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Conservation bulletin

Adapting to a Changing Climate

Climate change is happening. But what will it do to our historic environment? And how can our knowledge of the past help us adapt to the future?

Climate change is nothing new. Erected at a time when Cornwall's climate was starting to cool down, the Bronze Age Men Gurta longstone now stands in the shadow of the St Breock Downs windfarm, the latter a monument to a new phase of rising temperature. © English Heritage Photo Library

ENGLISH HERITAGE

Editorial: Adapting to a Changing Climate

The historic environment will have much to teach us on our journey to a more sustainable low-carbon way of life.

Damaging climate change, driven by greenhouse gas emissions, is now widely recognised as the defining issue of our time. It is the most significant environmental, social and economic challenge faced by humanity.

The UK is actively thinking about how we can adapt to the climatic changes that are now inevitable in the short term and how we can reduce emissions to avoid even more drastic changes in the future. This is influencing Government policy in many areas, including spatial planning, land use, agriculture and transport, and is increasingly affecting our personal behaviour.

The historic environment is not immune from the impacts of climate change. Shifts in temperature, sea level, storminess, flood risk and the distribution of pests and disease will inevitably take their toll on traditional buildings, historic townscapes, archaeological sites and cherished landscapes. This, in turn, could diminish the valuable contribution our heritage makes socially and economically. The measures necessary to adapt to and combat climatic instability will also necessitate significant change in the historic environment, not all of which will conform to current thinking about heritage management.

The challenge faced by our sector is considerable. We need to develop a far better picture of the nature, scale and timing of potential impacts. We need to define how change can be accommodated while the cultural significance of historic assets is conserved right across the whole spectrum of our heritage. We need to bridge the significant gap between the still uncertain predictions of climatic changes and the need for practical adaptive action on the ground. In particular we need to identify those changes that are low-risk, economic and effective and avoid those that are unnecessary, impractical or might reduce flexibility for further adaptation. Research by the historic environment sector and by others will play a fundamental role in delivering this agenda. Above all, we must remember that our historic buildings and places have always existed in a changing climate. We must not underestimate their resilience or capacity to adapt. We must not neglect the lessons we can learn from the record of past environmental change and human adaptation to it. And we must recognise that we have a wealth of information derived from ancestors who often lived more sustainably than we do today and for whom energy was not such a throw-away commodity.

If the historic environment is to play a creative role in forging a sustainable and cohesive low-carbon society we also need to understand much more about the contribution of the millions of traditional houses, factories, offices and places of worship that give our towns and villages their distinctive sense of place. To set the ball rolling, English Heritage recently invited delegates from across the spectrum of the built environment to pool their experience and begin to establish a new way forward (*Inventing the Future*, pp 20–25).

In this issue of *Conservation Bulletin* we examine work being undertaken by English Heritage and our partners to respond to the challenge of climate change. This work is still in its infancy but establishes a direction of travel that will become the dominant theme in the years ahead. We are therefore particularly pleased to announce a major partnership between English Heritage and E.ON. As organisations, we are both committed to caring for and protecting the environment for future generations and will be collaborating on a wide range of initiatives that will make a real contribution to the goal of reducing the impact of climate change upon the built environment. ■

Edward Impey
Director of Research and Standards, English Heritage

Conservation Bulletin is published three times a year by English Heritage and circulated free of charge to more than 15,000 conservation specialists, opinion-formers and decision-makers. Its purpose is to communicate new ideas and advice to everyone concerned with the understanding, management and public enjoyment of England's rich and diverse historic environment.

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Facing the Facts

Climate change is nothing new – but how is this current episode going to differ from those of the past, and what more do we need to know?

Projecting the UK's changing climate

Roger Street
Technical Director, UK Climate Impacts Programme

The climate in the UK is changing. This is particularly evident to those whose livelihoods are sensitive to the vagaries of the weather and climate, but is also reflected in the temperature and precipitation records from across the UK (Jenkins *et al* 2007):

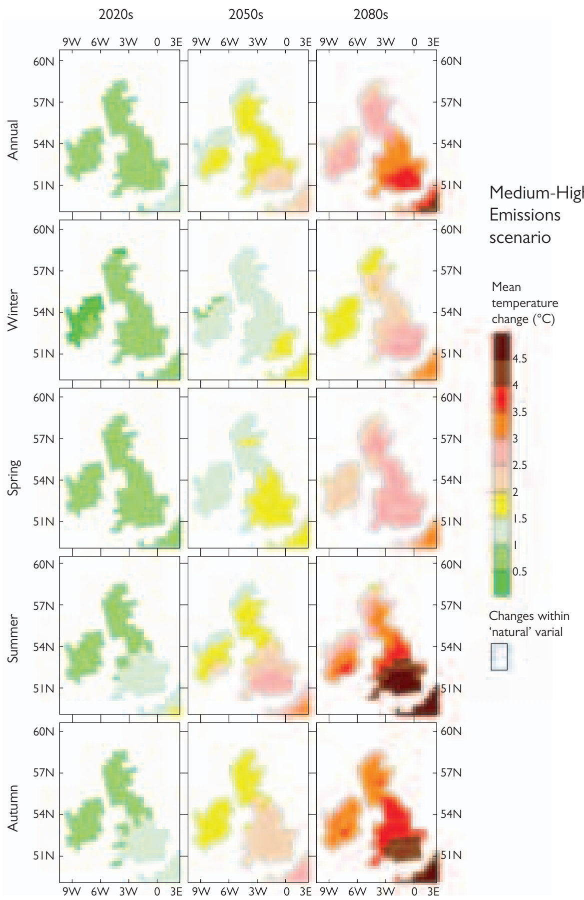
- Central England temperatures have risen by about a degree Celsius since the 1970s, with 2006 being the warmest on record. Temperatures in Scotland and Northern Ireland have risen by about 0.8°C since about 1980. The thermal growing season for plants has increased by up to 30 days since 1900.
- Annual mean precipitation over England and Wales has not changed significantly since records began in 1766. Seasonal rainfall is highly variable, but appears to have decreased in summer and increased in winter, although with little change in the latter over the last 50 years.
- All regions of the UK have experienced an increase over the past 45 years in the contribution to winter rainfall from heavy precipitation events; in summer all regions except NE England and N Scotland show decreases.
- Sea level around the UK rose by about 1mm/year in the 20th century, corrected for land movement. The rate for the 1990s and 2000s has been higher than this.

Furthermore, these changes in our climate and the associated impacts are projected to continue. This assertion is based on the conclusions of the recently released assessment report of the Intergovernmental Panel on Climate Change (IPCC AR4, 2007, **www.ipcc.ch**) and is reflected in the available climate change scenarios from the UK Climate Impacts Programme (UKCIP, **www.ukcip.org.uk**).

Over the past 10 years UKCIP and the Met Office Hadley Centre have made available climate change scenarios for the UK that are intended to help organisations identify how they might be affected by climate change and what they can do to minimise their risks or to exploit potential opportunities. The current set of these scenarios, referred to as UKCIP02, was released in 2002 and describes how the future climate of the UK is projected to evolve over the course of this century.

The UKCIP02 climate change scenarios are based on the results of a climate model (HadCM3) developed by the Met Office Hadley Centre. They reflect the best understanding, at that time, of how the climate system operates. The presentation of the information is based on four internationally recognised plausible emission futures for the 21st century. These four futures in turn are based on various assumptions about future human trends and behaviour (such as population growth, socio-economic development and technological advances), and how these might influence future global emissions of greenhouse gases and aerosols.

As such, UKCIP02 provides four alternative scenarios of climate change, ranging from that projected for a world of rapid economic growth with intensive use of fossil fuels (labelled High



Projected change in average annual, winter and summer temperature in 2020s, 2050s, and 2080s for the low and high emissions scenarios.

Emissions) to that projected for a world with increased economic, social and environmental sustainability with cleaner energy technologies (labelled Low Emissions).

UK climate projections

The headline messages from the UKCIP02 projections describe a different climate for the UK over this century.

The UK is projected to continue to get warmer

- By 2040, the average annual temperature for the UK is expected to rise by between 0.5 and 1°C, depending on region. By 2100, the average annual temperature for the UK is expected to rise by between 1 and 5°C, depending on region and emissions scenario (high confidence).
- There is expected to be greater warming in the south and east than in the north and west (high confidence).
- There is expected to be greater warming in the summer and autumn than in the winter and spring (medium confidence).
- The thermal growing season is expected to continue to lengthen (high confidence), but soil moisture levels in the summer and autumn are expected to decrease (high confidence).

Summers are projected to continue to get hotter and drier

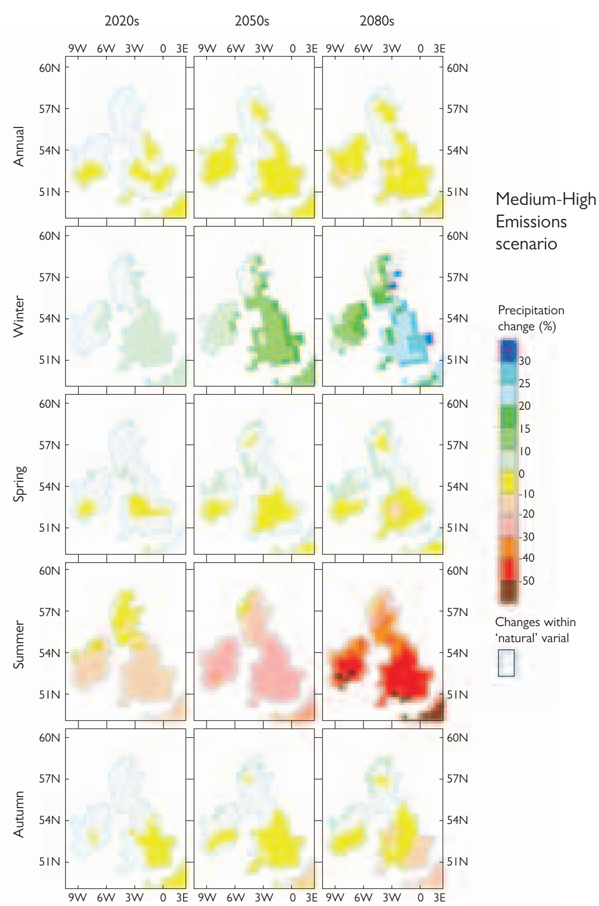
- By 2040, the average summer temperature for the UK is expected to rise by between 0.5 and 2°C, depending on region. By 2100, the average summer temperature for the UK is expected to rise by between 1 and 6°C, depending on region and emissions scenario (high confidence).
- By 2100, there is expected to be up to 50 per cent less precipitation in the summer months, depending on region and emissions scenario (medium confidence).
- The number of days when buildings require cooling is expected to increase (high confidence).

Winters are projected to continue to get milder and wetter

- By 2040, the average winter temperature for the UK is expected to rise by between 0.5 and 1°C, depending on region. By 2100, the average winter temperature for the UK is expected to rise by between 1 and 4°C depending on region and emissions scenario (high confidence).
- By 2100, there is expected to be up to 30 per cent more precipitation in the winter months, depending on region and emissions scenario (high confidence).
- Snowfall amounts are expected to decrease across the UK (high confidence), and large parts of the country are expected to experience long runs of winters without snow (medium confidence).
- The number of days when buildings require heating is expected to decrease (high confidence).

Some weather extremes are projected to become more common, others less common

- The number of very hot summer days is expected to increase, and high temperatures similar to those experienced in August 2003 or July 2006 (>3°C above average) are expected to become common by the end of this century, even under the Low Emissions scenario (medium confidence).
- The number of very cold winter days is expected to decrease, and low temperatures similar to those experienced in February 1947 or January/February 1963 (>3°C below average) are expected to become highly uncommon by the end of this century, even under the Low Emissions scenario (medium confidence).
- Heavier winter precipitation is expected to become more frequent (high confidence).



Projected per cent change in average annual, winter and summer precipitation for the 2020s, 2050s, and 2080s for the low and high emissions scenarios. © UKCIP

- Winter storms and mild, wet and windy winter weather are expected to become more frequent (low confidence).

Sea-levels around the UK are projected to continue rising

- Global sea level is expected to continue to rise (high confidence), and by 2100 it could have risen by as much as 80cm around the UK coast, depending on region and emissions scenario (low confidence).
- There is expected to be greater sea-level rise in the south of England than in western Scotland due to variations in natural land movements (medium confidence).
- Extreme sea levels are expected to be experienced more frequently, and by 2100 storm surge events could occur up to 20 times more frequently for some coastal locations and emissions scenarios (medium confidence).
- The temperature of UK coastal waters is expected to increase, though not as rapidly as air temperatures over land (high confidence).

Confidence in these projections

Not all of the changes described by UKCIP02 are given with the same degree of confidence. Based on both expert judgement and comparison with other global climate models, some changes in future UK climate have been assigned a higher confidence than others (see designations above). When using the UKCIP02 climate change scenarios, regardless of the level of detail, it is important to understand the confidence associated with the specific changes described and to ensure that the use of the information is consistent with and fully reflects the associated uncertainties.

Another way of looking at the confidence in these projections is to compare recent climate observations with projections. The most recent observations of trends for atmospheric carbon dioxide concentrations, global mean air temperature and global sea level have been compared with previous model projections as summarised in the 2001 assessment report of the Intergovernmental Panel on Climate Change (IPCC). Comparison of the coincident periods 1990 to 2006 suggests that:

- atmospheric carbon dioxide observations are remarkably consistent with the projections;
- global mean surface temperature observations are following a trend at the upper part of the range projected by the IPCC; and
- observed sea level has been rising faster (3.3mm+ 0.4 mm/year since 1993) than the rise projected by the models (best-estimate rise of 2 mm/year).

Although the time overlap is relatively short (16 years), these results suggest that the IPCC projections have not exaggerated but may in some respects be an underestimate of the projected change, underscoring the reason for concern and need for adaptation and mitigation.

REFERENCE
Jenkins, G J, Perry, M C, and Prior, M J O, 2007. *The Climate of the United Kingdom and Recent Trends*. Exeter: Met Office Hadley Centre

'Doggerland', now beneath the North Sea, was once home to Mesolithic hunters. Virtual reality model reconstructed from seismic terrain data and seeded with contemporary vegetation.

The past as a guide to the future: the long-term view

Stephen Trow
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Climate changes all the time – sometimes slowly, sometimes more quickly. 20,000 years ago, for example, an ice sheet covered northern England as far south as Birmingham, while 125,000 years ago elephants and hippos lived in southern England, with Trafalgar Square among the sites where their bones have been found. While climate change has never before been driven primarily by human activity, as it is now, an understanding of this past natural variation may nonetheless provide vital clues for those trying to predict future trajectories of change.

The longest continuous records of climate come from deep ocean cores, some going back for hundreds of millions of years, in which changes in micro-fossil species, and changes in isotope ratios in their shells, give a good record of past temperature changes. Cores through the Greenland and Antarctic ice sheets – built up from snowfall and now several kilometres thick – give a more detailed record over the past 200,000 (Greenland) to 600,000 (Antarctica) years from changes in stable isotopes in the ice, and from dust and air trapped in the ice.

Looked at against this long perspective, the last 10,000 years have been a slightly warmer interglacial during a cold and rather changeable period, the Pleistocene, which has been going on for the past 2 to 4 million years. Our present interglacial has been relatively stable, though not without change – pollen records show that in Britain and northern Europe it was probably about 1°C warmer on average during the Neolithic (4000–2000 BC), cooler and wetter in the later Bronze Age (1400–900 BC), warmer in the Roman period (AD 43–410) and in the 12th to 13th centuries, and colder between the 14th and 19th centuries, during the 'Little Ice Age', with white Christmases and ox-roasts on the frozen Thames during particularly cold winters.

Some past changes have been dramatic and often rapid. The sea level has risen by 130 metres over the past 20,000 years, since the coldest past of the last glacial, by as much as a metre a century for much of this time – a rate outstripping predictions for the next 80 years and there have been something like 20 very rapid temperature rises during the past 100,000 years.

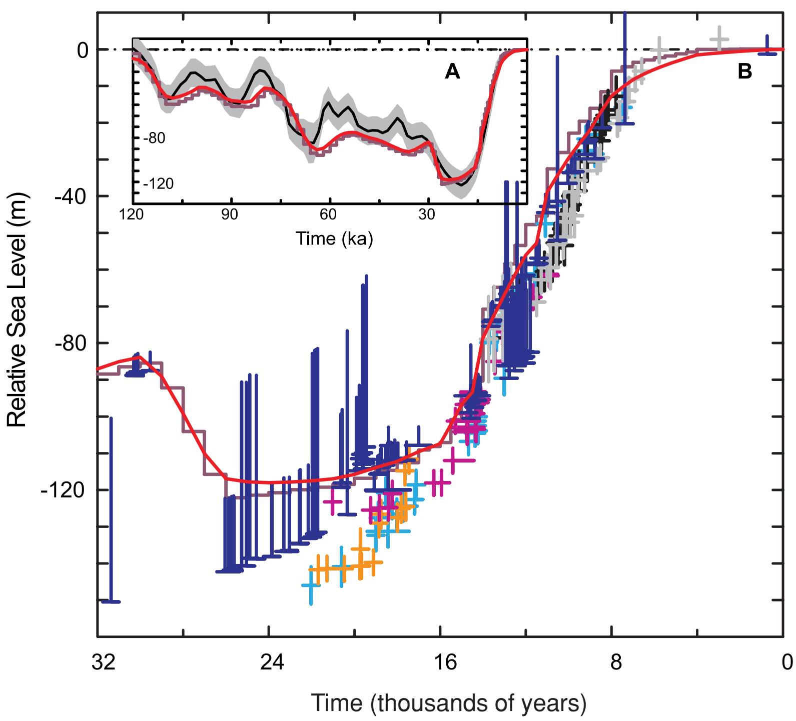
In contrast to today's populations, the people living through these dramatic changes were highly mobile bands of hunter-gatherers and total world populations probably numbered no more than a few millions. Over the last 500,000 years, therefore, Palaeolithic man was able to leave England at least twice during cold periods and re-colonise it during warmer periods. One recent study links the early Neolithic colonisation of south-east Europe around 7000–6000 BC to the loss of fertile land now drowned below the Black Sea. Similarly, the North Sea plain (or 'Doggerland') was probably home to large numbers of Mesolithic (8000–4000 BC) hunters who had to move to surrounding higher land when the North Sea was flooded by postglacial sea level rise around 5000 BC.

Today, the challenge faced by a world population of 6.6 billion – with its attendant pressures on productive land, food and water and its fixed and often low-lying cities and infrastructure – is of a fundamentally different order to those faced by much smaller and more mobile past societies. Nevertheless, there are still some significant lessons we can learn from the past and its record of climate change.

Firstly, we are developing an increasing understanding of the speed with which radical and long-term changes to climate can occur, so called climate 'flips' which are far more abrupt than scientists have previously thought possible. This knowledge must reinforce the sense of urgency with which we approach the reduction of greenhouse gas emissions.

Secondly, we can see how, in the past, it is people in productively marginal areas who are most vulnerable to change. For example, the cooler wetter conditions of the later Bronze Age ended farming in upland areas like Dartmoor and the Little Ice Age effectively terminated the Viking colonisation of Greenland. Today, this should emphasise the responsibility of both the developed and developing worlds to control future emissions if the climate impacts on today's most economically and productively marginal areas are to be minimised.

Thirdly, since the beginnings of the Neolithic, humankind has demonstrated an immense ability to innovate – especially in food production and storage, building methods and transport – in order to help people deal better with a wider range of conditions and to adapt to change. As a result of past greenhouse gas emissions, significant changes to the climate over the next few decades are



Faced with the onset of a cooler and wetter climate during the 1st millennium BC, Late Bronze Age farmers were forced to abandon their settlements on the uplands of Dartmoor.

now inevitable and society will need to devise strategies for adapting to, as well as mitigating, these changes. We will need to demonstrate, build upon and exceed the ingenuity of our ancestors if we are to do so successfully.

As part of our wider response to climate change, English Heritage's will continue to look to the past as a source of ideas for the future. This will involve the protection and, where appropriate, the investigation of historic sites that preserve a record of past climatic change and which may be of benefit to future climate change research. It will also include the lessons we can usefully draw from the low-carbon economies of past societies – an important theme in English Heritage's recent *Inventing the Future: Buildings in a Changing Climate* summit (see pp. 20–25).

Changes in global temperature lead to rises and falls in the level of the world's oceans. Since the coldest part of the last Ice Age 20,000 years ago typical sea levels have risen by 130 metres.
Source: IPCC 2007a (see p 41), Fig 6.8

Threats and opportunities: the historic environment and climate change

May Cassar
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The language of climate change can be highly scientific and everyday words can assume specific meanings. Two particular words have entered the climate change lexicon: mitigation and adaptation. These are often used casually and interchangeably by different users in different contexts. In climate science, mitigation means the actions taken to reduce the consumption of energy and water and the production of waste in order to ease future climate change. Adaptation means extending the useable life of materials and assemblies in order to adjust to present climate change.

Context

The historic environment is not facing the challenge of climate change alone. There are related sectors with which it can exchange knowledge. The construction industry uses materials, energy and water. Information can be shared on the cost/benefits of renewable energy, on waste reduction and management, and on local procurement of products and services. The management of the natural heritage through its observations of climate change impacts can inform the management of cultural heritage and cultural landscapes. For example the UNESCO World Heritage list includes cultural and natural heritage sites.

Threats, impacts and consequences

Climate change is usually perceived as a threat to the physical environment (under pressure from sea-level rise, desertification, flooding, etc) with consequences for the culture and way of life of communities. When it comes to historic buildings

TABLE 1

CLIMATE PARAMETERS	CLIMATE CHANGE RISK	PHYSICAL, SOCIETAL AND CULTURAL IMPACTS ON THE HISTORIC ENVIRONMENT
Atmospheric moisture change	Flooding (sea, river) Intense rainfall Changes in water table levels Changes in soil chemistry Ground water changes Changes in humidity cycles Increase in time of wetness Sea salt chlorides	pH changes to buried archaeological evidence Loss of stratigraphic integrity due to cracking and heaving from changes in sediment moisture Data loss preserved in waterlogged/anaerobic/anoxic conditions Eutrophication accelerating microbial decomposition of organics Physical changes to porous building materials and finishes due to rising damp Damage due to faulty or inadequate water-disposal systems; historic rainwater goods not capable of handling heavy rain and often difficult to access, maintain, and adjust Crystallisation and dissolution of salts caused by wetting and drying affecting standing structures, archaeology, wall paintings, frescos and other decorated surfaces Erosion of inorganic and organic materials due to flood waters Biological attack of organic materials by insects, moulds, fungi, invasive species such as termites Subsoil instability, ground heave and subsidence Relative humidity cycles/shock causing splitting, cracking, flaking and dusting of materials and surfaces Corrosion of metals Other combined effects eg increase in moisture combined with fertilisers and pesticides
Temperature change	Diurnal, seasonal, extreme events (heat waves, snow loading) Changes in freeze-thaw and ice storms, and increase in wet frost	Deterioration of façades due to thermal stress Freeze-thaw/frost damage Damage inside brick, stone, ceramics that has got wet and frozen within material before drying Biochemical deterioration Changes in 'fitness for purpose' of some structures. For example overheating of the interior of buildings can lead to inappropriate alterations to the historic fabric due to the introduction of engineering solutions Inappropriate adaptation to allow structures to remain in use
Sea-level rises	Coastal flooding Sea-water incursion	Coastal erosion/loss Intermittent introduction of large masses of 'strange' water to the site, which may disturb the meta-stable equilibrium between artefacts and soil Permanent submersion of low-lying areas Population migration Disruption of communities Loss of rituals and breakdown of social interactions
Wind	Wind-driven rain Wind-transported salt Wind-driven sand Winds, gusts and changes in direction	Penetrative moisture into porous cultural-heritage materials Static and dynamic loading of historic or archaeological structures Structural damage and collapse Deterioration of surfaces due to erosion

CLIMATE PARAMETERS	CLIMATE CHANGE RISK	PHYSICAL, SOCIETAL AND CULTURAL IMPACTS ON THE HISTORIC ENVIRONMENT
Desertification	Drought Heat waves Fall in water table	Erosion Salt weathering Impact on health of population Abandonment and collapse Loss of cultural memory
Climate and pollution acting together	pH precipitation Changes in deposition of pollutants	Stone recession by dissolution of carbonates Blackening of materials Corrosion of metals Influence of bio-colonisation
Climate and biological effects	Proliferation of invasive species Spread of existing and new species of insects (eg termites) Increase in mould growth Changes to lichen colonies on buildings Decline of original plant materials	Collapse of structural timber and timber finishes Reduction in availability of native species for repair and maintenance of buildings Changes in the natural heritage values of cultural heritage sites Changes in appearance of landscapes Loss of local skills Transformation of communities Changes the livelihood of traditional settlements Changes in family structures as sources of livelihoods become more dispersed and distant

Table 1
SOURCE
Adapted from May Cassar, 'Principal climate change risks and impacts on cultural heritage' in *Background Document UNESCO World Heritage Centre in Cooperation with the United Kingdom Government 'World Heritage and Climate Change' for the Broad Working Group of Experts at UNESCO HQ 16–17 March 2006* and in Working Document 30 COM 7.1 prepared for the 30th Session of the World Heritage Committee, Vilnius, July 2006 and also at http://whc.unesco.org/archive/2006/30com-en.htm

and landscapes where people live, work, worship, and socialise, these consequences arise from the degradation and abandonment of sites leading to the disruption of communities and the eventual loss of rituals and cultural memory. As far as the conservation of the historic environment is concerned, abandonment raises concerns for the traditional knowledge, skills and materials that are essential to ensure proper maintenance. An assessment of climate change impacts must therefore take account of the complex interactions between natural, cultural and social aspects (Table 1).

Potential opportunities from climate change

Climate change presents opportunities as well as challenges to the historic environment. These can be:

- political: ie opportunities to identify what the public values in the historic environment. At the same time, there is the need to capture the public-value argument through better evidence.
- economic: with climate change impacts being felt at regional and local level, regional responses to climate change need developing. The role of heritage volunteers might be developed as part of an early warning system able to respond to extreme events. Furthermore, climate change could provide an impetus for the historic environment to move away from an institutionally focused ethos to a user/service ethos that can embrace public involvement in heritage protection.
- social: ie opportunities for virtual access to the historic environment, particularly among younger age groups. Climate change can serve as a catalyst for discussions among culturally diverse groups on society's priorities for safeguarding the historic environment.
- technological: innovations leading to greater affordability, searchability and retrieval of digital records could deliver greater democratisation of research. The impact of climate change will place greater demands on the creation, quality analysis, maintenance and e-delivery of records ranging from non-invasive archaeological techniques to virtual reconstructions.
- legal: the opportunity to focus planning and protection systems and civil contingency

and emergency preparedness on managing climate change impacts.
- environmental: the opportunity presented by the growing scarcity of fossil fuels and the increase in energy prices to demonstrate alternative methods to air-conditioning to control the environment in historic properties.

Every aspect of the operation and management of the historic environment should be considered for its ability to mitigate and adapt to climate change. An overall improvement will be achieved because substantial improvements in any aspect will compensate for areas where few improvements are possible.

Key players

The key players can be grouped around the 'users' and the 'doers' of climate change research for the historic environment. The primary users are public and independent heritage organisations:

- English Heritage commissioned a scoping study, *Climate Change and the Historic Environment* (2002); led a foresight planning heritage task-group on *Construction Research and Innovation in the Heritage Sector* (2005), which included climate impact as one of the research themes; produced a policy document, *Climate Change and the Historic Environment* (2007); organised a Climate Change Summit (2008, see pp.20–25); launched a public information website (2008); and included a climate change special feature in *Heritage Counts* 2008.
- The National Trust published a report, *Forecast? – Changeable! Some Examples of Climate Change Impacts Around The National Trust*, to share some of its experiences and to outline a suggested approach for the future, as well as publishing numerous mitigation and adaptation case studies on its website. The National Trust and Magnum Photos also organised an exhibition, *Exposed: Climate Change in Britain's Backyard* with an associated poster tour and public debate, which was supported by the Defra fund, Tomorrow's Climate, Today's Challenge (2007).
- Historic Scotland carried out a scoping survey into the effects of climate change upon the fabric of the built historic environment to gather the current level of knowledge and to determine gaps in the knowledge that can be addressed by future research.
- The Council for British Archaeology organised a one-day conference, Adapting Archaeology: Foresight for Climate Change (2007).

The key doers are universities, including University College London, the University of East Anglia and Glasgow Caledonian University, which work collaboratively on both basic and applied research and disseminate information to other scholars, heritage organisations and the public.

The contribution that the historic environment can make to increasing knowledge on climate change is being noticed by policy-makers and research-funding bodies including the United Kingdom Climate Impacts Programme, the joint Arts and Humanities Research Council and the Engineering and Physical Sciences Research Council's Science and Heritage Programme. At an international level, the European Parliament Temporary Committee on Climate Change (CLIM) invited evidence to be submitted to it on climate change impacts on cultural heritage (2007) and the UNESCO World Heritage Committee working with its advisory bodies (ICOMOS, IUCN, ICCROM) has agreed a policy on climate change and world heritage (2007).

Key knowledge gaps and research needs

Table 2 lists the research areas and research outputs that have been identified as required to help reduce gaps in knowledge and meet recognised research needs.

Table 2

SOURCES

1 UCL, *Climate Change and the Historic Environment*. English Heritage, 2005
2 UEA, Scoping Report, *Sector Research Activity*, English Heritage, 2004
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4 CRISP, *Construction Research and Innovation in the Heritage Sector*. Foresight Planning for a Research Strategy for the Construction Industry, prepared by English Heritage, Draft Report MK1, 2005
5 EPSRC, *Engineering Historic Futures*. Stakeholder Dissemination and Scientific Research Report, UCL, 2007
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7 UNESCO, *Working Group Meeting to Develop the Policy Paper on Impacts of Climate Change on World Heritage Properties*. Background Document, February 2007
8 UNESCO World Heritage, Item 7.1 of Provisional Agenda: *Issues related to the State of Conservation of World Heritage Properties: The Impact of Climate Change on World Heritage Properties*. WHC-07/31.COM/7.1, Paris, 23 May 2007

TABLE 2

		SOURCES							
		1	2	3	4	5	6	7	8
RESEARCH OUTPUTS	Hazard recognition and risk quantification and prioritisation	●					●	●	●
	Extreme weather effects: damage probabilities and conservation	●				●		●	●
	Cross-field monitoring (eg interaction among different ageing/decay mechanisms; reconciling different metrics	●	●	●		●	●	●	●
	Simulation modelling (eg CFD modelling of env. and phase changes and amplification mechanisms)		●	●				●	
	Predictive modelling of real complex phenomena	●		●			●	●	
	Indoor/outdoor monitoring and assessment of vulnerability/performance	●				●		●	●
	Materials interface: Environment – new–old	●	●	●			●	●	●
	Conservation and maintaining value		●						●
	Materials conservation and sustainability eg marker; durable; traditional; new repair/conservation		●	●			●		
	Response of materials and assemblies to microclimates		●	●					
	Long-term behaviour of materials eg nanoscale degradation and treatment			●					
	Biodeteriorattion and biotechnology			●				●	
	Traditional and advanced physical and chemical technologies; re-engineering of techniques and instrumentation			●			●		●
	Environment, the low carbon economy, renewable energy and historic buildings				●	●	●		
RESEARCH AREAS	Remote sensing, bio-sensing and fail-safe technologies	●	●	●			●		●
	Non-destructive/micro destructive techniques	●							
	Simulation and IT tools	●	●				●		
	Datasets, databases and mapping	●							●
	Adaptations to climate change	●							
	Wireless protocols for data transmission	●							
	Indicators, thresholds and standards	●	●	●			●		
	Damage mitigation strategies for materials and assemblies		●	●					
	Integrated conservation management and public values		●	●				●	