Cooperation

- Sector NGOs should speak with one voice when lobbying government, and not necessarily through its statutory advisers.
- Multi-disciplinary think-tanks involving both the historic and the natural environment are needed.
- A mechanism is needed to gather, maintain and share information about the historic environment.
- Ways need to be found to recruit the public to the cause.

Funding

- Long-term funding especially for maintenance is needed.
- Different funding sources and funding approaches need to be linked.
- The insurance industry may prove to be a valuable ally.
- Tax incentives (VAT) could be given for sustainable maintenance.
- The government should fund the sector to provide free advice on sustainability.
- Resources need to be directed towards education and training (e.g. in craft skills).

Research

- An assessment is needed of what has been done already in historic environment and in complementary fields.
- To monitor change standards, protocols, indicators and databases, are needed.
- When modelling future changes, deterioration processes need to be understood. Only this will permit reliable vulnerability assessments.
- Awareness by the sector of public perceptions and public values in relation to the preservation of the historic environment needs to be developed.
- Research output must be used to:
  - Drive policy
  - Develop strategies
  - Disseminate knowledge and raise awareness

Education

- Awareness must be raised among owners, professionals, contractors and general public of heritage significance, and the relevance to this of climate change issues.
- Careers within the heritage sector, from crafts persons to management/ professionals, need to be promoted.
- Educational opportunities need to be provided at all levels, including practical experience (accreditation).
- The sustainable use and reuse of traditional materials – including sourcing of these materials needs to be promoted.
- A national plan to share knowledge and experience is required.
- Owners/managers should be encouraged if not obliged to maintain a building log book as part of a conservation plan for each listed property.

7 Gaps in information and research

7.1 Background

Environmental effects on the historic environment such as climate change are transboundary.

It is therefore important that research to better prepare the historic environment for the impact of climate change is included in the English Heritage research strategy. It is also important that the annual report on the state of England's historic environment, Heritage Counts [www.heritagecounts.org.uk] includes indicators of climate change impacts for all aspects of heritage. By assembling the range of databases and registers that exist for different parts of the historic environment in a Geographical Information System, real risk (rather than demonstration) maps which overlay climate data and heritage site locations can be produced.

7.2 Short-term actions

No-one can afford to wait for all the research to be completed before advice is produced on how to manage the historic environment in the face of climate change. While it may take English Heritage time to negotiate and develop practical adaptation strategies on preventive measures such as drainage and rainwater goods, and irrigation and water storage, interim guidelines are a necessary short –term action. In order to produce real vulnerability maps, the risks to different parts of the historic environment need to be quantified. A multidisciplinary meeting of key experts spearheaded by English Heritage should be organised with the aim of quantifying the exposure to different risks that different parts of the historic environment will be subjected.

English Heritage needs to engage with key climate change researchers as the science moves to produce finer grid climate change maps. This will ensure that climate data of direct relevance to the historic environment – namely extreme and local weather predictions, and the combined effects of different parameters such as wind-driven rain – are given the required priority.

7.3 Medium-term actions

No heritage agency can work alone in this complex field. English Heritage has been working in partnership on climate change issues with other departments, agencies and research councils such as Defra, UKCIP, Environment Agency and EPSRC. English Heritage's interest in long-term effects is evidenced by its support and participation in the EPSRC/UKCIP's *Building Knowledge for Climate Change* research portfolio, particularly in the project, 'Engineering Historic Futures'. English Heritage has also led the Task Group reviewing construction research and innovation for the heritage sector in the UK. The nCrisp Heritage Task Group highlighted climate change as one of the key areas in need of research. It has identified the research required to address the climate change problems that the historic environment sector is expected to encounter in the next 10–15 years.

Climate change impact

New scientific understanding of traditional materials and practices caused by extreme weather (including rain penetration, high summer temperatures and chloride loading) based on cross-field monitoring and leading to key indicators of impact in terms of scale and time and design guidance. Specific areas of need include:

- Climate change modelling and monitoring geared to the historic environment.
- Predicting subsidence and heave caused by extreme weather.
- Understanding damage mechanisms and remediation caused by extreme weather.
- Understanding the effect of wind driven rain at a local level leading to severe damp penetration.
- Understanding the effect of wind driven dust and pollutants at a local level leading to erosion.
- Understanding the effect of new pest migration and infestations, eg.termites.
- Understanding water resistance of building materials and techniques.
- Assessment of availability of renewable materials stocks and development of old technologies such as lime technology.
- Environmental performance of the historic fabric under extreme weather.
- The interface between fragile materials and very robust construction including the notion of robust detailing in the historic environment.

Monitoring, assessment and prediction technology

The application of remote sensing such as the use of satellite technology, non-destructive techniques coupled with simulation tools to predict the behaviour of old building stock and advances in bio-sensing to assess biological damage to materials are needed to evaluate the impact of climate change on the historic environment. Specific product needs include:

- Cheap effective instruments for monitoring environment/component/system failure.
- Remote sensing products.
- Gas phase bio-sensing.
- Non-destructive techniques for bio-degradation, structure and infrastructure determination.
- Wireless communication adaptation of wireless protocols to building sensors, advanced fire/security systems and infestation surveying equipment.

Disaster preparedness

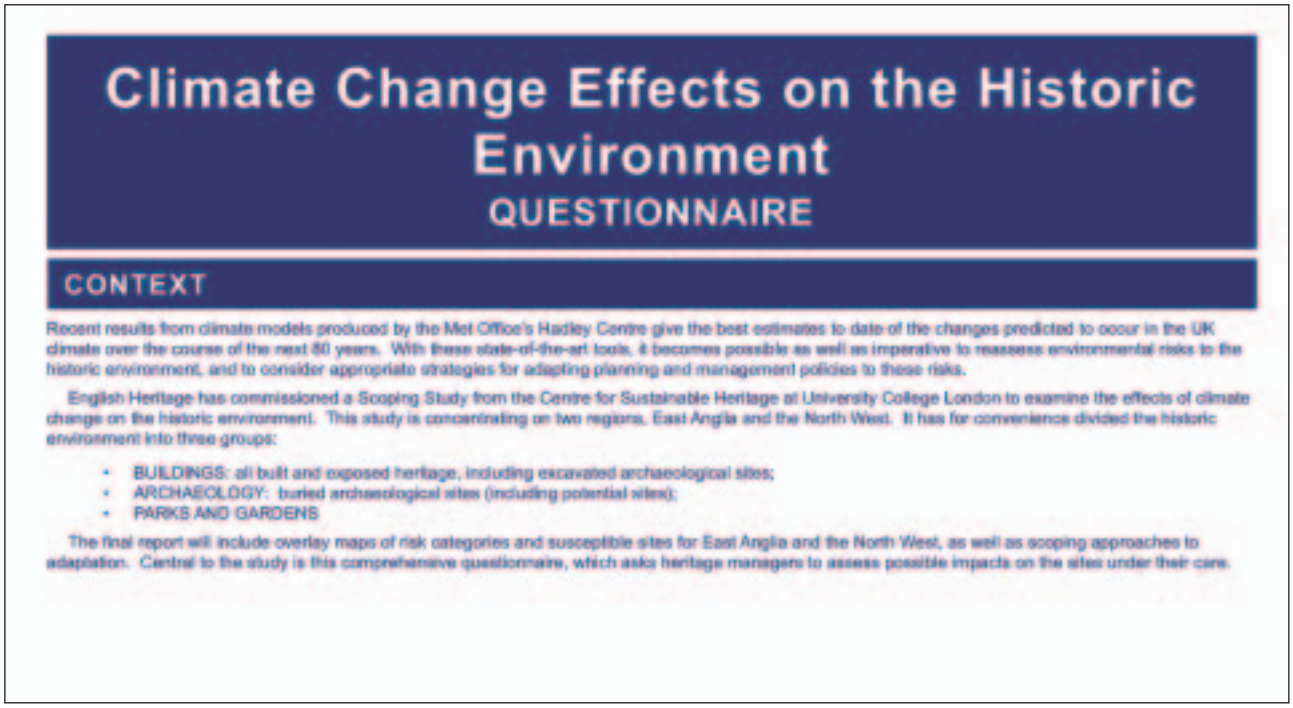
Research in this area should focus on the recognition of hazards and the quantification and prioritisation of the following climate change risks:

- Development of fire suppression technologies such as mist based fire suppressants.
- Development of flood recovery technologies.
- Vulnerability assessments including the development of vulnerability maps.
- Development, application and deployment of risk management protocols and training.

Annex 1
Climate change questionnaire

Questionnaire

A print version of the questionnaire follows. It is also available on the web at
www.ucl.ac.uk/sustainableheritage/research/climatechange/questionnaire.html



Climate Change Effects on the Historic Environment
QUESTIONNAIRE

CONTEXT

Recent results from climate models produced by the Met Office's Hadley Centre give the best estimates to date of the changes predicted to occur in the UK climate over the course of the next 80 years. With these state-of-the-art tools, it becomes possible as well as imperative to reassess environmental risks to the historic environment, and to consider appropriate strategies for adapting planning and management policies to these risks.

English Heritage has commissioned a Scoping Study from the Centre for Sustainable Heritage at University College London to examine the effects of climate change on the historic environment. This study is concentrating on two regions, East Anglia and the North West. It has for convenience divided the historic environment into three groups:

- BUILDINGS: all built and exposed heritage, including excavated archaeological sites;
- ARCHAEOLOGY: buried archaeological sites (including potential sites);
- PARKS AND GARDENS

The final report will include overlay maps of risk categories and susceptible sites for East Anglia and the North West, as well as scoping approaches to adaptation. Central to the study is this comprehensive questionnaire, which asks heritage managers to assess possible impacts on the sites under their care.

QUESTIONNAIRE

The questionnaire follows a simple layout, shown on the next page.

There are 18 questions, each of which presents the latest UK prediction for a single climate (or climate-related) parameter which is likely to have a significant effect on the preservation of the historic environment. Climate scenarios are for 2080, and comparisons are made with the same conditions measured in the period 1961-1990, so that it is possible to see the estimated degree of future change *(the sources of information are given in the Appendix at the end of this questionnaire)*.

For each question, you are asked to respond to the 2080 prediction: how will current management practices and future planning have to be adapted to mitigate damage to those aspects of the historic environment for which you are responsible?

To make responding easier and faster, we have included a list with tick boxes for the most likely adaptations – although these lists are certainly not exhaustive! There is a separate list for each of the three heritage categories, defined as follows:

- **Buildings**
  All built heritage, which for the purposes of this study incorporates **listed buildings, ruins** and **excavated archaeological structures**.
- **Archaeology**
  For the purposes of this study, Archaeology is limited to **unexcavated archaeological sites**.
- **Parks and Gardens**

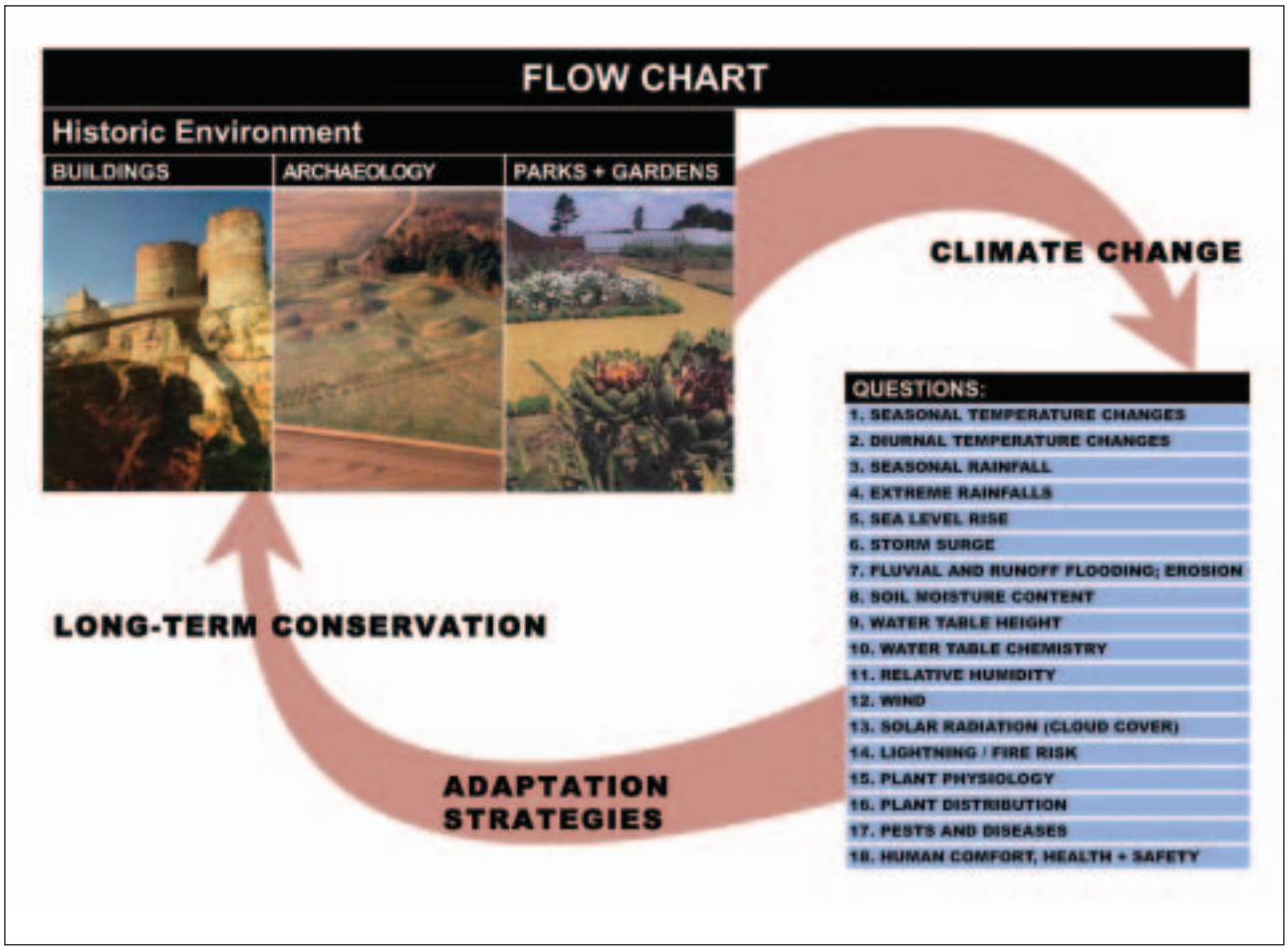
There is space for your comments on each question, and we would welcome any observations unique to the sites under your control, or which you feel have been omitted from the tick boxes. If the space provided is insufficient, please feel free to continue on the reverse of the page. In addition, on the final page of the questionnaire there is space to add any general comments you may wish to make.

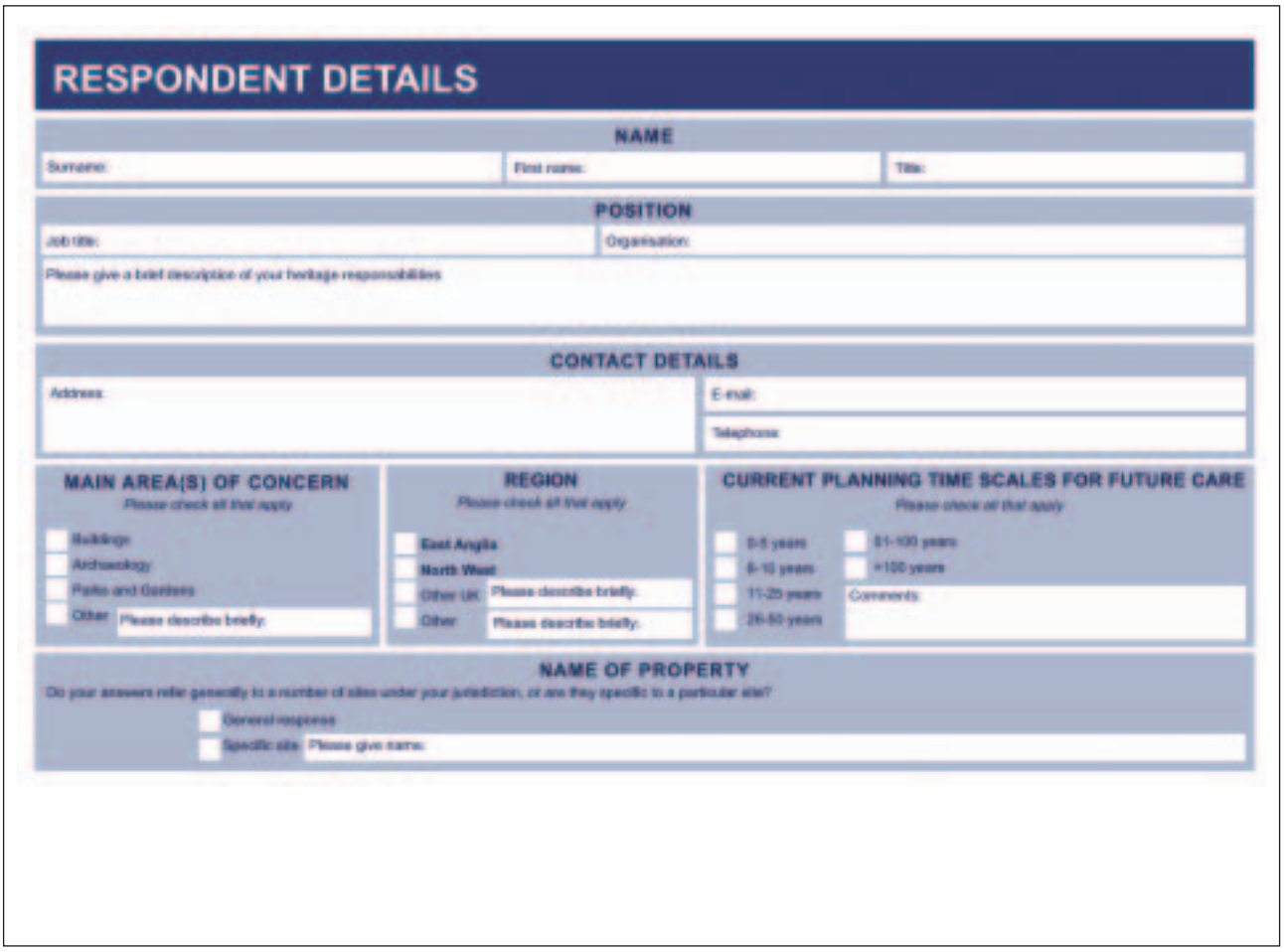
We have envisaged that those respondents who care for a number of different sites will answer in general terms; however, should you wish to answer the questionnaire in detail for one or more specific sites as well, you would of course be most welcome to do so. An optional field is given (on the Respondent Details page) for the property name(s), should you be responding in this manner.

We would be grateful if you could answer as many questions as you can, ticking as many of the boxes as are applicable and filling in details where asked. If possible, please return the questionnaire by **31 August 2002** to:

CC Scoping Study
UCL Centre for Sustainable Heritage
Bartlett School of Graduate Studies
(Torrington Place Site)
University College London
Gower Street
London WC1E 6BT
Attn: Robyn Pender

For faxed responses, the fax number is:
020 - 7916 1887


FLOW CHART
Historic Environment
BUILDINGS
ARCHAEOLOGY
PARKS + GARDENS
CLIMATE CHANGE
QUESTIONS:
1. SEASONAL TEMPERATURE CHANGES
2. DIURNAL TEMPERATURE CHANGES
3. SEASONAL RAINFALL
4. EXTREME RAINFALLS
5. SEA LEVEL RISE
6. STORM SURGE
7. FLUVIAL AND RUNOFF FLOODING; EROSION
8. SOIL MOISTURE CONTENT
9. WATER TABLE HEIGHT
10. WATER TABLE CHEMISTRY
11. RELATIVE HUMIDITY
12. WIND
13. SOLAR RADIATION (CLOUD COVER)
14. LIGHTNING / FIRE RISK
15. PLANT PHYSIOLOGY
16. PLANT DISTRIBUTION
17. PESTS AND DISEASES
18. HUMAN COMFORT, HEALTH + SAFETY
LONG-TERM CONSERVATION
ADAPTATION STRATEGIES



RESPONDENT DETAILS

NAME

Surname: | First name: | Title:

POSITION

Job title: | Organisation:

Please give a brief description of your heritage responsibilities

CONTACT DETAILS

Address: | E-mail: | Telephone:

MAIN AREA(S) OF CONCERN

Please check all that apply

- Buildings
- Archaeology
- Parks and Gardens
- Other — Please describe briefly:

REGION

Please check all that apply

- East Anglia
- North West
- Other UK — Please describe briefly:
- Other — Please describe briefly:

CURRENT PLANNING TIME SCALES FOR FUTURE CARE

Please check all that apply

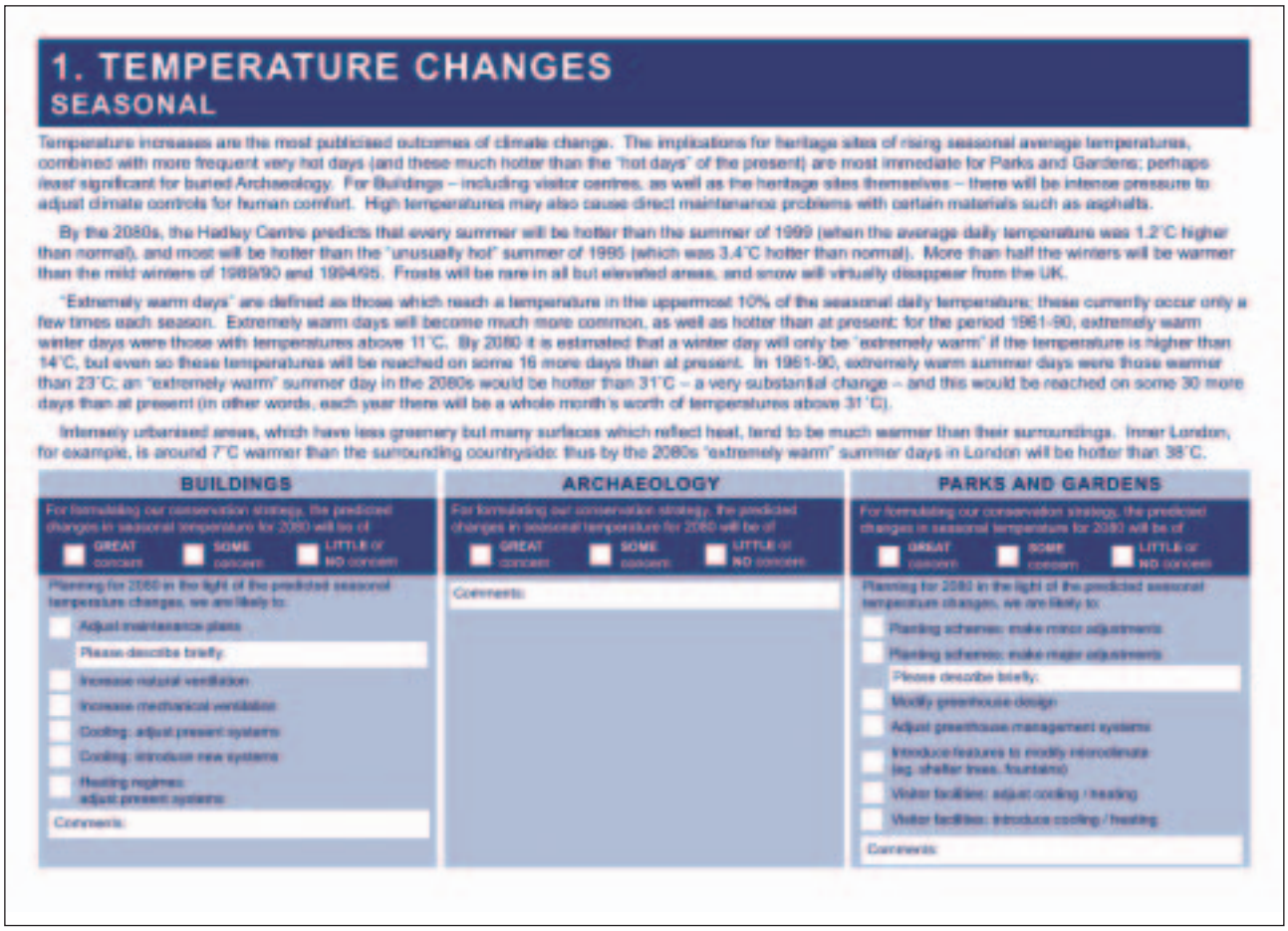
- 0-5 years
- 6-10 years
- 11-25 years
- 26-50 years
- 51-100 years
- >100 years

Comments:

NAME OF PROPERTY

Do your answers refer generally to a number of sites under your jurisdiction, or are they specific to a particular site?

- General response
- Specific site — Please give name:



1. TEMPERATURE CHANGES
SEASONAL

Temperature increases are the most publicised outcomes of climate change. The implications for heritage sites of rising seasonal average temperatures, combined with more frequent very hot days (and these much hotter than the "hot days" of the present) are most immediate for Parks and Gardens; perhaps *least* significant for buried Archaeology. For Buildings – including visitor centres, as well as the heritage sites themselves – there will be intense pressure to adjust climate controls for human comfort. High temperatures may also cause direct maintenance problems with certain materials such as asphalts.

By the 2080s, the Hadley Centre predicts that every summer will be hotter than the summer of 1999 (when the average daily temperature was 1.2°C higher than normal), and most will be hotter than the "unusually hot" summer of 1995 (which was 3.4°C hotter than normal). More than half the winters will be warmer than the mild winters of 1988/90 and 1994/95. Frosts will be rare in all but elevated areas, and snow will virtually disappear from the UK.

"Extremely warm days" are defined as those which reach a temperature in the uppermost 10% of the seasonal daily temperatures; these currently occur only a few times each season. Extremely warm days will become much more common, as well as hotter than at present: for the period 1961-90, extremely warm winter days were those with temperatures above 11°C. By 2080 it is estimated that a winter day will only be "extremely warm" if the temperature is higher than 14°C, but even so these temperatures will be reached on some 16 more days than at present. In 1961-90, extremely warm summer days were those warmer than 23°C; an "extremely warm" summer day in the 2080s would be hotter than 31°C – a very substantial change – and this would be reached on some 30 more days than at present (in other words, each year there will be a whole month's worth of temperatures above 31°C).

Intensely urbanised areas, which have less greenery but many surfaces which reflect heat, tend to be much warmer than their surroundings. Inner London, for example, is around 7°C warmer than the surrounding countryside: thus by the 2080s "extremely warm" summer days in London will be hotter than 38°C.

BUILDINGS

For formulating our conservation strategy, the predicted changes in seasonal temperature for 2080 will be of

GREAT concern SOME concern LITTLE or NO concern

Planning for 2080 in the light of the predicted seasonal temperature changes, we are likely to:

- Adjust maintenance plans
- Please describe briefly:
- Increase natural ventilation
- Increase mechanical ventilation
- Cooling: adjust present systems
- Cooling: introduce new systems
- Heating regimes: adjust present systems

Comments:

ARCHAEOLOGY

For formulating our conservation strategy, the predicted changes in seasonal temperature for 2080 will be of

GREAT concern SOME concern LITTLE or NO concern

Comments:

PARKS AND GARDENS

For formulating our conservation strategy, the predicted changes in seasonal temperature for 2080 will be of

GREAT concern SOME concern LITTLE or NO concern

Planning for 2080 in the light of the predicted seasonal temperature changes, we are likely to:

- Planting schemes: make minor adjustments
- Planting schemes: make major adjustments
- Please describe briefly:
- Modify greenhouse design
- Adjust greenhouse management systems
- Introduce features to modify microclimate (eg. shelter trees, fountains)
- Visitor facilities: adjust cooling / heating
- Visitor facilities: introduce cooling / heating

Comments:

2. TEMPERATURE CHANGES
DIURNAL

The daily range of temperature has an immediate effect on plants, and if extreme may initiate damage cycles in susceptible materials and structures.

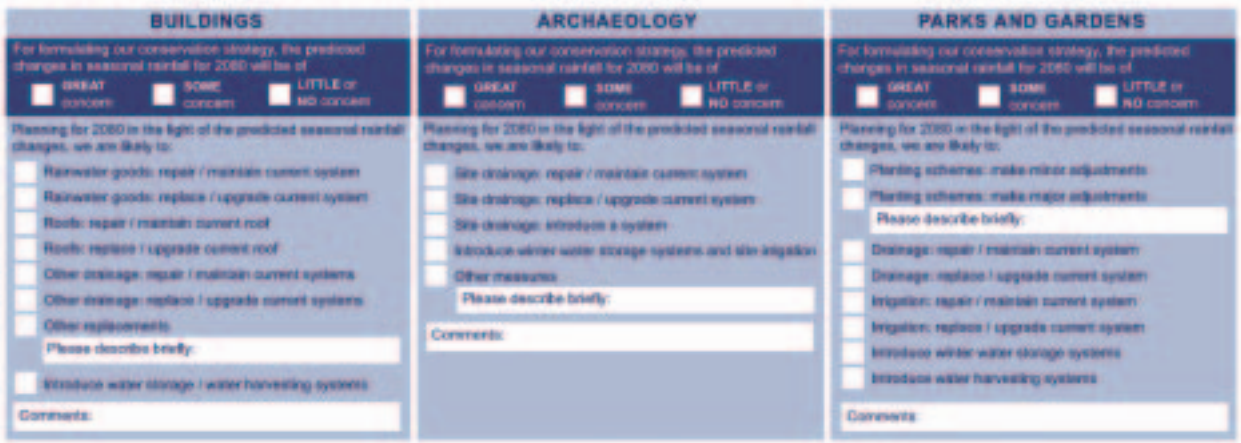
The changes in the diurnal temperature range predicted by the Hadley Centre for the 2080s are in fact relatively small: a very slight decrease in day–night differences in winter (as nights become relatively warmer), and slight increases at other times of year. The greatest change – an increase of around 1.2˚C in the difference between night and day temperatures – is predicted for summer. Urban areas, which will cool at night much more slowly than at present, will face hot nights throughout summer.

3. RAINFALL CHANGES
SEASONAL

The seasonal rainfall patterns affect many aspects of heritage management, from watering regimes in Parks and Gardens to maintenance of moisture levels in wetland Archaeological sites.

The "classic" UK rainfall patterns – rain on about one day in three, mostly in the form of fairly gentle showers – are expected to disappear as the global climate changes. By 2080 the Hadley Centre is "moderately confident" that one summer in three will be both hotter and drier than the unusual summer of 1995 (which was 37% drier than the summers we normally experience). If this is the case, one summer in ten will have no more than *one quarter* of the summer average rainfall as measured in the period 1961-90.

Winters will become warmer, but also wetter. The Hadley Centre is "confident" that 15% of winters in the 2080s will be wetter than the winter of 1994/95 (which was 66% wetter than a typical 1961/90 winter).



4. RAINFALL CHANGES
EXTREME RAINFALLS

The rainfall effects on heritage depend not only on the overall amount of precipitation, but also very significantly on the rate at which it falls. In particular, the extent of extreme rainfall sets the criteria for designing drainage and disposal systems *(intense rainfall also governs fluvial and runoff flooding and erosion, but these outcomes are considered separately in Question 7)*. Britain's weather has been characterised by frequent light showers, with heavy rain relatively rare and localised.

The 2080 predictions for winter and spring show heavy rainfalls becoming not only more common, but also stronger. Extreme events are described by how often they are likely to occur in a single year or a single season; so a rainfall sufficiently strong to be likely to occur only once every two years is called a "2-year-return" event. By 2080 the two-year-return winter rainfalls will be some 25% stronger than their 1961-90 equivalents. 5-year-return events will increase from their 1961-90 levels (44mm per day in East Anglia, and 48mm per day in the North West) to around 56mm per day. The strongest rainfalls – 50-year-return events – are predicted to increase from around 68mm per day (1961-90) to 76mm per day in the North West, and to 88mm per day in East Anglia.

As extreme events become stronger, the previous benchmark events become more frequent: winter rainfalls which in 1961-90 had once-yearly returns will have doubled in frequency to twice-yearly by 2080.

In contrast to winter and spring, the Hadley Centre is "moderately confident" that extreme rainfalls will become slightly less common in summer, and those which do occur will be considerably less strong: 2-year-return rainfalls will be up to 30% weaker in the summers of the 2080s.

Autumn rainfall extremes are expected to be very different in East Anglia and the North West. The North West can look to a 20% increase in the strength of 2-year-return rainfalls; by contrast East Anglia could face a drop in strength of some 15%.

BUILDINGS

For formulating our conservation strategy, the predicted changes in extreme rainfalls for 2080 will be of

☐ GREAT concern ☐ SOME concern ☐ LITTLE or NO concern

Planning for 2080 in the light of the predicted changes in extreme rainfalls, we are likely to:

- ☐ Rainwater goods: repair / maintain current system
- ☐ Rainwater goods: replace / upgrade current system
- ☐ Roofs: repair / maintain current roof
- ☐ Roofs: replace / upgrade current roof
- ☐ Other drainage: repair / maintain current systems
- ☐ Other drainage: replace / upgrade current systems
- ☐ Other replacements

Please describe briefly:

- ☐ Introduce water storage / water harvesting systems

Comments:

ARCHAEOLOGY

For formulating our conservation strategy, the predicted changes in extreme rainfalls for 2080 will be of

☐ GREAT concern ☐ SOME concern ☐ LITTLE or NO concern

Planning for 2080 in the light of the predicted changes in extreme rainfalls, we are likely to:

- ☐ Site drainage: repair / maintain current system
- ☐ Site drainage: replace / upgrade current system
- ☐ Site drainage: introduce a system
- ☐ Introduce winter water storage systems and site irrigation
- ☐ Other measures

Please describe briefly:

Comments:

PARKS AND GARDENS

For formulating our conservation strategy, the predicted changes in extreme rainfalls for 2080 will be of

☐ GREAT concern ☐ SOME concern ☐ LITTLE or NO concern

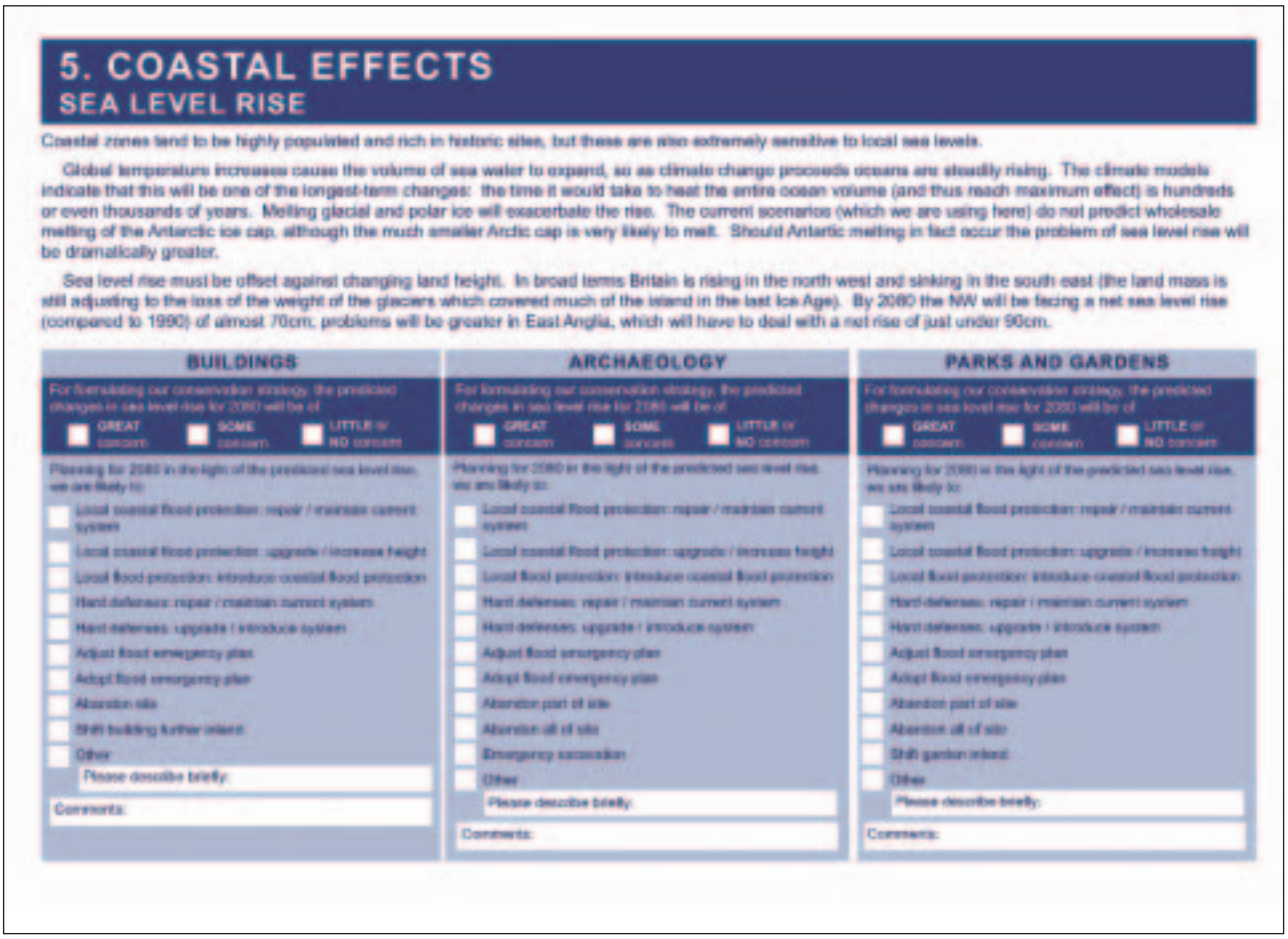
Planning for 2080 in the light of the predicted changes in extreme rainfalls, we are likely to:

- ☐ Planting schemes: make minor adjustments
- ☐ Planting schemes: make major adjustments

Please describe briefly:

- ☐ Drainage: repair / maintain current system
- ☐ Drainage: replace / upgrade current system
- ☐ Irrigation: repair / maintain current system
- ☐ Irrigation: replace / upgrade current system
- ☐ Introduce winter water storage systems
- ☐ Introduce water harvesting systems

Comments:



5. COASTAL EFFECTS
SEA LEVEL RISE

Coastal zones tend to be highly populated and rich in historic sites, but these are also extremely sensitive to local sea levels.

Global temperature increases cause the volume of sea water to expand, so as climate change proceeds oceans are steadily rising. The climate models indicate that this will be one of the longest-term changes: the time it would take to heat the entire ocean volume (and thus reach maximum effect) is hundreds or even thousands of years. Melting glacial and polar ice will exacerbate the rise. The current scenarios (which we are using here) do not predict wholesale melting of the Antarctic ice cap, although the much smaller Arctic cap is very likely to melt. Should Antartic melting in fact occur the problem of sea level rise will be dramatically greater.

Sea level rise must be offset against changing land height. In broad terms Britain is rising in the north west and sinking in the south east (the land mass is still adjusting to the loss of the weight of the glaciers which covered much of the island in the last Ice Age). By 2080 the NW will be facing a net sea level rise (compared to 1990) of almost 70cm; problems will be greater in East Anglia, which will have to deal with a net rise of just under 90cm.

BUILDINGS

For formulating our conservation strategy, the predicted changes in sea level rise for 2080 will be of

☐ GREAT concern ☐ SOME concern ☐ LITTLE or NO concern

Planning for 2080 in the light of the predicted sea level rise, we are likely to:

- ☐ Local coastal flood protection: repair / maintain current system
- ☐ Local coastal flood protection: upgrade / increase height
- ☐ Local flood protection: introduce coastal flood protection
- ☐ Hard defences: repair / maintain current system
- ☐ Hard defences: upgrade / introduce system
- ☐ Adjust flood emergency plan
- ☐ Adopt flood emergency plan
- ☐ Abandon site
- ☐ Shift building further inland
- ☐ Other

Please describe briefly:

Comments:

ARCHAEOLOGY

For formulating our conservation strategy, the predicted changes in sea level rise for 2080 will be of

☐ GREAT concern ☐ SOME concern ☐ LITTLE or NO concern

Planning for 2080 in the light of the predicted sea level rise, we are likely to:

- ☐ Local coastal flood protection: repair / maintain current system
- ☐ Local coastal flood protection: upgrade / increase height
- ☐ Local flood protection: introduce coastal flood protection
- ☐ Hard defences: repair / maintain current system
- ☐ Hard defences: upgrade / introduce system
- ☐ Adjust flood emergency plan
- ☐ Adopt flood emergency plan
- ☐ Abandon part of site
- ☐ Abandon all of site
- ☐ Emergency excavation
- ☐ Other

Please describe briefly:

Comments:

PARKS AND GARDENS

For formulating our conservation strategy, the predicted changes in sea level rise for 2080 will be of

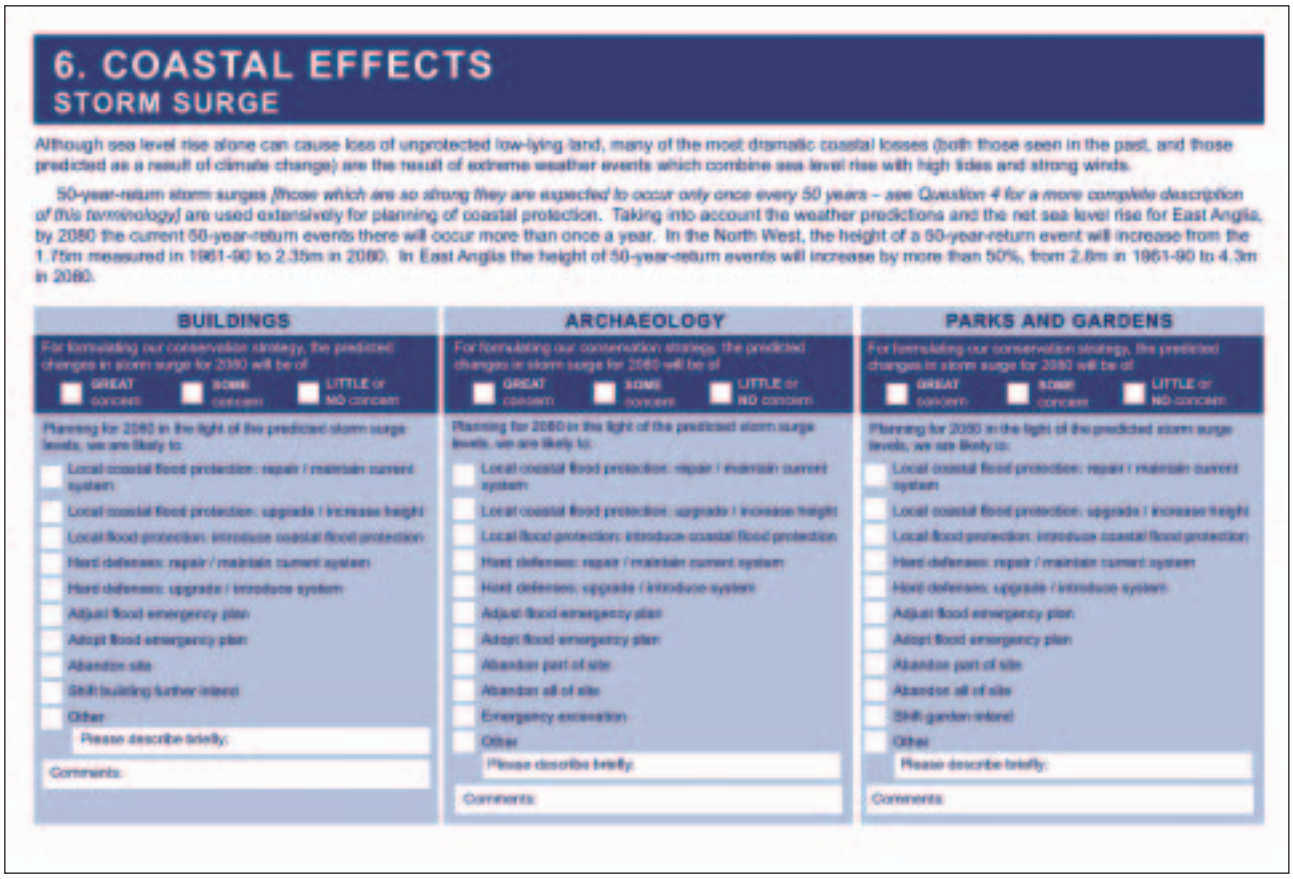
☐ GREAT concern ☐ SOME concern ☐ LITTLE or NO concern

Planning for 2080 in the light of the predicted sea level rise, we are likely to:

- ☐ Local coastal flood protection: repair / maintain current system
- ☐ Local coastal flood protection: upgrade / increase height
- ☐ Local flood protection: introduce coastal flood protection
- ☐ Hard defences: repair / maintain current system
- ☐ Hard defences: upgrade / introduce system
- ☐ Adjust flood emergency plan
- ☐ Adopt flood emergency plan
- ☐ Abandon part of site
- ☐ Abandon all of site
- ☐ Shift garden inland
- ☐ Other

Please describe briefly:

Comments:



6. COASTAL EFFECTS
STORM SURGE

Although sea level rise alone can cause loss of unprotected low-lying land, many of the most dramatic coastal losses (both those seen in the past, and those predicted as a result of climate change) are the result of extreme weather events which combine sea level rise with high tides and strong winds.

50-year-return storm surges *[those which are so strong they are expected to occur only once every 50 years – see Question 4 for a more complete description of this terminology]* are used extensively for planning of coastal protection. Taking into account the weather predictions and the net sea level rise for East Anglia, by 2080 the current 50-year-return events there will occur more than once a year. In the North West, the height of a 50-year-return event will increase from the 1.75m measured in 1961-90 to 2.35m in 2080. In East Anglia the height of 50-year-return events will increase by more than 50%, from 2.8m in 1961-90 to 4.3m in 2080.

BUILDINGS

For formulating our conservation strategy, the predicted changes in storm surge for 2080 will be of

☐ GREAT concern ☐ SOME concern ☐ LITTLE or NO concern

Planning for 2080 in the light of the predicted storm surge levels, we are likely to:

- ☐ Local coastal flood protection: repair / maintain current system
- ☐ Local coastal flood protection: upgrade / increase height
- ☐ Local flood protection: introduce coastal flood protection
- ☐ Hard defenses: repair / maintain current system
- ☐ Hard defenses: upgrade / introduce system
- ☐ Adjust flood emergency plan
- ☐ Adopt flood emergency plan
- ☐ Abandon site
- ☐ Shift building further inland
- ☐ Other

Please describe briefly:

Comments:

ARCHAEOLOGY

For formulating our conservation strategy, the predicted changes in storm surge for 2080 will be of

☐ GREAT concern ☐ SOME concern ☐ LITTLE or NO concern

Planning for 2080 in the light of the predicted storm surge levels, we are likely to:

- ☐ Local coastal flood protection: repair / maintain current system
- ☐ Local coastal flood protection: upgrade / increase height
- ☐ Local flood protection: introduce coastal flood protection
- ☐ Hard defenses: repair / maintain current system
- ☐ Hard defenses: upgrade / introduce system
- ☐ Adjust flood emergency plan
- ☐ Adopt flood emergency plan
- ☐ Abandon part of site
- ☐ Abandon all of site
- ☐ Emergency excavation
- ☐ Other

Please describe briefly:

Comments:

PARKS AND GARDENS

For formulating our conservation strategy, the predicted changes in storm surge for 2080 will be of

☐ GREAT concern ☐ SOME concern ☐ LITTLE or NO concern

Planning for 2080 in the light of the predicted storm surge levels, we are likely to:

- ☐ Local coastal flood protection: repair / maintain current system
- ☐ Local coastal flood protection: upgrade / increase height
- ☐ Local flood protection: introduce coastal flood protection
- ☐ Hard defenses: repair / maintain current system
- ☐ Hard defenses: upgrade / introduce system
- ☐ Adjust flood emergency plan
- ☐ Adopt flood emergency plan
- ☐ Abandon part of site
- ☐ Abandon all of site
- ☐ Shift garden inland
- ☐ Other

Please describe briefly:

Comments:

7. FLOODING
FLUVIAL AND RUNOFF FLOODING, AND WATER-DRIVEN EROSION

Floods, and their aftereffects, provide perhaps the most dramatic illustrations of the impact of climate on heritage sites.

In the scenarios for 2080, increased winter and spring rainfall suggest that local flooding will be a major problem in both the North West and East Anglia; indeed, the North West is likely to face autumnal flooding as well. It is difficult to put general figures on fluvial flood risk, since it depends so much on local conditions; but it is safe to say that any catchment area currently at risk can expect the problem to worsen significantly, with floods being both stronger and more frequent.

In the hot dry summers which will be typical of the 2080s, soil desiccation will exacerbate runoff flooding, and make erosion a problem.

Urban areas will be especially prone to problems with runoff. Drainage systems currently in use were certainly not designed to cope with downpours of the intensity predicted for the 2080s, but they may prove difficult to upgrade sufficiently.

BUILDINGS

For formulating our conservation strategy, the predicted changes in fluvial and runoff flooding for 2080 will be of

☐ GREAT concern ☐ SOME concern ☐ LITTLE or NO concern

Planning for 2080 in the light of the predicted fluvial and runoff flooding, we are likely to:

- ☐ Local flood protection: repair / maintain current system
- ☐ Local flood protection: upgrade / increase height
- ☐ Local flood protection: introduce flood protection
- ☐ Ground drainage: repair / maintain current system
- ☐ Ground drainage: upgrade / replace current system
- ☐ Adjust flood emergency plans
- ☐ Adopt flood emergency plan
- ☐ Introduce other control systems

Please describe briefly:

Comments:

ARCHAEOLOGY

For formulating our conservation strategy, the predicted changes in fluvial and runoff flooding for 2080 will be of

☐ GREAT concern ☐ SOME concern ☐ LITTLE or NO concern

Planning for 2080 in the light of the predicted fluvial and runoff flooding, we are likely to:

- ☐ Local flood protection: repair / maintain current system
- ☐ Local flood protection: upgrade / increase height
- ☐ Local flood protection: introduce coastal flood protection
- ☐ Site drainage: repair / maintain current system
- ☐ Site drainage: upgrade / replace current system
- ☐ Adjust flood emergency plans
- ☐ Adopt flood emergency plan
- ☐ Erosion: introduce / upgrade monitoring system
- ☐ Erosion: undertake remedial or protective works

Please describe briefly:

Comments:

PARKS AND GARDENS

For formulating our conservation strategy, the predicted changes in fluvial and runoff flooding for 2080 will be of

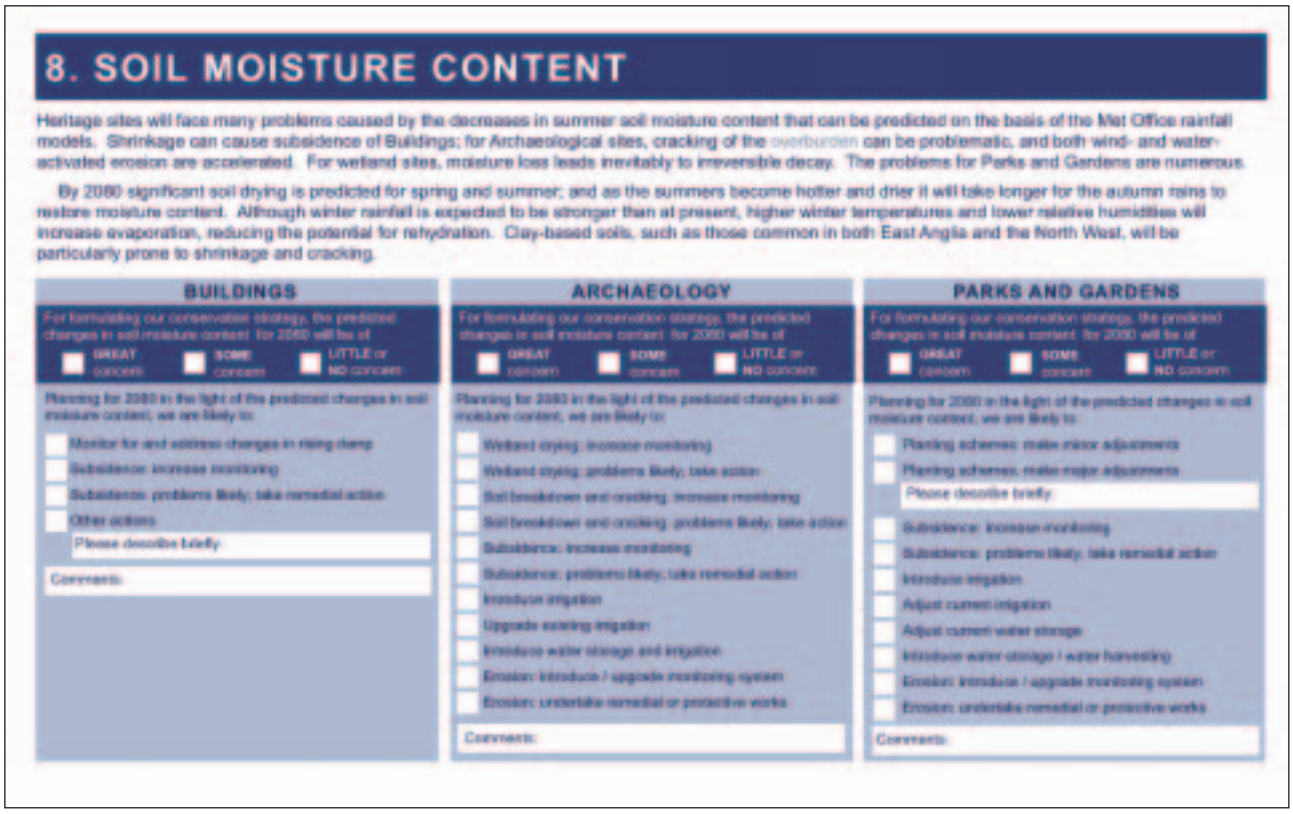
☐ GREAT concern ☐ SOME concern ☐ LITTLE or NO concern

Planning for 2080 in the light of the predicted fluvial and runoff flooding, we are likely to:

- ☐ Local flood protection: repair / maintain current system
- ☐ Local flood protection: upgrade / increase height
- ☐ Local flood protection: introduce coastal flood protection
- ☐ Site drainage: repair / maintain current system
- ☐ Site drainage: upgrade / replace current system
- ☐ Adjust flood emergency plans
- ☐ Adopt flood emergency plan
- ☐ Erosion: introduce / upgrade monitoring system
- ☐ Erosion: undertake remedial or protective works
- ☐ Planting schemes: make minor adjustments
- ☐ Planting schemes: make major adjustments

Please describe briefly:

Comments:



8. SOIL MOISTURE CONTENT

Heritage sites will face many problems caused by the decreases in summer soil moisture content that can be predicted on the basis of the Met Office rainfall models. Shrinkage can cause subsidence of Buildings; for Archaeological sites, cracking of the overburden can be problematic, and both wind- and water-activated erosion are accelerated. For wetland sites, moisture loss leads inevitably to irreversible decay. The problems for Parks and Gardens are numerous.

By 2080 significant soil drying is predicted for spring and summer, and as the summers become hotter and drier it will take longer for the autumn rains to restore moisture content. Although winter rainfall is expected to be stronger than at present, higher winter temperatures and lower relative humidities will increase evaporation, reducing the potential for rehydration. Clay-based soils, such as those common in both East Anglia and the North West, will be particularly prone to shrinkage and cracking.

BUILDINGS

For formulating our conservation strategy, the predicted changes in soil moisture content for 2080 will be of

☐ GREAT concern ☐ SOME concern ☐ LITTLE or NO concern

Planning for 2080 in the light of the predicted changes in soil moisture content, we are likely to:

- ☐ Monitor for and address changes in rising damp
- ☐ Subsidence: increase monitoring
- ☐ Subsidence: problems likely; take remedial action
- ☐ Other actions

Please describe briefly:

Comments:

ARCHAEOLOGY

For formulating our conservation strategy, the predicted changes in soil moisture content for 2080 will be of

☐ GREAT concern ☐ SOME concern ☐ LITTLE or NO concern

Planning for 2080 in the light of the predicted changes in soil moisture content, we are likely to:

- ☐ Wetland drying: increase monitoring
- ☐ Wetland drying: problems likely; take action
- ☐ Soil breakdown and cracking: increase monitoring
- ☐ Soil breakdown and cracking: problems likely; take action
- ☐ Subsidence: increase monitoring
- ☐ Subsidence: problems likely; take remedial action
- ☐ Introduce irrigation
- ☐ Upgrade existing irrigation
- ☐ Introduce water storage and irrigation
- ☐ Erosion: introduce / upgrade monitoring system
- ☐ Erosion: undertake remedial or protective works

Comments:

PARKS AND GARDENS

For formulating our conservation strategy, the predicted changes in soil moisture content for 2080 will be of

☐ GREAT concern ☐ SOME concern ☐ LITTLE or NO concern

Planning for 2080 in the light of the predicted changes in soil moisture content, we are likely to:

- ☐ Planting schemes: make minor adjustments
- ☐ Planting schemes: make major adjustments

Please describe briefly:

- ☐ Subsidence: increase monitoring
- ☐ Subsidence: problems likely; take remedial action
- ☐ Introduce irrigation
- ☐ Adjust current irrigation
- ☐ Adjust current water storage
- ☐ Introduce water storage / water harvesting
- ☐ Erosion: introduce / upgrade monitoring system
- ☐ Erosion: undertake remedial or protective works

Comments:

9. WATER TABLE EFFECTS
HEIGHT

Water table height is critical for Buildings, which can face problems of rising damp if the level increases, or subsidence if it falls. The stability of wetlands Archaeological sites depends on a high water table being maintained. For Parks and Gardens, water table height changes can affect plant physiology and health; at some sites the aquifer may be used as a water supply for irrigation.

The natural height of the water table is set primarily by winter rainfall in the catchment area. Climate changes are likely to affect levels in two ways:

- There may be rises due to increasing winter rainfall, though these are likely to be significantly offset by changes to runoff (particularly changes in soil moisture uptake as a result of long dry summers and dry autumns).
- Extended but very dry agricultural growing seasons, combined with demand from increasing local populations, are likely to increase demands on water from both the aquifers and the sources that feed them.

The North West is unlikely to experience meaningful changes, but in East Anglia – where agricultural pressure will be very strong – a significant drop in water table height must be anticipated. This has extremely important implications for the Fenlands and other low-lying areas.

BUILDINGS

For formulating our conservation strategy, the predicted changes in water table height for 2080 will be of

☐ GREAT concern ☐ SOME concern ☐ LITTLE or NO concern

Planning for 2080 in the light of the predicted changes in water table height, we are likely to:

☐ Monitor for and address changes in rising damp
☐ Subsidence: increase monitoring
☐ Subsidence: problems likely; take remedial action
☐ Other actions

Please describe briefly:

Comments:

ARCHAEOLOGY

For formulating our conservation strategy, the predicted changes in water table height for 2080 will be of

☐ GREAT concern ☐ SOME concern ☐ LITTLE or NO concern

Planning for 2080 in the light of the predicted changes in water table height, we are likely to:

☐ Increase monitoring
☐ Problems likely; take action

Please describe briefly:

☐ Subsidence: increase monitoring
☐ Subsidence: problems likely; take remedial action
☐ Introduce irrigation
☐ Upgrade irrigation
☐ Introduce water storage and irrigationPlease describe briefly: Comments:

Comments:

PARKS AND GARDENS

For formulating our conservation strategy, the predicted changes in water table height for 2080 will be of

☐ GREAT concern ☐ SOME concern ☐ LITTLE or NO concern

Planning for 2080 in the light of the predicted changes in water table height, we are likely to:

☐ Planting schemes: make minor adjustments
☐ Planting schemes: make major adjustments

Please describe briefly:

☐ Subsidence: increase monitoring
☐ Subsidence: problems likely; take remedial action
☐ Adjust current irrigation
☐ Introduce irrigation
☐ Adjust current water storage
☐ Introduce water storage / water harvesting

Comments:

10. WATER TABLE EFFECTS
CHEMICAL CHANGES

Built heritage already affected by rising damp from the water table may face accelerated decay if the salt content of the aquifer increases; related problems may beset Archaeological sites. Parks and Gardens may face alterations in growth patterns resulting from changes to aquifer nitrate concentrations.

RegIS *[see Appendix]* reports that, by 2080, summer sea water incursions are likely to be affecting rivers downstream, as well as coastal catchments.

Nitrate concentrations are predicted to change, although this change could be in either direction, depending on the evolution of farming practices. If these stay much the same as at present, but the water table drops (as is predicted for East Anglia), then nitrate concentrations will certainly rise. If however land management practices restrict the use of fertilizers, then we may see an overall decrease from the current concentrations.

BUILDINGS

For formulating our conservation strategy, the predicted changes in water table chemistry for 2080 will be of

☐ GREAT concern ☐ SOME concern ☐ LITTLE or NO concern

Planning for 2080 in the light of the predicted changes in water table chemistry, we are likely to:

☐ Rising damp: increase monitoring
☐ Rising damp: address changes

Please describe briefly:

☐ Other actions

Please describe briefly:

Comments:

ARCHAEOLOGY

For formulating our conservation strategy, the predicted changes in water table chemistry for 2080 will be of

☐ GREAT concern ☐ SOME concern ☐ LITTLE or NO concern

Planning for 2080 in the light of the predicted changes in water table chemistry, we are likely to:

☐ Increase monitoring
☐ Problems likely; take action

Please describe briefly:

☐ Introduce irrigation
☐ Upgrade irrigation
☐ Introduce water storage and irrigation

Comments:

PARKS AND GARDENS

For formulating our conservation strategy, the predicted changes in water table chemistry for 2080 will be of

☐ GREAT concern ☐ SOME concern ☐ LITTLE or NO concern

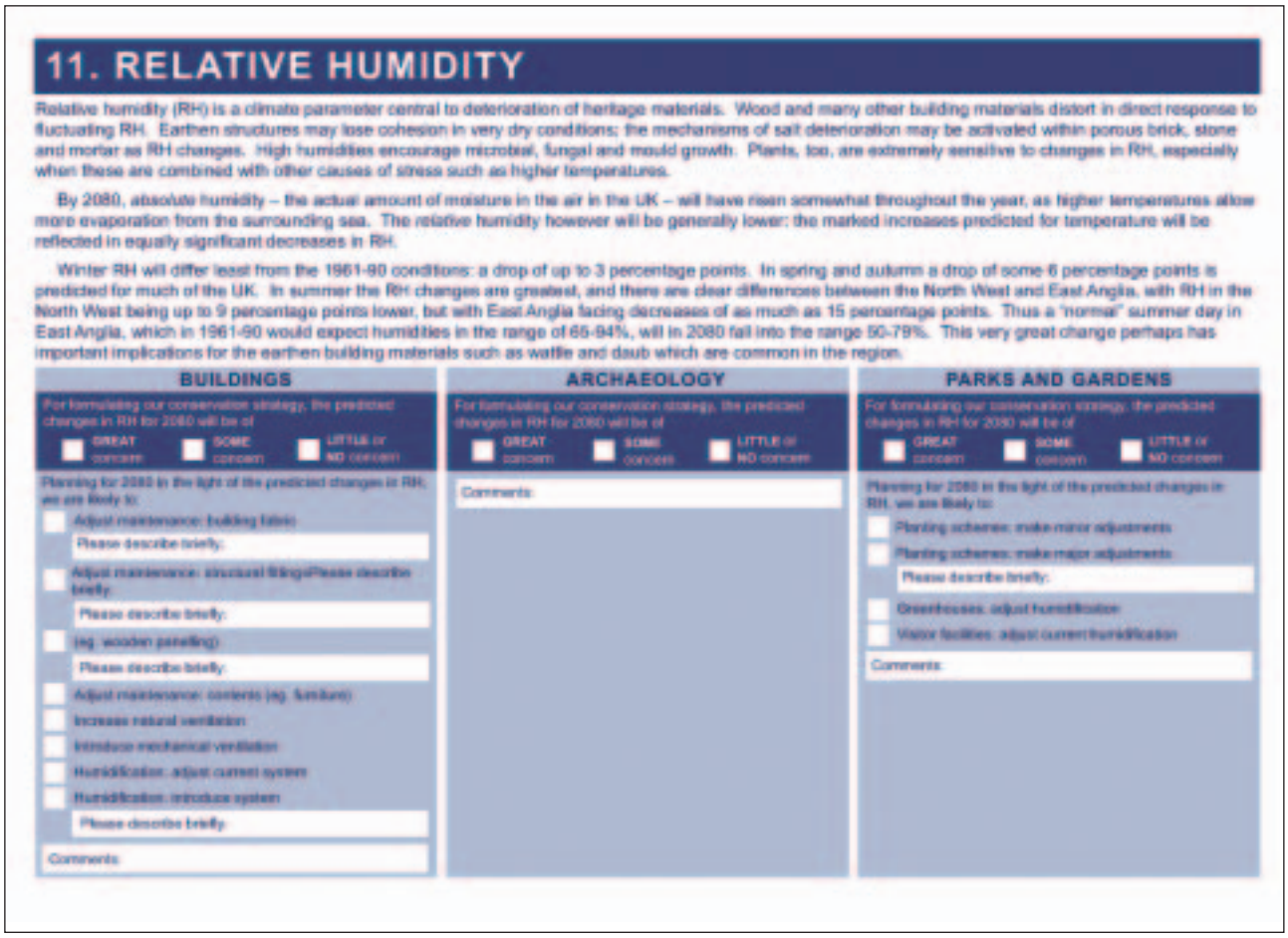
Planning for 2080 in the light of the predicted changes in water table chemistry, we are likely to:

☐ Planting schemes: make minor adjustments
☐ Planting schemes: make major adjustments

Please describe briefly:

☐ Adjust current water storage
☐ Introduce water storage / water harvesting

Comments:



11. RELATIVE HUMIDITY

Relative humidity (RH) is a climate parameter central to deterioration of heritage materials. Wood and many other building materials distort in direct response to fluctuating RH. Earthen structures may lose cohesion in very dry conditions; the mechanisms of salt deterioration may be activated within porous brick, stone and mortar as RH changes. High humidities encourage microbial, fungal and mould growth. Plants, too, are extremely sensitive to changes in RH, especially when these are combined with other causes of stress such as higher temperatures.

By 2080, absolute humidity – the actual amount of moisture in the air in the UK – will have risen somewhat throughout the year, as higher temperatures allow more evaporation from the surrounding sea. The relative humidity however will be generally lower: the marked increases predicted for temperature will be reflected in equally significant decreases in RH.

Winter RH will differ least from the 1961-90 conditions: a drop of up to 3 percentage points. In spring and autumn a drop of some 6 percentage points is predicted for much of the UK. In summer the RH changes are greatest, and there are clear differences between the North West and East Anglia, with RH in the North West being up to 9 percentage points lower, but with East Anglia facing decreases of as much as 15 percentage points. Thus a "normal" summer day in East Anglia, which in 1961-90 would expect humidities in the range of 65-94%, will in 2080 fall into the range 50-79%. This very great change perhaps has important implications for the earthen building materials such as wattle and daub which are common in the region.

BUILDINGS

For formulating our conservation strategy, the predicted changes in RH for 2080 will be of

☐ GREAT concern ☐ SOME concern ☐ LITTLE or NO concern

Planning for 2080 in the light of the predicted changes in RH, we are likely to:

☐ Adjust maintenance: building fabric

Please describe briefly:

☐ Adjust maintenance: structural fittings/Please describe briefly:

Please describe briefly:

☐ (eg. wooden panelling)

Please describe briefly:

☐ Adjust maintenance: contents (eg. furniture)

☐ Increase natural ventilation

☐ Introduce mechanical ventilation

☐ Humidification: adjust current system

☐ Humidification: introduce system

Please describe briefly:

Comments:

ARCHAEOLOGY

For formulating our conservation strategy, the predicted changes in RH for 2080 will be of

☐ GREAT concern ☐ SOME concern ☐ LITTLE or NO concern

Comments:

PARKS AND GARDENS

For formulating our conservation strategy, the predicted changes in RH for 2080 will be of

☐ GREAT concern ☐ SOME concern ☐ LITTLE or NO concern

Planning for 2080 in the light of the predicted changes in RH, we are likely to:

☐ Planting schemes: make minor adjustments

☐ Planting schemes: make major adjustments

Please describe briefly:

☐ Greenhouses: adjust humidification

☐ Visitor facilities: adjust current humidification

Comments:

12. WIND

Extreme winds, and especially gustiness, present many heritage risks, from uprooting of trees to structural damage to roofs.

Wind is a very localised phenomenon, and so the climate predictions are much less certain for this parameter than for temperature and rainfall. Nevertheless, it is possible to make some broad statements about likely wind conditions for the 2080s.

Daily average windspeeds, and the direction of prevailing winds, are unlikely to change significantly. Extreme wind events, however, are predicted to be different. *2-year-return winds (those which are so strong they are expected to occur only once every 2 years – see Question 4 for a more complete description of this terminology)* in winter in the North West will be some 8% stronger in 2080 than they were in 1961-90; in East Anglia the 2-year-return windspeed will rise by 6%. Summer 2-year-return events by contrast are predicted to be 6% weaker in both areas. In autumn East Anglia can again expect 2-year-return winds to be some 6% weaker, but in the North West they are predicted to be up to 4% stronger.

From these figures it is also possible to say that windy days will become more frequent and high winds stronger in winter; in the North West this will be true in autumn as well. At other times of year (and in East Anglia in autumn) there are expected to be fewer windy days.

It should be noted that these predictions to not take into account the possibility – which certainly cannot be discounted – that the destabilisation of climate may lead to much more dramatic wind events such as tornados.

BUILDINGS

For formulating our conservation strategy, the predicted changes in wind for 2080 will be of

☐ GREAT concern ☐ SOME concern ☐ LITTLE or NO concern

Planning for 2080 in the light of the predicted changes in wind, we are likely to:

☐ Adjust maintenance: building fabric

Please describe briefly:

☐ Adapt surroundings (eg. close planting)

Please describe briefly:

☐ Adjust high wind emergency plan

☐ Adopt high wind emergency plan

Comments:

ARCHAEOLOGY

For formulating our conservation strategy, the predicted changes in wind for 2080 will be of

☐ GREAT concern ☐ SOME concern ☐ LITTLE or NO concern

Comments:

PARKS AND GARDENS

For formulating our conservation strategy, the predicted changes in wind for 2080 will be of

☐ GREAT concern ☐ SOME concern ☐ LITTLE or NO concern

Planning for 2080 in the light of the predicted changes in wind, we are likely to:

☐ Planting schemes: make minor adjustments

☐ Planting schemes: make major adjustments

Please describe briefly:

☐ Adjust high wind emergency plan

☐ Adopt high wind emergency plan

Comments:

13. SOLAR RADIATION (CLOUD COVER)

Organic materials such as dyes and varnishes are susceptible to photodeterioration; in particular, the UV components of sunlight can accelerate or even instigate many types of deterioration. Solar radiation is rarely a direct problem for building materials themselves, but house contents and fittings often need protection. Sunlight exposure has wide-ranging implications for Parks and Gardens, of course, in greenhouse management as well as in planting and care regimes.

The degree of sunlight is determined by the degree of cloud cover. By 2080 cloud cover over the UK will have altered greatly from present conditions, with the Hadley Centre predicting that cover will generally decrease. In winter the North West may have 3% more cover (and less sunlight) than in 1961-90, but East Anglia in winter is more typical of the future conditions, with up to 3% less cloud cover in winter. In both areas spring will have up to 6% less cover; in autumn this is predicted to shrink still further, to 9% less cover than was measured in 1961-90.

The hot dry summers of the 2080s will have perhaps 15% less cloud cover than at present; in East Anglia, the predicted fall is 18%. This translates to levels of solar radiation rising from 150 watts per square metre in 1961-90 to 180 watts per square metre in 2080. There will however be no change in the relative levels of UV.

BUILDINGS

For formulating our conservation strategy, the predicted changes in sunlight levels for 2080 will be of

☐ GREAT concern ☐ SOME concern ☐ LITTLE or NO concern

Planning for 2080 in the light of the predicted changes in sunlight levels, we are likely to:

☐ Adjust maintenance: building fabric

Please describe briefly:

☐ Introduce light filters on windows

☐ Introduce light-blocking blinds, shutters etc.

Comments:

ARCHAEOLOGY

For formulating our conservation strategy, the predicted changes in sunlight levels for 2080 will be of

☐ GREAT concern ☐ SOME concern ☐ LITTLE or NO concern

Comments:

PARKS AND GARDENS

For formulating our conservation strategy, the predicted changes in sunlight levels for 2080 will be of

☐ GREAT concern ☐ SOME concern ☐ LITTLE or NO concern

Planning for 2080 in the light of the predicted changes in sunlight levels, we are likely to:

☐ Planting schemes: make minor adjustments

☐ Planting schemes: make major adjustments

Please describe briefly:

☐ Greenhouses: adjust shading

Please describe briefly:

Comments:

14. LIGHTNING / FIRE RISKS

Lightning ground strikes directly endanger tall building elements and specimen trees. As well, increases in ground strikes means increases in the risk of fire, especially given the much drier conditions predicted for the UK. Such risks may force reassessment of planting schemes and management policies, especially for meadow and grassland.

Although no change is predicted in lightning levels for summer or winter by the 2080s, the models do suggest an increase in lighting storms in autumn and spring. This will be of particular concern in autumn, which will follow the future hot dry summers: the combination greatly heightens the fire risk.

BUILDINGS

For formulating our conservation strategy, the predicted changes in lightning levels for 2080 will be of:

☐ GREAT concern ☐ SOME concern ☐ LITTLE or NO concern

Planning for 2080 in the light of the predicted changes in lightning levels, we are likely to:

☐ Adjust lightning conductors etc.

☐ Make structural changes

Please describe briefly:

☐ Adjust emergency preparedness plan

☐ Other

Please describe briefly:

Comments:

ARCHAEOLOGY

For formulating our conservation strategy, the predicted changes in lightning levels for 2080 will be of:

☐ GREAT concern ☐ SOME concern ☐ LITTLE or NO concern

Comments:

PARKS AND GARDENS

For formulating our conservation strategy, the predicted changes in lightning levels for 2080 will be of:

☐ GREAT concern ☐ SOME concern ☐ LITTLE or NO concern

Planning for 2080 in the light of the predicted changes in lightning levels, we are likely to:

☐ Planting schemes: make minor adjustments

☐ Planting schemes: make major adjustments

Please describe briefly:

☐ Adjust maintenance of meadows etc.

Please describe briefly:

☐ Adjust emergency preparedness plan

Comments:

15. VEGETATION
PLANT PHYSIOLOGY

Changes in the growth patterns of plants may require changes to maintenance of Parks and Gardens, especially of formal plantings and finely-balanced borders. For Archaeological sites, overplanting may need to be monitored for signs of intrusive change such as deepening of roots. Similarly, planting which may begin to endanger Building walls, roofs, or foundations may require adaptation.

Physiological alterations will be provoked mainly by changes in temperature and soil moisture content, and in the length of the growing season. By 2080 this will have increased in the North West by 90 days, and in East Anglia by 100 days – that is, by more than three months. Dry summers are likely to stimulate deeper root penetration. Changing temperatures and moisture availability patterns may also affect seed-setting and germination times.

BUILDINGS

For formulating our conservation strategy, the predicted changes in plant growth for 2080 will be of:

☐ GREAT concern ☐ SOME concern ☐ LITTLE or NO concern

Planning for 2080 in the light of the predicted changes in plant growth, we are likely to:

☐ Adapt close planting

Please describe briefly:

☐ Remove close planting

Comments:

ARCHAEOLOGY

For formulating our conservation strategy, the predicted changes in plant growth for 2080 will be of:

☐ GREAT concern ☐ SOME concern ☐ LITTLE or NO concern

Planning for 2080 in the light of the predicted changes in plant growth, we are likely to:

☐ Monitor root growth of overplanting

☐ Adapt overplanting

Please describe briefly:

☐ Remove overplanting

Comments:

PARKS AND GARDENS

For formulating our conservation strategy, the predicted changes in plant growth for 2080 will be of:

☐ GREAT concern ☐ SOME concern ☐ LITTLE or NO concern

Planning for 2080 in the light of the predicted changes in plant growth, we are likely to:

☐ Planting schemes: make minor adjustments

☐ Planting schemes: make major adjustments

Please describe briefly:

Comments:

16. VEGETATION
PLANT DISTRIBUTION

The period of climate change being considered in this study, 2002-2080, is well within the life-span of many of the core species (such as oaks and beeches). As the "typical" climate changes, many plants familiar to the English landscape will find conditions progressively more hostile to them, while other previously marginal species will find it easier to establish themselves.

The pressures of changing climate will apply additional stress to those species (and individual plants) which are already struggling to cope with problems from other sources such as pollution and local land use patterns. Historic parks and gardens may find it increasingly problematic to maintain some of the core plants in acceptable condition.

Ecosystem changes are complex to study, but RegIS (see Appendix) has concluded that the North West will face significant alterations, especially to Arctic-Alpine habitats. It is clear, however, that indirect climate change problems – such as limited water supplies and increasing problems from pests and diseases – are likely to have more marked effects on plant distribution patterns than will the actual changes in temperature, humidity, sunlight and so forth.

BUILDINGS

For formulating our conservation strategy, the predicted changes in plant distribution for 2080 will be of

☐ GREAT concern ☐ SOME concern ☐ LITTLE or NO concern

Comments:

ARCHAEOLOGY

For formulating our conservation strategy, the predicted changes in plant distribution for 2080 will be of

☐ GREAT concern ☐ SOME concern ☐ LITTLE or NO concern

Comments:

PARKS AND GARDENS

For formulating our conservation strategy, the predicted changes in plant distribution for 2080 will be of

☐ GREAT concern ☐ SOME concern ☐ LITTLE or NO concern

Planning for 2080 in the light of the predicted changes in plant distribution, we are likely to:

☐ Planting schemes: make minor adjustments

☐ Planting schemes: make major adjustments

Please describe briefly:

☐ Adjust special care regimes

Please describe briefly:

☐ Adopt special care regimes

Please describe briefly:

Comments:

17. PESTS AND DISEASES

Fungal and insect pests can seriously damage Building structures – especially timber – and cause decay of organic Archaeological materials.

In the past, the UK has benefited from winters cold enough to kill off pests (or at least induce dormancy). With cold winters predicted to be a great rarity by 2080, many established pests and diseases will become increasingly problematic, and new varieties are likely to be able to gain a foothold. Stringent monitoring and fast and flexible reaction strategies may be required to restrict outbreaks of exotic pests such as termites.

BUILDINGS

For formulating our conservation strategy, the predicted changes in pests and diseases for 2080 will be of

☐ GREAT concern ☐ SOME concern ☐ LITTLE or NO concern

Planning for 2080 in the light of the predicted changes in pests and diseases, we are likely to:

☐ Adjust monitoring regime

☐ Adopt monitoring regime

☐ Make structural adjustments (eg. termite proofing)

Please describe briefly:

☐ Undertake integrated pest management (current problems likely to be exacerbated)

☐ Import of materials: adjust policy

☐ Import of materials: adopt policy

Comments:

ARCHAEOLOGY

For formulating our conservation strategy, the predicted changes in pests and diseases for 2080 will be of

☐ GREAT concern ☐ SOME concern ☐ LITTLE or NO concern

Planning for 2080 in the light of the predicted changes in pests and diseases, we are likely to:

☐ Adjust monitoring regime

☐ Introduce monitoring regime

Comments:

PARKS AND GARDENS

For formulating our conservation strategy, the predicted changes in pests and diseases for 2080 will be of

☐ GREAT concern ☐ SOME concern ☐ LITTLE or NO concern

Planning for 2080 in the light of the predicted changes in pests and diseases, we are likely to:

☐ Planting schemes: make minor adjustments

☐ Planting schemes: make major adjustments

Please describe briefly:

☐ Make structural adjustments (eg. termite proofing)

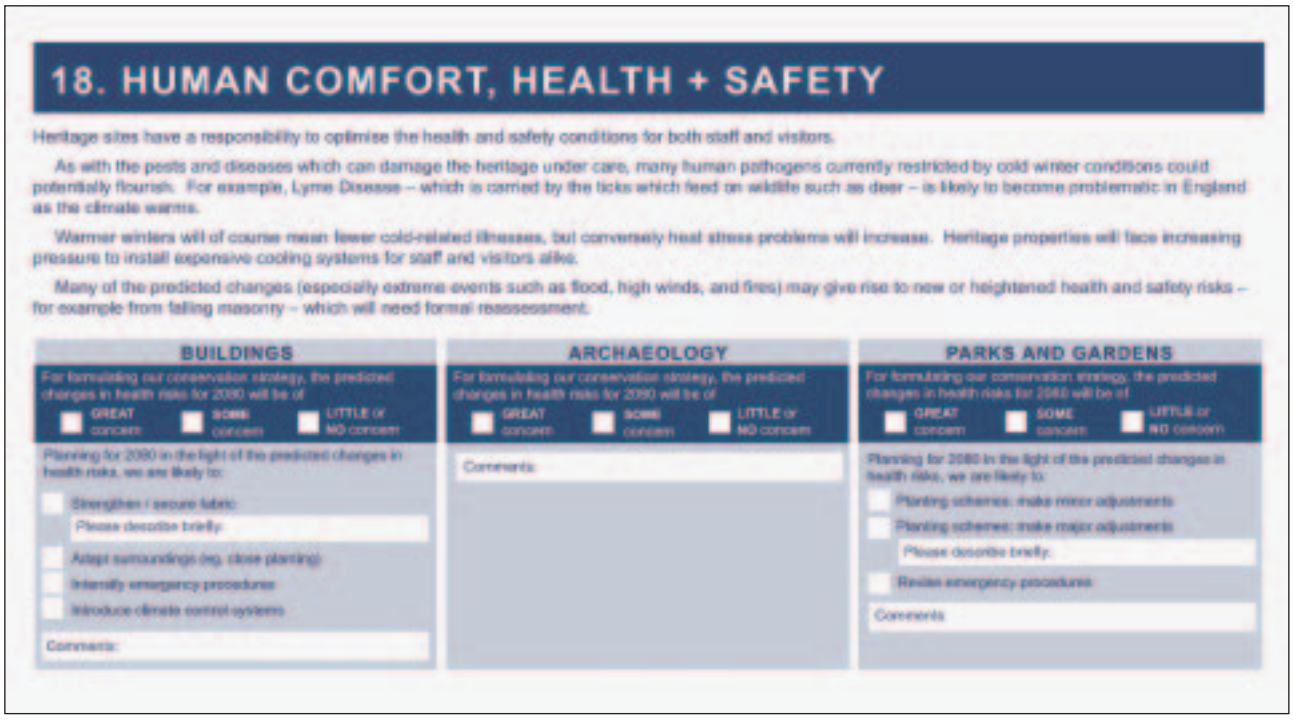
Please describe briefly:

☐ Undertake integrated pest management (current problems likely to be exacerbated)

☐ Import of materials: adjust policy

☐ Import of materials: adopt policy

Comments:



18. HUMAN COMFORT, HEALTH + SAFETY

Heritage sites have a responsibility to optimise the health and safety conditions for both staff and visitors.

As with the pests and diseases which can damage the heritage under care, many human pathogens currently restricted by cold winter conditions could potentially flourish. For example, Lyme Disease – which is carried by the ticks which feed on wildlife such as deer – is likely to become problematic in England as the climate warms.

Warmer winters will of course mean fewer cold-related illnesses, but conversely heat stress problems will increase. Heritage properties will face increasing pressure to install expensive cooling systems for staff and visitors alike.

Many of the predicted changes (especially extreme events such as flood, high winds, and fires) may give rise to new or heightened health and safety risks – for example from falling masonry – which will need formal reassessment.

BUILDINGS

For formulating our conservation strategy, the predicted changes in health risks for 2080 will be of

☐ GREAT concern ☐ SOME concern ☐ LITTLE or NO concern

Planning for 2080 in the light of the predicted changes in health risks, we are likely to:

☐ Strengthen / secure fabric

Please describe briefly:

☐ Adapt surroundings (eg. close planting)

☐ Intensify emergency procedures

☐ Introduce climate control systems

Comments:

ARCHAEOLOGY

For formulating our conservation strategy, the predicted changes in health risks for 2080 will be of

☐ GREAT concern ☐ SOME concern ☐ LITTLE or NO concern

Comments:

PARKS AND GARDENS

For formulating our conservation strategy, the predicted changes in health risks for 2080 will be of

☐ GREAT concern ☐ SOME concern ☐ LITTLE or NO concern

Planning for 2080 in the light of the predicted changes in health risks, we are likely to:

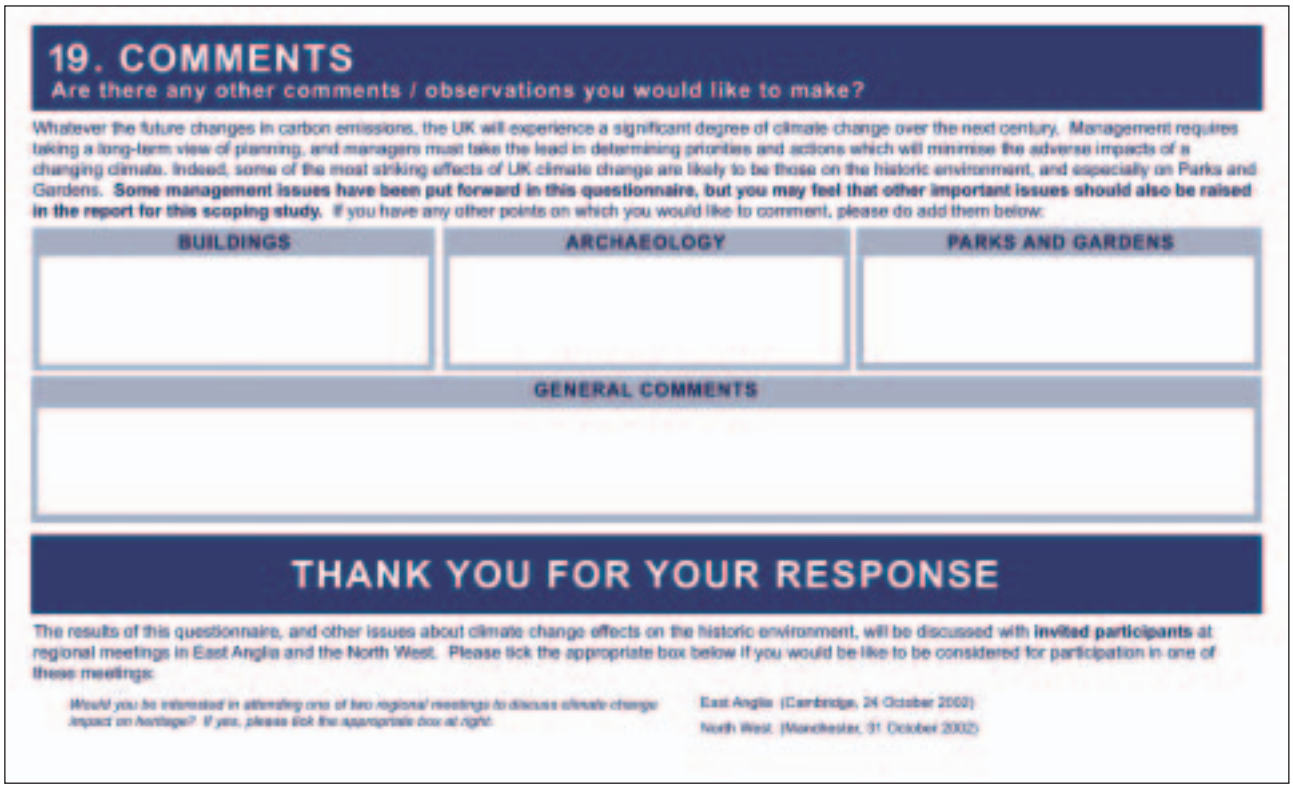
☐ Planting schemes: make minor adjustments

☐ Planting schemes: make major adjustments

Please describe briefly:

☐ Revise emergency procedures

Comments:



19. COMMENTS

Are there any other comments / observations you would like to make?

Whatever the future changes in carbon emissions, the UK will experience a significant degree of climate change over the next century. Management requires taking a long-term view of planning, and managers must take the lead in determining priorities and actions which will minimise the adverse impacts of a changing climate. Indeed, some of the most striking effects of UK climate change are likely to be those on the historic environment, and especially on Parks and Gardens. **Some management issues have been put forward in this questionnaire, but you may feel that other important issues should also be raised in the report for this scoping study.** If you have any other points on which you would like to comment, please do add them below:

BUILDINGS

ARCHAEOLOGY

PARKS AND GARDENS

GENERAL COMMENTS

THANK YOU FOR YOUR RESPONSE

The results of this questionnaire, and other issues about climate change effects on the historic environment, will be discussed with **invited participants** at regional meetings in East Anglia and the North West. Please tick the appropriate box below if you would be like to be considered for participation in one of these meetings:

Would you be interested in attending one of two regional meetings to discuss climate change impact on heritage? If yes, please tick the appropriate box at right:

East Anglia (Cambridge, 24 October 2002)

North West (Manchester, 31 October 2002)

APPENDIX: DATA SOURCES

CLIMATE SCENARIOS

Except where otherwise stated, the climate scenarios used in this questionnaire are taken from "Climate Change Scenarios for the United Kingdom: The UKCIP02 Scientific Report", which may be found at www.ukcip.org.uk/scenarios/sci_report/sci_report.html.

Planning and management require assessing the worst-case scenarios (for example, the magnitude of the heaviest rain showers, rather than of the average daily rainfall). Except where otherwise stated, however, the values given here are the mean predictions. Mean values are those most likely to occur, but there is still a strong possibility that the eventual outcome will prove higher than the mean. Therefore we have used the High Emissions and Medium-High Emissions scenarios, which project the most extreme changes in the UK climate.

The figures given are the maxima of the range of mean values predicted for East Anglia and the North West, for the High Emissions and Medium-High Emissions scenarios.

Whatever the future carbon emissions might prove to be, emissions to date have committed the world to some degree of climate change over the next century. It is expected that changes over the next 20 years in the UK will be reasonably steady, with predictions looking much the same whatever the emission scenario. After this the predicted patterns begin to diverge, as differences in atmospheric carbon content from different scenarios become more acute.

The scenarios presented here are those for 80 years hence (the 2080s). Predicted values are presented by comparing them to the measured value for the period 1961-1990, the UKCIP02 baseline (these figures therefore do already include some limited climate change).

The particular case of urban temperatures is discussed in H. M. Graves and M. C. Phillipson, Potential Implications of Climate Change in the Built Environment, FBE Report 2, 2000, which can be obtained through the Building Research Establishment bookshop www.brebookshop.com; the temperature increase for central London is taken from this report.

OTHER PREDICTIONS

Information about land use, water use and aquifers was taken from the RegIS report (Regional Climate Change Impact and Response Studies in East Anglia and North West England) which is available from the UKCIP website at www.ukcip.org.uk/ (under Climate Impacts Research / Integrated assessment (REGIS)). Information about vegetation changes also comes primarily from the RegIS report.

Storm surge heights in East Anglia and the North West were taken from R. A. Flather and J. A. Smith, *First estimates of changes in extreme storm surge elevations due to the doubling of* CO_2, Global Atmospheric Ocean Systems 6:193-208, 1998.

Rainfall extremes were taken from P. D. Jones and P. A. Reid, *Assessing future changes in extreme precipitation over Britain using regional climate model integrations*, International Journal of Climatology 21:1337-135, 2001.

List of respondents

Professor Jonathan Ashley-Smith, former Head of Conservation, Victoria & Albert Museum

Professor John Ashurst, Ingram Consultancy

Kim Auston, Regional Landscape Architect, English Heritage – South West

Brian Ayers, Norfolk County Council Archaeology and Environment

Baberg District Council, Baberg District Council Planning (Control) Division

Chris Bally, Regional Landscape Manager English Heritage – South West

Peter Bates, EPSRC

Professor Mike Batty, CASA, University College London

Keith Benjamin, English Heritage, GIS and Mapping Team

Drew Bennellick, Regional Landscape Architect, English Heritage – London

Ian Bond, Executive Manager, West Lancashire District Council, Planning and Development Services

Professor Bill Bordass, William Bordass Associates

Professor Peter Brimblecombe, University of East Anglia

Julius Bryant, Victoria and Albert Museum

David G Buckley, County Archaeologist, Essex County Council Planning Division

Mike Calnan, Head of Gardens, The National Trust

Carlisle City Council, Local Plans and Conservation

Sharon Cather, Conservation of Wall Painting Department, Courtauld Institute of Art

Chester City Council, Chester City Council, Conservation Officers

Brian Clarke, Regional Landscape Manager, English Heritage – London

Richenda Connell, UK Climate Impact Programme (UKCIP)

Jane Corcoran, MoLAS (Museum of London Archaeological Service)

Mike Corfield, former Chief Scientist, English Heritage

John Darlington, Lancashire County Archaeological Service

Dominique de Moulins, South East Regional Adviser, English Heritage

Martin Duncan, Head Gardener, Audley End, English Heritage

Eden District Council

John Ette, English Heritage

Graham Fairclough, Head of Monument Protection, English Heritage

John Fidler, Director of Conservation, English Heritage

Professor Mirjam Foot, School of Library, Archive and Information Studies, UCL

John Fullard, Head of Department, English Heritage, GIS and Mapping Team

Andrew Gayton, Historic Buildings Officer, Breckland District Council

Debs Goodenough, Head Gardener, Osbourne House, English Heritage

Kuni Gough, Regional Landscape Manager, English Heritage – Midlands

Robert Gowing, Building Conservation and Research Team, English Heritage

David Gregory, National Museum of Denmark

Professor Michael Grubb, Centre for Environmental Policy and Technology, Imperial College

David Gurney, Norfolk County Council, Archaeology and Environment

Mike Harley, Climate Change Adviser, English Nature

Paul Harrigan, Head Gardener, Belsay Hall, English Heritage

Tom Hassall, ICOMOS UK

Fran Hegyi, Regional Policy Adviser, Museums, Libraries and Archives Council

Mike Hervey, National Trust

Virginia Hinze, Regional Landscape Architect, English Heritage – South East

John Hodgson, Archaeologist, Lake District National Park Authority

Philip Holdsworth, County Archaeologist, Cumbria County Council, Economy & Environment

John Holmes, Head of Research and Development, Environment Agency

Professor Michael Hulme, Tyndall Centre for Climatic Change Research, University of East Anglia

Professor Lord Julian Hunt, University College London

Marylla Hunt, Historic Gardens, Environmental Design Associates

Jacqui Huntley, North East Regional Advisor, English Heritage

Ipswich City Council

Steven Jardine, Cheshire County Council

Rob Jarman, Head of Environmental Practices, The National Trust

Dr Geoff Jenkins, Hadley Centre for Climate Prediction and Research, Met Office

Henk Kars, Head of Dept. of Geoarchaeology, Vrije Universiteit, Amsterdam

Chris Kitching, formerly The National Archives

Barry Knight, British Library

Michael Knights, Norfolk County Council, Building Conservation

George Lambrick, Council for British Archaeology

Lancaster City Council, Listed Buildings

Christine Leveson, St. Edmundsbury Borough Council, Department of Planning and Transportation

Julian Limentani, Cathedral Architects Association

Liverpool City Council, Conservation Team

Professor Peter Loveland, Cranfield University

Ed Maltby, Royal Holloway College

Manchester City Council, Planning Division

Dr Vanessa Marshall, formerly National Preservation Office

Bill Martin, Building Conservation and Research Team, English Heritage

Ingval Maxwell, Historic Scotland

Jacqui McGlade, Professor of Mathematics, University College London

Robina McNeil, Greater Manchester Archaeological Unit, Greater Manchester City Council

Mid-Suffolk District Council

Rick Minter, Countryside Agency

Lisa Moffett, West Midlands Regional Adviser, English Heritage

M Morris, City Archaeologist, Chester City Council

Peter Murphy, English Heritage

Taryn Nixon, MoLAS (Museum of London Archaeological Service)

Norfolk County Council, Buildings Conservation Team

North Norfolk District Council, Cromer Offices

Norwich City Council

Adrian Olivier, English Heritage

Dr Tim Padfield, formerly National Museum of Denmark

Ian Panter, Yorkshire Regional Adviser, English Heritage

Pendle Borough Council, Conservation and Environmental Improvements Officer

Professor Clifford Price, Institute of Archaeology, University College London

Jez Reeve, English Heritage Greater London Archaeology Advisory Service

Ben Robinson, Archaeological Officer, Peterborough City Council, Planning Department

Ben Rowland, English Heritage

Sarah Rutherford, Head of Designed Landscape, English Heritage

Salford City Council Planning Division

Dr Nigel Seeley, formerly National Trust (deceased)

Chris Shearlock, Policy and Research Manager, Sustainability Northwest

Judith Shepherd, Blackburn with Darwen Borough Council

Jane Sidell, London Regional Adviser, English Heritage

Professor Peter Smith, Sustainable Futures Committee, RIBA

Sue Stallibrass, North West Regional Science Adviser, English Heritage

Sarah Staniforth, The National Trust

Elizabeth Stazicker, Head of Heritage, Cambridgeshire County Council, Heritage Service

Professor Phil Steadman, The Bartlett School of Graduate Studies, UCL

Vanessa Straker, South West Regional Adviser, English Heritage

Suffolk Coastal District Council, Grants Listed Building Suffolk County Council

David Thackeray, Director of Archaeology, The National Trust

Caroline Thackeray, The National Trust

Andy Thomas, Senior Archaeologist, Cambridgeshire County Council, County Archaeology Office

A Tindall, Principal Conservation Officer (Archaeology), Cheshire County Council, Environmental Planning

David Tomback, Property Adviser, English Heritage

Steve Trow, Countryside Policy, English Heritage

Andy Turner, South East Regional Landscape Manager, English Heritage

Robert van der Noort, Senior Lecturer in Archaeology, University of Exeter

Dr David Viner, Climate Research Unit, University of East Anglia

Keith Wade, Archaeological Service Manager, Suffolk County Council, Environment and Transport Dept.

Tim Walker, Midlands Regional Landscape Manager, English Heritage

Dr Merlyn Waterson, formerly The National Trust

John Watkins, Head of Gardens & Landscape, English Heritage

Waveney District Council, Planning Department

Paul White, Broadland District Council

Jennifer White, Senior Landscape Adviser, English Heritage

Richard Whittaker, Chief Quantity Surveyor, English Heritage

Rob Whytehead, Greater London Archaeology Advisory Service, English Heritage

Diana Wilkins, Global Atmosphere Division, Defra

Jim Williams, West Midlands Regional Adviser, English Heritage

Dr Tom Williamson, History Department, University of East Anglia

Mick Wilson, North Regional Landscape Manager, English Heritage

Andy Wimble, North Regional Landscape Architect, English Heritage

Peter Winsor, Museums, Libraries and Archives Council

Philip Wise, Colchester Borough Council, Museum Service

Corinna Woodall, Policy Research Officer, Heritage Lottery Fund

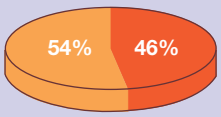
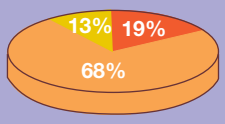
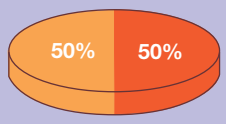
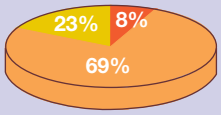
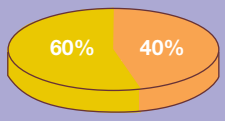
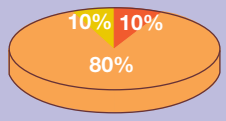
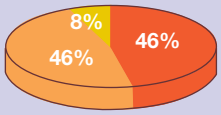
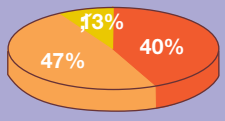
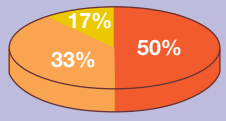
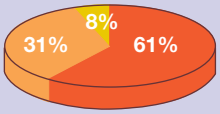
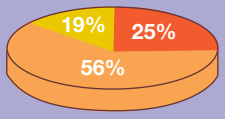
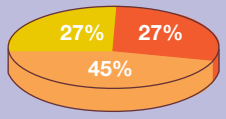
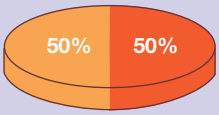
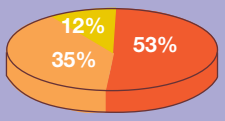
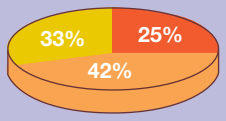
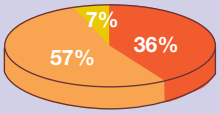
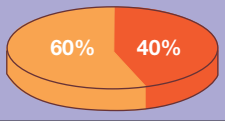
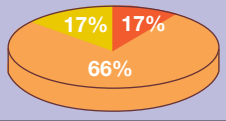
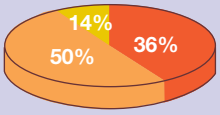
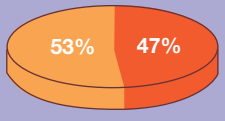
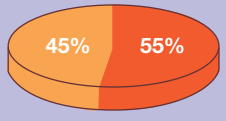
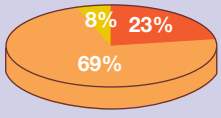
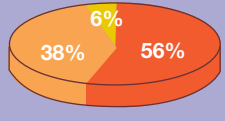
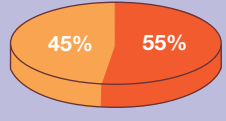
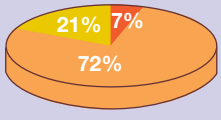
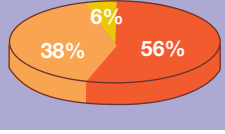
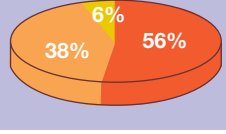
Michael Wright, English Heritage, GIS and Mapping Team

Amber Xavier Rowe, Head of Collections Management, English Heritage

Results of Questionnaire

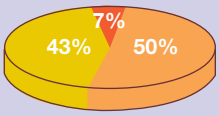
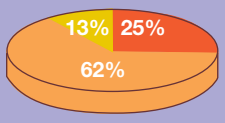
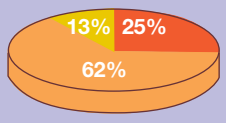
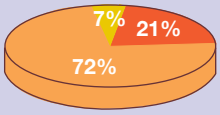
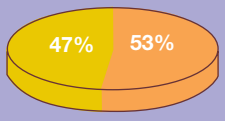
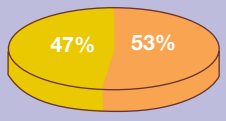
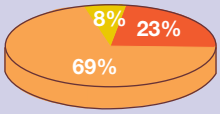
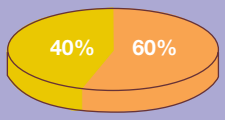
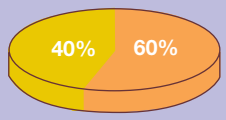
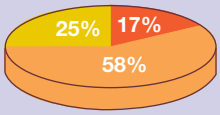
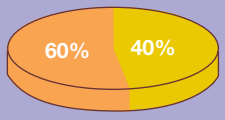
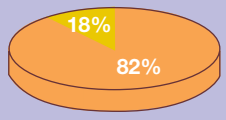
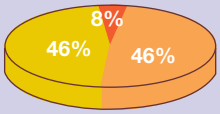
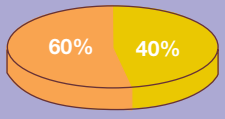
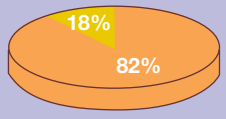
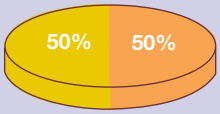
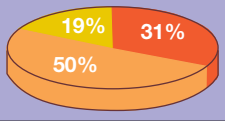
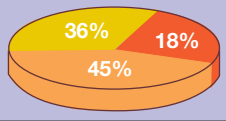
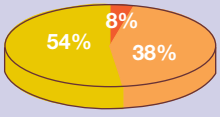
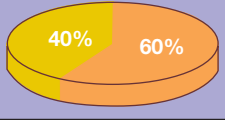
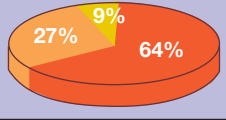
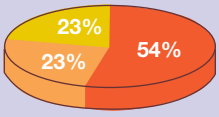
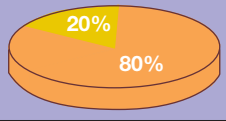
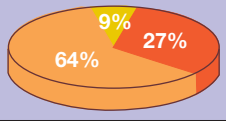
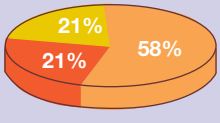
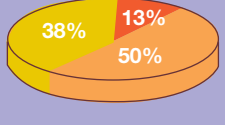
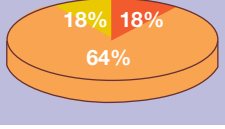
The responses to the three different levels of concern for each question are expressed below as a percentage of the total response for buildings, archaeology, and parks and gardens.

Key Great concern Some concern Little/No concern

Question	Buildings & Contents	Buried Archaeology	Parks, Gardens, Landscapes
1 Temperature: Seasonal			
2 Temperature: Diurnal			
3 Rainfall: Seasonal			
4 Rainfall: Extreme			
5 Sea Level Rise and Coastal Loss			
6 Storm Surge			
7 Fluvial and Run-off Flooding			
8 Soil Moisture Content			
9 Water Table Height			

Results of Questionnaire

Key Great concern Some concern Little/No concern

Question	Buildings & Contents	Buried Archaeology	Parks, Gardens, Landscapes
10 Water Table Chemistry			
11 Relative Humidity			
12 Wind			
13 Solar Radiation (Cloud Cover)			
14 Lightning/ Fire Risk			
15 Vegetation: Plant Physiology			
16 Vegetation Plant Distribution			
17 Pests and Diseases			
18 Human Comfort Health & Safety			

Annex 2
Site visits

SITE LOCATION		SITE MANAGEMENT	SITE CHARACTERISTICS	SITE TYPE A=Archaeology B=Buildings P=Parks/Gardens
Audley End	East of England	English Heritage	Large stately house with extensive gardens	B, P
Beeston Castle	North West	English Heritage	Ruined castle on steep hilltop site	A, B, P
Birdoss Wald	North West	English Heritage/ Local Council	One of a series of sites on Hadrian's Wall	A, B, P
Birkenhead Park	North West	Metropolitan Borough of Wirral	Extensive Victorian Park in metropolitan area	P, B
Brough Castle	North West	English Heritage	Ruined castle on steep eroding hill	A, B
Broughton Castle	North West	English Heritage	Ruined castle by river	A, B
Chester Castle	North West	English Heritage	Medieval tower and later elements	B
Chester Roman amphitheatre	North West	English Heritage	Partially excavated site in centre of Chester, prone to flooding	A
Dunwich	East of England	N/A	Medieval town largely lost to encroaching sea	A, B
Flag Fen	East of England	Flag Fen Bronze Age Centre	Archaeological park built over extensive Bronze Age deposits; wetland site	A
Furness Abbey	North West	English Heritage	Ruins of a large abbey on a peninsula	A, B
Lanercost Priory	North West	English Heritage	Ruined priory in town by river	A, B
Languard Fort	East of England	English Heritage/ Languard Fort Trust	Largely Victorian fortification at mouth of Felixstowe harbour	B
Poltross Burn	North West	English Heritage	One of a series of sites on Hadrian's Wall	A, B
Stott Park Bobbin Mill	North West	English Heritage	Preserved factory complex, in woodland that was once coppiced	B, P
Sutton Hoo	East of England	National Trust	Hilltop barrow site with sandy soil; riverside site on inlet of sea	A
Walton Old Rectory	North West	English Heritage	Ruined 13th century complex in a small town	A, B

Annex 3
Regional workshops

List of participants

Nick Balaam, former East of England Assistant Regional Director, English Heritage

Professor May Cassar, Centre for Sustainable Heritage, University College London

Mike Corfield, former Chief Scientist, English Heritage

Sarah Dunnicliffe, Caseworker for Suffolk, English Heritage

Jacqui Huntley, North East Regional Scientific Adviser, English Heritage

Leslie-Ann Mather, Bedfordshire District Council

Peter Murphy, former East of England Regional Scientific Adviser, English Heritage

Judith Nelson, North West Land Use Planner, English Heritage

John Oxley, Archaeologist, York City Council

Ian Panter, Yorkshire Regional Scientific Adviser, English Heritage

Sebastian Payne, Chief Scientist, English Heritage

Robyn Pender, former Researcher, Centre for Sustainable Heritage, University College London

Colin Pendleton, County SMR Officer, Ipswich City Council

Francis Pryor, Archaeologist (Flag Fen) and President, Council of British Archaeologists

Ian Smith, English Heritage, Yorkshire

Jennifer White, Senior Landscape Adviser, English Heritage

Steve Williams, South East Land Use Planner, English Heritage

Andrea Winn, Assistant Curator, Museum of Science and Industry in Manchester

Handouts for breakout sessions

UCL

Centre for Sustainable Heritage

Climate Change and the Historic Environment
Regional Meetings

Breakout Groups

Background Information

Climate and Heritage Preservation

Unless otherwise stated, comparisons are with the measured climate of the UK for the period 1961 to 1990.

Coastal Loss: Sea Level Rise

- Net sea level rise by 2080 will be around 70cm in the North West, and 87 cm in East Anglia.
- Current 50-year-return storm surges will occur more than yearly. The 50-year-return events predicted for 2080 in the North West will increase by 60cm to 2.35m; in East Anglia, the increase will be more than 50%, from 2.8m to 4.3m.

Flooding

- Heavy rainfalls become both stronger and more common in winter and spring. 50-year-return rainfalls increase from 68mm to 76mmin the North West, and from 68mm to 88mm in East Anglia.
- Fluvial and run-off flooding: all catchments currently at any risk can expect problems to worsen significantly.
- Drying of soils between showers, and in dry summers, will exacerbate run-off problems.
- Built-up areas will be particularly susceptible to run-off flooding.
- Coastal storm surge: 50-year-return surges increase from 1.75m in the North West to 2.35m, and from 2.8m to 4.3m in East Anglia.

Water Shortages

- Summers are likely to become drier, especially in the South East: one summer in ten is predicted to have less than a quarter of the summer average rainfalls measured in the 1961-90 period.
- Surface drying in summer will mean that the autumn rainfalls will take longer to restore soil moisture content.

- Strong winter rainfalls are predicted, but these will be somewhat offset by the jigher temperatures and lower relative humidities, which lead to increased evaporation.
- The water table is likely to be adversely affected both by the uptake problems already mentioned, and also by losses to agriculture in summer, especially in East Anglia.

Storminess (Extreme Winds and Rainfall)

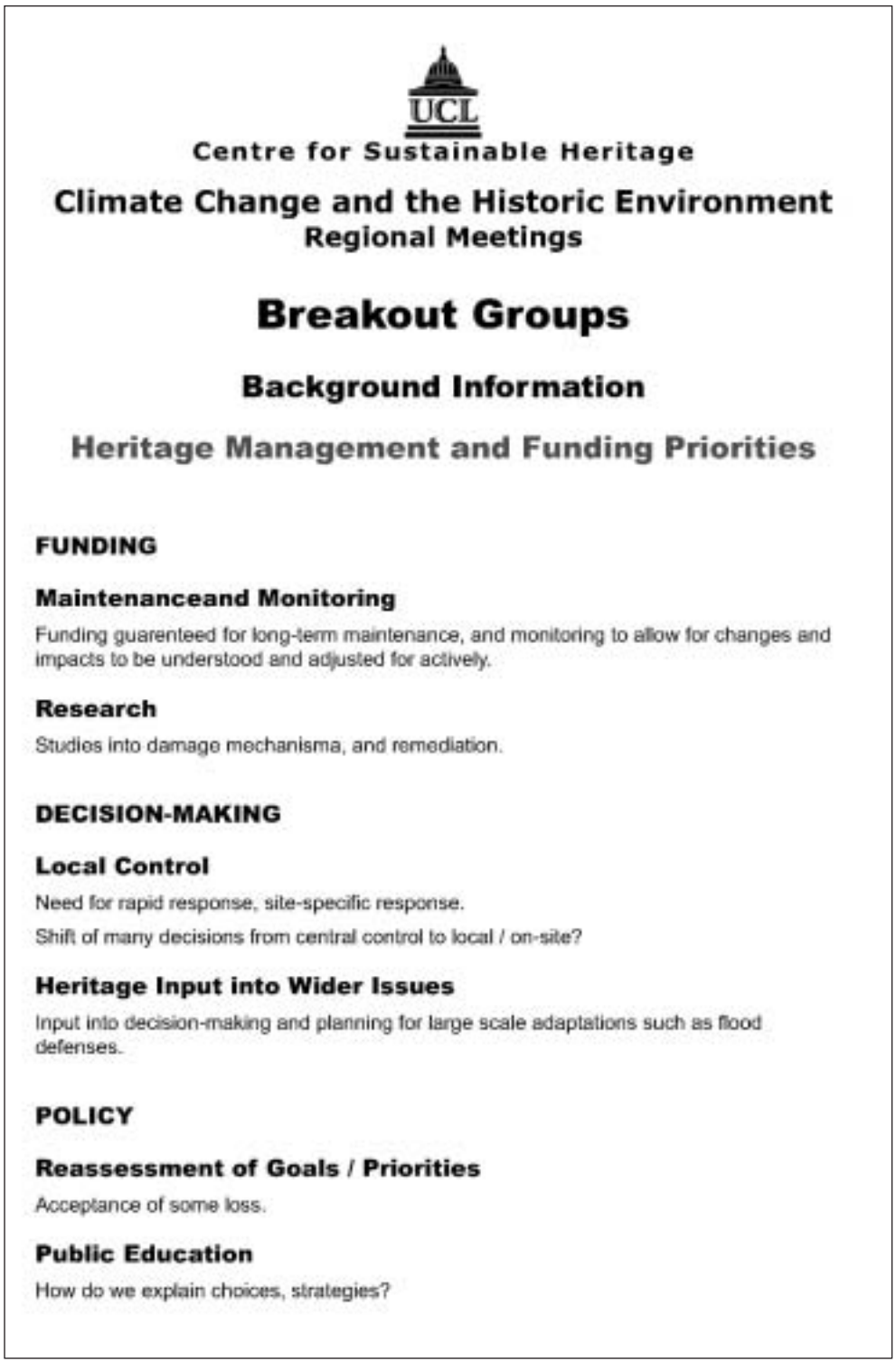
- Heavy rainfalls become both stronger and more common in winter and spring. 50-year-return rainfalls increase from 68mm to 76mmin the North West, and from 68mm to 88mm in East Anglia.
- Windiness is very hard to predict, since it is strongly governed by local conditions (future UK climate models will be concerntrating on improving wind predictions). There is however a strong expectation that strong winds will indeed become more frequent: storminess is a very likely result of rapid change, which destabilises weather patterns.
- Electrical storms are predicted to increase in autumn.

Temperature and Humidity

- Summer: most will be warmer than the "unusually hot" summer of 1995 (which was 3.4˚C hotter than usual). Extremely warm days (those in the upper 10% of temperatures measured for the season) will beome more common: 30 more days per season than at present . They will also be hotter: at present, an "extremely warm" summer day is warmer than 23˚C, but by 2080 it would need to be warmer than 31˚C to be so defined.
- Winter: more than half will be warmer than the mild winters of 1989/90 and 1994/95. Frosts will be rare in all but elevated areas, and snow will virtually disappear from the UK. Currently an "extremely warm" winter day is warmer than 11˚C; by 2080 this would be warmer than 14˚C, and such days would occur some 16 more days per season.
- Temperature problems will be particularly acute in built-up areas, which retain more heat overnight.
- The absolute humidity, which is largely governed by sea evaporation, is predcited to rise somewhat, but – with the rapid rise in temperature – the RH will generally be significantly lower.
- The strongest changes in RH are predicted for summer, with East Anglia in particular facing a decrease of as much as 15 percentage points.

Pests + Diseases Human Comfort, Health and Safety

- Changing conditions may exacerbate current pests, and / or allow new pests to gain a foothold. Dormant risks may be activated.
- Visitor numbers are likely to increase.
- Working conditions may become more challenging.
- Heating will become less necessary, but cooling is likely to become an important issue.



UCL

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Background Information

Heritage Management and Funding Priorities

FUNDING

Maintenanceand Monitoring

Funding guarenteed for long-term maintenance, and monitoring to allow for changes and impacts to be understood and adjusted for actively.

Research

Studies into damage mechanisma, and remediation.

DECISION-MAKING

Local Control

Need for rapid response, site-specific response.

Shift of many decisions from central control to local / on-site?

Heritage Input into Wider Issues

Input into decision-making and planning for large scale adaptations such as flood defenses.

POLICY

Reassessment of Goals / Priorities

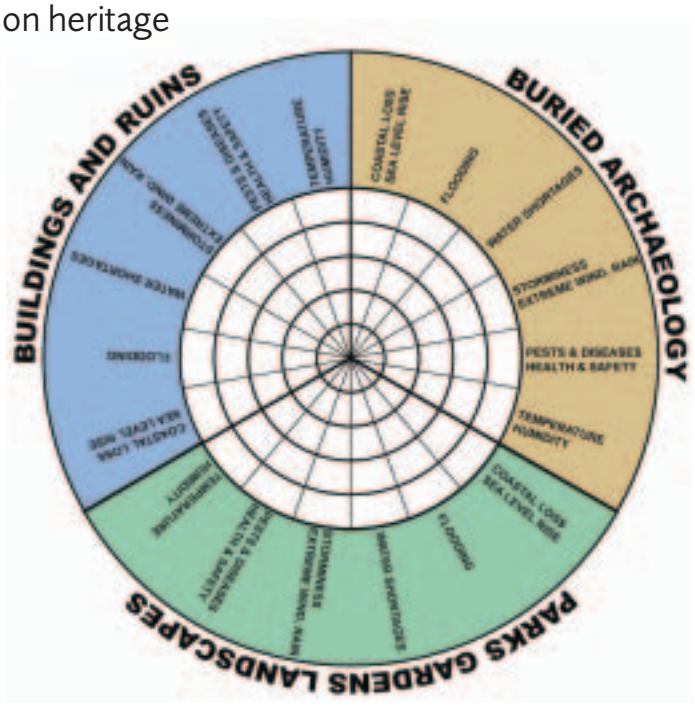
Acceptance of some loss.

Public Education

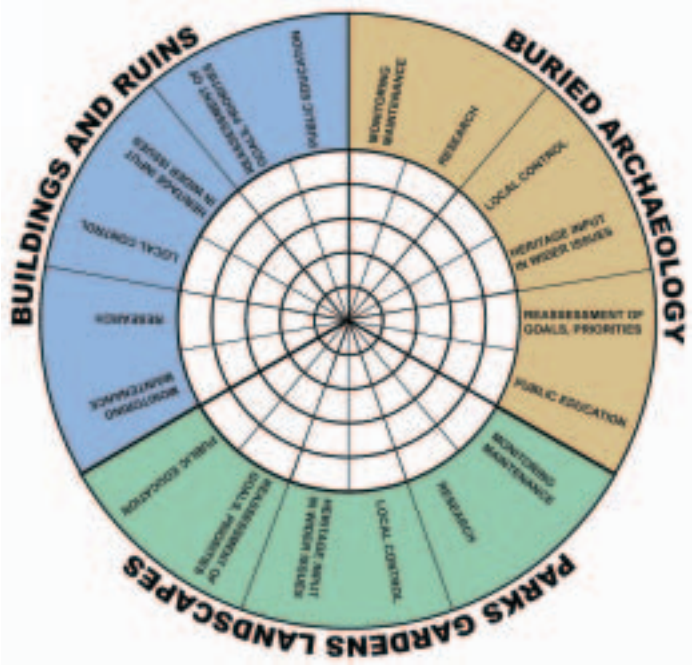
How do we explain choices, strategies?

Discussion wheels

Wheel 1 Climate impacts on heritage



Wheel 2 Priorities for management and funding



Summary of results from breakout sessions

Results taken from completed Decision wheels and associated presentation.

Wheel 1 results

	Buildings and Contents EA	Buildings and Contents NW	Buried Archaeology EA	Buried Archaeology NW	Parks Gardens & Landscapes EA	Parks Gardens & Landscapes NW
Coastal loss Sea level rise	3/5	5	5	5	3	4
Flooding	5	5	4	5	4.5	3
Water shortages	2	3	4	5	4	3
Storminess Extreme winds and rain	4.5	5	3	2	4	4
Pests and diseases Health and safety	3	5	3	1	4	4
Temperature Humidity	4	4	1	1	4	4

Level of concern	
5	Extreme
4	Very High
3	Definite
2	Some
1	Low
0	None

Wheel 2 results

	Buildings and Contents EA	Buildings and Contents NW	Buried Archaeology EA	Buried Archaeology NW	Parks Gardens & Landscapes EA	Parks Gardens & Landscapes NW
Monitoring Maintenance	5	5	5	5	4.5	5
Research	4.5	5	5.5	5	3.5	5
National/regional decision-making	3	0	4	0	3	0
Heritage input in broader issues	2	5	5	5	3	5
Evaluation of priorities	3	5	4	5	4.5	5
Education Traditional skills	3	5	3	5	4	5

Annex 4
Policy-makers' workshop

This workshop was held on 12 December 2002 at The Royal Society in London and was facilitated by George Gawlinski, Planning Together Associates.

Julius Bryant, Victoria and Albert Museum (formerly English Heritage)

Mike Calnan, Head of Gardens, The National Trust

Gill Campbell, Head of Environmental Studies, English Heritage

Sarah Carmona, Policy and Research Adviser, Commission on the Built Environment

Professor May Cassar, Centre for Sustainable Heritage, University College London

Richenda Connell, UK Climate Impact Programme (UKCIP)

Mike Corfield, former Chief Scientist, English Heritage

Rachel Fleming, Research and Development, Environment Agency

Clare Goodess, Climatic Research Unit, University of East Anglia

Mike Harley, Climate Change Adviser, English Nature

Professor Lord Julian Hunt, University College London

Rob Jarman, Head of Environmental Practices, The National Trust

Pat Mandeville, Department of Culture, Media and Sport, Education and Social Policy Unit

Bill Martin, Building Conservation and Research Team, English Heritage

Peter Murphy, former East of England Regional Science Adviser, English Heritage

Taryn Nixon, MoLAS (Museum of London Archaeological Service)

Professor Tadj Oreszczyn, Bartlett School of Graduate Studies, University College London

Robyn Pender, formerly Centre for Sustainable Heritage, University College London

John Preston, Institute of Historic Building Conservation and Cambridge City Council

Neil Ross, formerly Historic Scotland (retired)

Chris Sanders, Glasgow Caledonian University

Sarah Staniforth, The National Trust

Professor Phil Steadman, Bartlett School of Graduate Studies, University College London

Ian Wainwright, Chief Surveyor, Ecclesiastical Insurance

Jennifer White, Senior Landscape Adviser, English Heritage

Peter Winsor, Museums, Libraries and Archives Council

Corinna Woodall, Policy Research Officer, Heritage Lottery Fund

Ken Wright, Assistant Scientific Adviser, Defra Global Atmosphere Division