A GUIDE TO CLIMATE CHANGE IMPACTS

ON SCOTLAND'S HISTORIC ENVIRONMENT

Our Place in Time

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#ClimateHeritage

Cover image: Scalpay, Eilean Glas Lighthouse

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Primary Authors:
David Harkin, Dr Ewan Hyslop, Hazel Johnson and Emily Tracey (Historic Environment Scotland). Contact: ClimateChange@hes.scot

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Our Place in Time (OPiT)[1] is Scotland's strategy for the historic environment. It sets out a vision of how our historic environment can be understood, valued, cared for and enjoyed.

The strategy was developed collaboratively by organisations and specialists in the historic environment sector, and further.

- **Vision:** Scotland's historic environment is understood and valued, cared for and protected, enjoyed and enhanced. It is at the heart of a flourishing and sustainable Scotland and will be passed on with pride to benefit future generations.
- **Purpose:** To ensure that the cultural, social, environmental and economic value of Scotland's heritage makes a strong contribution to the wellbeing of the nation and its people.

OPIT Climate Change Working Group

A number of Working Groups have been established under OPiT in order to address key current issues and challenges facing the historic environment sector. One of these is climate change, and in 2017 the Climate Change Working Group was established to coordinate action and bring together individuals and organisations from across the sector. Membership of the group also includes a number of key support organisations with specialist knowledge of climate change and sustainability.

Collaboratively, the Climate Change Working Group has produced this guide to:

- raise awareness of the impacts of climate change on our historic environment
- improve the knowledge base of custodians/ owners of historic assets
- form the foundation of climate change risk assessments for specific assets
- prompt consideration of what possible climate change adaptation solutions may be most appropriate for certain historic assets
- identify gaps in knowledge and point people in the direction of relevant resources and research.

[1] Historic Environment Scotland. 2014. Our Place in Time.
Available at: https://www.historicenvironment.scot/about-us/who-we-are/our-place-in-time/.

AN IAR 'S AN EAR, AN DACHAIGH AS FHÈARR - CÙL RI GAOITH, 'S AGHAIDH RI GRÈIN.

IN THE WEST AND THE EAST, THE HOUSE THAT'S BEST - BACK TO WIND AND FACE TO SUN.

CONTENTS

1 CLIMATE IN MIND

Pennan, Aberdeenshire

Things that many of us take for granted today, such as security and communication, access to clean water or readily available sources of food, could not always be counted on in the past. Our ancestors used Scotland's different landscapes to their advantage whilst coping with harsh weather and exposure to challenging environmental conditions.

They occupied strategic locations such as river crossings or high vantage points in order to stake their claim on the surrounding lands and defend themselves against attackers. Settlements would develop in areas that could support agriculture and industry. Coastal communities would grow to make use of rich marine resources, accessing important communication and trading routes and creating livelihoods by fishing and farming on fertile coastal land. The low-lying, often flat land at the coastal edge and in valley bottoms was typically the preferred setting for key infrastructure including settlements, industry, roads, railways and fortifications. Over time, settlements grew and developed around these strategic points in the landscape. Because of this, much of Scotland's historic environment is located in areas vulnerable to natural hazards and weather extremes. In many cases these places remain the focal points of today's society.

Historic sites were often designed and constructed to fit a specific environment. For example, the Blackhouses on the Isle of Lewis were built low into the landscape, with rounded corners and thick walls to give protection and insulation against the strong Atlantic winds. In many coastal communities dwellings were constructed 'gable-end' to the sea in order to reduce exposure to gales and prevailing weather. Roof pitches in Scotland were usually steeply inclined in order to shed rainwater rapidly, and many historic sites or buildings were given raised footings designed to promote drainage away from buildings.

Broch of Mousa, Shetland Islands

The materials and methods used for their construction were typically selected carefully to provide maximum protection against the harsh Scottish climate. Because of this much of our historic environment has demonstrated an extraordinary ability to survive and cope with severe weather and periods of environmental change.

Today, the historic environment is an important resource that reflects several thousand years of human occupation in Scotland. Much of it may appear robust, but decades of poor maintenance, misguided interventions or abandonment has left many sites in poor condition. Careful stewardship is now needed if their continued survival is to be assured.

Our historic environment has an important role to play in today's world where the climate is rapidly changing. It gives us visible reminders of the resilience and determination of the people who came before us. In many cases it also records past change and reminds us that our natural environment has always been in a state of flux. We have much to learn from the past, and from the evidence presented to us by the historic environment.

Climate Change and the Historic Environment

The changes in our climate that we are experiencing today, and will continue to experience in the decades ahead, are a consequence of human influence on the global climate system. Rapid industrialisation, dependence on fossil fuels and population growth in the past few hundred years have led to unprecedented concentrations of greenhouse gases in the atmosphere. In 2018, the World Meteorological Organisation reported that atmospheric concentrations of carbon dioxide (one of several such gases) was at a level that had not been matched in the past 3 to 5 million years[2]. The result is that our planet is undergoing a relatively rapid period of warming, which in turn is driving additional changes in our climate beyond what is naturally expected.

The impact of these changes is extensive and wide-reaching. Climate change doesn't respect boundaries or borders, social classes or cultures, age or location. It is an issue we must all face together. It will be possible to avoid the most extreme predicted changes to our climate if there is a determined global effort starting now to lower greenhouse gas emissions. However, the action required as outlined in international agreements has yet to be met, and the levels of current action are well below those needed to avoid catastrophic climate change[3]. Many changes to our climate are already happening and further changes are unavoidable. If we are to reduce their impact, adaptation is essential.

For the historic environment in Scotland, this means addressing the physical impact of increased rainfall, more frequent extreme weather events, increasing temperatures, rising seas and shifting coasts. These changes, individually and collectively, are already having a damaging impact on our historic environment. Other secondary impacts such as changes in land use, a longer growing season and changing visitor habits will also affect historic sites. In facing this new reality we need, as a sector, to question whether a 'business as usual' approach will be sufficient in the future. We must also think about new and more effective ways to manage our heritage in a world where the climate is rapidly changing.

In Scotland there are strong economic and social benefits to having a healthy and resilient historic environment. In 2017 alone, the historic environment generated £4.2bn for Scotland's economy, supported 66,000 full-time-equivalent jobs and attracted 18 million visitors[4]. Globally, there is evidence that visiting historic sites and places can be beneficial to health and wellbeing, as well as reducing social vulnerability and increasing resilience[5].

However, the historic environment is not just about visitor attractions. Most of us interact with the historic environment on a daily basis. This can be through the buildings and places where we live, work and meet to socialise, as well as the physical built infrastructure we depend on. Some of these are designated sites of local, national or international significance. There are 47,000 listed buildings, 8,000 scheduled monuments and a range of other protected places spread across Scotland. On top of this, approximately one in five of Scotland's homes are more than 100 years old (numbering approximately 483,000 'traditional buildings')[4].

The historic environment is a part of our lives. As such it is important not only to address the impact of climate change on it, but to continuously develop our understanding of the benefits and wider role of the historic environment for society. As we respond to the reality of climate change in new ways, we can take the opportunity to highlight how the historic environment demonstrates resilience and adaptability, as a lesson for the future.

[2] World Meteorological Organization. 2018. Greenhouse Gas Levels Reach New Record.
Available at: https://public.wmo.int/en/media/press-release/greenhouse-gas-levels-atmosphere-reach-new-record.

[3] Committee on Climate Change. 2019. Net Zero – The UK's contribution to stopping global warming.
Available at: https://www.theccc.org.uk/publication/net-zero-the-uks-contribution-to-stopping-global-warming/

Buchanan Street, Glasgow

Purpose of This Guide

The information presented over the following pages is intended to inform the reader of the key hazards and impacts of climate change on the historic environment. We want it to open up conversations about climate change adaptation solutions that might help protect individual historic assets – or to consider options to responsibly and sensitively manage deterioration and loss where no other viable alternatives can be found. It should be noted that this guide does not consider the impact of climate change on the cultural significance of historic environment assets, which in some cases will be protected through statutory designation, and will vary from site to site.

The Impact Tables themselves are intended to act as a starting point in understanding the wide-range of different climate change impacts that exist, and are known about. They use a simple structure designed to increase awareness and to stimulate discussions about possible actions.

The historic environment is highly diverse, and solutions will need to be tailored to specific situations. Many solutions will require wider consideration of adjacent assets, rather than viewing a specific asset in isolation.

This guide is not exhaustive. It focuses on a number of known hazards and impacts, while acknowledging that there are likely to be other aspects that are less well understood and may become more significant over time. There are undoubtedly other hazards (or combinations of hazards) and impacts, and it is important that ongoing research is carried out to help address these gaps in our knowledge.

The actions outlined in this publication are not intended to be prescriptive. Rather, they indicate general types of approach that might be considered as climate change is taken into account in our decision-making for the historic environment. Changes to practice and interventions should consider cultural signficance and any specific policies related to statutory designation.

[4] Historic Environment Scotland. 2018. Scotland's Historic Environment Audit 2018.
Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=7821f0c5-cf3f-4ecc-87e4-a9a601032e54.

[5] Historic England. 2018. Wellbeing and the Historic Environment.
Available at: https://historicengland.org.uk/images-books/publications/wellbeing-and-the-historic-environment/wellbeing-and-historic-environment/

2 HOW TO USE THIS GUIDE

Cunndal, Lewis

To help readers identify the impacts most relevant to them, Scotland's historic environment has, for the purposes of this guide, been divided into seven distinct components or 'elements', presented as a series of tables (Impact Guide Tables). Each of these elements will experience, or be vulnerable to, impacts of climate change that are specific to their physical form and material structure as well as their location and particular environment.

For each of the seven elements of the historic environment, a range of different 'hazards' has been identified that have the potential to cause damage (e.g. Flooding, Heatwave, Ground Instability). For each of these hazards, the current climatic conditions that influence how and when they occur have been highlighted (Weather Drivers), and linked to changes in climate (Climate Change). Where possible, these have been grouped in categories that best link them to a causative climate or hazard variable (Causative Factor) – this demonstrates the important point that damage is often the result of a combination of several weather and hazard variables. A tailored 'Further Reading' section for each of the following seven impact tables is provided at the end of the guide.

Impact Guide table headings and what they mean

Type of hazard in question, such as physical or environmental (e.g. flooding, ground instability, etc.), meteorological (heatwave, wetting and drying), ecological (e.g. spread of pest species) or chemical (changing soil chemistry)

Adaptation: potential measures that might be considered or implemented to address the expected impact, by:

Resistance – an approach that actively seeks to halt or reverse the impact and/or increases the ability of the asset to cope with the impact(s) in question

Acceptance – an approach that accepts change will occur, but plans accordingly before any substantial damage/loss occurs

Short code showing main weather / hazard variables linked to impact

Weather conditions that are the primary drivers of the hazard in question

Predicted change in climate that will affect severity and occurrence rate of the hazard

Causative Factor	Impact <Cause and Effect>	Hazard			Exposure	Vulnerability/Sensitivity	Adaptation	
		Type of Hazard	Weather Drivers	Climate Change			Resistance	Acceptance
R, EXW	Increased rainfall and more frequent and prolonged saturation of historic fabric causing **enhanced rates of decay**	**Water Penetration** ▪ Wind-driven rain ▪ Overflow ▪ Splashback from hard surfaces	Heavy, prolonged rainfall over days and/or short, intense periods of rainfall over hours leading to fluvial flooding	Increased frequency of prolonged rainfall in winter months; Increased occurrence of intense summer rainfall events	Proximity to watercourse; Local geology and superficial deposits; Presence/absence of hard ground surfaces	Structural integrity of historic fabric; Materials used; State of maintenance/repair	Increase size/capacity of rainwater systems at critical points; More frequent maintenance; Improved/new protective weathering details	▪ Record assets in anticipation of damage/loss (e.g. excavation, laser scanning, collation of archival materials) ▪ Put in place a protocol for a 'be prepared' response to extreme weather events. This may involve inspection followed by implementation of programme of archaeological work commensurate with the scale of loss to recover information and inform any potential clean-up or stabilisation works
R, EXW, FL	More frequent saturation of historic fabric, as result of increased occurrence rates of flooding, causing **enhanced rates of decay**	Flooding: ▪ Fluvial	Prolonged periods of rainfall over days/weeks ; Short, intense periods of rainfall over hours		Topography; Proximity to watercourse		Attend culverts and adjacent burns; Route for surge water flows around assets; General improved drainage	
	Increased occurrence rates/severity of flooding causing structural **damage/loss of historic fabric**	Flooding: ▪ Pluvial/ Surface Water	Short, intense periods of rainfall over hours		Topography; Presence/absence of hard ground surfaces			
		Flooding: ▪ Groundwater	Prolonged periods of rainfall over weeks/months		Topography; Local geology and superficial deposits			

Short description that describes the potential result of a 'hazard' occurring. The description highlights the causative factor (hazard) and the effect of its occurrence

Key natural landscapes and environmental features that influence / control the potential for a hazard to occur

The features of an asset that make it more or less susceptible to the hazard – some of which can be controlled

Causative Factors

Each of the Impacts is grouped according to one or more causative factors, presented as a series of short codes or abbreviations. This allows the reader to quickly assess the primary weather and/or climate drivers that influence how and when each specific Impact occurs. Each causative factor is described below.

Impact

The impact is presented as a short statement that describes the cause that drives the hazard in question, and the effect that the hazard could have if it were to occur. In many cases these are existing hazards where damage is understood. However, the impact is likely to increase in frequency and intensity with climate change.

Causative Factors		
Code	**Hazard/Weather Variable**	**Description**
T	Temperature	Impacts resulting from temperature change and extremes, for example drought and heatwaves, and the spread of invasive pests and plant species.
R	Rainfall	Hazards resulting from increased or reduced rainfall, including changing patterns of rainfall.
EXW	Extreme Weather	Events caused by weather extremes, such as heatwaves, droughts, floods, ground instability events, high winds and storms.
SLR	Sea-level Rise	Primary impacts resulting from sea-level rise, including coastal erosion and coastal flooding.
FL	Flooding	Impacts caused by various types of flooding, including coastal, fluvial, surface water and groundwater.

Type of Hazard

Each hazard is presented as three components:

Type: Physical or environmental (e.g. flooding/ground instability, etc.); meteorological (e.g. heatwave/wetting and drying, etc.); ecological (e.g. spread of pest species); chemical (e.g. changing soil chemistry).

Weather Drivers: The primary weather conditions that control how and when specific hazards occur. Where possible, a temporal element to the weather driver is provided (e.g. fluvial flooding caused by prolonged rain over hours/days, or groundwater flooding caused by prolonged rainfall over weeks/months).

Climate Change: Predicted changes to our climate that will control the future occurrence rates and severity of each specific hazard are listed. These are based on published sources such as UK Climate Projections 2018 (UKCP18). UKCP18 has a range of datasets and tools that can be used to predict future changes in various weather variables, such as temperature and precipitation. Outputs from UKCP18 are summarised into shorthand statements that describe the trends predicted in the coming decades (e.g. warmer, wetter winters and hotter, drier summers)[6].

Exposure

A summary of the key landscape and environmental features that influence whether an impact is likely to occur for example, proximity to a watercourse for fluvial flooding. In many cases the position of an asset in the landscape and whether it is exposed to (or sheltered from) the prevailing weather will determine its exposure. Users of the guide looking to understand climate change impacts on particular historic assets would need to carry out a 'local' appraisal of such factors. This will allow them to determine the specific level of exposure to various climate change impacts.

Threave Castle, Dumfries and Galloway

Ardnish peninsula wild fire

[6] The Met Office. 2018. UKCP18 Key Results.
Available at: https://www.metoffice.gov.uk/research/collaboration/ukcp/key-results

Vulnerability/Sensitivity

This section provides a short statement describing the features of an asset that are likely to make it more or less susceptible to the hazard. Many of these are likely to be controlled through human intervention and site management. For example, a roofed building in a good state of maintenance/repair is more resilient (less vulnerable) to weather and climate drivers such as increased rainfall, in comparison to one in a state of disrepair. Users of the guide looking to understand climate change impacts on particular historic assets would need to carry out a site-specific appraisal of these factors to determine the level of vulnerability.

Cousland, Smithy

Adaptation

The Intergovernmental Panel on Climate Change defines climate change adaptation as 'adjustments in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities'[7]; in short, the modifications needed to make our historic environment more resilient to changes in our climate.

The adaptation section is split into 'Resistance' and 'Acceptance'. Both are direct responses to climate change but represent different approaches:

Resistance is an approach that actively seeks to halt/reverse the impact and/or increase the capacity of the asset to cope with the impact(s) in question. This could be through physical interventions on historic assets, such as improving the drainage systems allowing sites to handle increased levels of rainfall.

Acceptance is an approach that accepts change will occur, but plans accordingly before any substantial damage or loss occurs. This could involve putting in place a plan to adequately record and/or excavate a site before it is damaged or lost, or the adoption of a long-term strategy in order to manage the progressive loss of a site.

Recording an intertidal wreck, Loch Fyne ©Wessex Archaeology

[7] IPCC. 2001.
Available at: https://www.ipcc.ch/report/ar3/wg3/

3 HISTORIC ENVIRONMENT ELEMENTS

Edinburgh Waverley

Roofed Buildings and Infrastructure

Roofed buildings are visible structures such as public buildings, private dwellings, town and city tenements or vernacular rural cottages, ecclesiastical buildings or iconic historic monuments. Infrastructure is the physical component of the connected systems that sustain or enhance society (e.g. bridges, roads, railways, canals, dams and reservoirs, boundary and retaining walls, embankments and other engineering structures). Much of Scotland's infrastructure is historic and was constructed using similar materials and methods to buildings. Historic structures within this element may either be of traditional construction, using traditional materials and skills (typically built before 1919 and with stone, timber, lime, etc.), or constructed with modern materials and techniques (e.g. 20th-century concrete construction).

- Increased rainfall causing more frequent and prolonged saturation of building fabric.
- High winds/storms and potential changes in frequency/intensity resulting in increased physical damage to external building fabric.
- Increased rates of biological growth (e.g. moss, algae and higher plant colonisation) leading to enhanced rates of fabric decay.
- Increased thermal stress causing damage to external building fabric.
- Increased rainfall causing more frequent and prolonged saturation of building fabric and enhanced rates of internal/external building fabric decay.
- High winds/storms and potential changes in frequency/intensity resulting in increased physical damage to external building fabric.
- Ground movement and associated structural instability/movement of foundations causing damage/loss of building fabric and engineered slopes.
- Increased occurrence rates/severity of flood events causing damage/loss to external building fabric/infrastructure.

Wemyss Bay Railway Station

Roofed Buildings and Infrastructure

Causative Factor	Impact <Cause and Effect>	Hazard			Exposure	Vulnerability/Sensitivity	Adaptation	
		Type of Hazard	Weather Drivers	Climate Change			Resistance	Acceptance
T, R, EXW	Ground movement and associated structural instability/movement of foundations causing **damage/loss of building fabric and engineered slopes**	**Ground Instability** (e.g. landslide/shrink-swell)	Heavy, prolonged rainfall over days/months leading to ground saturation; Alternating saturation and drying of ground	Increased rainfall over weeks/months; Changing frequency/intensity of rainfall; Increasing annual temperatures; Increasing occurrence rates of extreme weather events such as heatwaves	Topography; Local geology and soil types; Proximity to water sources, such as springs	Structural integrity of the building fabric or engineered slope or materials; State of maintenance/repair; Local drainage; Susceptibility of building materials used; Presence/absence of people/staff on site	More frequent below-ground drainage maintenance/checks; Adapt surface drainage and landscaping/planting; Consider ground investigation, underpinning and strengthening of vulnerable slopes	
R, EXW	Increased rainfall causing more frequent and prolonged saturation of building fabric and **enhanced rates of building fabric decay**	**Water Penetration** ▪ Wind-driven rain ▪ Overflow of drainage systems ▪ Splashback from hard surfaces	Intense rainfall in isolated events and as a cluster of events; High winds	Increased frequency of prolonged rainfall in winter months; Short, intense periods of rainfall in summer months	Local geology and superficial deposits and their influence on natural drainage systems; Presence/absence of hard surfaces; Site exposure to prevailing weather systems	Structural integrity of the building fabric/materials; State of maintenance/repair; Materials used; Exposure of building/structure	Increase size/capacity of rainwater systems at critical points; More frequent maintenance; Remove hard-ground surfaces adjacent to walls; Improve drainage around site	
T, R, EXW	Increased rates of biological growth (e.g. moss, algae and higher plant colonisation) leading to **enhanced rates of fabric decay**	**Ecological** (Increase in plant species distribution and number of growing days)	Rainfall; Humidity; Temperature; Hours of sunshine and cloud cover	Increasing annual temperatures; Increased frequency of prolonged rainfall in winter months; Short, intense periods of rainfall in summer months	Topography; Soil types; Site exposure to prevailing weather systems	Building materials used; Aspect of building; State of maintenance/repair	Improved protective weathering details; Repointing of masonry; Appropriate traditional external coatings	
R, EXW	Increased occurrence rates/severity of flood events causing **damage/loss to external building fabric/infrastructure**	Flooding: ▪ Fluvial	Prolonged periods of rainfall over days/weeks; Short, intense periods of rainfall over hours	Increased frequency of prolonged rainfall in winter months; Increased occurrence of intense summer rainfall events	Topography; Proximity to watercourse	Structural integrity of the building fabric; State of maintenance/repair; Materials used; State of maintenance/repair of local drains/water management systems; Presence/absence of people/staff on site	Attend culverts and adjacent burns; Route for surge water flows around buildings; Flood plans in place; Changes to layout of buildings to lower impact (e.g. move sensitive services high off ground)	
	Increased occurrence rates/severity of flood events causing **restricted or limited access to sites**	Flooding: ▪ Pluvial/Surface water	Short, intense periods of rainfall over hours		Topography; Presence/absence of hard-ground surfaces			
	Increased occurrence rates/severity of flood events causing **damage and disruption to subsurface services and infrastructure**	Flooding: ▪ Groundwater	Prolonged periods of rainfall over weeks/months		Topography; Local geology and superficial deposits			

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Roofed Buildings and Infrastructure *(continued)*

Causative Factor	Impact <Cause and Effect>	Hazard			Exposure	Vulnerability/Sensitivity	Adaptation	
		Type of Hazard	Weather Drivers	Climate Change			Resistance	Acceptance
T, R, EXW	High winds/storms and potential changes in frequency/intensity resulting in increased **disruption/damage caused by falling trees/branches**	**Wind/Storms**	High winds; Low pressure systems; Storm events	Changing patterns of extreme weather events	Topography; Soil types; Exposure to prevailing weather systems; Tree species used and their tolerance of extreme weather events	Type of plant/tree species and its inherent resilience or vulnerability to high winds; Season in which storm events occur (trees in full leaf more prone to damage); Proximity to trees/woodland areas	More regular condition checking and maintenance; Use of more tolerant species when planting new trees	Regular monitoring and condition checking of vulnerable/at risk trees, which can be replaced with more tolerant species if felled
	High winds/storms and potential changes in frequency/intensity resulting in increased **physical damage to external building fabric**				Location (e.g. promontory, height in landscape); Exposure to prevailing weather systems	State of repair/maintenance; Presence/absence of people/staff on site	Additional fastenings to ridges and slates; Higher codes of lead; Improved weathering details; Increased frequency of inspection, maintenance and repair cycles	
R, EXW	Increased intensity and frequency of fluvial flooding undercutting and bridge scour at vulnerable locations causing **damage/collapse of buildings and infrastructure**	**Flooding** ▪ Fluvial	Prolonged periods of rainfall over days/weeks; Short, intense periods of rainfall over hours	Increased frequency of prolonged rainfall in winter months; Increased occurrence of intense summer rainfall events	Topography; Proximity to watercourse; Local geology and superficial deposits	Structural integrity of the building fabric; State of maintenance/repair; Materials used; State of maintenance/repair of water management systems and existing defences	Consider ground investigation, underpinning and strengthening; Enhanced monitoring and associated pro-active programme of works	Possible loss of historic structures or infrastructure accepted, plans in place for replacement
	Increased intensity and frequency of fluvial flooding making riverside assets vulnerable to **collapse/instability from sudden extreme river spate destroying river banks**							
T, EXW	Increased thermal stress causing damage to external **building fabric from cracking of hard materials**	**High Temperatures/Heatwave/Fluctuating Temperatures**	Rapidly fluctuating temperatures over hours/days	Increasing temperatures across all seasons; More extreme variations in temperature	Topography; site aspect (certain aspects more exposed to incoming solar radiation, e.g. south-facing)	Structural integrity of the building fabric; Materials used; State of maintenance/repair	Repair with traditional materials such as lime mortars, traditional paints	
T, EXW	Increased frequency of wetting/drying events causing **damage/loss of external building fabric**	**Wetting and Drying Cycles**	Alternating wet and dry spells; Temperature change	Increased rainfall over weeks/months; Changing frequency/intensity of rainfall; Increasing annual temperatures; Increasing occurrence rates of extreme weather events such as heatwaves	Topography; Proximity to watercourse or poorly drained surfaces; Exposure to prevailing weather systems	Structural integrity of building fabric, materials; State of maintenance/repair; Materials used	Improved weathering details; More frequent maintenance; Repair of mortar joints	

Continued on next spread

Roofed Buildings and Infrastructure *(continued)*

Causative Factor	Impact <Cause and Effect>	Hazard			Exposure	Vulnerability/Sensitivity	Adaptation	
		Type of Hazard	Weather Drivers	Climate Change			Resistance	Acceptance
T, R	Changing frequency of freeze-thaw weathering events causing **damage/loss of historic fabric**	**Freeze-Thaw Weathering**	Fluctuating temperatures (above and below 0°C over hours/days	Increased temperatures during winter months resulting in the +/- 0°C threshold being crossed more often	Site aspect (certain aspects exposed to less solar radiation, e.g. north-facing)	Structural integrity of the building fabric; State of maintenance/repair; Materials used	Improved weathering details; More frequent maintenance; Repair of mortar joints	
T, R, EXW	Changing growing conditions leading to reduction or loss of supply of natural materials for traditional vernacular building maintenance and repair (e.g. reedbeds for roofing thatch, specific timber types for structural and decorative elements)	**Ecological** (Increase in plant species distribution and number of growing days)	Rainfall; Humidity; Temperature; Hours of sunshine and cloud cover	Increasing annual temperatures; Increased frequency of prolonged rainfall in winter months; Short, intense periods of rainfall in summer months	Topography; Soil types; Site exposure to prevailing weather systems	Building materials used; Aspect of building; State of maintenance/repair	Increase frequency of inspection, maintenance and repair cycles to prolong lifespan of existing materials where possible, lowering demand	Consider alternative materials

Gardens and Designed Landscapes

Gardens and designed landscapes are intentionally laid out for artistic effect. They typically contain a combination of different features such as built structures, plantings and open ground, commonly with evidence of earth-moving (e.g. garden terraces), water management, visible and buried remains, and natural landscape features. This category of asset includes botanic garden collections and urban parks.

- High winds/storm events causing physical damage to plantings, gardens and natural habitats.
- Localised destabilisation of ground causing tree safety issues.
- Spread of pests and diseases causing damage/ loss of existing tree and plant species.
- Ground movement causing damage to gardens and designed landscapes.
- Increased occurrence of waterlogging and associated lack of aeration (suffocation) of roots affecting plant health.
- Changing climate conditions altering species of plant communities.
- Saturation of ground, flash floods and run-off from adjacent areas causing erosion of landscapes and damage/loss of plantings.

Culzean Castle Walled Garden

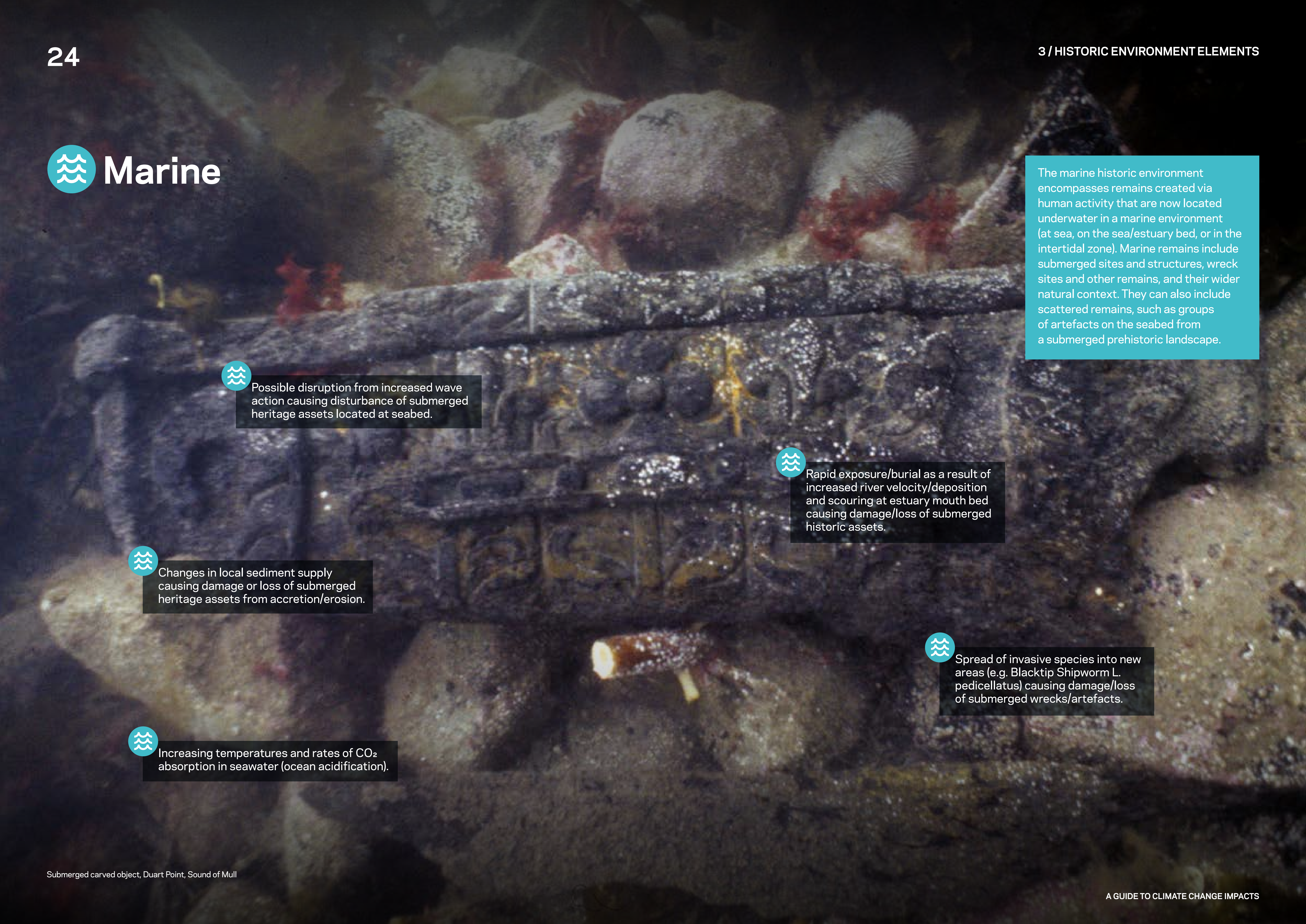
Gardens and Designed Landscapes

Causative Factor	Impact <Cause and Effect>	Hazard			Exposure	Vulnerability/Sensitivity	Adaptation	
		Type of Hazard	Weather Drivers	Climate Change			Resistance	Acceptance
R, T	Spread of pests and diseases causing **damage/loss of existing tree and plant species**	**Ecological** (Increase in plant species distribution, spread of pests (plant/animal/insect), increase in number of growing days etc.)	Rainfall; Humidity; Temperature; Hours of sunshine and cloud cover	Increasing annual temperatures; Increased frequency of prolonged rainfall in winter months; Short, intense periods of rainfall in summer months	Topography; Soil types; Site exposure to prevailing weather systems	Type of plant species; Tolerance or vulnerability to pests and diseases; Proximity to neighbouring plant communities	Consider use of disease-resistant modern hybrids of plant species after conducting an impact assessment; Ongoing skilled horticultural husbandry (healthy plants are more resilient)	Regular monitoring, including signing up to services such as 'Tree Alert'
R, T	Changing climate conditions **altering species of plant communities; Change of habitats/spread of invasive species**							
R, EXW	Saturation of ground, flash floods and run-off from adjacent areas causing **erosion of landscapes and damage/loss of plantings**	**Flooding** ▪ Fluvial	Prolonged periods of rainfall over days/weeks; Short, intense periods of rainfall over hours	Increased frequency of prolonged rainfall in winter months; Increased occurrence of intense summer rainfall events	Topography; Proximity to watercourse	Type of plant species; Tolerance or vulnerability to saturation of ground	Consideration given to surfaces used/size of any drains/frequency of repair/maintenance; Use of tolerant plant species to ground saturation; Improve drainage of nearby hard surfaces; modify and maintain accessibility routes, footpaths, etc.	Plan and arrange sites within conservation landscape management plans, to allow for larger areas to be specifically designed for flood alleviation
		Flooding ▪ Pluvial/Surface Water	Short, intense periods of rainfall over hours		Topography; Presence/absence of hard-ground surfaces			
		Flooding ▪ Groundwater	Prolonged periods of rainfall over weeks/months		Topography; Local geology and superficial deposits			
R, EXW, T	Ground movement causing **damage to gardens and designed landscapes**	**Ground Instability** (e.g. landslide/shrink-swell)	Heavy, prolonged rainfall over days/weeks leading to ground saturation; Alternating saturation and drying of ground	Increased rainfall over weeks/months; Changing frequency/intensity of rainfall; Increasing annual temperatures; Increasing occurrence rates of extreme weather events such as heatwaves	Local geology; topography; Proximity to water sources (springs, rivers etc.); Type and depth of superficial deposits	State of maintenance/repair of surrounding surfaces, local drainage systems; Presence/absence of people/staff on site	Adapt surface drainage and landscaping/planting; Investigate use of more resilient plant species	Relocation of sensitive plants/planting schemes
R, T, EXW	Localised destabilisation of ground causing **tree safety issues**					Type of tree species and its tolerance or vulnerability to alternating cycles of wetting and drying	Change of tree species planted to those more suited to the changing climatic and ground conditions	Individual trees removed as and when they become unsafe, replaced with more tolerant species
R, T, EXW	Localised destabilisation of ground causing **physical damage to access paths/walkways**					Materials used in construction; State of maintenance/repair	Improved surface drainage and regular drain maintenance; Change in path type (raised walkway/cambered paths etc.)	Relocate pathways
R, T, EXW	Increased frequency/intensity of wildfire causing **physical damage/loss of plantings, gardens and natural habitats**	**Wildfire**	Prolonged dry spells over days/weeks; High (and above normal) temperatures over weeks/months	Increasing temperatures across all seasons; Changing patterns and intensities of rainfall, particularly drier summers	Topography; Local geology and soil types	Type of plant/tree species	Change of plant material used/right plants for changing ground and climatic conditions; Controlled burning to reduce hazard where appropriate	Recording of vulnerable sites in anticipation of loss

Continued on next spread

Gardens and Designed Landscapes *(continued)*

Causative Factor	Impact <Cause and Effect>	Hazard			Exposure	Vulnerability/Sensitivity	Adaptation	
		Type of Hazard	Weather Drivers	Climate Change			Resistance	Acceptance
R, EXW, FL	Increased occurrence of waterlogging and associated **lack of aeration (suffocation) of roots affecting plant health**	**Water Penetration/ Saturation**	Prolonged rainfall over days/weeks leading to rise in groundwater table	Increased frequency of prolonged rainfall in winter months; Increased occurrence of intense summer rainfall events	Topography; Local geology and soil types; Proximity to watercourse/poorly drained surfaces	Condition of surrounding surfaces; Type of local drainage or absence of effective water management system; Type of plant/tree species and its tolerance	Use of resistant plant species to ground saturation; Investigate potential for 'rain gardens' designed to retain and slowly release water; Investigate means of improving local drainage, particularly for key specimens (Champion Specimens, rare species/ cultivars)	Ground conditions left to respond naturally to these changes over time; Relocation of sensitive plants/planting schemes
EXW	High winds/storm events causing **physical damage to plantings, gardens and natural habitats**	**Wind/Storms**	High winds; Low pressure systems; Storm events	Changing patterns of extreme weather events	Exposed location (promontory, height in landscape); Exposure to prevailing weather systems	Type of plant/tree species and tolerance/vulnerability to high winds	Change of tree/plant species used; Appropriate plants/trees for changing climatic conditions	Individual trees/plants removed as and when they become unsafe or damaged, and replaced with more tolerant species
T, R	**Changing look/ character of gardens and designed landscapes** as a result of a lack of wood maturation and consequent flowering, fruiting and setting of seed	**Ecological** (Increase in plant species distribution, spread of pests (plant/ animal/insect), increase in number of growing days etc.)	Rainfall; Humidity; Temperature; Hours of sunshine and cloud cover	Increasing annual temperatures; Increased frequency of prolonged rainfall in winter months; Short, intense periods of rainfall in summer months	Topography; Soil types; Site exposure to prevailing weather systems	Type of plant species and its tolerance/vulnerability to changing climatic conditions	Change of tree/plant species used	Appropriate plants/ trees for changing climatic conditions after assessment for impact on conservation and authenticity
R, EXW	Increased occurrence of water penetration/ saturation resulting in **rotting of traditional ancillary structures** (e.g. historic glasshouses, cold frames, plant supports, raised beds, benches, decorative features)	**Water Penetration/ Saturation**	Prolonged periods of rainfall over days/ weeks; Short, intense periods of rainfall over hours	Increased frequency of prolonged rainfall in winter months; Increased occurrence of intense summer rainfall events	Exposed location (e.g. promontory, height in landscape); Exposure to prevailing weather systems	State of maintenance/repair; Materials used; State of maintenance/repair of local drains/water management systems	Remove for inside winter storage where possible. Paint and/or treat regularly where possible and appropriate	
R, EXW, FL	Compaction of lawns/turfed areas; Puddling by animals; Damage from footfall; Rutting from mowers, vehicles etc., leading to **saturation and waterlogging of ground**				Topography; Local geology and soil types; Proximity to watercourse/poorly drained surfaces	State of maintenance/repair; Tolerance of species used; Volume of traffic/footfall	Appropriate grass species and substrate mixes; Consider sub-surface modification to improve drainage	Accept visual and access impacts; Re-route paths to less vulnerable areas if possible



Marine

The marine historic environment encompasses remains created via human activity that are now located underwater in a marine environment (at sea, on the sea/estuary bed, or in the intertidal zone). Marine remains include submerged sites and structures, wreck sites and other remains, and their wider natural context. They can also include scattered remains, such as groups of artefacts on the seabed from a submerged prehistoric landscape.

- Possible disruption from increased wave action causing disturbance of submerged heritage assets located at seabed.
- Rapid exposure/burial as a result of increased river velocity/deposition and scouring at estuary mouth bed causing damage/loss of submerged historic assets.
- Changes in local sediment supply causing damage or loss of submerged heritage assets from accretion/erosion.
- Spread of invasive species into new areas (e.g. Blacktip Shipworm L. pedicellatus) causing damage/loss of submerged wrecks/artefacts.
- Increasing temperatures and rates of CO_2 absorption in seawater (ocean acidification).

Submerged carved object, Duart Point, Sound of Mull

Marine

Causative Factor	Impact <Cause and Effect>	Hazard			Exposure	Vulnerability/Sensitivity	Adaptation	
		Type of Hazard	Weather Drivers	Climate Change			Resistance	Acceptance
T	Spread of invasive species into new areas (e.g. Blacktip Shipworm L. pedicellatus) causing **damage/loss of submerged wrecks/ artefacts**	**Ecological** (Increase in plant species distribution, spread of pests (plant/ animal/insect), increase in number of growing days etc.)	Surface and sea temperatures	Increasing temperatures across all seasons	Sea/ocean chemistry (pH/Salinity)	▪ Structural integrity of asset; Pre-existing condition and inherent resilience to the specific impact in question ▪ Type of material and its inherent resilience to the specific impact in question ▪ Depth to asset and its resting location (e.g. an exposed setting or relatively protected	Where appropriate, consider use of protective barriers to prevent and/or minimise biological decay	▪ Loss of historic asset accepted and process managed. Used as opportunity to excavate and record sites that will otherwise be lost ▪ Relocation or removal of asset(s), where desirable and feasible, from current position
T	Increasing temperatures and rates of CO^2 absorption in seawater (ocean acidification) causing **enhanced rates of corrosion in metal shipwrecks, structures and artefacts**	**Ocean Acidification**					Consider use of sacrificial anodes to prevent corrosion	
R, EXW	Rapid exposure/ burial as a result of increased river velocity/deposition and scouring at estuary mouth bed causing **damage/loss of submerged historic assets**	**Flooding** ▪ Fluvial	Heavy, prolonged rainfall over days; Short, intense periods of rainfall over hours leading to fluvial flooding	Increased frequency of prolonged rainfall in winter months; Increased occurrence of intense summer rainfall events	Proximity to river/ estuary mouth; Local sediment type		Undertake routine monitoring to anticipate periods of exposure and plan accordingly	
SLR, T, EXW	Changes in local sediment supply causing **damage or loss of submerged heritage assets from accretion/erosion**	**Sea Level Rise** **Wind/Storms**	High winds; Low pressure systems; Storm frequency/ intensity and associated storm-surge/storm-wave intensity	Increasing temperatures across all seasons driving changing patterns of extreme weather events	Submerged landscape topography (exposed or sheltered); Exposure to prevailing weather systems			
SLR, T, EXW	Possible disruption from increased wave action causing **disturbance of submerged heritage assets located at seabed**	**Wind/Storms**	Temperature; High winds; Low pressure systems; Storm events					
SLR, T, EXW	Impact of storms possibly amplified by changes in sea level and rates of erosion/ accretion causing **exposure/erosion and damage/loss of underwater and intertidal historic assets**	**Sea Level Rise** **Wind/Storms**	High winds; Low pressure systems; Storm events					

Coastal

Coastal elements of the historic environment are historic assets located directly in the coastal zone, an area influenced by both sea and land processes. The term 'coastal' can encompass all elements of the historic environment as defined in the other themes, as well as more specific elements relating solely to the coast (e.g. harbours, piers, slipways and sea defences).

- Salt water intrusion into buried coastal archaeological deposits (dunes/soils).
- Increased salt decay weathering causing enhanced rates of fabric decay on coastal historic assets.
- Changes in coastal dynamics and soft coastline recession/erosion causing exposure and damage/loss of coastal historic assets.
- Increased frequency and extent of coastal flooding causing damage /loss of historic assets.
- Possible increased wave height and enhanced rates of erosion causing destruction/loss of historic assets on immediate coastline.

Easdale Harbour, Village and Quarries

Coastal

Causative Factor	Impact <Cause and Effect>	Hazard			Exposure	Vulnerability/Sensitivity	Adaptation	
		Type of Hazard	Weather Drivers	Climate Change			Resistance	Acceptance
EXW, R, FL	High-velocity terrestrial flood events causing **damage/ loss as a result of exposure/erosion or burial of low-lying historic assets**	**Flooding** ▪ Fluvial	Heavy, prolonged rainfall over days and/or short, intense periods of rainfall over hours leading to fluvial flooding	Increased frequency of prolonged rainfall in winter months; Increased occurrence of intense summer rainfall events	Proximity to river/ estuary mouth; Local sediment type	Type of asset in question; state of maintenance/repair; Presence/absence of flood defences	▪ Undertake local risk assessments and create adaptation plans; Consider how to effectively prioritise assets ▪ Use temporary coastal defences, e.g. sandbags, to protect a site or coastal exposure to allow time for more information to be recovered ▪ Adapt historic assets so that they can recover from hazard events more quickly (e.g. moving vulnerable services from basement/ground level to a higher level) ▪ Where it is feasible to do so, for example in salt marsh and sand dune environments, and usually carried out as part of a wider programme of coastline management, dune stabilisation and salt marsh restoration could protect coastal heritage assets ▪ In certain and exceptional circumstances, hard defences may be deemed essential to protect outstanding heritage assets, human burial sites or essential historic coastal infrastructure	▪ Record assets in anticipation of damage/ loss (e.g. excavation, laser scanning, collation of archival materials) ▪ Put in place a protocol for a 'be prepared' response to extreme weather events. This may involve inspection followed by implementation of programme of archaeological work commensurate with the scale of loss to recover information and inform any potential clean-up or stabilisation works ▪ In some cases, relocation of historic assets may be the preferred option, generally driven by engaged and active communities – this will not always be a viable option ▪ Loss of historic asset accepted and process managed. Used as opportunity to excavate and record sites that may have otherwise been lost
SLR, EXW	Changes in coastal dynamics and soft coastline recession/ erosion causing **exposure and damage/loss of archaeological deposits or structural instability of upstanding historic assets**	**Coastal Erosion**	High winds; Low pressure systems; Storm events	Increasing temperatures across all seasons driving changing patterns of extreme weather events	Topography; Local geology and soil types; Location (e.g. exposed promontory or sheltered bay); Exposure to prevailing weather systems; Coast type (hard/soft)			
		Wind/Storms						
FL, SLR, EXW	Increased frequency and extent of coastal flooding causing **damage /loss of historic assets**	**Flooding** ▪ Coastal	Low pressure systems; Storm events; High winds	Increasing temperatures across all seasons driving changing patterns of extreme weather events combined with rising sea levels		Proximity to coastal edge; State of maintenance/repair of asset in question; Presence or absence of coastal defences; Height at which the asset is situated		
FL, SLR, EXW	Salt water intrusion into buried coastal archaeological deposits (dunes/ soils) **changing environmental conditions and preservation potential**					Proximity to coastal edge; State of maintenance/repair of asset in question; Type of material used and its sensitivity to salt induced decay		
T, EXW	Hotter, drier conditions combined with high winds leading to increased rates of aeolian erosion and deposition. This leads to **exposure and loss of formerly buried archaeological deposits, or burial of existing surface historic assets**	**Heatwave and/or Drought**	Prolonged dry spells over weeks/months; High temperatures over weeks/months	Increasing temperatures across all seasons; Changing patterns and intensities of rainfall, particularly drier summers	Topography; Local geology and soil types/ surface sediment types	Proximity to coastal edge; State of maintenance/repair; Type of material used and its sensitivity to salt induced decay		
		Winds/Storms (Aeolian Erosion)	High winds; low pressure systems; storm events and associated storm-surge and storm-wave intensity	Increasing temperatures across all seasons driving changing patterns of extreme weather events; Sea-level rise	Exposed location (promontory, height in landscape); Exposure to prevailing weather systems	Proximity to coastal edge; State of maintenance/repair		
EXW, SLR	Possible increased wave height and enhanced rates of erosion causing **destruction/loss of historic assets on immediate coastline**	**Winds/Storms Coastal Erosion**						

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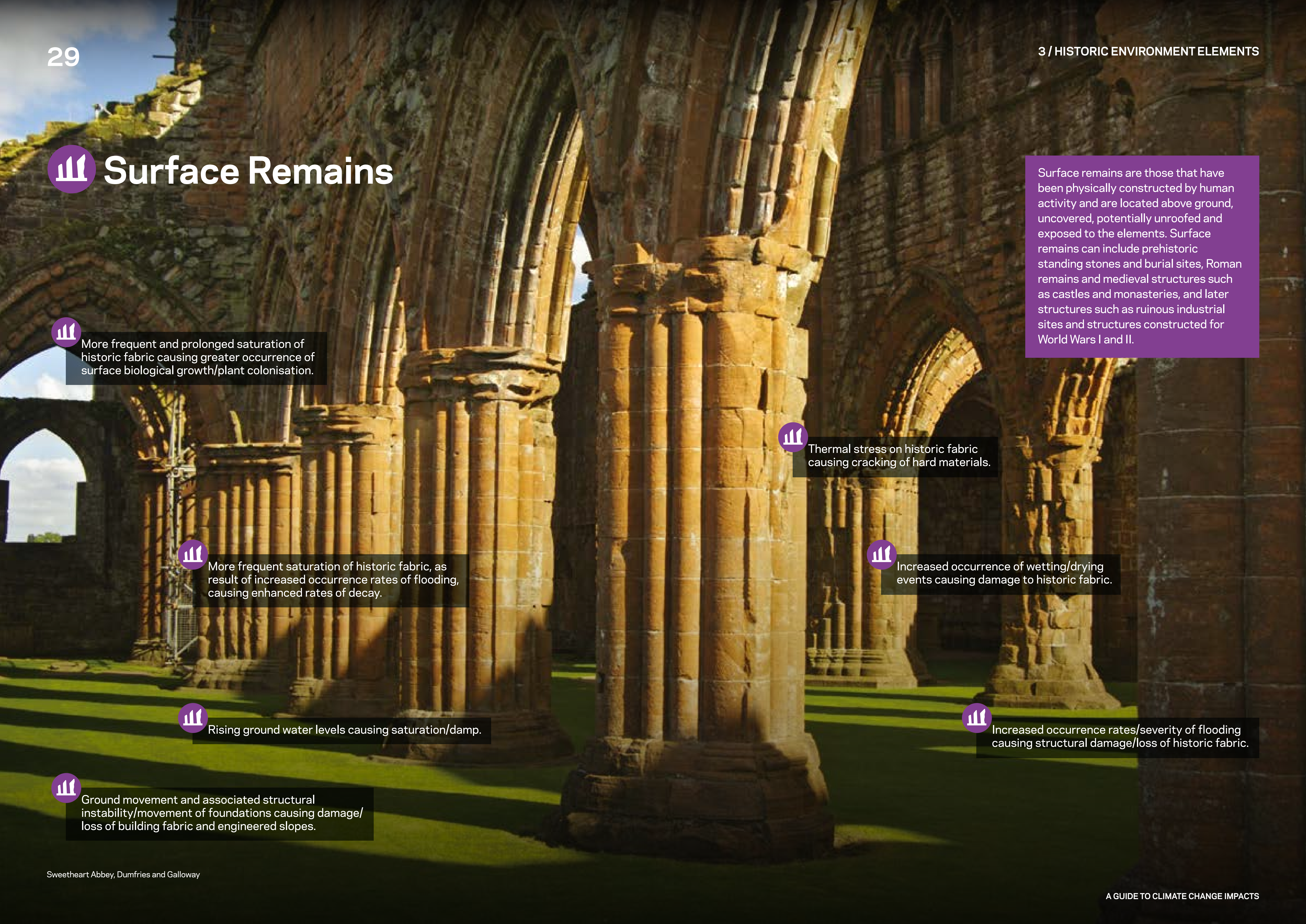
Coastal *(continued)*

Causative Factor	Impact <Cause and Effect>	Hazard: Type of Hazard	Hazard: Weather Drivers	Hazard: Climate Change	Exposure	Vulnerability/Sensitivity	Adaptation: Resistance	Adaptation: Acceptance
FL, SLR, EXW	Greater flood frequency and consequential damage at river mouths, when there is a coincidence of river and coastal flooding **causing damage and/or loss of historic assets**	**Flooding** ▪ Coastal	Low pressure systems; Storm events; Temperature; High winds	Increasing temperatures across all seasons driving changing patterns of extreme weather events combined with rising sea-levels	Topography; Local geology and soil types; Location (e.g. exposed promontory or sheltered bay); Exposure to prevailing weather systems; Coast type (hard/soft)	Proximity to coastal edge; State of maintenance/repair of asset in question; Presence or absence of coastal defences; Height at which the asset is situated		
		Flooding ▪ Fluvial	Prolonged periods of rainfall over days/ weeks; Short, intense periods of rainfall over hours	Increased frequency of prolonged rainfall in winter months; Increased occurrence of intense summer rainfall events	Topography; Proximity to watercourse	Type of asset in question; State of maintenance/repair of asset; Presence/absence of flood defences		
EXW, SLR, T	Increased salt decay weathering causing **enhanced rates of fabric decay on costal historic assets**	**Water Penetration/ Saturation**	Prolonged periods of rainfall over days/ weeks; Short, intense periods of rainfall over hours	Increased frequency of prolonged rainfall in winter months; Increased occurrence of intense summer rainfall events	Exposed location (e.g. promontory, height in landscape); Exposure to prevailing weather systems	Type of materials; Their porosity and ability to absorb and retain water and ability to dry out after wetting events; Proximity to coast/marine environment; State of maintenance/repair of asset		
		Winds/Storms	High winds; Low pressure systems; Storm events	Increasing temperatures across all seasons driving changing patterns of extreme weather events	Exposed location (promontory, height in landscape, aspect to prevailing weather systems)			
EXW, SLR, T,	Salinisation of coastal soils causing **changes to the preservation potential of buried remains in coastal soils**	**Sea Level Rise** **Wind/Storms**	High winds; Low pressure systems; Storm events	Increasing temperatures across all seasons driving changing patterns of extreme weather events	Topography; Local geology and soil types; Location (e.g. exposed promontory or sheltered bay); Exposure to prevailing weather systems; Coast type (hard/soft)	Type of material and inherent sensitivity to changing environmental conditions		



Surface Remains

Surface remains are those that have been physically constructed by human activity and are located above ground, uncovered, potentially unroofed and exposed to the elements. Surface remains can include prehistoric standing stones and burial sites, Roman remains and medieval structures such as castles and monasteries, and later structures such as ruinous industrial sites and structures constructed for World Wars I and II.

- More frequent and prolonged saturation of historic fabric causing greater occurrence of surface biological growth/plant colonisation.
- Thermal stress on historic fabric causing cracking of hard materials.
- More frequent saturation of historic fabric, as result of increased occurrence rates of flooding, causing enhanced rates of decay.
- Increased occurrence of wetting/drying events causing damage to historic fabric.
- Rising ground water levels causing saturation/damp.
- Increased occurrence rates/severity of flooding causing structural damage/loss of historic fabric.
- Ground movement and associated structural instability/movement of foundations causing damage/loss of building fabric and engineered slopes.

Sweetheart Abbey, Dumfries and Galloway

Surface Remains

Causative Factor	Impact <Cause and Effect>	Hazard: Type of Hazard	Hazard: Weather Drivers	Hazard: Climate Change	Exposure	Vulnerability/Sensitivity	Adaptation: Resistance	Adaptation: Acceptance
R, EXW	Increased rainfall and more frequent and prolonged saturation of historic fabric causing **enhanced rates of decay**	**Water Penetration** ▪ Wind-driven rain ▪ Overflow ▪ Splashback from hard surfaces	Intense rainfall events over hours/days; High winds	Increased frequency of prolonged rainfall in winter months; Increased occurrence of intense summer rainfall events	Proximity to watercourse; Local geology and superficial deposits; Presence/absence of hard ground surfaces	Structural integrity of historic fabric; Materials used; State of maintenance/repair	Increase size/capacity of rainwater systems at critical points; More frequent maintenance; Improved/new protective weathering details	▪ Record assets in anticipation of damage/loss (e.g. excavation, laser scanning, collation of archival materials) ▪ Put in place a protocol for a 'be prepared' response to extreme weather events. This may involve inspection followed by implementation of programme of archaeological work commensurate with the scale of loss to recover information and inform any potential clean-up or stabilisation works ▪ In some cases, relocation of historic assets may be the preferred option, generally driven by engaged and active communities – this will not always be a viable option ▪ Loss of historic asset accepted and process managed. Used as opportunity to excavate and record sites that may have otherwise been lost
R, EXW, FL	More frequent saturation of historic fabric, as result of increased occurrence rates of flooding, causing **enhanced rates of decay**	Flooding ▪ Fluvial	Prolonged periods of rainfall over days/weeks; Short, intense periods of rainfall over hours		Topography; Proximity to watercourse		Attend culverts and adjacent burns; Route for surge water flows around assets; General improved drainage	
	Increased occurrence rates/severity of flooding causing structural **damage/loss of historic fabric**	Flooding ▪ Pluvial/Surface Water	Short, intense periods of rainfall over hours		Topography; Presence/absence of hard ground surfaces			
		Flooding ▪ Groundwater	Prolonged periods of rainfall over weeks/months		Topography; Local geology and superficial deposits			
T, R	More frequent and prolonged saturation of historic fabric causing **greater occurrence of surface biological growth/plant colonisation**	**Ecological** (Increase in plant species distribution, spread of pests (plant/animal/insect), increase in number of growing days etc.)	Rainfall; Humidity; Temperature; Hours of sunshine and cloud cover	Increasing annual temperatures; Increased frequency of prolonged rainfall in winter months; Short, intense periods of rainfall in summer months	Topography; Soil types; Site exposure to prevailing weather systems	Materials used; Exposure of asset; State of repair maintenance/repair	Improved protective weathering details; Repointing where appropriate; Generally more regular, routine maintenance	
T, EXW	Increasing temperatures/dry conditions and associated increased risk of fire causing **damage/loss of historic asset fabric, e.g. thermal shock of vulnerable historic fabric**	**Fire (caused by Heatwave/Drought)**	Prolonged dry spells; High (and above normal) temperatures over weeks/months	Increasing temperatures across all seasons	Topography; Exposure to prevailing weather systems	Structural integrity of the historic asset fabric; State of maintenance and repair; Susceptibility of materials used;	Repair with appropriate traditional materials such as lime mortars, traditional paints	
R, EXW	Ground movement and associated structural instability/movement of foundations causing **damage/loss of building fabric and engineered slopes**	**Ground Instability** (e.g. Landslide/shrink-swell)	Heavy, prolonged rainfall over days/months leading to ground saturation; Alternating saturation and drying of ground	Increased rainfall over weeks/months; Changing frequency/intensity of rainfall; Increasing annual temperatures; Increasing occurrence rates of extreme weather events such as heatwaves	Topography; Local geology and soil types; Proximity to water sources, such as springs	Structural integrity of the historic fabric; Materials used in construction; State of maintenance/repair of asset/surrounding local drainage	More frequent below-ground drainage maintenance/checks; Adapt surface drainage and landscaping/planting to stabilise vulnerable surfaces; Consider ground investigation, underpinning and strengthening of vulnerable slopes	

Continued on next spread

Surface Remains *(continued)*

Causative Factor	Impact <Cause and Effect>	Hazard			Exposure	Vulnerability/Sensitivity	Adaptation	
		Type of Hazard	Weather Drivers	Climate Change			Resistance	Acceptance
T, EXW	Thermal stress on historic fabric causing **cracking of hard materials**	**High Temperatures/ Heatwave/Fluctuating Temperatures**	Rapidly fluctuating temperatures over hours/days	Increasing temperatures across all seasons; More extreme variations in temperature	Topography; Site aspect (certain aspects more exposed to solar radiation, e.g. south-facing)	Structural integrity of the fabric; State of maintenance/repair; Materials used	Repair with appropriate traditional materials such as lime mortars, traditional paints	
R, FL	Rising ground water levels causing **saturation/damp, and associated decay, of historic assets with sub-surface components** (e.g. basements/cellars)	**Groundwater Flooding**	Prolonged periods of rainfall over weeks/ months	Increased frequency of prolonged rainfall in winter months; Increased occurrence of intense summer rainfall events	Topography; Local geology and superficial deposits	Structural integrity of the historic fabric; State of maintenance/repair; Materials used; State of maintenance/ repair of local drains/water management systems	Increase size/capacity of rainwater systems at critical points; More frequent maintenance; Remove hard ground surfaces adjacent to walls; Improve drainage around site	
EXW	High winds/storm events **causing damage to historic fabric**	**Wind/Storms**	High winds; Low pressure systems; Storm events	Changing patterns of extreme weather events	Exposed location (e.g. promontory, height in landscape); Exposure to prevailing weather systems	State of maintenance/repair of historic assets; Presence/ absence of people/staff on site for a proactive response	Increase frequency of inspection, maintenance and repair	
R, T, EXW	Increased occurrence of wetting/drying events **causing damage to historic fabric**	**Wetting and Drying Cycles**	Alternating wet and dry spells; Temperature change	Increased rainfall over weeks/months; Changing frequency/ intensity of rainfall; Increasing annual temperatures; Increasing occurrence rates of extreme weather events such as heatwaves	Topography; Proximity to watercourse or poorly drained surfaces; Exposure to prevailing weather systems	Structural integrity of building fabric, materials; State of maintenance/repair; Materials used	Improved weathering details; More frequent maintenance; Repair of mortar joints	

Buried Remains

Buried remains are those that have been physically constructed by human activity, or artefacts that record human activity, some of which may have been recorded and/or previously excavated. Buried remains include subsurface prehistoric burial sites, hillforts and mottes, crannogs, cropmarks and artefacts of human activity such as midden sites, as well as structures that have been reburied to aid in their preservation.

- Increase in length of growing season causing damage to buried remains and possible loss of soil stratigraphy from plant and tree roots.
- Drying out of waterlogged deposits causing decay of organic materials used in dating methods.
- High winds/storm events resulting in damage/uprooting of trees and exposure of buried remains.
- Increasing temperatures leading to greater risk of fire, causing thermal shock/heat alteration of buried remains.
- Spread of new and invasive species, and possible increased rates of bioturbation, causing damage to buried remains and soil stratigraphy.
- More frequent and prolonged saturation of buried remains causing changes in preservation potential and damage/loss of historic assets.
- Movement of the ground causing disturbance of buried remains and possible damage or exposure and loss.

Links of Noltland, Westray, Orkney

Buried Remains

Causative Factor	Impact <Cause and Effect>	Hazard			Exposure	Vulnerability/Sensitivity	Adaptation	
		Type of Hazard	Weather Drivers	Climate Change			Resistance	Acceptance
R, FL, EXW	More frequent and prolonged saturation of buried remains causing **changes in preservation potential and damage/loss of historic assets**	Flooding ▪ Fluvial	Prolonged periods of rainfall over days/ weeks ; Short, intense periods of rainfall over hours	Increased frequency of prolonged rainfall in winter months; Increased occurrence of intense summer rainfall events	Topography; Proximity to watercourse	Type of material (e.g. wood, metal, stone) and its susceptibility to changing ground conditions; Age and condition of buried remains	More frequent below-ground drainage maintenance/checks; Adapt surface drainage and landscaping/planting as needed to manage water flow throughout the site	▪ Record assets in anticipation of damage/ loss (e.g. excavation, laser scanning, collation of archival materials) ▪ Put in place a protocol for a 'be prepared' response to extreme weather events. This may involve inspection followed by implementation of programme of archaeological work commensurate with the scale of loss to recover information and inform any potential clean-up or stabilisation works ▪ In some cases, relocation of historic assets may be the preferred option, generally driven by engaged and active communities – this will not always be a viable option ▪ Loss of historic asset accepted and process managed. Used as opportunity to excavate and record sites that may have otherwise been lost
		▪ Pluvial/ Surface Water	Short, intense periods of rainfall over hours		Topography; Presence/ absence of hard ground surfaces			
		▪ Groundwater	Prolonged periods of rainfall over weeks/ months		Topography; Local geology and superficial deposits			
FL, R, EXW	Erosion of susceptible stream/river banks (associated with increased occurrence rates of flood events and high-velocity water flow) **causing exposure, and possible loss of buried remains**	**Flooding** ▪ Fluvial	Prolonged periods of rainfall over days/ weeks; Short, intense periods of rainfall over hours	Increased frequency of prolonged rainfall in winter months; Increased occurrence of intense summer rainfall events	Topography; Proximity to watercourse; Local geology and superficial deposits			
FL, T, EXW	Movement of the ground causing disturbance of buried **remains and possible damage or exposure and loss**	**Ground Instability** (e.g. Landslide/shrink-swell)	Heavy, prolonged rainfall over days/ months leading to ground saturation; Alternating saturation and drying of ground	Increased rainfall over weeks/months; Changing frequency/ intensity of rainfall; Increasing annual temperatures; Increasing occurrence rates of extreme weather events such as heatwaves	Topography; Local geology and soil types; Proximity to water sources, such as springs		Adapt surface drainage and landscaping/planting to stabilise vulnerable surfaces; Consider ground investigation, underpinning and strengthening of vulnerable slopes where appropriate	
R, T	Increase in length of growing season causing **damage to buried remains and possible loss of soil stratigraphy from plant and tree roots**	**Ecological** (Increase in plant species distribution, spread of pests (plant/ animal/insect), increase in number of growing days etc.)	Rainfall; Humidity; Temperature; Hours of sunshine and cloud cover	Increasing annual temperatures; Increased frequency of prolonged rainfall in winter months; Short, intense periods of rainfall in summer months	Topography; Local geology; Soil types; Local vegetation/crop types	Depth of deposit; Type of material and its tolerance against bioturbation; Age/ condition of buried remains	Active management of site to control the spread of invasive species	
R, T	Spread of new and invasive species, and possible increased rates of bioturbation, causing **damage to buried remains and soil stratigraphy**				Topography; Local geology; Soil types; Local vegetation types; Local animal species			

Continued on next spread

Buried Remains *(continued)*

Causative Factor	Impact <Cause and Effect>	Hazard			Exposure	Vulnerability/Sensitivity	Adaptation	
		Type of Hazard	Weather Drivers	Climate Change			Resistance	Acceptance
R, T	More frequent cycles of wetting and drying, and associated changes in ground conditions, causing preservation potential **of buried artefacts/ organic materials to be effected and possible damage or loss of artefacts/ organic material as a result**	**Wetting and Drying Cycles**	Alternating wet and dry spells; Temperature change	Increased rainfall over weeks/months; Changing frequency/ intensity of rainfall; Increasing annual temperatures; Increasing occurrence rates of extreme weather events such as heatwaves	Topography; Proximity to watercourse or poorly drained surfaces; Exposure to prevailing weather systems	Type of material (e.g. wood, metal, stone) and its susceptibility to changing ground conditions; Age and condition of buried remains	Improved weathering details; More frequent maintenance and monitoring	
T, EXW	Drying out of waterlogged deposits causing **decay of organic materials used in dating methods**	**High Temperatures/ Heatwave/Drying out of soils**	Prolonged dry spells over weeks/months; High temperatures over weeks/months	Increasing temperatures across all seasons; Changing patterns and intensities of rainfall, particularly drier summers	Topography; Local geology; Soil types/ surface sediment types; Proximity to body of water	Depth of deposit; Type of material; Age/condition of buried remains	Consider use of appropriate plantings that hold/retain water and provide shade; Modification of drainage systems	
T, EXW	Increasing temperatures leading to greater risk of fire, **causing thermal shock/heat alteration of buried remains**	**Wildfire**					Change of plant material used/right plants for changing ground and climatic conditions; Controlled burning to reduce hazard where appropriate	
T, R	Changing soil chemistry causing **damage to buried remains/negative impacts on preservation potential**	**Chemical**	Rainfall; Humidity; Temperature; Hours of sunshine and cloud cover	Increasing temperatures across all seasons; Changing patterns and intensities of rainfall	Local geology; Soil types/superficial deposits	Type of material (e.g. wood, metal, stone) and its susceptibility to changing ground conditions; Age/ condition of buried remains	Consider use of appropriate plantings that hold/retain water and provide shade	
EXW	High winds/storm events resulting in damage/uprooting of trees and **exposure of buried remains**	**Wind/Storms**	High winds; Low pressure systems; Storm events	Changing patterns of extreme weather events	Exposed location (e.g. promontory, height in landscape); Exposure to prevailing weather systems; Local vegetation types	Depth of deposit; Type of material; Age/condition of buried remains	Improved management of plantings to minimise damage; Change of tree species to those more tolerant of extreme weather	

Collections and Internal Fabric

Collections and internal fabric are moveable historic objects and fixed architectural fabric located within internal environments (e.g. museums, galleries and other roofed buildings). Collections are ex situ objects constructed or modified by human activity, varying in size, type, age and material. This might include an ornament or tool, fine and decorative arts, textiles and furniture, books, archives, photography, natural history specimens and industrial artefacts. Internal fabric is the in situ decorative and structural 'fixed' objects found inside roofed buildings and structures, such as wall linings, panels, plasterwork, timber beams, floor tiles, window glass and doors. This element also includes 'ecofacts', defined as excavated organic/palaeoenvironmental material such as seeds, unworked animal bone, mollusc shells and nutshells that are typically components of archaeological assemblages and curated alongside artefacts in museums.

Increased fire risk causing physical damage and loss of internal fabric and collections.

Increased rainfall causing more frequent and prolonged saturation of building fabric and enhanced rates of internal/external building fabric decay.

Higher internal humidity as a result of warmer temperatures and increased rainfall rates.

Fluctuating internal humidity levels as a result of more frequent wetting and drying cycles.

Higher internal temperatures causing drying out/ thermal stress on internal fabric and objects.

Increased occurrence rates/severity of flood events causing damage/loss of internal building fabric and collections.

Elgin Stones Exhibition, Elgin Cathedral

Collections and Internal Fabric

Causative Factor	Impact <Cause and Effect>	Hazard			Exposure	Vulnerability/Sensitivity	Adaptation	
		Type of Hazard	Weather Drivers	Climate Change			Resistance	Acceptance
T, R, EXW	Ground movement and associated structural instability/movement of foundations causing **damage/loss of building fabric and engineered slopes**	**Ground Instability** (e.g. Landslide/shrink-swell)	Heavy, prolonged rainfall over days/ months leading to ground saturation; Alternating saturation and drying of ground	Increased rainfall over weeks/months; Changing frequency/ intensity of rainfall; Increasing annual temperatures; Increasing occurrence rates of extreme weather events such as heatwaves	Topography; Local geology and soil types; Proximity to water sources, such as springs	Structural integrity of the building fabric or engineered slope or materials; State of maintenance/repair; Local drainage; Susceptibility of building materials used; Presence/absence of people/ staff on site	More frequent below-ground drainage maintenance/checks; adapt surface drainage and landscaping/ planting; Consider ground investigation, underpinning and strengthening of vulnerable slopes	
R, EXW	Increased rainfall causing more frequent and prolonged saturation of building fabric and **enhanced rates of internal/ external building fabric decay**	**Water Penetration** ▪ Wind-driven rain ▪ Overflow ▪ Splashback from hard surfaces ▪ Run-off from adjacent areas	Intense rainfall in isolated events and as a cluster of events; High winds	Increased frequency of prolonged rainfall in winter months; Short, intense periods of rainfall in summer months	Local geology and superficial deposits and their influence on natural drainage systems; presence/ absence of hard surfaces; Site exposure to prevailing weather systems	Structural integrity of the building fabric/materials; State of maintenance/repair; Materials used; Exposure of building/ structure	Increase size/capacity of rainwater systems at critical points; More frequent maintenance; Remove hard ground surfaces adjacent to walls; Improve drainage around site	
T, R, EXW	Increased rates of internal biological growth (e.g. mould) and spread of pest species (existing/new/invasive) causing **condition of internal fabric and collections to be compromised**	**Ecological** (Increase in plant species distribution, spread of pests (plant/ animal/insect), increase in number of growing days etc.)	Rainfall; Humidity; Temperature; Hours of sunshine and cloud cover	Increasing annual temperatures; Increased frequency of prolonged rainfall in winter months; Short, intense periods of rainfall in summer months	Topography; Soil types; Site exposure to prevailing weather systems	Type of plant species; Tolerance or vulnerability to pests and diseases; Proximity to neighbouring plant communities	Improved protective weathering details; Repointing of masonry; Apply appropriate external coatings; Use of traditional materials to dissipate moisture	
R, EXW, FL	Increased occurrence rates/severity of flood events causing **damage/loss of internal building fabric and collections**	**Flooding** ▪ Fluvial	Prolonged periods of rainfall over days/ weeks; Short, intense periods of rainfall over hours	Increased frequency of prolonged rainfall in winter months; Increased occurrence of intense summer rainfall events	Topography; Proximity to watercourse	Structural integrity of the building fabric; State of maintenance/repair; Materials used; State of maintenance/ repair of local drains/water management systems; Presence/absence of people/ staff on site	Attend culverts and adjacent burns; Route for surge water flows around buildings; Flood plans in place; Changes to layout of buildings to lower impact (e.g. move sensitive services from basements/ ground floors to higher levels where possible)	
		▪ Pluvial/Surface Water	Short, intense periods of rainfall over hours		Topography; Presence/ absence of hard-ground surfaces			
		▪ Groundwater	Prolonged periods of rainfall over weeks/ months		Topography; Local geology and superficial deposits			

Continued on next spread

Collections and Internal Fabric *(continued)*

Causative Factor	Impact <Cause and Effect>	Hazard			Exposure	Vulnerability/Sensitivity	Adaptation	
		Type of Hazard	Weather Drivers	Climate Change			Resistance	Acceptance
T, R	Higher internal humidity as a result of warmer temperatures and increased rainfall rates causing: ▪ **greater prevalence of mould, mildew and fungal attack** ▪ **likelihood of new species of insects/pests and additional life cycles of existing insects/pests per year** ▪ **swelling, distortion or discolouration of organic objects, corrosion of metals and increased frequency of failure of conservation treatments**	**Air Temperature and Humidity**	Temperature; Hours of sunshine and cloud cover; Humidity	Increasing temperatures across all seasons	Aspect to sun	Aspect to sun; solar gain potential of room in question; Pre-existing condition of room	▪ Regular object inspection and environmental monitoring ▪ Extra resources towards preventative conservation ▪ Increased use and monitoring of insect traps to ensure pest issues are assessable in terms of follow-on treatments ▪ Regular risk-assessment and review of exhibition and storage environments ▪ Emergency plans should be established and kept up-to-date to mitigate risks ▪ Check ventilation	Moving objects and collections to more suitable conditions should be considered
		Water Penetration ▪ Wind-driven rain ▪ Overflow ▪ Splashback from hard surfaces ▪ Run-off from adjacent areas	Intense rainfall events over hours/days; High winds	Increased frequency of prolonged rainfall in winter months; Increased occurrence of intense summer rainfall events	Proximity to watercourse; Local geology and superficial deposits; Presence/absence of hard ground surfaces	Structural integrity of the building fabric; State of maintenance/repair; Materials used; State of maintenance/repair of local drains/water management systems		
T, EXW	Fluctuating internal humidity levels as a result of more frequent wetting and drying cycles causing **cracking, splitting and warping of objects and internal fabric**	**Wetting and Drying Cycles**	Alternating wet and dry spells; Temperature change	Increased rainfall over weeks/months; Changing frequency/intensity of rainfall; Increasing annual temperatures; Increasing occurrence rates of extreme weather events such as heatwaves	Topography; Proximity to watercourse or poorly drained surfaces; Exposure to prevailing weather systems	Structural integrity of building fabric, materials; State of maintenance/repair; Materials used	Regular object inspection; Continuously monitor the exhibition/storage environment and modify or change as required; Install additional primary housing and protection (boxes, covers, etc.); Improved external weathering details; More frequent maintenance/repair	
T	Higher internal temperatures causing drying out/thermal **stress on internal fabric and objects, distortion and cracking and accelerated failure of paint systems and conservation treatment**	**High Temperatures/Heatwave/Fluctuating Temperatures**	Rapidly fluctuating temperatures over hours/days	Increasing temperatures across all seasons; Changing patterns and intensities of rainfall, particularly drier summers	Topography; Site aspect (certain aspects more exposed to solar radiation, e.g. south-facing)	Structural integrity of the building fabric; Materials used; State of maintenance/repair	Regular inspection of internal fabric/objects and modification of environment as required; Reinstate traditional passive systems (i.e. install traditional blinds, canopies); Improve passive cooling and ventilation; Improve storage environments of objects	Continuous monitoring of internal fabric and objects; Install additional primary housing and protection (i.e. boxes, covers, etc.)
T	Increased fire risk causing physical **damage and loss of internal fabric and collections**	**Fire**	Prolonged dry spells over days/weeks; High (and above normal) temperatures over weeks/months			State of maintenance/repair	Install fire protection and fire-resistance systems; Remove/control potential hazards; Ensure that emergency evacuation/salvage procedures and formalised agreements with local Fire Services are in place	Install fire detection systems; Ensure doors and windows are shut when premises are unattended; Maintain a hazard-free environment

4 SCOTLAND'S CHANGING CLIMATE: THE FACTS

Moray Place, Edinburgh New Town

We know that our climate has already shifted as a result of climate change, and we know that it will continue to change over the coming decades. Understanding what has happened already, and being aware of what future trends are likely, are useful starting points when we start to think about ways to lessen the impact.

It's Getting Warmer

Based on data provided in the State of the UK Climate 2018 and Extreme Weather supplement reports[8]:

- If we compare climate averages for the most recent decade (2009 to 2018) with climate averages for 1981 to 2010 they show that average temperatures in the UK have increased by 0.3°C.
- If we compare current climate averages for the most recent decade (2009 to 2018) with climate averages for a period further back in the 20th century (1961 to 1990) the observed change is greater, with annual temperatures now 0.9°C warmer.
- The top 10 warmest years recorded, in a series that began in 1884, have occurred since 2002, whereas none of the top 10 coldest years recorded have occurred since 1963.
- In the recent past (1981–2000), the probability of seeing an 'exceptional' summer as hot as 2018 was low (<10% in any given year). This probability has already increased due to climate change, and is now estimated to be between 10% and 20%.
- The hottest day of the year is now on average 0.8°C hotter than it was earlier in the 20th century, and warm spells have more than doubled in length, increasing from an average of 5.3 days in 1961–1990 to 13.2 days in 2008–2017.

This warming trend is set to continue. If greenhouse gas emissions continue at their current levels, by 2070 central Scotland, for example, could experience additional warming in the winter months of between 0.6°C and 4.5°C, and between 0.6°C and 4.8°C in the summer months[9].

[8] The Met Office. 2019. State of the UK Climate Reports. Available at https://www.metoffice.gov.uk/research/climate/maps-and-data/about/state-of-climate.

[9] The Met Office. 2018. UKCP18 Key Results Available at: https://www.metoffice.gov.uk/research/collaboration/ukcp/key-results.

Rainfall Patterns Are Changing

Based on data provided in the State of the UK Climate 2018 and Extreme Weather supplement reports[10]:

- If we compare climate averages for the most recent decade (2009 to 2018) with climate averages for 1981 to 2010 they show that summers have been on average 11% wetter and winters 5% wetter.
- If we compare current climate averages for the most recent decade (2009 to 2018) with climate averages for a period further back in the 20th century (1961 to 1990) the observed change is greater, with summers now on average 13% wetter and winters 12% wetter.
- Rainfall extremes have also changed, with the highest rainfall accumulation over five days during the most recent decade (2008–2017) recorded as being 4% higher than it was between 1961 and 1990.
- The amount of rainfall recorded on the wettest days has also risen dramatically. In the west of Scotland, for example, up to 36% more rainfall is now recorded on the wettest days compared to the totals recorded on average between 1961 and 1990.

Further changes in the amount of rainfall, and when and how it occurs, are predicted in the coming decades. In short, we are expecting winters to become wetter and summers to become drier. If greenhouse gas emissions continue at their current levels, by 2070 the winter months in central Scotland could be anywhere between 4% drier to 9% wetter, and summer months anywhere between 40% drier to 8% wetter[11].

Rising Floodwaters

How and when we experience flooding is intrinsically linked to our climate. The most common time to experience flooding is when a large amount of rain occurs – either from a short, intense period of rainfall, or a longer period of persistent rainfall – resulting in high river levels. Other flooding mechanisms include the rapid melting of snow, rising groundwater levels, surface water flooding and high tides combined with storm surges.

Scotland has a considerable freshwater resource[12]. There are:

- approximately 125,000 km of running waters (rivers and burns)
- over 27,000 lochs and lochans
- an estimated 198,000 ponds
- 220 km of canal habitat.

This represents around 90% of the volume of surface freshwater in the UK. There is also an extensive coastline, around 21,000 km in length, which represents around 12% of Europe's total coastline. In short, the natural landforms and conditions that enable flooding to occur are found extensively across Scotland. There are also abundant hard, poorly draining surfaces in our towns and cities, which can make surface water flooding more likely.

The risk of flooding is expected to rise as patterns of rainfall change. In particular, increased levels of precipitation are expected in winter months alongside an expected rise in the number of short, intense periods of rainfall in summer months. The UK Climate Change Risk Assessment 2017 (Evidence Report)[13] *'presents compelling evidence that climate change may lead to increases in heavy rainfall and significantly increased risks from fluvial and surface flooding by mid-century. Rising sea-levels will further increase the risk of flooding and erosion along the coastal edge.'*

[10] The Met Office. 2019. State of the UK Climate Reports.
Available at https://www.metoffice.gov.uk/research/climate/maps-and-data/about/state-of-climate.

[11] The Met Office. 2018. UKCP18 Key Results
Available at: https://www.metoffice.gov.uk/research/collaboration/ukcp/key-results.

[12] Scotland's Environment. State of the Environment Report 2014.
Available at: https://www.environment.gov.scot/our-environment/state-of-the-environment/2014-state-of-the-environment-report/.

[13] Committee on Climate Change. 2017. UK Climate Change Risk Assessment 2017 Evidence Report.
Available at: https://www.theccc.org.uk/tackling-climate-change/preparing-for-climate-change/uk-climate-change-risk-assessment-2017/.

A Dynamic Coast

The impacts of climate change on our historic environment are clearly demonstrated in the coastal zone, an area influenced by both marine and land processes. Since the mid-1800s, rates of sea-level rise (SLR) have been consistently measured at tide gauges around the UK. The measurements recorded show an annual sea-level increase of around 1.4 mm, which is consistent with the globally averaged figure of around 1.8 mm. Rates of SLR are highly variable, with data showing that certain parts of the UK are now experiencing more rapid rates of change. Over the last 20 years, rates of SLR measured at Scottish ports have been in the region of 3mm a year[14 15], and we know that rising sea levels are increasing the frequency of flood events recorded at Scotland's tide gauges[16].

The predictions for future SLR are stark. As an example, if greenhouse gas emissions continue as they are now, by the year 2100 Edinburgh could experience a rise in sea level of anywhere between 30 and 90cm[17]. Rising seas combined with future storm wave activity have the potential to significantly increase future rates of erosion around our vulnerable coast.

A project to assess rates of coastal erosion in Scotland, 'Dynamic Coast: Scotland's National Coastal Change Assessment'[18], has used over 1 million data points summarising 2,000 Ordnance Survey maps to determine historic and modern rates of coastal erosion. The project mapped the changing position of Scotland's 'soft' coastline in 1890, 1970 and today alongside future projections. 'Soft' coastlines are those composed of unconsolidated materials that have the potential to erode. The results show that:

- since the 1970s, there has been a 39% increase in the extent of erosion
- average erosion rates have doubled to 1 meter per year compared with the historic baseline of 0.5 meters per year.

Events in Combination

Some of the greatest impacts from climate change occur when events happen in combination; for example, high temperatures and low rainfall leading to drought and/or wildfire[19]; rising seas and storm events leading to enhanced rates of coastal erosion; and changing rainfall patterns and warmer temperatures leading to the spread of invasive plant and insect species.

There is an enhanced threat to certain exposed historic assets from combination events such as intense rainfall and high winds or storm events resulting from wind-driven rain. This is rain that is given a horizontal velocity component by wind, leading to increased penetration into structures and materials. Projected increases in rainfall and rainfall intensity are likely to increase the impact of wind-driven rain as a mechanism of decay in the historic environment[20]. Furthermore, warmer and drier summers will increase the rate of drying of saturated materials, potentially enhancing rates of decay as a result of more frequent wetting and drying cycles. Increasing warmer and wetter conditions will lead to the need for more frequent maintenance on buildings, in order to address increased vegetation growth and the potential for blocking of rainwater disposal and drainage systems.

[14] Hansom, J.D., Fitton, J.M., and Rennie, A.F. (2017) Dynamic Coast - National Coastal Change Assessment: National Overview, CRW2014/2.

[15] Rennie, A. F., & Hansom, J. D. (2011). Sea level trend reversal: Land uplift outpaced by sea level rise on Scotland's coast. *Geomorphology*, 125(1), 193-202.

[16] Ball, T., Booth, L. M., Duck, R. W., Edwards, A., Hickey, K. R., & Werrity, A. (2009). Coastal flooding in Scotland: past, present and future. *Coasts, Marine Structures and Breakwaters: Adapting to Change.*

[17] The Met Office. 2018. UKCP18 Key Results. Available at: https://www.metoffice.gov.uk/research/collaboration/ukcp/key-results.

[18] Hansom, J.D., Fitton, J.M., and Rennie, A.F. (2017) Dynamic Coast - National Coastal Change Assessment: National Overview, CRW2014/2.

[19] Ryan, K. C., Jones, A. T., Koerner, C. L., & Lee, K. M. (2012). Wildland fire in ecosystems: effects of fire on cultural resources and archaeology. *Gen. Tech. Rep. RMRS-GTR-42-vol. 3. Fort Collins, CO: US Department of Agriculture, Forest Service, Rocky Mountain Research Station. 224 p., 42(3).*

[20] Orr, S. A., Young, M., Stelfox, D., Curran, J., & Viles, H. (2018). Wind-driven rain and future risk to built heritage in the United Kingdom: Novel metrics for characterising rain spells. Science of the Total Environment, 640, 1098-1111.

Scotland's Changing Climate

IT'S GETTING WARMER
Annual average temperatures have risen by **0.9°C**.*

THE HOTTEST DAYS ARE GETTING HOTTER
The hottest day of the year is now on average **0.8°C** hotter.*

IT'S GETTING WETTER
Over the last decade, summers have been **13%** wetter and winters **12%**.*

THE WETTEST DAYS ARE GETTING WETTER
36% more rainfall is now recorded on the wettest days in the West of Scotland.*

OUR COASTS ARE CHANGING
Sea levels are rising **3mm** per year and the rate of erosion increasing.

* Compared to 1961 to 1990

5 KNOWLEDGE GAPS AND FURTHER RESEARCH

Wheen, Angus

Further human-induced climate change is inevitable and will increasingly impact upon all aspects of our historic environment. Despite these certainties there are fundamental gaps in our knowledge of the impacts, and further research is needed. A number of key areas for consideration have been identified during the production of this guide, and these are summarised below. The following list is not exhaustive, and those working within particular parts of the historic environment are likely to be best placed to express what additional evidence is needed to step up preparedness for climate change.

Intangible Cultural Heritage (ICH)

The impacts of climate change are not restricted solely to the physical elements of heritage. There are direct and indirect impacts upon intangible aspects of heritage that do not have a physical form. Such impacts may be harder to quantify, but are no less important. Intangible heritage includes *'traditions or living expressions inherited from our ancestors and passed on to our descendants, such as oral traditions, performing arts, social practices, rituals, festive events, knowledge and practices concerning nature and the universe or the knowledge and skills to produce traditional crafts'*[21]. The traditional skills, knowledge and practices of communities living within particular environments has often been an important marker of local innovation and survival. For example, the ways in which people adapted their homes to deal with the particular extreme weather conditions of their local environment. This former appreciation of, and respect for, the natural environment is perhaps something that modern society does not do so well, and we may be able learn a great deal from the successful adaptation strategies of previous generations who were 'closer' to their natural environment.

Impacts of Tourism

The historic environment brings in hundreds of millions of pounds to our economy every year through tourism. This has many benefits for the wider economy, and provides resources that are used in the management and conservation of historic assets. Climate change, together with the dramatically increasing visitor numbers of recent years, can result in a detrimental impact on historic assets through wear and tear as well as diminishing the visitor experience. Further research is required to better understand these impacts and to develop solutions around sustainable tourism. The relationship between the historic environment and the wider social and cultural benefits it brings should also be a key consideration.

A New Approach?

Climate change is a threat multiplier, and damage to the historic environment is commonly the result of events occurring in combination. Whilst we have increasingly good data on individual environmental threats (e.g. projections on sea level rise, changing rainfall patterns, etc), we do not yet fully understand how to quantifiably assess the impact of such factors in combination. Identifying whether established management practices could simply be scaled up (for example, increasing the frequency of maintenance and repair) to counteract these impacts, or whether entirely new approaches and methods of conservation will be required, are essential questions that need answered in light of our rapidly shifting climate.

[21] UNESCO. What is Intangible Cultural Heritage?
Available at: https://ich.unesco.org/en/what-is-intangible-heritage-00003.

Communities and coastal climate change ©SCAPE

Managing the impacts of tourism, Ring of Brodgar, Orkney

6 GLOSSARY AND FURTHER READING

Montrose

GLOSSARY

Acceptance: An adaptation approach that accepts changes are expected, but plans pro-actively for them.

Adaptation: Measures that can be implemented in response to expected changes in our climate.

Buried remains: An element of the historic environment comprising remains that have been physically constructed by human activity, or artefacts that record human activity.

Climate change: Expected change in climate that will affect the severity and occurrence rate of a hazard.

Climate change factor: Short code detailing the relevant climate and hazard variables (e.g. temperature, rainfall, flooding, extreme weather, sea-level rise).

Climate/weather stimuli: Current weather conditions that are the primary drivers of a particular hazard (e.g. rainfall, temperature).

Coastal: An element of the historic environment including remains located directly in the coastal zone, an area influenced by both sea and land processes.

Coastal erosion: The gradual destruction of susceptible coastline rock and sediments by wave action, tidal currents and storms.

Drought: An extended period of unusually low rainfall that can lead to water shortages.

Ecological hazard: A hazard relating to or concerned with living organisms (plant and animal species).

Exposure: The natural features of an asset's position within the landscape that render it vulnerable to harm or damage.

Extreme weather: Events caused by weather extremes, such as heatwaves, droughts, floods, ground instability events, high winds and storms.

Fluvial Flooding: Inundation of normally dry land, caused by a river exceeding its normal capacity.

Freeze-Thaw Weathering: Occurs when water seeps into cracks/voids, freezes and expands, exerting pressures on susceptible building materials.

Gardens and designed landscapes: A category of asset encompassing botanic gardens, parks, landscapes laid out for artistic effect and a range of features within these areas.

Ground instability: describes the inherent 'strength' of a slope, and its potential to fail, causing ground movement / landslips.

Groundwater Flooding: Flooding caused by a rise in the water table, generally during periods of above average rainfall.

Hazard: A potential source of harm or damage to the historic environment, often discussed in terms of a particular impact.

Heatwave: An extended period of unusually high temperatures in a particular area.

Historic environment: Our surroundings as they have been shaped, used and valued by people in the past, and continue to be today. The historic environment includes natural and built features, and it can be valued for both its tangible and intangible aspects.

Impact: the potential result of a 'hazard' occurring. In the 'Impact Tables' the description highlights the causative factor (hazard) and the effect of its occurrence.

Intangible Cultural Heritage: traditions or living expressions inherited from our ancestors and passed on to our descendants, such as oral traditions, performing arts, social practices, rituals, festive events, knowledge and practices concerning nature and the universe or the knowledge and skills to produce traditional crafts (UNESCO).

Internal fabric and collections: Movable historic objects and fixed architectural fabric located within internal environments.

Marine: An element of the historic environment comprising remains created via human activity that are now located underwater in a marine environment.

Ocean Acidification: a term used to describe significant changes to the chemistry of the ocean. It occurs when carbon dioxide gas (or CO_2) is absorbed by the ocean and reacts with seawater to produce acid.

Pluvial Flooding: Occurs where artificial drainage systems are saturated to levels they cannot cope with.

Resistance: An adaptation approach that actively seeks to lower the impact of expected changes, often through physical intervention.

Rainfall: The quantity of rain falling within a specific area in a given period of time. Rainfall has a controlling influence over many other environmental hazards.

Roofed buildings and infrastructure: A category of asset that includes structures such as public buildings, private dwellings and monuments, as well as the physical component of the connected systems that sustain or enhance society.

Sea-level rise: A hazard that contributes to issues such as coastal erosion and coastal flooding.

Surface remains: Remains that have been physically constructed by human activity and are located above ground, uncovered and exposed to the elements.

Temperature: A weather variable encompassing hazards such as temperature changes and extremes, as well as influencing the spread of invasive pests and plant species.

Type of hazard: The specific nature of a hazard (e.g. natural, meteorological, biological, chemical).

Vulnerability / Sensitivity: The features of an asset that we can influence or control in order to make it more or less susceptible to a particular hazard.

Wetting and Drying Cycles: Alternating periods of wetting/saturation and drying of susceptible ground/building materials.

Wildfire: a large, destructive fire that spreads quickly over woodland or brush.

FURTHER READING

This section provides links to widely used, and freely available, resources that users of this guide may find useful. Where relevant, short descriptions have been provided. Tailored lists have also been provided for each of the seven historic environment elements.

GENERAL

Adaptation Scotland – A Capability Framework for a Climate Ready Public Sector
Provides detailed, step by step guidance that will help public sector bodies adapt to climate change. *Adaptation Scotland. 2019. A Capability Framework for a Climate Ready Public Sector.*

Available at: https://www.adaptationscotland.org.uk/how-adapt/your-sector/public-sector

Committee on Climate Change - UK Climate Change Risk Assessment 2017 Evidence Report
Based on the latest understanding of current, and future, climate risks/opportunities, vulnerability and adaptation, the UK CCRA provides evidence on what the priorities for the next UK National Adaptation Programme and adaptation programmes of the devolved administrations should be. *Committee on Climate Change. 2017. UK Climate Change Risk Assessment 2017 Evidence Report.*

Available at: https://www.theccc.org.uk/tackling-climate-change/preparing-for-climate-change/uk-climate-change-risk-assessment-2017/

Dynamic Coast - Scotland's Coastal Change Assessment
Provides an evidence base of national coastal change. The project summarised the last 130 years of coastal change across all of Scotland's erodible shores (beaches, dunes and saltmarshes) and projected the changes forward to 2050. In 2018 a second phase of research was commissioned and is due to conclude early in 2020. *Dynamic Coast: Scotland's Coastal Change Assessment.*

Available at: http://www.dynamiccoast.com/

Historic Environment Scotland - Climate Risk Assessment for Heart of Neolithic Orkney World Heritage Site
A trial of a new methodology developed to rapidly assess climate impacts – both to Outstanding Universal Value (OUV) and the associated 'community' (local, domestic and international) – for all types of World Heritage properties (natural, cultural or mixed) Historic Environment Scotland. 2019. *Climate Risk Assessment for Heart of Neolithic Orkney World Heritage Site.*

Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=c6f3e971-bd95-457c-a91d-aa77009aec69

IPCC - Impacts, Adaptation and Vulnerability (Summary for Policy Makers)
Outlines an approach to assessing and managing the risks of climate change, the core concepts of which were used to frame this guide's Impact Tables. *IPCC. 2014. AR5 Climate Change 2014: Impacts, Adaptation, and Vulnerability.*

Available at: https://www.ipcc.ch/report/ar5/wg2/

ICOMOS - Future of Our Pasts
A report that aims to increase engagement of cultural heritage in climate action. Contains detailed Impact Tables that provide an international perspective on climate change impacts on the historic environment. *ICOMOS. 2019. Future of Our Pasts.*

Available at: https://www.icomos.org/en/about-the-centre/publicationsdoc/77-articles-en-francais/59522-icomos-releases-future-of-our-pasts-report-to-increase-engagement-of-cultural-heritage-in-climate-action

Met Office – State of the UK Climate – Annual Reports
An annual publication which provides an up-to-date assessment of the UK climate. Provides statistics on observed changes in the UK's climate. *The Met Office. 2019. State of the UK Climate Reports.*

Available at: https://www.metoffice.gov.uk/research/climate/maps-and-data/about/state-of-climate

Met Office – State of the UK Climate – 2017 Extremes Supplement
A supplement to the State of the UK Climate 2017 report that presents a series of changes in extreme weather indices recorded in the UK. Provides statistics on observed changes in the UK's climate. *The Met Office. 2019. State of the UK Climate Reports.*

Available at: https://www.metoffice.gov.uk/research/climate/maps-and-data/about/state-of-climate

Met Office – UKCP18 Key Results
Provides headline analysis of the UKCP18 datasets, with general statements and high-level figures on how the UK's climate is predicted to change in the future. *The Met Office. 2018. UKCP18 Key Results.*

Available at: https://www.metoffice.gov.uk/research/collaboration/ukcp/key-results

US National Park Service – Cultural Resources Climate Change Strategy:
The Cultural Resources Climate Change Strategy sets out a vision and broad approach for managing impacts to and learning from cultural resources under modern climate change. It contains more detailed information on different adaptation strategies that may be used on the historic environment. National Parks Service. 2017. *Cultural Resources Climate Change Strategy.*

Available at: https://www.nps.gov/subjects/climatechange/culturalresourcesstrategy.htm

ROOFED BUILDINGS AND INFRASTRUCTURE:

Historic Environment Scotland – Climate Change Adaptation Short Guide
This Short Guide describes the key aspects of the external envelope of a traditional building that provide protection against the elements, and considers how these can be improved or adapted to increase a building's resilience to extreme weather events. *Historic Environment Scotland. 2017. Short Guide: Climate Change Adaptation for Traditional Buildings.*

Available at: https://www.historicenvironment.scot/archives-and research/publications

Historic Environment Scotland – Maintaining Your Home Short Guide
This short guide focuses mainly on the external features of a house, but also considers internal conditions as these can be indicators of problems elsewhere. While primarily aimed at homeowners, it will be relevant to anyone that is responsible for the maintenance of traditional buildings. *Historic Environment Scotland. 2014. Short Guide: Maintaining Your Home.*

Available at: https://www.historicenvironment.scot/archives-and-research/publications

Transport Scotland - Scottish Road Network Landslides Study
Contains an overview of the impact of climate change on road infrastructure. Transport Scotland. 2009. *Scottish Road Network Landslides Study: Implementation.*

Available at: https://www.transport.gov.scot/publication/scottish-road-network-landslides-study-implementation/

GARDENS AND DESIGNED LANDSCAPES:

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A summary of the impacts of erosion on coastal archaeology, and how to manage the issue. *Dawson, T. (2013). Erosion and coastal archaeology: Evaluating the threat and prioritising action. Ancient maritime communities and the relationship between people and environment along the European Atlantic coasts.*

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The Impact of Climate Change on Historic Interiors

Contains information on climate change impacts to historic interiors and collection, collated as part of a PhD thesis. *Lancaster, p. 2013. The Impact of Climate Change on Historic Interiors.*

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