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National Trust

Climate Change Adaptation Guidance – Infrastructure

Bridges, Culverts and Tunnels

Climate change vulnerability: high

Bridges, culverts and tunnels – introduction

Bridges, culverts and tunnels are an important feature of the built environment at many National Trust places. Bridges, in particular, may be of special architectural, historical or cultural significance and they may be designated as listed buildings or scheduled monuments. But they are also functioning parts of our infrastructure, which allow pedestrians, vehicles and the emergency services to access our sites.

Bridges, culverts and tunnels need to be inspected on a regular basis and maintained as necessary. As a result of more intense rainfall and flooding, increased water flow may put additional pressure on the material and structural integrity of bridges over time. Isolated extreme weather events may also cause severe damage.

This guidance chapter offers an overview of how these structures are likely to be affected by climate change, and suggests options for adapting them to make them more resilient for the future. The focus here is bridges, but many of the same principles apply to culverts and tunnels.

Image credit:

View of the eighteenth-century bridge and woodland beyond at Kedleston Hall, Derbyshire (© National Trust Images/Chris Lacey).

Bridges, culverts and tunnels – why do they matter?

Many of our places are accessed via bridges that cross watercourses, ditches, railways and roads. These include footbridges. Without these structures, we simply wouldn't be able to operate some of our sites.

Nor would we be able to get emergency vehicles onto our properties when needed, which would put staff, volunteers and visitors in danger, as well as our buildings and collections. In some cases, our bridges are used by the local community to get to work and access services, and any failure or closure would have a serious impact on people's lives.

There are many examples of beautiful bridges in the National Trust's care. These include bridges that have been designed to complement the wider landscape – making them major attractions for visitors – as well as historically significant bridges such Thomas Telford's Conwy suspension bridge, which was opened in 1826. Other bridges within our estate may have less aesthetic, historical or cultural significance but still need to be inspected, maintained and potentially adapted so that they remain safe for use and fit for purpose. Many of these structures sit within our let estates.

Although culverts are less visible than bridges, they are still important. They direct water away from parts of a site and often form a key line in a property's flood defences. When they are blocked or silted up, this may result in flooding. Just like bridges, they need to be checked and maintained on a regular basis. Deeply buried circular culverts will not normally require vehicle weight assessment checks. However, many culverts are box-type structures built just below the road surface. These will need vehicle weight assessments to be carried out by an engineer with the right skills, knowledge and experience, as well as regular condition inspections.

Generally, tunnels are also located beneath the ground, but they often have historical significance. At Calke Abbey in Derbyshire, for instance, visitors can explore the brewhouse tunnel, which connects the house's ale cellars to the brewery and stables. The engine tunnel at Levant Mine in Cornwall is similarly a visitor attraction in its own right.

We are already observing the impacts of climate change on tunnels at many of our sites, especially where there is heavier and more prolonged rainfall. Water ingress, flooding and scour – the erosion of sediment from around a tunnel caused by water flow – are all leading to an increase in defects. In addition, an increase in humidity and moisture content can lead to the deterioration of the tunnel material itself, especially masonry or concrete. Such impacts need to be monitored carefully, and we may need to make adaptations to these structures to safeguard them for the future. The following page outlines the potential climate hazards that are likely to affect bridges, tunnels and culverts, the possible impacts of the hazards on these structures, and options for adaptation.

Image credit:

Visitors walking in a long cellar passage at Calke Abbey, Derbyshire (© National Trust Images/Peter Greenway).

Bridges, culverts and tunnels – hazards, impacts and options

Hazard	Impact	Options
Higher temperatures	Cracks to masonry and asphalt surfaces; shrink/swell (when higher temperatures/ periods of drought are combined with heavier rainfall); accelerated corrosion of concrete and metals and biodegradation of timber.	Increase frequency of inspections; step up maintenance regime; where consents allow, replace like with better, rather than like-for-like. Infrastructure must be capable of withstanding the impact of future weather conditions, so build in adaptations at construction and asset renewal stages.
Heavier rainfall	Flash flooding leading to scour (erosion of the sediment around bridge foundations), causing some bridges to collapse; culverts cannot cope with increased flow and may become blocked as material is washed into them by flash floods; water ingress in tunnel structures; erosion to river banks and slope failure.	Embed climate change considerations in business as usual through updated, climate-informed policies, standards and procedures. This will enable rapid recovery from the impacts of adverse rainfall and extreme weather events; it will also enhance the National Trust's reputation and confidence in our ability to manage and respond to weather events. Consider natural adaptations such as tree planting to absorb water, and engineered adaptations such as attenuation tanks to hold excess water temporarily, and also scour protection methods such as concrete or metal plating around the bridge footings.
Drought	Shrink/swell and/or settlement to bridge foundations and approach, especially in areas with clay soil; dropping water levels expose pillars to oxygen, causing biodegradation.	Embed climate change considerations in business as usual; conduct further research to understand interdependencies of climate factors that lead to shrink/swell; work closely with infrastructure operators, local government and relevant stakeholders to manage these; reinforce structures in a climate-informed way where necessary.
Storm events	Structural damage from high wind and/or scour related to flooding; higher wave impact on piers and abutments.	Undertake climate risk assessments for assets vulnerable to storm events and determine priority locations; work with local stakeholders to manage risks and potential impacts; reinforce structures in a climate-informed way where necessary.

Bridges, culverts and tunnels – options and thresholds

Adapting bridges, culverts and tunnels to the impacts of climate change is a large-scale and challenging task. The National Trust and other heritage organisations need to develop short-term and long-term adaptation plans and programmes, including operational weather management, weather-risk task teams, and research and analysis. Remote condition monitoring can be used to improve proactive asset management and operational response.

Specific options for adaptation measures include:

'Slowing the flow' – using methods such as rewiggling rivers and installing leaky dams across the catchment will help to reduce scour.

Drainage renewal and refurbishment – many of our on-site drainage systems are old and not fit to deal with larger volumes of rainfall, leading to flooding.

Slope stabilisation – when the ground slips around a bridge's foundations, this can lead to structural damage or collapse.

Reducing load – if a bridge affected by climate hazards is deemed unsafe for the kinds of loads that are regularly imposed upon it, a change in its use may be necessary. For example, a weight limit may be imposed, or the bridge may be closed to vehicles and open only to pedestrians.

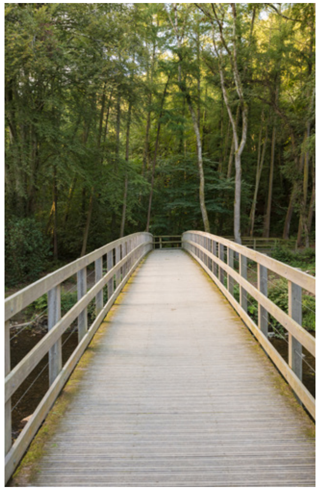


Image credits:

Left to right: Medieval packhorse bridge at Allerford, Somerset (© National Trust Images/Chris Lacey); drainage culvert at Croome Park, Worcestershire (© National Trust/Andrew Butler); Palladian bridge at Stowe, Buckinghamshire (© National Trust Images/Arnhel de Serra); footbridge at Llanerchaeron, Ceredigion, Wales (© National Trust Images/James Dobson).

Thresholds & tipping points

At what point might you diverge from your current management strategy? What are the events/factors that may trigger this change of approach (action/philosophy)?

Regular monitoring of all structures is key, as is routine maintenance. In making climate-informed decisions about the care of bridges, culverts and tunnels, you should consult the National Trust's hazard map to see what climate hazards are most likely to affect your site. But you should also remember that heightened risk is not the same as actual impact. You should use your first-hand experience of the site and your knowledge of which bridge, culvert and tunnel structures are already at the limit of their adaptability when deciding what needs to be adapted (as opposed to maintained in a routine way).

Tipping points prompting adaptive action may include the following:

- Higher or lower water levels are observed, which triggers more intensive inspections and monitoring.
- More regular flooding incidents that lead to significant observed defects.
- High risk of failure identified during a regular inspection (this is likely to prompt further structural assessment before any adaptive action is taken).

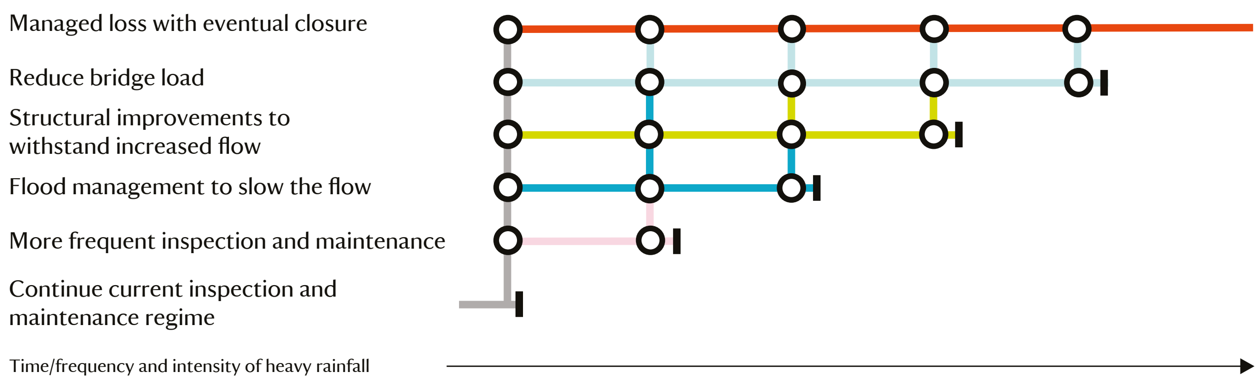
Bridges, culverts and tunnels – worked pathway example

This page explores adaptive pathways and thresholds for a real site example, showing how and when you might wish to make changes to your adaptive response to climate hazards.

Working with a multi-disciplinary group to think about options and thresholds for a typical structure is key. This cannot be done in isolation as there are significant implications for everything from facilities teams to aesthetics to archaeology. It is always most effective to bring together the right people to work on a mutually acceptable solution for a period of time between thresholds for change.

Adaptations to a bridge, culvert or tunnel may focus on safety and structural integrity, but they may also have an effect on the historic environment and possibly also on species and habitats. Therefore, **significance** should always inform the approach – and the approach is likely to be very different for structures of historic significance or where statutory designations apply.

Options for adaptation must not be selected in isolation from the unique characteristics, significance, vulnerabilities and use of your specific site. This may mean that different adaptive pathways apply to each site.[1] The example below is based on a hypothetical non-historic bridge identified as vulnerable to extreme rainfall events.



(Response thresholds are most likely to be based on observed impacts on site and not solely on climate hazard data. The specific trigger points would need to be agreed by the operations decision-maker and relevant consultants and consultees such as site users, infrastructure operators and local government, where relevant. Response thresholds and decision-making processes will be different for historic structures.)

[1] Dynamic Adaptive Pathways Approach (Haasnoot, Kwakkel, Walker & Ter Maat, 2013).

Legal responsibility for bridges and other structures

The repair and maintenance of highway structures such as bridges, tunnels, walls, embankments and culverts may be the responsibility of the relevant highways authority, the National Trust, or another party. If a road is publicly maintained and it passes over a bridge, the usual rule is that the bridge should be maintained by the highways authority; the same rule applies to tunnels. However, if a former owner of the land, or the National Trust, has carried out maintenance of the bridge or tunnel for many years, it may be deemed to have assumed legal liability to do so. Bridges carrying a public highway across a railway or canal are also subject to special rules.

You should check the legal situation to establish whose responsibility a structure is before planning any works. In the case of historic bridges, you should check whether any statutory designations apply. Specialist consultants should be engaged to undertake any surveys of listed or historic bridges.

As with other built structures, regular inspection and maintenance are always key and if carried out properly may alleviate the need for adaptive work; National Trust teams should refer to the Bridge Management Manual, which is based on nationally recognised good practice.

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Case studies, signposting and references

These case studies show how bridges and culverts have already been affected by climate-related hazards which are likely to intensify in future, and how sites have adapted.

At **Sizergh in the Lake District**, an extreme storm event in December 2015 caused flooding which washed tree trunks downstream and damaged the structure of a historic footbridge. This required short-term temporary repairs followed by structural repairs carried out in 2022. To preserve heritage value, the repairs were like-for-like but the National Trust may need to consider further options to protect the structure from storm damage in future.

At **Lyme Park, Cheshire**, flooding of the gardens in 2019 revealed that the existing culvert, which runs through the garden and under the main visitor car park, does not have sufficient capacity. In its current form, the culvert also channels water onto a lower-lying area of the site, which exposes a number of important buildings to higher risk of flooding in the future. A plan has been made to open up the culvert and convert the car park back to meadow to try and absorb water before it reaches the lower end of the site. However, relocating the car park has generated significant controversy, even though its capacity will not increase.

In August 2017, counties Londonderry, Tyrone and Donegal experienced extreme rainfall resulting in five bridges being damaged almost 'beyond repair'. The B2-listed **Glenrandal Bridge** (c. 1800–19) was eventually reopened in 2020 after repairs costing £420,000. The original three-span masonry arch structure was replaced with a single span to improve river flow capacity. Stone from the old bridge was salvaged and incorporated into the new bridge parapets to preserve heritage value as far as possible.[2]

Image credit:
The Italian garden at Lyme Park, Cheshire, with the car park visible beyond. The culvert runs to the left of the garden and under the car park (photo by Katherine Shingler).

[2] https://www.northernireland.gov.uk/news/glenrandal-bridge-claudy-reopens-following-ps420000-replacement-scheme

Signposting & additional guidance

CIRIA has published a Manual on scour at bridges and other hydraulic structures.

Nasr, Kjellström et al, 'Bridges in a changing climate: a study of the potential impacts of climate change on bridges and their possible adaptations', *Structure and Infrastructure Engineering*, 16.4 (2020), 738–49.

Network Rail has already done significant planning to adapt its infrastructure, including bridges, to climate change. See especially their Third Adaptation Report (2021).

National Trust staff should refer to the Bridge Management Manual for all bridge-related matters in the first instance.

Image credit:
The damaged bridge at Glenrandal, Northern Ireland (photo courtesy of Natalie O'Rourke, © Department for Communities, Crown Historic Environment Division).