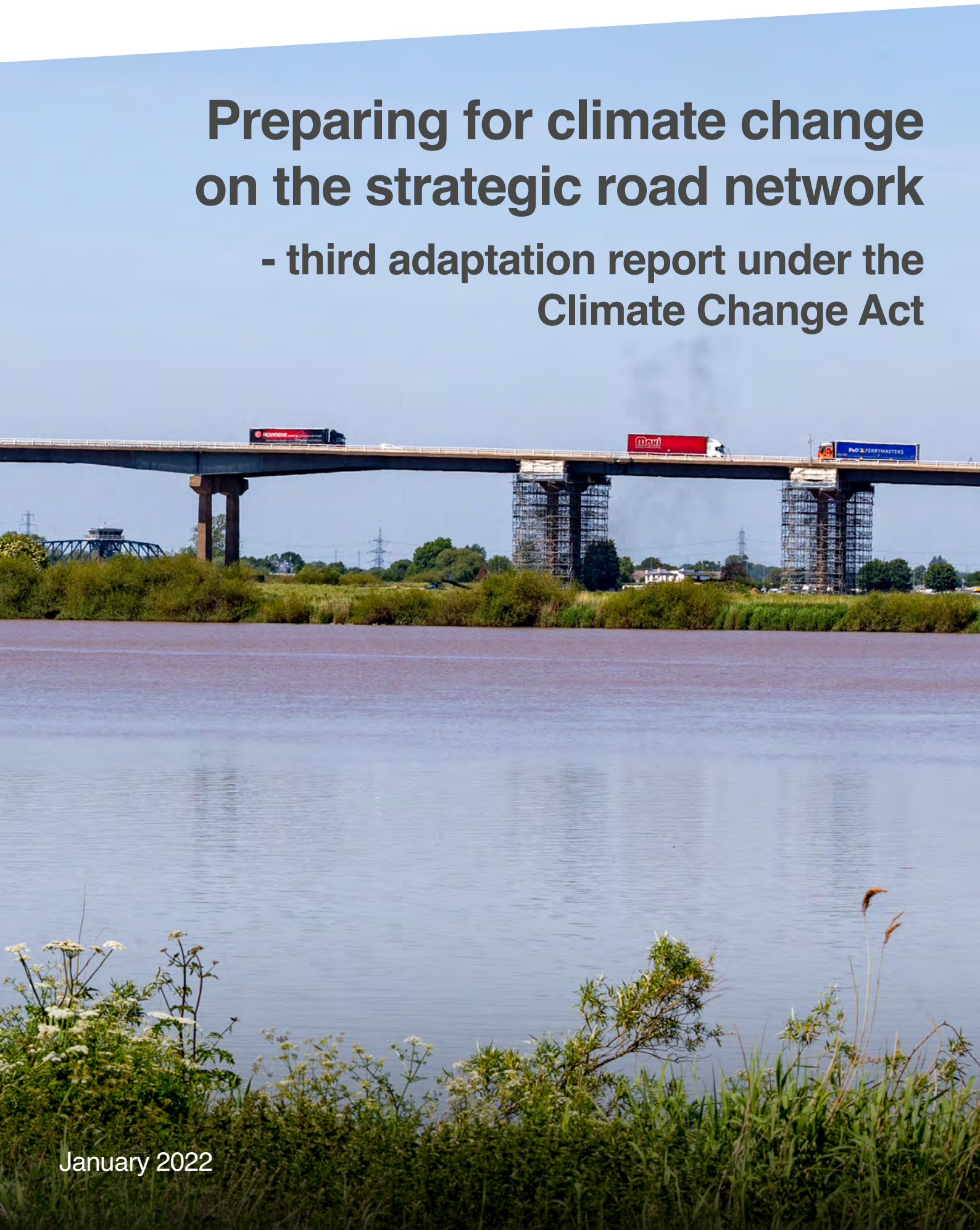
national highways

Preparing for climate change on the strategic road network

- third adaptation report under the Climate Change Act



January 2022

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Foreword

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Climate change is affecting every country on every continent. It is disrupting national economies and affecting lives. And as custodians of the strategic road network (SRN), our role at National Highways is to ensure that our roads are prepared for climate change, now and in the future.

We have already seen the effects of climate change on the SRN and the communities that live alongside it. In one severe rainfall event alone, in October 2021, we saw significant flooding on the M25, A3 and M23.

We are working hard to reduce carbon, the biggest cause of climate change. In 2021, we published our *Net zero highways plan*. This sets out our ambitious programme to be net zero for our own operations by 2030, net zero for maintenance and construction by 2040 and to have net zero carbon travel on our roads by 2050. But we also need to recognise that the climate continues to change, and will continue to do so for many decades to come.

We have already seen projects build resilience to climate change. For example, through our Environment and wellbeing fund we partnered with the Environment Agency on a project in Keadby near Scunthorpe. This saw us renew the pumping station's critical flood defences, with diesel pumps replaced with more carbon efficient electric pumps. The project is helping protect 22 miles of the M18 and M180, around 28,000 homes and 30,000 hectares of land from flooding. The new pumps will also be safer for fish to pass though. Projects like these demonstrate that in making a change to respond to a risk to the SRN, and by working in partnership with others, we can deliver many other benefits.

While many of our standards already take account of future climate change, we must keep up to date with the latest climate science. This, our third climate change assessment, uses the latest climate change projections from the Met Office. It provides the detail to determine whether the work we carry out is prepared for climate change across the coming century. This will inform the future work that we deliver to ensure our roads continue to offer safer, smoother and more reliable journeys.

Mike Wilson
Chief Highways Engineer

Executive summary

Climate change and how it affects us

Climate change is affecting society as a whole, and the transport sector is no exception. As the government owned company tasked with building and maintaining the Strategic Road Network we need to show both how we can help tackle the causes of climate change and how we are preparing for a changing climate. In 2021 we published our Net zero highways plan to show how we will meet the target of net zero greenhouse gas emissions. However, this report is about how we are preparing for a changing climate.

Using the latest climate projections from the Met Office has helped us to understand how the climate is changing, including that summers will on average be hotter and drier, while winters will be milder and wetter and critically, that extreme weather will become more common. We have also seen, from reports such as the Climate Change Committee's third and most recent independent assessment of climate risk, that there are key risks from a changing climate for infrastructure, such as risks to bridges from flooding and erosion and risks to subterranean and surface infrastructure from subsidence.

National Highways and the adaptation reporting power

Part 4, Section 62, of the Climate Change Act covers 'impact of and adaption to climate change'. This allows the Secretary of State to direct reporting bodies, including National Highways, to prepare reports setting out the risks presented by a changing climate, proposals and policies to deal with climate risk, and to set out progress made. This is commonly referred to as the 'adaptation reporting power'. To date there have been 3 rounds of reporting.

We have carried out reporting in relation to this adaptation reporting power twice to date, with ARP1 published in 2011 and ARP2 in 2016. These reports have been published on the government's website and sit alongside reports from other reporting bodies (including other national infrastructure providers). ARP3 is a voluntary reporting round. However, like many other bodies we agreed to report in this round.

Strategies, plans and standards to address climate risk

Adapting to climate change is a business priority for us. For example, our Strategic Business Plan for this, our second Road Period (2020-25), includes a performance outcome on 'delivering better environmental outcomes' where we prioritise 'creating a network resilient to a changing climate'.

It is also central to our Sustainable Development Strategy which states that our vision for climate change adaptation is:

"In order to become more resilient to future changes in climate, which may result in more frequent and severe weather events, it is important that we adapt our network and make effective investment decisions. Climate adaptation today is tomorrow's resilience."

While adapting to climate change has become an inevitable reality, it is still crucial to continue our efforts to cut GHG emissions to avoid future climate change. Our goal to become net zero is set out in *Net zero highways: our 2030 / 2040 / 2050 plan.*

In Road Period 1 (RP1), we updated our Design Manual for Roads and Bridges (DMRB), which, now includes climate risk and resilience in several new and updated standards.

We also published our standard LA114: Climate which includes a methodology to be applied in environmental assessments of road projects. Importantly it requires that *'the environmental assessment shall identify how the project can be adapted to protect it from future climate scenarios'*.

A challenge in adapting to climate change has been how to do so in a way that still delivers sustainable development and a net zero future. To this end a sustainability assessment has been carried out on the actions in this plan.

Putting the right governance in place

Ensuring we are resilient to climate change requires lines of reporting, accountability and escalation to be defined to ensure we make progress. With good governance structures in place we will be better equipped to dealing with risks and adaptation to climate change and responding appropriately to stakeholders and regulators.

A key outcome from this round of adaptation reporting has been inclusion of actions resulting from this ARP3 within our Asset Management Transformation Programme to allow for identification of the most effective way of advancing progress and monitoring. To this end the Asset Management Transformation Committee will provide the ongoing governance to monitor delivery.

Assessing the risk

The report identifies key areas of risk including:

- increased precipitation, including risks of flooding, waterlogging of pavement surfaces and ground saturation affecting geotechnical assets
- temperature changes, including deformation of asphalt, expansion of concrete
- different climate variables acting together, for example changes to ground shrinkage / earth pressures affecting dependent assets such as structures and drainage.

Progress towards adaptation

A key purpose of this report has been to report on progress since our last adaptation report. Since we published this report we have:

- published standards for design that take account of climate change and seen projects apply these standards
- developed new guidance, for instance on ground hazards
- established monitoring processes
- updated our data on key risks such as flooding and geotechnical risk
- progressed pilot projects to adapt to climate change
- carried out research on key climate risks

Planned actions for ARP

Following review of the latest Met Office UK Climate Projections (UKCP18) we were able to identify new actions that build on progress to date or explore new areas. While some of these actions are already underway other actions will require further development. The actions are set out in this report and we will put internal processes in place to measure progress.

We will also progress further work to advance our understanding of the 'interdependent risks' that exist between asset types, and also between ourselves and other organisations.

While our adaptation report sets out our latest assessment of our activity to respond to climate change, we know that there is more to do and as we look to our future Road Investment Strategies we will continue to advance our understanding of climate risk and the necessary response.

1

Introduction

Introduction

1.1 National Highways

1.1.1.

National Highways, formerly Highways England (until 2021), is the publicly owned company responsible for operating, maintaining, and improving England's strategic road network (SRN). This comprises of motorways and major A-roads, as well as associated assets such as bridges, tunnels, and signage. Our priorities are focused around keeping our customers safe on well operated and maintained roads:

- **Safety** – This is our main priority and we aim to deliver a network that is safe, dependable, and durable. We aim to halve the number of people killed or seriously injured on our roads by the end of 2025, relative to the 2005-2009 average, and have a zero-harm target by 2040.
- **Customers** – We will keep our roads running safely and smoothly, while keeping our customers informed and prepared. We will ensure that our assets, including everything from bridges to roadside signs, are well maintained and that we protect the surrounding environment.
- **Delivery** – Our plans were developed before the outbreak of COVID-19, and we remain committed to delivering them. Our priorities remain: safety, customers, and delivery, to manage and improve the SRN to make journeys safer, smoother, and more reliable. We have invested billions in new routes and extra capacity, and we also plan and manage a programme of works to make sure our roads and the various structures along them are safe.

1.1.2.

Adapting to climate change to ensure safety and a high level of service is an explicit component of the Licence under which we carry out our duties.

1.2 What is ARP3?

1.2.1.

Under the Climate Change Act 2008, organisations with key responsibilities, including National Highways (then the Highways Agency), were required to produce a report detailing their climate change adaptation strategies, and, optionally, every five years thereafter. This is known as the Adaptation Reporting Power (ARP). We developed ARP1 in 2011, and ARP2 in 2016. This report, ARP3:

- re-evaluates significant climate risks threatening the safe operation of England's SRN using more up-to-date climate projections
- assesses progress against previously identified adaptation actions; and
- identifies areas for improvement and appropriate actions

1.2.2.

During this round of reporting, it was decided that organisations with similar or connected functions should collaborate in their approach. A common ARP approach was developed and agreed between key organisations in the surface transport sector, and in conjunction with Defra. This common approach will improve consistency and transparency and improve the ease of understanding interconnected risks.

1.3 Our understanding of how the UK climate will change

1.3.1.

This report uses the Met Office's UK Climate Projections (UKCP18). These projections use cutting-edge climate science to provide updated observations and climate change projections out to 2100. This data shows that by the end of the twenty-first century:

- All areas of the UK are projected to be warmer
- Summers will be, on average, hotter and drier
- Winters will be, on average, milder and wetter
- Extreme weather will become more common
- Lying snow will disappear almost entirely; and
- Sea levels will rise, and the increase will be greater in the south and east

1.4 Climate risks for National Highways

National Adaptation Programme and Climate Change Risk Assessement (CCRA)

1.4.1.

The government's National Adaptation Programme (NAP) sets out the actions that government and others will take to adapt to the challenges of climate change in the UK. It sets out key actions for five year periods. The third NAP runs from 2018 to 2023.

1.4.2.

As part of this five-yearly cycle of requirements laid down in the Climate Change Act 2008, the latest Climate Change Committee's (CCC) Independent Assessment of UK Climate Risk (June 2021), known as CCRA3, informed the development of the UK government's third Climate Change Risk Assessment which was published in 2022, and makes recommendations for climate adaptation. These national assessments of risk provide the evidence base to inform the government-led National adaptation programme.

1.4.3.

The Independent Assessment of UK Climate Risk involved a comprehensive assessment of the risks and opportunities facing the UK from climate change.

1.4.4.

It found that, overall, the rate of progress on adaptation in the UK has not kept pace with increasing climate risk.

CCRA3 relevance for National Highways

1.4.5.

The CCC's recent independent advice report (informing CCRA3) found that, in the transport sector, more action was needed on the following priority risks:

- Risks to infrastructure networks (water, energy, transport, ICT) from cascading failures
- Risks from river, surface water and groundwater flooding
- Risks from coastal flooding and erosion
- Risks to bridges and pipelines from flooding and erosion
- Risks from slope and embankment failure; and
- Risks from high and low temperatures, high winds, lightning[1]

1.4.6.

The government published UK Climate Risk Assessment recognises the risks in the Climate Change Committee's report and states:

"The UK government and devolved administrations fully recognise the scale of the challenge of adapting to climate change, as set out in the CCRA3 and its underlying reports. We have made some progress as the CCC notes, but we must go much further and faster to truly prepare for the impacts of a warmer world. The UK government is committed to developing a third National Adaptation Programme (NAP3) for England which will set out how we will meet that challenge"[2].

1.4.7.

In our ARP3 risk assessment we have considered the above transport sector risks, reviewed the evidence on climate change, and discussed the National Highways specific aspects with specialists across the organisation.

1 Climate Change Committee, 2021. Independent Assessment of UK Climate Risk. Available online at https://www.theccc.org.uk/publication/independent-assessment-of-uk-climate-risk/

2 HM Government, 2022. UK Climate Change Risk Assessment 2022. Available online at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1047003/climate-change-risk-assessment-2022.pdf

2

Strategy and plans to address our **climate risks**

Strategy and plans to address our climate risks

2.1.1.

Climate change is a business priority for us. In 2021, we published Net zero highways: our 2030, 2040, 2050 plan to set out our commitments to decarbonisation. However, climate change is already with us, and the climate will continue to change even as nations around the world decarbonise. The key plans and strategies that we operate within set out what we are required to do to adapt to climate change.

2.2 Road investment strategy 2: 2020-2025

2.2.1.

The second Road Investment Strategy (RIS2) sets out a plan to *"achieve more for road users, residents and businesses, natural habitats and wildlife, townscapes and landscapes"*. RIS2 sets out the strategic vision, performance specification and investment plan for the SRN for the second Road Period (RP2), which covers the financial years of 2020/21 – 2024/25. This covers most of the period that this ARP is applicable to.

2.2.2.

The long-term strategic vision for the network in 2050 includes:

In 2050:

The SRN is resilient to climate change and incidents, such as flooding, poor weather conditions, blockages on connecting transport networks.

2.2.3.

RIS2 also states that we will seek to work in partnership with the Environment Agency and other bodies working to improve the environment, reduce flood risk, and increase resilience to extreme weather and other climate impacts.

2.3 Strategic business plan and delivery plan

2.3.1.

Our Strategic Business Plan (2020 – 2025) describes our portfolio of investment and our commitment to protecting the environment and communities while getting our roads ready to support future businesses, jobs and homes.

2.3.2.

The Strategic Business Plan is supported by our Delivery Plan (2020 – 2025) which explains how Government funding will be invested into the SRN up to 2025. Furthermore, it sets out how the programme of work will be delivered, and targets met.

2.3.3.

As part of our performance outcome on 'delivering better environmental outcomes' our Strategic Business Plan prioritises 'creating a network resilient to a changing climate' and sets out that we will focus on reducing flooding, minimising risks to local communities, and retrofitting assets to meet new environmental and drainage standards. As well as this there is a focus on improving the resilience of our concrete pavements to prolonged high temperatures. Further detail on how this approach is to be delivered is set out in the Delivery Plan.

2.3.4.

The methodology taken by this ARP3, alongside other work, including work to update standards and procedures, and project level climate assessments, are all contributing towards achieving the aim of the Strategic Business Plan and Delivery Plan.

2.3.5.

We also aim to work with organisations such as the Environment Agency, the Met Office, and local authorities to improve the resilience of our network to severe weather.

“Creating a network resilient to a changing climate”

“*We will monitor, assess and respond to the impacts of climate change on our network. We will work in partnership with organisations such as the Environment Agency, the Met Office, and local authorities to improve the resilience of our network to more severe weather. We will focus on reducing flooding on our roads and minimising risks for local communities, retrofitting our assets to meet new environmental and drainage standards. We will also improve the resilience of our concrete pavements to prolonged high temperatures as part of our concrete maintenance and renewals programme, taking remedial action where necessary.*”

2.4 Sustainable development strategy 2017

2.4.1.

In addition to the Strategic Business Plan and Delivery Plan, we published a Sustainable Development Strategy in 2017. Work is currently underway to refresh and update this strategy.

2.4.2.

Our vision for climate change adaptation is:

“In order to become more resilient to future changes in climate, which may result in more frequent and severe weather events, it is important that we adapt our network and make effective investment decisions. Climate adaptation today is tomorrow’s resilience.”

2.4.3.

Our ambitions for achieving this vision include:

- Investing in the road network for the long term to improve resilience to climate change
- Embedding adaptation into the organisation
- Managing and maintaining our network with increasing efficiency; and
- Maximising the benefits of stakeholder engagement

2.4.4.

The Sustainable Development Strategy seeks to ensure resilience to climate change is embedded in the activities of our business to reduce whole life costs and increase safety. We aim to move away from a reliance on historical weather records as a basis for standards and specifications to a position where standards are informed by the latest science on climate change.

Our Strategic Business Plan, Delivery Plan, as well as the Road Investment Strategy all show that we will work towards a climate resilient SRN.

2.5 Net zero highways: our 2030 / 2040 / 2050 plan

2.5.1.

While adapting to climate change has become an inevitable reality, it is still crucial to continue our efforts to cut GHG emissions to avoid future climate change. Our goal to become net zero is set out in *Net zero highways: our 2030 / 2040 / 2050 plan*, which is an ambitious programme putting roads at the heart of Britain's net zero future. Our targets are:

- Net zero for our own operations by 2030: the actions covering our own energy and travel include the following:
  - We have bought certified, renewable electricity for our network lighting and operations since 2020
  - We will replace 70% of our road lighting with LEDs by 2027
  - Our non-traffic officer vehicles will be 100% electric by 2027, with traffic officer vehicles to be 100% electric by 2030
  - We will plant at least 3 million trees by 2030; and
  - We will reduce our corporate emissions by 75% by 2025 when compared to a 2017/18 baseline

- Net zero for maintenance and construction by 2040: the actions covering emissions from making and transporting the materials used to maintain our network include the following:
  - Launch a zero-carbon construction innovation programme
  - Develop a near-zero plan for each of our procurement categories by the end of 2022
  - Design and build the first net-zero major road enhancement scheme, open by 2035
  - Increase capacity on existing roads by roll out of our digital roads vision; and
  - We will follow a trajectory of 0-10% reduction by 2025, 40-50% by 2030, 70-80% by 2035 and net zero by 2040 against a 2020 baseline
- Net zero carbon travel on our roads by 2050: the actions covering emissions from users of our network include the following:
  - We will publish our proposed approach to zero carbon HGV trials by the end of 2022
  - We will publish a blueprint for electric vehicle charging services on our roads by 2023
  - Integrate a strong modal shift programme in Road Period 3 (RP3) building on our work to date; and
  - We are planning for a trajectory of 31-26 $MtCO_2e$ by 2025, 25-15 $MtCO_2e$ by 2030, 20-7 $MtCO_2e$ by 2035, 8-3 $MtCO_2e$ by 2040, 5-1 $MtCO_2e$ by 2045 and net zero by 2050 against a 33 $MtCO_2e$ 2020 baseline

2.5.2.

These are ambitious and necessary targets that will contribute to cutting GHG emissions from the surface transport sector. However, the impacts of climate change are already being felt on our assets, services and operations and will increase in the future due to the climate change that we are already locked into because of past global GHG emissions. In addition, while strong commitments to reduce carbon have been made by many countries, for instance at the recent United Nations Framework Convention on Climate Change Conference of Parties (COP 26), the precautionary principle means we must consider the possibility that not all global commitments will be delivered. Planning to adapt to climate impacts, in a way that supports our plan for decarbonisation, is thus a priority for us.

2.5.3.

A challenge in adapting to climate change has been how to do so in a way that still delivers sustainable development and a net zero future. To this end a sustainability assessment has been carried out on the actions in this plan.

2.6 Our standards

2.6.1.

In Road Period 1 (RP1), we updated our Design Manual for Roads and Bridges (DMRB), which, as well as including climate risk and resilience in several new and updated standards, also established a series of goals for sustainable development.

2.6.2.

Our Standard 'GG103; Introduction and General Requirements for Sustainable Development and Design' sets out the sustainable development goals which are to be applied to all schemes.

2.7 Designing for resilience at a local level

2.7.1.

Many of the recommendations in this report are around changes to national standards or procedures. These apply to the whole of the SRN and allow for assessment of local circumstances when they are applied.

2.7.2.

However, often the design of the road scheme as a whole may interact with local climate risks. For example, there may be features of a road design that are more vulnerable to climate change because the planned location is more exposed to future climate impacts. For all climate risks to be considered within the local context, climate change has been integrated into both our standards for all designs and our standards for environmental assessment (including for both for non-statutory and statutory environmental assessment). This includes the standards *GG103: 'Introduction and general requirements for sustainable development and design and LA114: 'Climate'.*

2.7.3.

The requirements in GG103 applies to all designs, big or small. It includes 12 'goals of sustainable development' including to 'minimise greenhouse gas emissions' and 'to be resilient to future climate change'. Specifically, *'resilience to future climatic conditions specific to the local and surrounding area shall be identified, assessed and incorporated into design'.* The goals in GG103 were based on documents such as the United Nations (UN) Sustainable Development Goals (SDGs), including goal 13: Climate Action.

2.7.4.

LA114 includes a methodology to be applied in environmental assessments. This includes how climate change shall be scoped into assessment, how data shall be collected and how an assessment of a scheme determines if a climate impact is significant. Importantly it requires that *'the environmental assessment shall identify how the project can be adapted to protect it from future climate scenarios'.*

2.7.5.

To help ensure that our schemes are fully resilient to local climate risk, it is important that we fully apply our standards.

2.8 Sustainable development goals

2.8.1.

Our goals of sustainable development in GG103 are based on the UN SDGs. From the outset of ARP3, an important principle has been that adaptation to climate change should help deliver wider sustainable development.

UN SDG 13 – Take urgent action to combat climate change and its impacts

The 17 UN SDGs provide a shared blueprint for the world in 2030. They apply to all countries, with all sectors playing a role in supporting their delivery. The UK is responsible for achieving the goals domestically and for supporting their attainment internationally. The latest SDG report by the UN states that despite the economic slowdown caused by the COVID-19 pandemic, greenhouse gas (GHG) concentrations reached record levels by the end of 2020. In response to this, increasing numbers of countries are developing national adaptation plans and commitments, and the flow of climate finance has increased.

2.9 Climate change adaptation plans

2.9.1.

As climate change has been a long-standing priority risk in our organisation, making it central to organisational planning, we have an appreciation for how climate change can impact our Strategic Business Plan outcomes. To address these challenges, we have been regularly reporting on our progress on adaptation to climate change to central government since the publication of our first climate change risk assessment in 2011 (ARP 1) and our updated risk assessment and adaptation plan in 2016 (ARP2).

2.9.2.

We are committed to understanding and assessing the risks posed to the SRN from a changing climate and taking appropriate management action to mitigate these risks and make the SRN resilient.

Section 5 of this ARP3 sets out the planned actions for the next five years to address the climate risks identified in this ARP3 assessment.

3

Climate change **governance**

Climate change governance

3.1 The importance of good governance on climate

3.1.1.

We are monitored by the Office of Rail and Road (ORR), and Transport Focus, the consumer watchdog. Both organisations provide advice to the Secretary of State for Transport on our performance.

3.1.2.

Within our organisation we have a clear division of responsibilities between the Chairman, Chief Executive, and members of the Board and Executive Teams.

3.1.3.

Ensuring we are resilient to climate change requires lines of reporting, accountability and escalation to be defined to ensure we make progress.

3.2 About climate governance at National Highways

3.2.1.

Climate governance is the structure of rules and processes a company puts in place to manage its responses to the risks (both physical and transitional) and opportunities of climate change.

3.2.2.

Climate governance is important because climate change is a potential strategic risk to our organisation. As an organisation we appreciate that an effective climate governance structure is critical to ensure that our organisation properly assesses climate-related risks and opportunities, takes appropriate strategic decisions on how to manage those risks and opportunities, and sets and reports on relevant goals and targets. With good governance structures in place we will be better equipped to dealing with risks and adaptation to climate change and responding appropriately to stakeholders and regulators.

Sustainable Development and Environment Leadership Group (SDELG)

3.2.3.

To ensure that we have a more coordinated and proactive approach and to discuss all challenges and opportunities pertaining to sustainability and the environment, we established a strategic Sustainable Development and Environment Leadership Group (SDELG) in 2019.

3.2.4.

The SDELG is chaired by the Chief Highway Engineer.

3.2.5.

In addition to the Chief Highway Engineer, this group consists of core members and has representatives on it from across our organisation.

3.2.6.

The SDELG currently considers climate risk by monitoring the Sustainable Development Strategy, of which climate adaptation is a core part, takes a forward look of key activities and reviews progress towards delivery of the strategy on a quarterly basis.

Internal monitoring and governance

3.2.7.

Best practice in climate adaptation includes the recently published ISO14090 standard (on adaptation to climate change), which includes principles of 'transparency' and 'accountability'. Here leadership and commitment are described as key components of the adaptive capacity of an organisation, and the commitment of senior leadership is specified as necessary to demonstrate accountability for implementing climate adaptation plans. Embedding climate change adaptation in policies, strategies and plans is also specified by the standard.

3.2.8.

As many of the climate risks and actions are related to our assets, it is important that these are looked at within the context of wider governance around asset management. The Asset Management Transformation Programme is currently working with all directorates to improve asset management capability. It brings together all of our asset management initiatives to ensure an effective end-to-end asset management approach, including investment in planning, asset management planning, asset knowledge, whole life delivery and review. Linking to new governance protocols emerging through the programme should help ensure effective delivery of progress on adaptation.

In the near term, inclusion of actions resulting from this ARP3 (related to assets and their management) within the Asset Management Transformation Programme will allow for identification of the most effective way of advancing progress and monitoring.

3.3 Corporate risks and performance reporting

3.3.1.

Each of our directorates owns a directorate risk register which captures the key risks to the organisation and scores the risks according to their impact and likelihood. This risk register acts as a framework for management of risks at a corporate and directorate level within the organisation.

3.3.2.

Climate risks can occur across the risk categories in the directorate risk assessments. For example:

- **Reputation:** Climate change presents risks to many of our assets not just in the longer term, but increasingly we see probable climate change related events occurring now. In these cases, failure to either avoid risk or recover quickly could lead to reputational damage.
- **Asset:** Our ARP shows the key risks to asset categories and current and proposed responses. Failure to make progress on addressing risk could mean our ability to deliver improvements to the SRN is reduced.
- **Delivery:** The work we do can be affected by climate change. Project level assessments of climate risk need to be of sufficient quality to ensure that delivery is not compromised.
- **Environment:** Further deterioration of the environment can result in impacts to the resilience of the strategic road network to climate related risks. However, if we fail to ensure we recognise the value of the environment in managing climate risk, an opportunity to build resilience will be lost.
- **Safety:** The climate risks to assets can accentuate the risk of failure, with effects on the safety of road workers or users. By incorporating actions to reduce these risks, we will have systems in place which document and better prepare them for weather and climate-related threats.
- **People:** People, including our workforce, suppliers and road users may all be faced with climate related risks, from increased levels of flooding to the wellbeing and productivity impacts of climate change. We must understand the risks to the asset to ensure safety.
- **Cost:** Potential risks to spend could occur as a result of climate change. While adapting itself may incur some costs, these are in contrast to the costs of recovery from climate impacts.

3.3.3.

The breadth of these identified risks highlights the necessity to consider climate change as a cross-cutting risk that needs to be comprehensively applied as a lens through which we should consider all of our corporate and directorate risks and review their risk rating if necessary.

Further recommendation on corporate and directorate risk

3.3.4.

In addition to the measures to better define governance and monitoring above, this report recommends further review of risk registers through the lens of climate change resilience. As a cross cutting subject, climate change impacts will be considered across all directorate risk registers.

The overall action for corporate and directorate risk for the ARP3 timeframe, is to review climate change in corporate and directorate risk registers where relevant.

Business planning and performance

3.3.5.

A further component of governance is the inclusion of climate change in business planning and performance reporting. We are members of the Transport Infrastructure Efficiency Strategy (TIES) Living Lab project along with other Department for Transport arm's length bodies to share good practice on adaptation work including the development of future metrics.

3.3.6.

Climate change adaptation will require staff time in designing and reporting against governance procedures, and costs will be involved for resources and measures to implement and progress the actions set out in Section 5 of this ARP3. Additional business case development and approvals will be required for the implementation of some adaptation measures that affect our business planning and asset management and performance.

Our assessment identifies risks to the assets that underpin the customer experience of the SRN, and adaptation actions will also help towards meeting all of our RIS performance outcomes, either directly or indirectly. These performance outcomes include 'improving safety for all', 'fast and reliable journeys', 'a well maintained and resilient network', 'delivering better environmental outcomes', 'achieving efficient delivery' and 'meeting the needs of all road users'.

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Est. 1927
Wm. Armstrong
Haulage
Contractors
LONGTOWN
CARLISLE
GB
GB
PEARSON
Ltd.

Our approach to **climate risk assessments**

Our approach to climate risk assessments

4.1.1.

In our last adaptation report, we undertook an assessment of climate risk against the then latest climate projections from the Met Office, called the UK Climate Projections, 2009 (UKCP09). Since then the UK Climate Projections have been updated with a new set of projections, called the UK Climate Projections 2018 (UKCP18).

4.1.2.

This report builds on the risk assessment and adaptation work undertaken in the previous ARP1 (2011) and ARP2 (2016) reports. The methodology reflects best practice climate risk assessment and uses UKCP18 as the basis for the assessment. It is in line with the approach developed in collaboration with Defra and the surface transport sector organisations who are reporting to Defra under ARP3. Working closely with other stakeholders to develop this common methodology provides a standardised approach for the land transport sector. This will enable Defra to more easily assess the risks to the land transport sector as a whole, drawing conclusions for the sector from across our reports.

4.1.3.

The methodology is undertaken in the following stages:

- Step 1: Identification of relevant climate variables and the associated risks
- Step 2: Assessment of vulnerability; and
- Step 3: Assessment of risk

Step 1. Initial identification of relevant climate variables and associated risks

4.1.4.

A detailed baseline review was conducted through an extensive literature review and consultation process with our teams and staff, with a focus on key asset classes to be used in the assessment. The following asset classes were included in the assessment:

- Drainage (e.g. gullies, outfalls and culverts, soakaways, ponds, pipes and ditches and channels)
- Geotechnical (e.g. embankments and cuttings)

- Pavements (e.g. road surface and underlying structural layers)
- Structures (e.g. bridges, footbridges, cycle bridges, bridge components, culverts, signals, gantries, retaining walls, buildings, road restraint systems and tunnels); and
- Soft estate (e.g. biodiversity, ecological corridors)

4.1.5.

In addition, impacts on customers and workforce (e.g. roadworkers, traffic officers etc.) were also included.

4.1.6.

This ARP3 has not looked at cultural heritage assets, hard landscaping or roadside technology outside of structures and further review of these will be required. During the authoring of this report it has become apparent that further work is required to understand potential risks, so to enable this a specific action to further review climate risks beyond the asset classes listed here has been added to the actions in this report.

4.1.7.

Early on in the baseline review it became apparent that there were interrelationships between asset classes. For example, there is a clear relationship between drainage and a number of other asset classes. A 'systems' view of asset vulnerability was, therefore, incorporated into the review.

4.1.8.

The baseline review process identified the relevant climate risks for each climate variable for each asset class. The following hazards were taken forward to step 2.

- Increase in mean summer temperature
- Increase in extreme summer temperature
- Change in extreme winter temperature
- Increase in mean annual precipitation
- Change in extreme precipitation
- Rise in sea level
- Change in fog; Increase*[3]
- Change in solar radiation exposure*
- Change in wind and storminess*

3 While most hazards are drawn from UKCP18 datasets, hazards marked with a * have been assessed using a qualitative approach

- Change in snowfall*; and
- Change in freeze-thaw cycles*

4.1.9.

Climate Projections: UKCP18 provides climate projections aligned to Representative Concentration Pathways (RCPs). Multiple RCPs are available for the probabilistic projections (25km resolution) and provide a range of possible trajectories of how global land use and emissions of GHGs may change through to 2100. RCP 4.5 and RCP 8.5 were chosen for this assessment as they roughly align to a future world where global average temperatures are 2°C and 4°C above pre-industrial levels respectively.[4]

4.1.10.

Table 1 provides a summary of the RCPs used for this assessment. At present, data from the Committee on Climate Change suggests we are on course for somewhere between the two, so this provides a useful spread for testing risks and adaptation.

Table 1 - RCPs used in this assessment adapted from IPCC AR5[5]

Representative concentration pathways used in this assessment adapted from IPCC AR5.	Description	Percentile used & rationale	Temperature increase by 2046-2065	Temperature increase by 2081-2100
RCP4.5	High mitigation (broadly aligned with 2°C)	The 50th percentile has been used in accordance with Defra requirements.	1.4 (0.9 to 2.0)	1.8 (1.1 to 2.6)
RCP8.5	Business as usual (broadly aligned with 4°C)	The 90th percentile has been used to encapsulate the upper limit and therefore more likely to capture 4°C warming.	2.0 (1.4 to 2.6)	3.7 (2.6 to 4.8)

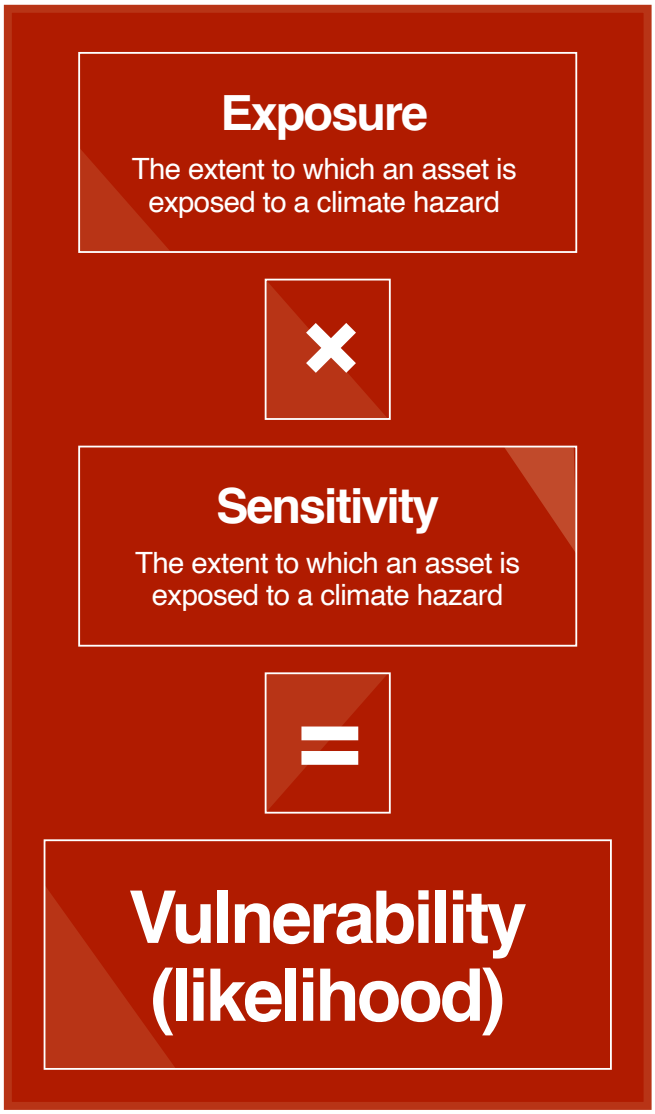
4 This approach is in line with the approach taken in CCRA3 - https://www.ukclimaterisk.org/wp-content/uploads/2021/06/Technical-Report-The-Third-Climate-Change-Risk-Assessment.pdf.

5 IPCC AR5 WG1 (2013), Stocker, T.F.; et al., eds., "Climate Change 2013. The Physical Science Basis". Working Group 1 (WG1) Cambridge University Press.

Step 2. Assessment of vulnerability

4.1.11.

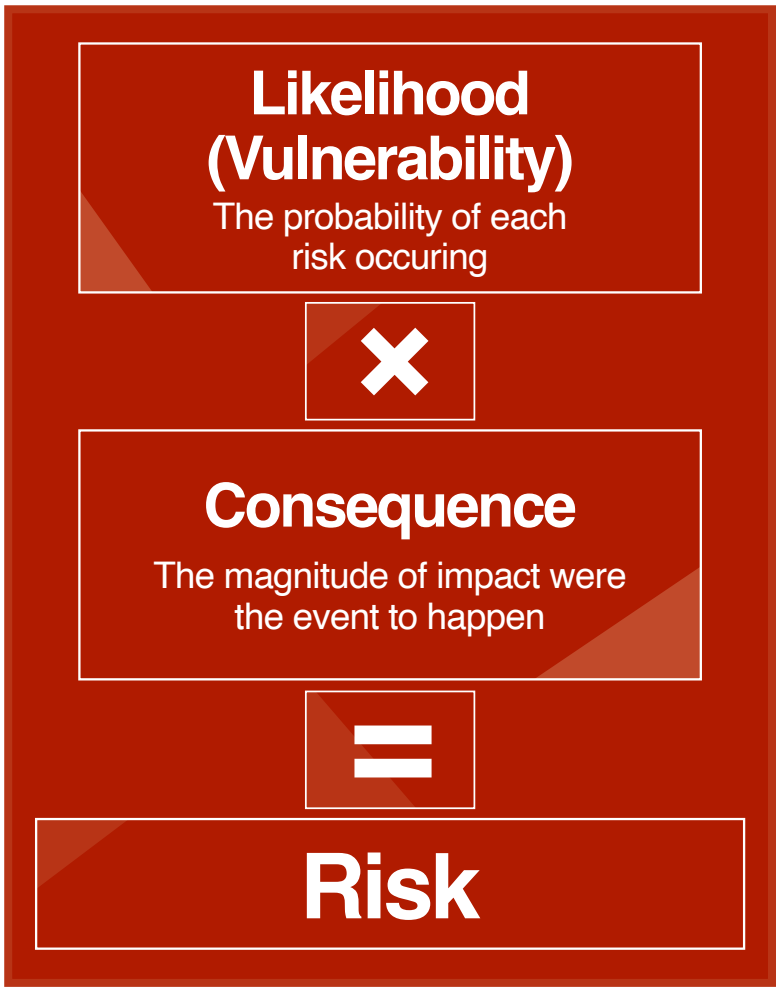
The vulnerability assessment considers the exposure and sensitivity of assets across the portfolio. To analyse the exposure, regional climate projections have been derived for each of the regions in which an asset is located, across short-, medium- and long-term time periods (2030s, 2050s & 2080s). The sensitivity assessment considers the inherent characteristics of the asset which may make it more or less vulnerable to a particular change in climate. These scores are based on the current state of the assets, prior to any mitigation measures. The following section details this process.



4.1.12.

The latest UK Climate Projections (UKCP18) were used in the assessment at the regional level to determine the region's exposure to each climate variable across the three different time periods as recommended in industry guidance. Exposure was rated on a 6-point scale from negligible to very high based on the magnitude of change. Sensitivity was determined through the baseline review process and included regional variation such as material use, soil types and frequency of previous incidents and rated either low, medium, or high. These were combined in a matrix to ascertain how each asset class in each region may be vulnerable to the different climate hazards and associated risks, thus, resulting in a vulnerability rating for each risk and region. The vulnerability rating is carried into Step 3 as representative of likelihood, i.e., the probability of each hazard occurring.

Step 3. Assessment of risk



4.1.13.

Likelihood ratings ranged on a 5-point scale from highly unlikely to almost certain. The consequence assessment captured the magnitude of impact of the climate related risks through different lenses (finance, service continuity, health & safety and legal). A consequence rating of 1 to 5 (from minimal to catastrophic) was given for each climate risk for every asset class. The highest consequence rating (consistent with the precautionary approach) was taken forward to be combined with the likelihood rating to undertake the final calculation of risk, giving either a minor, moderate, major, or severe risk rating. By using this precautionary approach, the more extreme risks and anomalies are more likely to be captured. The major and severe risks are summarized in the remaining report as 'key' risks.

4.1.14.

The key risks are subsequently focused on in Section 5 for the identification of adaptation actions that are already taking place or need to be undertaken as a result of the ARP3. Risk that are not classed as 'key' for the purpose of this assessment (because their risk score was either minor or moderate) were also captured through the risk assessment process and still ought to be regularly monitored as well.

5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Climate risk and **adaptation actions**

Climate risk and adaptation actions

5.1 Risks and actions by climate variable

5.1.1.

In this section we explain the results of the assessment of climate change impacts on the asset classes and other components of the SRN, following the methodology in section 4, and set out the actions already taken and to be taken to improve resilience.

5.1.2.

This section addresses key risks associated with climate change. Following review of climate variables relevant to the asset classes considered, broadly we have organised risks around:

- Precipitation (risks to assets identified from review of the increase in mean precipitation (winter), and extreme precipitation (winter and summer) variables)
- Temperature (this includes risks to assets identified from review of the increase in mean temperature (summer), and change in extreme temperature (summer and winter))
- The interaction between temperature and precipitation (this includes interacting risks where both temperature changes and precipitation are a component)
- Additional risks (this includes risks to assets identified from review of sea level rise, change in storminess (wind speed), change in storminess (lightning), change in the number of fog days, freeze-thaw, change in snowfall and solar radiation risks)

5.1.3.

Each respective sub-section also highlights actions that we have identified that need to be taken forward. We also highlight a few additional risks and actions that whilst not necessarily identified as 'key' (i.e. not major or severe) we feel are worth highlighting here.

5.1.4.

The actions we set out include actions that were directly identified and taken forward from ARP2, those that we have done additionally over the last five years and those actions and ambitions that we have identified in direct response to the risks identified for ARP3.

5.1.5.

Identified actions fall into 2 categories: ‘actions we will develop further’: these are at a sufficient state of maturity that resources are identified to take forward; and ‘ambitions that we will seek to develop further’: these are measures that we have identified that may need further development or resource planning to put in place, but which we will actively pursue to help ensure climate resilience.

5.1.6.

This section contains the following sub-sections focused on: risks and actions by climate variable (precipitation, temperature, the interaction between precipitation and temperature); and additional risks and actions and risks and actions for customers and the workforce. Each of these sections then states:

- The identified key risks
- The actions taken forward from ARP2
- Additional actions undertaken over the last 5 years
- Actions identified in response to the risks identified in this round of reporting

5.1.7.

In developing and recording actions an internal adaptation register was populated using a template that was initially developed by Defra, and further refined by a group of transport infrastructure providers. This categorised actions into broad overarching categories as shown in Figure 1.

Figure 1 - Overarching categories of adaptation actions

Precipitation

How will the climate change in the future?

5.1.8.

Climate projections show that in the UK, we can expect to have wetter winters and drier summers.

5.1.9.

Climate projections for the 2070s under a high emission scenario state that summer precipitation will change by between -47% - +2% and by -1% - +35% in winter compared to the 1981-2000 baseline.[6] These wetter winters, with periods

6 Met Office Hadley Centre 'UK Climate Projections Headline Findings July 2021' Available online: ukcp18_headline_findings_v3.pdf (metoffice.gov.uk); Accessed on 2.11.2021.

of prolonged rainfall can result in a higher chance of flooding from rivers. It is also projected that extreme events will increase in intensity and severity, potentially increasing the likelihood of surface water flooding or flash floods. Wetter periods will also affect the water table increasing the risk of groundwater flooding.

5.1.10.

Whilst the relative increase in winter precipitation is expected to be greater in central and southern England, it is also the south that is expected to see the greatest reduction in summer precipitation.[7] However, whilst the summers are expected to be drier in all regions, when it does rain, storms are projected to be more intense.[8]

Key risks that have been identified

Overwhelming of drainage due to fluvial (river) and pluvial (surface) and groundwater flooding

5.1.11.

Surface water flooding is a major risk for the SRN, and adequate drainage is the most important factor mitigating this risk. Impacts occur when rain falls on the carriageway or surrounding land at a greater rate than it can be removed by drainage assets.

5.1.12.

Prolonged rainfall can also affect the water table and lead to local flooding in the winter months. While less common than surface water flooding, as climate change projections show wetter winters we can expect risks from groundwater flooding to rise. In some locations this may interface with the SRN.

5.1.13.

The reliability of the drainage assets is a key internal interdependency for us as the overwhelming of the drainage system can cause the pavement and the underlying geotechnical asset to become and remain water-logged, leading to its premature deterioration.

7 Met Office Hadley Centre 'UKCP 18 Factsheet: Precipitation' Available online: https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/research/ukcp/ukcp18-factsheet-precipitation.pdf Accessed on 5.11.2021.

8 Met Office Hadley Centre 'UKCP18 National Climate Projections' Available online: https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/research/ukcp/ukcp18-overview-slidepack-march21.pdf Accessed on 5.11.2021.

Case Study #1 - A1 at Catterick - flood storage and conveyance

Repeated flooding at the A1 at Catterick was a risk to traffic, the economy, and the local community of Catterick village. We worked in partnership with others such as the Environment Agency and North Yorkshire County Council to design a solution, which included a flood storage reservoir, and adding meanders and hydro-brakes to slow and control the flow of water through Brough Beck. This solution delivered £2million of benefits to the regional economy and protected 149 properties from flooding.

Fluvial flooding and high river flows.

5.1.14.

Water is the main cause of deterioration of structures. Fluvial flooding is a major risk to bridges, leading to scour – which is the main cause of bridge failure in the UK – and damage due to the impact of debris carried by flood waters.

5.1.15.

Scour is the erosion of soil or rock below or near the foundation of a structure due to hydraulic effects. Increased scour at bridges could potentially compromise structural integrity, which could ultimately lead to failure. Scour and other hydraulic failures mostly occur at older structures with shallow foundations and structures at tidal locations. Structures built alongside watercourses, particularly tidal rivers, are at the highest risk. Masonry arch bridges are particularly susceptible to failure due to scour and other hydraulic actions.

5.1.16.

Fluvial flooding and increased river levels also impact the effectiveness of drainage assets where outfalls to rivers are not able to discharge effectively. This localised problem can lead the drainage system to back up, resulting in the highway not draining properly and inundating the road. It may also have structural integrity consequences on the drainage assets themselves. Currently we design new roads to be resilient to off network sources of flooding by ensuring sufficient freeboard, requiring them to be resilient to a 1% event plus climate change.

Case Study #2 – Critical Care for Keadby Pumping Station

Keadby Pumping Station, near Scunthorpe, is situated at the end of a complex network of rivers and pumping stations and improves flood resilience for around 500 square kilometres across North-East England. The station, which has been in operation for over 80 years and protects over 28,000 homes, 30,000 hectares of agricultural land and 22 miles of the M18 and M180 from flooding, needed renewal. National Highways partnered with the Environment Agency to carry out improvements to the station's critical flood defences. Replacing Keadby's diesel pumps with electric pumps reduced the station's carbon footprint, and the new pumps will also be safer for fish and eels passing through the station on their natural migration.

Ground saturation affecting stability of geotechnical assets

5.1.17.

Approximately one third of defects in geotechnical assets are related to excess water. In the worst case, slopes can fail and deposit material on the carriageway, which can be dangerous and disruptive while the issue is resolved. This risk is exacerbated when earthworks are constructed across an existing landslip (identified as a risk in ARP2). Drainage is key to earthwork stability, but drainage systems are often not well maintained.

Destabilisation of earthworks due to standing water

5.1.18.

If the drainage assets are overwhelmed, then standing water may remain at the toe of earthworks which are not designed to be submerged. Although this risk has not been experienced on the SRN to date, it is something that could become frequent in the future if drainage capacity is not sufficient to allow for higher precipitation levels.

Waterlogging of pavement surface

5.1.19.

During rainfall events, water soaks into the porous upper layers of the pavement surface and percolates downwards. This weakens the asphalt and causes it to degrade, leading to faults and potholes. Prolonged water saturation will also have adverse effects on the stability of granular foundation layers and can result in substantial deformation. This both decreases the support from the lower layers and weakens the material and can lead to rutting.

Case Study #3 - M6 Junction 10 Improvements

The M6 junction 10 currently experiences significant congestion, particularly during peak times. Road capacity has been identified as one of the main transport issues facing the Black Country. The improvements we are undertaking, due for completion in 2022, are aimed at reducing congestion and journey times for the thousands of drivers who use it daily whilst at the same time creating co-benefits for climate resilience.

To prepare for future increases in rainfall and to mitigate against surface water flooding, the drainage design includes an additional capacity allowance of 30%.

Existing M6 Junction 10 layout prior to works starting

New M6 Junction 10 layout after work has finished

Key actions to mitigate precipitation risks

What have we done to address these risks between 2015-2021?

5.1.20.

Our focus has been on working on design standards and specifications, implementing actions in relation to our maintenance programs and on investing in R&D to further explore specific climate variables and risks. Our actions fall within a range of different categories that speak to the diversity of activities as well as the different stages of actions we are undertaking.

5.1.21.

In response to the risks identified in ARP2 we identified and undertook the following actions:

- We published LA114: Climate – which requires a climate change risk assessment to inform design (applies to any new / upgrade schemes). LA114 puts in place a methodology to be applied in environmental assessments. This includes how climate change, including precipitation risks, shall be scoped into assessment, how data shall be collected, and how a scheme can determine if a climate impact is significant. Importantly it requires that 'the environmental

assessment shall identify how the project can be adapted to protect it from future climate scenarios'.

- We have reviewed and where necessary updated our design standards and aligned these with planning policy in relation to Flood risk.
- We continued to identify high-risk areas and develop a Drainage Data Management System (DDMS) database, which records the location and condition of the assets and any flooding incidents.
- We monitored pavement condition using the established techniques in the DMRB design standards and collated feedback on thin surfacing on the network from surfacing contractors through liaison with the Mineral Products Association (MPA). The feedback highlighted that the pavement condition has remained at a serviceable level over the monitoring period and improved slightly throughout the last RIS (see ORR benchmarking report).

5.1.22.

In addition to those actions listed above, we have also:

- Reviewed, updated, and published the DMRB standards across different asset classes:
  - CD529: Design of outfall and culvert details, which requires culverts conveying a public watercourse to be discussed and agreed with the Environment Agency.
  - CG501: Design of highway drainage assets, which focuses on reducing risk through increasing drainage capacity, and this now requires a climate change allowance of 20% in design with a sensitivity test to 40%.
  - LA113: Road drainage and water environment. This requires that all new schemes are supported by a Flood Risk Assessment to assess flood risk to and from the scheme, including the latest allowances for climate change.
  - CD522: Drainage of runoff from natural catchments includes references to climate allowances.
  - CS641: Managing the maintenance of highways geotechnical assets, which includes a risk-based approach to asset management and maintenance, encompassing a range of factors including flood risk; and
  - CD356: Design of highway structures for hydraulic action, which includes scour assessment requirements and guidance including requirements to apply climate change allowances.

5.1.23.

We have addressed further geotechnical risks from precipitation by:

- Completing a climate change adaptation assessment for geotechnical design, construction, and management activities, which is considering the interactions between geotechnical, drainage and pavement assets; and

- Introducing ground related hazard mapping layers into the Geotechnical Data Management System (GDMS).

5.1.24.

We have also addressed further drainage risks from precipitation by:

- Developing a collaborative programme of flooding schemes with the EA to support flood risk reduction on the SRN and to adjacent communities
- Commencing initiatives in 2020 / early 2021 for improving flood recording and reporting processes; and
- Piloting natural flood management (NFM) as a means of potentially improving flood resilience of the SRN.

5.1.25.

Finally, we have addressed further structures risks from precipitation by:

- Commencing the preparation of a scour management document (CS 469: Management of scour and other hydraulic actions), which includes climate change and uses a risk-based approach.

What should we do in response to ARP3?

5.1.26.

We will focus on further reviewing our design standards and specifications, improving our maintenance programs, investing into R&D and we will also concentrate on monitoring our actions and improving our adaptive management.

In response to the risks identified above we will:

5.1.27.

Address geotechnical risks from precipitation by:

- Completing a study on the links between geotechnics and drainage and support ongoing R&D into the impacts of climate change on geotechnical assets.

5.1.28.

Address drainage risks from precipitation by:

- Reviewing and normalising the drainage metric to take account of future weather. This presents the opportunity to monitor longer term trends of severe storm impact on drainage resilience (i.e. the percentage of carriageway that does not have a significant susceptibility to flooding). In turn, this will offer the potential to track asset performance against the current design specification and can inform future asset performance requirements. We also aim to review the application of updates to the Environment Agency climate change allowances.

- Completing a task on the impact of drainage on ground related and geotechnical assets.

5.1.29.

In addition to the above actions we have identified the following ambitions that we will seek to develop further:

- Investigate the risks to the existing drainage asset to identify and prioritise specific locations that may need proactive intervention in the next years. (The design standard CG501 addresses the risk to new build assets only and not to the existing asset.)
- Evaluate the natural flood management pilot to inform a review of nature-based solutions as a form of adaptation. Nature-based solutions are also included in the scope of the Climate Resilience Call 2021: a research project co-funded by a number of national road administrations, including National Highways.
- Develop our understanding how many flood events are greater than the design standard (1 in 5 years).

5.1.30.

Address structures risks from precipitation by:

- Continuing to monitor and review the use of standards and update them if necessary
- Publishing and implementing the DMRB design standard CS 469: Inspection and assessment of scour and other hydraulic actions at structures and seek feedback on its application

5.1.31.

In addition to the above actions we have identified the following ambition that we will seek to develop further:

- Conduct R&D into different soil types to understand which are more sensitive to impacts affecting structures and understand the interdependency between structures and geotechnics.

5.1.32.

Address pavements risks from precipitation by:

- Continuing to monitor pavement conditions using the established techniques and reporting metrics; and
- Continuing to monitor operational feedback regarding problematic weather conditions for laying pavement materials and the applicability of current standards and specifications.

Table 2 - Summary table for ARP3 actions and ambitions for responding to precipitation change

Drainage / Environment	Structures	Geotechnics	Pavements
R&D: links between geotechnics and drainage	Monitor, review, update use of standards	R&D: links between geotechnics and drainage	Monitor pavement conditions
Normalise drainage metric (incl. future weather)	Publish & implement the DMRB design standard CS 469		Monitor operational feedback regarding problematic weather conditions for laying pavement materials
Investigate risks to existing drainage asset	Conduct R&D into different soil types		Monitor operational feedback on applicability of current standards and specifications
Evaluate natural flood management pilot			
Understand how many flood events are greater than the design standard			
Conduct task on 'Impact of drainage on ground related and geotechnical assets'			

Case Study #4 – A66 Flood Risk Mitigation, Cumbria

The A66, a key strategic route in Cumbria, is situated close to the River Derwent and several tributaries that are prone to flooding. The route is an important strategic connection for the local community and economy, including providing access to key tourist destinations in the Lake District.

Improvement works that have been carried out to mitigate flood risk include:

- Carriageway raising works
- Installation of large diameter cross-carriageway culverts; and
- Emergency crossing points

Temperature

How will the climate change in the future?

5.1.33.

Climate projections for the UK show that all parts of the UK will be warmer in future, particularly during the summer, with an increase in the frequency of heatwaves and a reduction in the frequency of cold spells.[9] The top 10 warmest years the UK has experienced since 1884 have all occurred since 2002.[10]

5.1.34.

Under a high emission scenario, it is projected that by 2070 summers will be warmer by between 0.9°C – 5.4°C and winters will be warmer by between 0.7°C - 4.2°C. By 2050 it is projected that the chance of having a summer as hot as that of 2018 is likely to increase by nearly 50% and hot spells are also due to increase in frequency.[11] Cold weather events will become less frequent, but the effects of climate change on cold events are much smaller than hot events. However, they will continue to occur.[12]

9 Arnell, N. W., & Freeman, A. (2021). The impact of climate change on policy-relevant indicators of temperature extremes in the United Kingdom. Climate Resilience and Sustainability. https://doi.org/10.1002/cli2.12.

10 Kendon, M., McCarthy, M., Jevrejeva, S., Matthews, A., Sparks, T., & Garforth, J. (2021). State of the UK Climate 2020. International Journal of Climatology, 41 (Suppl. 2), 1– 76. https://doi.org/10.1002/joc.7285.

11 Met Office Hadley Centre 'UK Climate Projections Headline Findings July 2021' Available online: ukcp18_headline_findings_v3.pdf (metoffice.gov.uk); Accessed on 2.11.2021.

12 Arnell, N. W., & Freeman, A. (2021). The impact of climate change on policy-relevant indicators of temperature extremes in the United Kingdom. Climate Resilience and Sustainability. https://doi.org/10.1002/cli2.12.

5.1.35.

Temperatures in the UK are affected by five air masses which originate from:

- Colder, northerly areas, such as the arctic maritime (bringing cold and snow)
- Polar continental (bringing cold and dry weather)
- Polar maritime (bringing cold and wet weather)
- Warmer southerly areas, such as the tropical maritime (warm and wet); and
- Tropical continental (bringing hot and dry weather)

5.1.36.

The weather in the south and south east of the UK is strongly influenced by the tropical continental air mass which brings hot, dry air from North Africa across the region. Thus, resulting in hotter summer temperatures and making heatwaves more likely in this region. As such, as temperatures continue to rise globally, the temperatures in the south and south-east regions will increase, and the intensity, frequency and duration of heatwave events will become greater in this region relative to that of more northern regions across the UK.

Key risks that have been identified from temperature changes

Concrete 'blow-ups' on pavements

5.1.37.

In high temperatures, concrete slabs expand and cause 'blow up'. Roads with a concrete surface course are a particular problem, although those with concrete sub-layers overlain with asphalt also incur this risk. We plan to phase out existing concrete roads over the next 20 years, including those with an asphalt overlay, but this is likely to remain a concern for some roads until at least 2040. We have thus included these risks in the assessment and assumed no further adaptation for the existing concrete roads until they will be replaced.

Thermal action and failure of expansion joints and bridge bearings on structures

5.1.38.

Expansion joints may fail if the temperature exceeds that for which they are designed. This impact is a particular concern regarding older structures, or those which have been built with errors. Bridge bearings are also vulnerable to temperature change. The bearings are designed to accommodate the movement of the bridge for a temperature range which is set at the time of installation. Climate change could potentially result in the range being exceeded which could lead to the bearings failing. We have previously undertaken work to identify the key vulnerabilities of structures to thermal effects which showed that provided that all the bridges and their components are constructed to standards, current design standards are deemed to be conservative. Thermal movements can be caused

by changes in the overall temperature of the structure as well as the temperature difference within each component.

Melting and deformation of asphalt surface course

5.1.39.

In high temperatures, asphalt softens, ruts, and, in extreme cases, melts. This leads to an uneven road surface and early replacement of the surface course. Although the exact relationship between air temperature and road surface temperature is unclear, surface temperatures of 50°C have been recorded on sunny days with air temperatures approaching 30°C. The asphalt used on UK roads is stress tested to 60°C and initial findings of our Pavement Resilience Research Project showed that in one location, on a day of record air temperatures in July 2019, the road surface temperature reached 59.4°C, though large variations were identified across different road surface types.

5.1.40.

Sub-optimal conditions in summer, for example very hot, sunny conditions, pose difficulties for laying conventional hot-mixed asphalt. Freshly laid asphalt retains heat and remains soft for longer and is therefore susceptible to rutting if the road is opened before it has fully cooled. As the cooling process takes longer, this also leads to longer road closures and more disruption due to the resurfacing process. Warm mix asphalts are now included in our specifications for use on the SRN, as of July 2021. Taking less time to cool, warm mixtures are likely to prove to be a useful solution for highway maintenance in hot ambient temperatures.

5.1.41.

Weather conditions impact the quality of new and replacement surfaces that are laid, and some road surfacing materials have temperature and weather restrictions. If asphalt is laid in particularly cold or windy conditions, the quality of the result can be poorer, since the asphalt cannot be sufficiently worked on site prior to cooling, and the lifespan of the resulting surface can be shorter. Climate change has the potential to make these conditions more common, meaning that the window of opportunity for surfacing works during winter may be shorter and/or replacement cycles may become shorter.

Key actions to mitigate temperature risks

What have we done to address these risks between 2015-2021?

5.1.42.

Our key areas of focus over the past few years has been on:

- Research and development
- Design standards
- Maintenance programmes
- Monitoring and adaptive management

In response to the temperature risks identified in ARP2 we identified and undertook the following actions:

- Updated DMRB design standards HD 32: Maintenance of concrete roads and HD: 38 Concrete surfacing and materials to ensure that requirements for joint sealants are included in new forms of contract. Jointed rigid pavements (with concrete surfacing) and continuously reinforced concrete pavements (with a concrete surfacing) have requirements for joint sealants set out in DMRB design standard CD227: Design for pavement maintenance, with supporting information in MCHW. The confidence in seals (and other associated materials) within the bounds of extreme temperature rises is currently high.

  Consideration of the resilience of sealants up to 2050s within updates of the Manual of Contract Documents for Highways Works (MCHW) will likely involve technology transfer and adjustment in the UK, but our starting point is that concrete pavements technologies are currently widely used in both very hot and freezing climates. The confidence of / terminations being within the bounds of extreme temperature rises currently varies dependent on the concrete pavement asset type. The confidence is high for concrete pavements designed to current standards (CD 226) and reduces within the legacy concrete pavement assets (e.g. 30-year-old jointed pavements). The legacy concrete pavement assets are currently on a prioritised programme for reconstruction prior to the end of Road Period 6. There are requirements to further future proof CD 226 designs and continue de risking the legacy concrete pavement assets.

- Monitored the performance of and gathered feedback from surfacing contractors through liaison with the Mineral Products Association (MPA) on the current surfacing material of choice: Thin Surface Course Systems (TSCS). We found that the TSCS have a low propensity to rut, compared to the other predominant material type: Hot Rolled Asphalt (HRA). The split of TSCS relative to other material types is 60:40 and the proportion of TSCS will continue to increase in the course of cyclic pavement surface renewal works. We found that the pavement condition has remained at a serviceable level over the monitoring period and improved slightly throughout the last RIS.

In addition to those actions listed above, we have also:

5.1.43.

Addressed further structures risks from temperature changes by:

- Reviewing thermal (as well as wind actions) on bridges against UKCP18 data and concluded that whilst bridges will not be affected by changes in temperature at least within the time period considered under UKCP18, this will have to be kept under review following future climate projections. The study also found that thermal effects and wind loads could influence other structures' behaviour, such as gantries or tunnels, and that this finding will require further work.

5.1.44.

We have addressed further risks to pavements from temperature changes we have by:

- Deciding to phase out concrete pavements. Their entire phase out will be complete by 2045.
- Including a requirement into the DMRB design standard CD 226 Design for new pavement construction that states *'the termination details of Continuously Reinforced Concrete Pavement (CRCP) and Continuously Reinforced Concrete Base (CRCB) pavements shall be designed to ensure that forces are not transmitted to structures and adjacent forms of pavement construction by thermally induced structures'.*
- Collaborating with the University of Nottingham on a study entitled 'Enhancing the Climate Resilience of Asphalt Pavements'. The study looks at the potential exceedance of critical thresholds using UKCP18 data to highlight the potential for changes to design and specifications.
- Introducing a new clause to the Specification for Highways Works that permits routine use of warm mix asphalt (WMA). WMA takes less time to cool before the highway can be re-opened post-maintenance. WMAs are therefore appropriate for working in elevated ambient temperatures. There are also carbon savings associated with WMA.

What should we do in response to temperature in ARP3?

5.1.45.

Our focus in the coming years in terms of addressing the risks from temperature changes should be on design standards, monitoring and adaptive management.

In response to the risks identified from temperature above we will:

5.1.46.

Address structure risks from temperature changes by:

- Reviewing expansion joint failure analysis reports and asset data to assess whether failures are associated wholly or partially with extreme temperatures, or attributable to other causes
- Reviewing standards and guidance for designers, manufacturers, contractors, and inspectors, to work proactively to ensure that expansion joint failures are reduced
- Liaising with specialist manufacturers to seek improved performance of expansion joints.

5.1.47.

Address pavement risks from temperature changes by:

- Developing future proof designs. We will consider the resilience of sealants / terminations up to the 2050s as MCHW is updated.
- Evaluating and, where appropriate, implementing key recommendations where specification thresholds are likely to be exceeded for Thin Surfacing Course System (TSCS) as a result of climate change. TSCS is the preferred surfacing option and this type of surfacing covers over 50% of the SRN.
- Continuing to monitor operational feedback regarding problematic weather conditions for laying pavement materials and the applicability of current standards and specifications.

Table 3 - Summary table for ARP3 actions and ambitions for temperature changes

Structures	Pavements
Review expansion joint failure analysis reports and asset data	Develop Future Proof Designs. Consider resilience of sealants / terminations up to 2050s as MCHW is updated
Review standards and guidance on expansion joint failure for designers, manufacturers, contractors, and inspectors	Evaluate & implement key recommendations where specification thresholds are likely to be exceeded for Thin Surfacing Course System (TSCS)
Liaise with specialist manufacturers to improve performance of expansion joints	Monitor operational feedback regarding problematic weather conditions for laying pavement materials

Interaction between temperature and precipitation changes

Key risks that have been identified

5.1.48.

The risks and impacts to our assets and functions set out below result from the interaction of two different climate variables: temperature and rainfall. Both must therefore be considered in conjunction when assessing the future climate change risks. As set out in the previous sections, summers are projected to become hotter and drier and an increased likelihood of extreme storms will result in higher intensity precipitation. This is likely to be particularly evident in the south east where higher temperatures, higher intensity rainfall, and winter rainfall is projected and there are more clay soils present, which increase the sensitivity of the region.

Shrink-swell cycles leading to destabilisation of geotechnical assets (due to mean temperature and precipitation changes)

5.1.49.

In hot, dry conditions, soil shrinks and cracks. Subsequent rainfall is then able to penetrate deeper into the soil, which increases the speed at which soil becomes saturated, increases pore pressure, and causes slope defects and failure. These impacts will be most acute in the high plasticity soils of South East England[13].

Ground shrinkage destabilising drainage assets (due to mean temperature and precipitation changes)

5.1.50.

During prolonged hot, dry periods, soil dries out and shrinks, which can destabilise and damage underground assets. With regard to drainage assets, this will be a particular issue for outfalls which may become dislodged, or pipes which may crack and leak. Damage to drainage assets will exacerbate the impact of precipitation when it does occur, especially if the precipitation event is sudden and heavy.

Structural integrity affected by changes in earth pressures (mean precipitation changes and warmer, drier summers)

5.1.51.

Changes in annual precipitation will impact groundwater levels and thus earth pressure exerted on structure foundations. The increased difference between wetter winters and drier summers could result in increased ground movement and heave, reducing headroom and causing differential settlement and potentially the failure of components; it may also lead to a need for increased drainage and stronger foundations. This in turn would lead to increased costs and increased build time.

Key actions to mitigate risks from interaction between temperature and precipitation changes

What have we done to address these risks between 2015-2021?

5.1.52.

Whilst these risks resulting from multiple variables have not as such been identified in ARP2, we have already taken a number of actions to address them.

5.1.53.

We have addressed further geotechnical risks from interaction between temperature and precipitation changes by:

13 Defra, 2017. UK Climate Change Risk Assessment 2017, Available online https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/584281/uk-climate-change-risk-assess-2017.pdf

- Conducting research into a geotechnical climate change adaptation assessment which includes review of temperature and rainfall risks
- Developing a shrink swell layer ground related hazard map
- Providing industrial support to the ACHILLES (assessment, costing and enhancement of long life, long linear assets) programme through the A34 Newbury test site. The Achilles programme is a 4-year EPSRC funded research programme (2018 – 2022) aiming to examine how infrastructure assets can be better maintained and monitored for future resilience.

5.1.54.

We have addressed further drainage risks from the interaction between temperature and precipitation changes by:

- Completing a specific task on climate change adaptation, which is considering the interactions between geotechnical and drainage assets
- Developed Hazard Guidance Notes covering a number of different ground hazards.

5.1.55.

Addressed further structure risks from interaction between temperature and precipitation changes by:

- Publishing Hazard Guidance Notes covering a number of different ground hazards as well as a Technical Guidance Note – Remote assessment for detection and monitoring of geohazards affecting highways England's network.

What will we do in response to the interaction between temperature and precipitation in ARP3?

In response to the risks identified above we will:

5.1.56.

Address structure risks from interaction between temperature and precipitation changes by:

- Completing a future task: Integrating climate change data into shrink/swell susceptibility ratings (e.g. BGS mapping layers).

5.1.57.

And we have identified the following ambition that we will seek to develop further:

- Conduct R&D into different soil types to understand which are more sensitive to impacts affecting structures. Understand the interdependency with geotechnics in this regard.

Table 4 - Summary table for ARP3 actions for the interaction between temperature and precipitation changes

Structures	Geotechnics
Conduct R&D into different soil types (sensitivity to impacts affecting structures). Understand the interdependency with geotechnics.	Integrate climate change data into shrink/swell susceptibility ratings (e.g. BGS mapping layers).

5.2 Additional risks and actions we have identified

5.2.1.

Above we have addressed the key risks and actions. In this section we highlight some of the additional risks we have identified that currently do not have a major or severe risk rating and relate to other climate hazards that aren't covered in the analysis of precipitation and temperature above. Below we highlight some of the things we need to consider and action.

How will the climate change in the future?

5.2.2.

Whilst precipitation is projected to increase during the winter, snow cover (a type of precipitation occurring during cold temperatures) is projected to decrease by almost 100% except in mountainous regions in the north and the west. Sea level is projected to increase more in the south compared to the north, with London projected to witness a sea level rise by the end of the century under a high emissions scenario of between 0.53m – 1.15m. Extreme coastal water levels are also expected to increase[14]. Near surface wind speeds are projected to increase for the second half of the 21st century, this is predominantly likely to during winter season.[15] Winds associated with major winter storms are projected to increase in frequency. There is an interaction between sea level and wind speed as it can increase wave height.

14 Met Office Hadley Centre 'UK Climate Projections Headline Findings July 2021' Available online: ukcp18_headline_findings_v3.pdf (metoffice.gov.uk); Accessed on 2.11.2021.

15 Met Office Hadley Centre 'UKCP18 Factsheet: Wind' Available online: https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/research/ukcp/ukcp18-fact-sheet-wind_march21.pdf; Accessed 5.11.2021.

Risks that have been identified

Wind action damaging structures

5.2.3.

Structures are often exposed to high winds, and wind is the most common cause of closure for critical bridges. Bridges are often in open, exposed locations, and smaller structures such as gantries are vulnerable to wind action due to their height. Smaller structures are also more vulnerable to increases in wind loading, particularly if errors have been made in their design or construction. Installations such as signs or electronics, which are an increasingly important element of traffic management, may also be damaged or blown away in strong winds.

Scour from storm surges causing damage to the structure and can result in structure failure

5.2.4.

Storm surges can lead to scour and damage due to impact from debris carried by water and could become more common in the future as a result of sea level rise and changes to wind patterns. Even the lower projection for potential rise in mean sea levels could increase scour potential along the coastline by 16% for vertical structures, although only 2% for sloping embankments and shingle beaches.[16] However, the vast majority of the SRN is not exposed to coastal risk, apart from a few localised hotspots.

UV light causing surface course to degrade

5.2.5.

UV light is damaging to the surface course of roads, as it causes degradation and premature aging of the surface course. However, the impact of climate change on the amount of UV radiation reaching the ground is complex and uncertain. Climate projections suggest that the UK is likely to receive more solar radiation as a result of less cloud cover, and therefore more UV radiation, particularly during summer.

16 CCRA3 2017 'Chapter 4: Infrastructure' available online: UK-CCRA-2017-Chapter-4-Infrastructure.pdf (theccc.org.uk) Accessed on: 11.11.2021.

Freeze-thaw and frost heave damaging the pavement and causing it to break up

5.2.6.

When the temperature dips below freezing point, water pores in the pavement freeze and expand, exerting pressure on the pores and causing them to increase in size. This allows more water to enter the pavement during subsequent rainfall events, which once again freezes and expands when the temperature falls below freezing. This causes premature pavement failure. This impact is caused by a combination of precipitation and variable temperatures, particularly in winter when the temperature is low. This problem is most frequently encountered after extreme or prolonged precipitation events. Whilst mean temperatures are projected to increase in winter, so is precipitation. Consequently, this is still a risk to monitor.

Increase in wildfires due to increased intensity and frequency of hot spells and decreased precipitation

5.2.7.

This risk is greatest in absolute terms in the south and south east and will continue to increase. However, the increase in risk is considered to be highest in the north and north west, which also include areas of peatland that may be prone to fire risk. The potential risk is that wildfires either start directly on the SRN or on third party land and subsequently spread on to the soft estate bordering the SRN. This not only damages the SRN itself, requiring more management, but the smoke resultant from wildfires would cause unsafe driving conditions.

Tree windthrow

5.2.8.

The potential increase in wind speed as well as the increased occurrence and frequency of storms, combined with the planned tree planting for carbon offsetting – and hence a larger number of trees in the soft estate, could lead to increased damage to and resultant loss of trees. The resultant risk to customer disruption and workforce maintenance regimes is discussed in Section 5.3.

Case Study #5 - A590 Green Transport Corridors

Our soft estate can allow the network to function as a green corridor to enhance the resilience of ecosystems to climate change. The latest UK Climate Change Risk Assessment (2022) identifies risks to habitats and species as a priority risk requiring more action. Improvement works to the soft estate along the A590 have included 'landscape scale' solutions in the Morecambe Bay Nature Improvement Area supported through Environmental Designated Funds, which involved establishing limestone grassland, hedge planting and woodland management. This benefits species by facilitating movement, particularly for species at the limit of their range, and protects vulnerable habitats. In particular, improvement to drainage in the scheme was critical to protect isolated populations of vendace (***Corregonance albula***) – Britain's rarest freshwater fish.

Climate related design assumptions

5.2.9.

In addition to these physical risks from climate change there is also a recognition in this report that there will be changes to climate related design assumptions and requirements, for instance, at the European standards level for temperature, wind, snow, ice, flooding and associated hydraulic actions. For example, some of these changes will be accounted for in the second-generation Eurocodes.

Case Study #6 - LA114 Climate Risk Assessment

LA114 is a document in the Design Manual for Roads and Bridges (DMRB) developed to ensure that greenhouse gases (GHGs) and climate change resilience are considered in major projects. First published in 2019 and updated in 2021, it details a high-level methodology for identifying key climate risks and vulnerabilities. Its provisions include:

- stating that UK climate projections (high emissions scenario, 50th percentile) should be used, and a H++ (reasonable worst-case) scenario should be used for safety-critical features, with historical regional weather data as the baseline
- defining the receptors as the construction process, the operational asset (including maintenance and refurbishment), and end users
- Outlining a methodology, including definitions of 'likelihood' and 'consequence' and significance criteria, for use in climate change risk assessments; and
- Requiring monitoring of the asset once operational, to check for vulnerabilities such as flooding hotspots and identify whether corrective action is required.

Actions to mitigate additional risks

5.2.10.

Many of the actions we have taken and, are intending to take, to address risks resulting from precipitation and flooding also apply to risks resulting from sea level rise. Please see actions above for further information on what we are doing and planning to address these risks.

What have we done to address these risks between 2015-2021?

- Engaged with the European standards committees and working groups to influence and keep abreast of climate related developments in the second-generation Eurocodes
- Designed and commissioned a pan European research project in partnership with other road administrations through the Conference of European Directors of Roads (2021 call) looking at climate resilience at a pan European level
- Undertook research in Hampshire with Fire and Rescue and Local Authority into increased risk of wildfire; and

- Minimised risk of tree windthrow through LD 177: Landscape Design. This includes planting distances to minimise this risk, as well as risk from trees falling onto the carriageway due to windthrow. This could cause injury or potentially, in some cases, fatalities involving road users.

What should we do in response to additional risks in ARP3?

5.2.11.

Our focus in the coming years in terms of addressing these additional risks should be on design standards, R&D, and monitoring/ adaptive management. Many ongoing and future actions have already been set out above and here we just seek to highlight some additional ones.

In response to the risks identified above we will:

5.2.12.

Address drainage risks by:

- Developing a collaborative programme of schemes with the Environment Agency (EA) to address flood risk and improve future resilience to climate change. We already have a full programme in development via Environment Designated Funds to support our corporate commitment to work with the EA towards the National Flood and Coastal Erosion Risk Management Strategy and will seek to build further on that.

5.2.13.

Address pavement risks by:

- Conducting trials of long-life bitumen which is more UV-resistant. The next stage of the research project with University of Nottingham will assess whether increased UV reaching the pavement surface is a likely outcome of climate change.
- Reviewing operating procedures and maintenance standards for flexible asphalt and durable pothole repairs. This review is underway, but climate change must be considered. There is also a need to determine how freeze-thaw cycles might change in frequency as a result of climate change and respond accordingly.

5.2.14.

Address additional risks by:

- Continuing to influence and keep abreast of climate change related developments in the second-generation Eurocodes. This is achieved by committee membership, working group participation and by providing feedback on proposed documents.

- Reviewing climate related changes in the second-generation Eurocodes for their impact on DMRB documents. If a significant event causes concern that the requirements and assumptions in DMRB documents may not be adequate, undertake research to establish whether this is the case.
- Managing known risks from pests and diseases as part of the update to MCHW Series 3000, including investigating tree species selection and management in relation to design. As different pests and diseases are identified in different parts of the country this is an issue designers should be aware of and design appropriately.
- Continuing to implement designated funds, standards, and targets to strengthen the net biodiversity resource

5.2.15.

We have also identified the following ambitions that we will seek to develop further:

- Review the outcome from research and the feedback from users on temperature, wind, snow, ice, flooding and associated hydraulic actions and determine whether DMRB or MCHW documents need to be updated
- Conduct further research into managing fire risk in proximity to roads
- Taking care when specifying different tree species to be adaptive to long term climate change

Table 5 - Summary table for ARP3 actions and ambitions for additional risks

Drainage / Environment	Pavements	Cross Asset Class	Soft Estate
Develop collaborative programme of schemes with EA to address flood risk and improve future resilience to climate change.	Conduct trials of long-life bitumen which is more UV-resistant.	Continue to influence and keep abreast of climate change related developments in the second-generation Eurocodes. Influence nationally determined parameters for the UK.	Managing known risks from pests and diseases as part of the update to MCHW Series 3000, including investigating tree species selection and management in relation to design. As different pests and diseases are identified in different parts of the country this is an issue designers should be aware of and design appropriately.
	Review operating procedures and maintenance standards for flexible asphalt and durable pothole repairs.	Review climate related changes in the second-generation Eurocodes for their impact on DMRB documents.	Taking care when specifying different species to be adaptive to long term climate change.
		Review outcome from research and the feedback from users on temperature, wind, snow, ice, flooding and associated hydraulic actions. Update DMRB documents if necessary.	Continuing to implement designated funds, standards, and targets to strengthen the net biodiversity resource.
		Further research into managing fire risk in proximity to roads	

5.3 Risks and actions for customers and workforce

5.3.1.

This section focuses on risks that have been specifically identified in relation to our customers (that is anyone who uses the SRN) and our workforce. Workforce includes both our direct employees (e.g. traffic officers and road maintenance workers) as well those who are employed though our supply chain.

Unsafe driving and working conditions

5.3.2.

Climate change hazards can cause unsafe driving conditions for our customers and unsafe working conditions for our workforce on the ground. These conditions can be caused by a number of different climate variables including:

Increasing extreme summer temperature, precipitation, wind:

- Extreme summer temperature: Customers travelling during periods of peak temperature are at risk of impacts from extreme heat which may be uncomfortable or unsafe. Workforce responsible for day-to-day traffic management are also exposed to high temperatures so would also be at risk from these impacts such as heat stroke, likely resulting in decreased productivity.
- Extreme precipitation: Surface water and decreased visibility can result in unsafe driving conditions for our customers, increasing the likelihood of accidents occurring.
- Wind: Accidents can occur due to driving in high wind events, particularly from strong gusts of wind and for taller vehicles.

Decreasing extreme winter temperature, fog, snow:

- Extreme winter temperature: Customers travelling during low winter temperatures may find unsafe driving conditions due to the ice on the roads which may increase the likelihood of accidents occurring. Decreased productivity for workforce working in these conditions may also occur. However, climate projections show a future decrease in this climate variable, so these impacts are likely to decrease in frequency and severity in the future.
- Fog: Poor visibility caused by fog events can result in a higher chance of accidents for customers. However, climate projections show a future decrease in this climate variable.
- Snow: Customers driving during snowstorm or sleet events would experience decreased visibility and a lack of traction whilst driving on settled snow, resulting in unsafe conditions and increasing the likelihood of an accident. However, climate projections show a decrease in the snowfall in the UK in the future.

- A possible risk from structures is falling ice, which could present a risk to the public. This has closed bridges such as the Queensferry Bridge in Scotland. While warmer winters are likely to mean less ice formation, wetter winters are also projected so this is still a risk to monitor.

Disruption and management requirements

5.3.3.

Workforce may have increased management requirements as a result of increased traffic incidents caused by unsafe driving conditions. These unsafe driving conditions are described above and are a result of extreme precipitation and wind, both with increasing trend projections; and extreme winter temperature, fog, and snow, which are all projected to decrease in the future.

5.3.4.

Customers may experience disruptions to their journeys as a result of road closures caused by:

- Flooding from an increase in mean precipitation
- Debris in the road caused by strong winds
- Coastal erosion management caused by sea level rise; and
- Heavy and settled snow. However, climate projections show a decrease in the snowfall in the UK in the future.

5.3.5.

These road disruptions would result in increased management requirements for our' workforce.

5.3.6.

Workforce could also have changes to maintenance requirements as a result of the following climate variables:

- Drying out of soft estate alongside SRN resulting in heightened fire risk; and
- Snowfall / frost requiring snow to be cleared and roads to be gritted. However, the climate projections show a decrease in low temperatures and snowfall in the UK, and a decreased requirement on the maintenance regime may therefore be considered a future beneficial effect of climate change.

Actions to mitigate additional risks

What have we done to address these risks between 2015-2021?

5.3.7.

Many of these risks our dealt with through our processes for managing health and safety or dealing with weather related risks:

- We have dealt with incidents such as safety and wellbeing, initial response, scene management and recovery to normality through Traffic Officer Manual, which also covers severe weather procedures.
- We have considered working conditions in the Health and Safety Management System with requirements to conduct risk assessments and report incidents.
- We have issued safety alerts to deal with extreme weather, including a safety alert to coincide with extreme heat.
- Our regional resilience, emergency, winter, and severe weather plans are routinely developed by Operations Teams.
- We have routinely developed winter and severe weather plans used by regional operations teams. Variable Message Signs are used where available to warn drivers of soon to be experienced weather conditions.

What should we do in response to the risks identified in ARP3?

In response to the risks identified above we will:

5.3.8.

Address risks by:

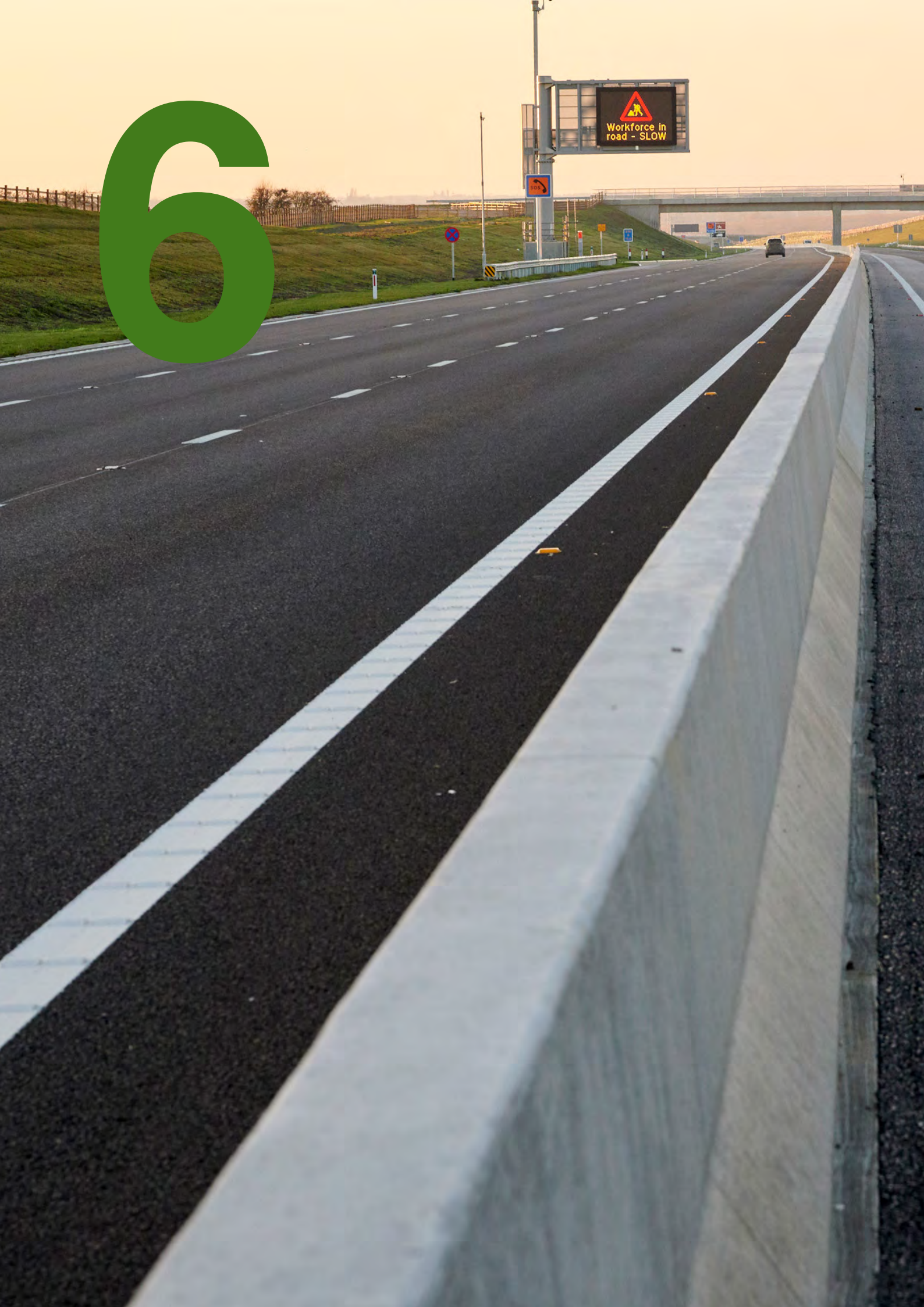
- Continuing to monitor and consider opportunities to input climate considerations to guidance
- Continue to issue severe weather alerts as appropriate

5.3.9.

We have identified the following ambitions that we will seek to develop further:

- Review /update regional resilience, emergency, winter, and severe weather plans. Work with resilience teams to ensure these align with climate risks and explore where further research may be needed.

6



Interdependencies

Interdependencies

6.1 Understanding interdependencies

6.1.1.

We recognise the importance of understanding the interdependencies between National Highways and other organisations and infrastructure categories, in particular those interdependencies that are influenced by climate risks. In this context, interdependencies refer to systems or organisations which are connected to, or rely on, another system or organisation to fully operate. Internal interdependencies can be defined as assets within the organisation which are connected to, or rely on, other departments to fully operate; these internal interdependencies are also relevant to this assessment and are taken into account in section 5 of this report.

6.1.2.

As emphasised in the UK CCRA, vulnerabilities within transport infrastructure can cause problems in other infrastructure systems. For example, due to the interconnected nature of infrastructure systems, events such as flooding on the SRN can lead to delays and disruptions on other transport networks or the inability for essential vehicles such as emergency service vehicles to travel. Understanding and managing these interdependent climate risks is thus essential for improving the overall resilience of the transport network as a whole.

6.1.3.

Of particular importance are cascading risks, whereby climate change impacts can propagate as cascades, compounding impacts across infrastructure categories. Examples of possible cascading risks that are relevant to us include:

- Extreme precipitation events can lead to flooding, resulting in blockages and congestion of the SRN. This could prevent goods, passengers, or staff from reaching airports or ports on time.
- Extreme weather events such as heatwaves can cause track buckling and speed restrictions, damaging rail infrastructure and causing delays and cancellations. This could then lead to congestion on the SRN if passengers switch to road transport as an alternative means of completing their journey.
- Storm events can cause power outages, resulting in communication failures and safety risks on the SRN due to lack of signage.
- Extreme precipitation events could cause flooding of the SRN, disrupting maintenance operations, by impacting the supply of materials.

6.2 Mapping interdependencies

6.2.1.

Considering the range of climate risks that pose a threat to our assets and functions and related organisations and infrastructure, a number of interdependencies have been identified as summarised in Figure 2 below. These interdependencies relate primarily to three categories which are most relevant to us:

- Physical interdependencies whereby services offered by one organisation are required by another system or organisation to operate, and vice versa
- Geographic interdependencies where the impact of a local climatic event effects multiple infrastructure systems located in close spatial proximity; and
- Logical interdependencies when disruption to a system causes cascading consequences throughout other systems

Figure 2 - Overview of National Highways Interdependencies

Interdependency overview

Utilities

Electricity network:
The SRN is dependent on the electricity network for communications, lighting, signage. Electricity distribution network and power stations are dependent on SRN for maintenance, delivery of biomass.

Gas network:
Gas network is dependent on the SRN for maintenance access.

Water suppliers:
SRN is dependent on water supplies primarily for construction and maintenance. Water suppliers are dependent on SRN for transport of staff and maintenance vehicles.

Waste infrastructure:
Waste companies are dependent on SRN for transport of waste, staff, and vehicles.

Data & telecommunications:
SRN will become increasingly reliant on data and telecommunications through shift to use of mobile networks for signage and emergency roadside telephones, and the rise of autonomous vehicles.

Refuelling infrastructure / Motorway Service Areas:
Refuelling stations are dependent on the SRN for transport of fuel. This dependence may change as uptake of electric vehicles increases and there is a shift to electric / hydrogen infrastructure.

Key:
Co-dependency ⟷
Arrow pointing towards NH indicates dependence on NH
Arrow pointing away from NH indicates a dependence from NH

Transport Infrastructure

Airports:
Airports are dependent on SRN for delivery of supplies and passengers.

Rail:
Rail networks are dependent on SRN for delivery of supplies and passengers and as a means of passengers and freight accessing rail transit.

Ports:
Ports are reliant on the SRN for transport of passengers and goods. Ports generally have fewer alternative transport options if the SRN is disrupted.

Sub national transport bodies, city and local authorities: SRN and other road networks are co-dependent on the SRN for transport of passengers, goods, diversions, and also in the case of shared assets.

Other networks

Co-ordinated approach to flood mitigation and response:
Interdependency with LAs and EA to ensure a coordinated approach to flood mitigation.

Adjoining communities:
Interdependency with adjoining communities/nearby landowners to ensure a coordinated approach to flood mitigation

Emergency services: Police, Fire, Ambulance services are dependent on SRN for travel. SRN is dependent on emergency services to respond to accidents.

National Highways is interdependent on other organisations and infrastructure systems.

These include:

- Physical interdependencies whereby services offered by one organisation are required by another system or organisation to operate, and vice versa
- Geographic interdependencies where the impact of a local climatic event effects multiple infrastructure systems located in close spatial proximity
- Logical interdependencies when disruption to a system causes cascading consequences throughout other systems.

Climate change impacts can propagate as cascades, compounding impacts across infrastructure categories.

Examples of **cascading risks** include:

- Extreme precipitation events can lead to flooding, resulting in blockages and congestion of the SRN. This could prevent goods/passengers/staff from reaching airports or ports on time.
- Extreme weather events such as heatwaves can cause track buckling and speed restrictions, damaging rail infrastructure and causing delays and cancellations. This could then lead to congestion on the SRN if passengers rely on alternative modes of transport.
- Storm events can cause power outages, resulting in communication failures and health and safety risks on the SRN due to lack of signage.
- Extreme precipitation events could cause flooding of the SRN, disrupting maintenance services, transport of goods, and services such as waste collection services.

6.2.2.

At this stage it is not possible to quantify the strength of each interdependency, but several important linkages and themes have been identified as summarised in the following sections.

Transport infrastructure

6.2.3.

Looking across the interdependencies identified between National Highways and other transport infrastructure organisations, the direction of dependence is thought to be more towards National Highways. In other words, there are a number of transport organisations that are dependent on the SRN for successful functioning of their networks.

6.2.4.

For example, rail networks are dependent on the SRN for delivery of supplies and passengers, and also as a means of passengers and freight accessing rail transit. This could include passengers accessing a rail station via the SRN or freight accessing an intermediate facility such as a rail freight interchange.

6.2.5.

Cascading risks are relevant to the interdependencies between SRN and the UK's rail network, in particular, where weather-related damage to one network can increase reliance on the other.

6.2.6.

Also, airports and ports are heavily dependent on the successful functioning of the SRN. Both kinds of travel hubs are reliant on the SRN to bring passengers, products, and staff to and from the airports/ports in a timely fashion to avoid onward travel delays. Weather-related congestion on the SRN can therefore have knock-on effects for passengers or staff not being able to reach the airport or port on time. With ports in particular, alternative travel options tend to be more limited if, for example, key roads are blocked or congested near to the port.

6.2.7.

Although the dependence is considered to be directed towards National Highways, it is worth noting that the dependence is relevant, although to a lesser extent, in the other direction as well. For example, our projects are dependent on ports for the delivery of imported construction materials.

Electricity networks

6.2.8.

One utility-related interdependence of particular importance to us is the dependence on electricity transmission and distribution infrastructure. The SRN is highly dependent on the electricity network for communications, signage, lighting and generally the safe functioning of the SRN. Extreme weather events such as windstorms can cause power outages, potentially resulting in communication failures on the SRN and health and safety risks to drivers.

6.2.9.

This dependence on the electricity network is likely to increase with increasing requirements for communication signage. As electric vehicle uptake increases, there will also be an increasing dependence on charging infrastructure, which will potentially need to be considered.

Data & telecommunications

6.2.10.

An emerging interdependency of particular importance is the anticipated dependence of our assets and functions on data and telecommunications infrastructure and services. As outlined in our Introduction to Digital Roads,[17] we anticipate that Digital Roads will play a critical role in using data and connectivity to improve the way the SRN is designed, built, operated, and used.

6.2.11.

As this vision is achieved, the reliance of the SRN on data and telecommunications infrastructure will increase significantly throughout the different elements of the SRN. This will include:

- The increased use of data sharing to enable collaboration with construction partners and improve efficiencies
- Predictive analytics to manage and plan work appropriately
- Incident detection used at scale to automatically identify incidents
- Updated control room technology to provide greater oversight and control of the network
- Provision of data to the emergency services to open the road earlier following a collision
- Better use of variable signs and signals to manage traffic flow more efficiently; and
- Providing on-road workers with IT equipment that allows them to conduct their jobs as efficiently as possible.

17 National Highways, Introduction to Digital Roads https://nationalhighways.co.uk/media/2chotw13/introducing-digital-roads.pdf

6.2.12.

The understanding of climate risks to ICT infrastructure is still evolving, though it has been noted that the physical ICT infrastructure in place is generally resilient to climate change due to short asset life allowing more resilient assets to be deployed as part of the natural replacement cycle and the fast pace of technology development. However, as this dependence on data and telecommunications infrastructure grows, we will need to monitor any weather-related disruptions which result in data outages which affect the SRN, given the increasing reliance on a functioning data and telecommunications network.

6.3 Next steps on interdependencies

6.3.1.

In order to better understand these interdependencies and improve the climate resilience of both the SRN and organisations dependent on the SRN, the following measures can be undertaken, and will be further developed:

- Further engagement around interdependencies in the next steps of progressing adaptation, including engagement with relevant organisations to understand the strength of the interdependencies and existing processes to manage emergent climate risks.
- Understand new interdependencies, working with stakeholders to share evidence; and
- Continue to share good practice and research on climate interdependencies through forums such as the Infrastructure Operators Adaptation Forum.

7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Conclusions

Conclusions

7.1.1.

This report comes 10 years after we started our climate adaptation journey with the ARP1. This is an iterative process and we have sought to not only review the risks identified in ARP2 and our progress against those but to also identify new risks.

7.1.2.

Key risks for us will likely result from changes in precipitation (flooding as well as drought) and increases in temperatures and prolonged and more frequent hot spells.

7.1.3.

Section 6 highlighted the key risks and it is worth particularly reiterating the risks around ground saturation affecting the stability of assets, destabilisation of earth works due to standing water, scour, overwhelming of pavements and drainage due to fluvial and pluvial flooding and expansion joint failure.

7.1.4.

Our progress review has highlighted that we have undertaken a number of actions to address these risks, and in many cases continue to do so. We have also set out our plans for further actions going forward. This adaptation action plan will be turned into an implementation plan which is to be owned and actioned by the asset management teams.

7.1.5.

Beyond the actions we have outlined in Section 5, we also consider a number of broader further considerations to achieve progress against adaptation and assist our journey. They address broad areas that could further increase our climate resilience as we seek to implement the actions in this report.

Further Considerations

- **Governance & ownership:** We will strive to ensure that climate risk will be effectively governed through the Asset Management Transformational Programme. Better governance and ownership of climate risks and actions will contribute to more effective implementation and more efficient progress.
- **Review/ embed/ align with standards:** It is crucial that we review how our environmental standards are embedded across our organisation. It would also be beneficial to consider alignment with ISO 14090 – Adapting to climate change. This standard specifies principles, requirements, and guidelines for adaptation to climate change, which includes how adaptation is to be integrated within/ across organisations, understanding impacts and uncertainties and how these can be used in decision-making. We will work to promote the climate resilience aspects of standards such as GG103 and LA114, for example through further training and promotion, which help ensure that resilience is considered across design work.
- **Engagement:** Whilst we already engage with many partners through e.g. Local Resilience Forums, we should aim to build further on this engagement with partners, other surface transport organisations and other infrastructure providers to enhance our understanding of the strength of the interdependencies between risks and the existing processes to manage any emergent risk.
- **Assign costs:** It is our aim to achieve a better understanding of the cost of adaptation actions. This understanding will help us to create climate-resilient budgets and assign sufficient funds to implement planned actions. We will work to understand the impact of resilience on future Road Investment Strategies.
- **Explore cross-class linkages and review further risks:** There are strong linkages between drainage and other asset key classes (geotechnical, pavements and structures). It will be important to view cross-asset condition data collectively to better understand the potential cross asset impacts of drainage, to inform maintenance and renewals programmes, strategic budgets as well as opportunities to combine works, and identify and deliver efficiencies. In addition, while this report has considered a range of asset categories and other elements of the SRN, during drafting it became clear there is a need to further investigate other areas in more detail. These include climate risks to electronic assets (which will overlap with work on interdependencies).
- **Understand interdependencies:** We have set out our current understanding of our interdependencies in Section 6 and we need to build further on this to better understand interdependencies with other infrastructure providers and work together to build shared resilience.
- **Risk registers:** Having in place an established process through the ARP that helps us to identify and monitor climate-related risks, it would be sensible to include climate risks across our organisational risk registers.

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