Our sustainable development vision is to deliver ‘a railway fit for the future’ and our aim is to increase the resilience of the network to weather events and future climate change impacts.

As the owner, manager and operator of Great Britain’s rail infrastructure, Network Rail is committed to supporting the second round of adaptation reporting under the Climate Change Act 2008, and providing evidence for the development of the second national Climate Change Risk Assessment.

Weather resilience is a critical factor in achieving effective management of the GB rail infrastructure, both operationally and strategically, and therefore justifies our commitment to increase the understanding of potential future changes in weather related risks, and implement appropriate resilience actions.

Recent events such as the damage to the section of track on the Dawlish coastline, the unprecedented scale of flooding around our assets in the Somerset Levels and the significant landslip at Botley in Hampshire have shown how extreme weather events can impact rail infrastructure and the consequences of network disruption on train services.

This climate change adaptation report summarises our progress in understanding the potential impacts of climate change on performance and safety of the rail network, and how we are implementing actions to increase our resilience.

Graham Hopkins, Director of Safety Technical and Engineering.
Overview of Network Rail

Network Rail is the not for dividend owner and operator of Britain’s railway infrastructure, and is responsible for managing an extensive range of assets; including 20,000 route miles of track, 30,000 bridges and tunnels and 2,500 stations. Our role is to provide ‘a better railway for a better Britain’.

Our purpose
(Why we exist)
To generate outstanding value for taxpayers and customers

Our role
(What we do)
A better railway for a better Britain

Our vision
(What we want to be)
To be a trusted leader in the railway industry

Our strategy
(How we are going to do it)
To work with our partners and use our full potential to improve safety, reliability, capacity and value for customers and taxpayers

Our behaviours
(How we need to work)
Customer driven  Accountable  Challenging  Collaborative

The age of rail assets is varied, with many civil assets over 150 years old, and they are changing significantly through enhancements of the network, such as electrification programmes and replacement of the traditional railway signalling system with the European Rail Traffic Management System (ERTMS).

Network Rail is regulated by the Office of Rail and Road for the stewardship of the rail infrastructure. We publish delivery plans every five years setting out what we will deliver over the next Control Period (CP), and publish an update each year.

The current control period, CP5, runs from April 2014 to March 2019 and regulated outputs include our performance targets; Public Performance Measure (PPM) and Cancellations and Significant Lateness (CaSL), tracked throughout the control period. The target for the end of CP5 for PPM is 92.5 % and CaSL is 2.2 %. 
Organisational changes

Since our first climate change adaptation report there have been changes to our organisational structure. In order to increase efficiency, we carried out a process of devolution creating ten Routes operating as distinct business units with their own management teams and budgetary control, supported by Central business functions. The network is currently managed by 8 Route teams, as London North East and East Midlands merged, and Sussex and Kent is managed by the newly created South East Route.

On the 1st September 2014 Network Rail was reclassified from the private sector to the public sector due to changes in European statistical guidelines. We retain the commercial and operational freedom to manage the network within regulatory and control frameworks. A framework agreement between Network Rail and the Department for Transport sets out how we interact in terms of financial management and corporate governance.
Network Rail is one of many organisations in the GB railway industry working together to support safer, more reliable and better value rail services for passengers and freight customers.

**Our stakeholders include:**

- **Department for Transport (DfT) and Transport Scotland (TS)** – are responsible for overarching rail strategy, set priorities for long-term development, and provide funding to support infrastructure maintenance, renewal and enhancements. Funding and outputs for each Control Period are agreed through the Office of Rail and Road.

- **Welsh Government** – under the Government of Wales Act, is able to: develop and fund infrastructure enhancement schemes, develop new rail passenger services, invest in improving the journey experience for rail users, and fund rail freight improvement schemes through Freight Facility Grants.

- **Office of Rail and Road (ORR)** – is the independent economic and safety regulator for the rail network in Great Britain. It regulates Network Rail, holding us to account for delivery of high levels of performance and service, and providing good value for money for customers and tax payers.

- **Train and freight operating companies (TOCs and FOCs)** – over 40 companies operate trains on the rail network under track access agreements with Network Rail.
• **Association of Train Operating Companies (ATOC)** – manages the National Rail customer information service. TOCs are also responsible for day-to-day management of the majority of stations.

• **Rail Delivery Group** – was formed in 2011 to bring together the TOCs, FOCs and Network Rail to facilitate greater co-operation between the rolling stock and infrastructure operators, and leads on cross-industry initiatives.

• **Rail Safety and Standard Board (RSSB)** – a not-for-profit organisation, RSSB supports the industry through guidance, research and co-ordination activities, and manages the railway group standards.

• **Suppliers** – Network Rail is responsible for procuring an extensive volume and range of services through suppliers and contractors.

In addition to rail organisations, other key national organisations support our management of rail assets with respect to weather-related risks, including the Environment Agency, Scottish Environment Protection Agency, Natural Resources Wales, Natural England, Forestry Commission England and Forestry Commission Scotland.

We also work with many organisations at the local level, including Local Authorities and community groups, to ensure we deliver local benefits through our projects.
Many rail assets are vulnerable to weather, a reflection of the characteristics of a nationwide transport system. Controls are in place to mitigate the impacts from weather-related events; ranging from train speed restrictions during high temperatures and high winds for example, through to accelerated investments to improve the condition of high risk assets. In 2009 a climate change risk assessment was undertaken to understand potential changes in current risks and effectiveness of our controls.

Our climate change risks have not significantly changed from that first assessment due to the extensive knowledge of our assets and awareness of their weather vulnerabilities at that time, and the long-life nature of the majority of assets.

The refinement, rather than revision, of international emission scenarios released by the Intergovernmental Panel for Climate Change (IPCC) in 2013 has also resulted in no revision to the climate change projections for the United Kingdom.

What has changed is the level of detailed internal analysis we have on the weather resilience of rail assets, and the implication on long-term resilience. The table below provides our priority risks based on our current understanding of performance and safety impacts with respect to climate change.

### Key climate change risks to rail infrastructure

<table>
<thead>
<tr>
<th>Weather-related hazard</th>
<th>Asset associated with risk</th>
<th>Consequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature (high, low and rate of change)</td>
<td>Track</td>
<td>Buckles and breaks and derailment risk Reduced opportunities for track maintenance</td>
</tr>
<tr>
<td>Temperature (high, low and rate of change)</td>
<td>Switches and crossings</td>
<td>Frozen or snow blocked points Failure of point operating equipment</td>
</tr>
<tr>
<td>High temperatures</td>
<td>Overhead line equipment</td>
<td>Sag of overhead line and risk of dewirement</td>
</tr>
<tr>
<td>High temperatures</td>
<td>Lineside equipment</td>
<td>Failure of temperature controls and overheating of electronic equipment</td>
</tr>
<tr>
<td>Low temperatures</td>
<td>Third rail and overhead line equipment</td>
<td>Loss of power to rolling stock due to ice and snow build up and contact failure</td>
</tr>
<tr>
<td>Low temperatures</td>
<td>Overhead line equipment</td>
<td>Icicle build up causes damage to pantograph</td>
</tr>
<tr>
<td>Low temperatures</td>
<td>Buildings (depots, stations and offices)</td>
<td>Slips, trips and falls risk to staff and station users</td>
</tr>
<tr>
<td>Low temperatures</td>
<td>Level crossings</td>
<td>Ice on roads and vehicle incursion onto track system</td>
</tr>
<tr>
<td>Increase in flooding</td>
<td>All</td>
<td>Closure of line due to track flooding Failure of lineside equipment due to inundation of water Access issues to depots, stations and offices Scour of embankment material</td>
</tr>
<tr>
<td>Weather-related hazard</td>
<td>Asset associated with risk</td>
<td>Consequence</td>
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<tr>
<td>----------------------------------------</td>
<td>---------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Change in river flows</td>
<td>Bridges</td>
<td>Risk of asset failure from: Scour of river bed material at bridge foundations due to hydraulic action. Accumulation of debris under structure</td>
</tr>
<tr>
<td>Increased rainfall</td>
<td>Earthworks</td>
<td>Landslide and earthwork failure and risk to rolling stock and staff</td>
</tr>
<tr>
<td>Decreased rainfall</td>
<td>Earthworks</td>
<td>Desiccation of embankments resulting in track geometry faults and failures in supported lineside equipment</td>
</tr>
<tr>
<td>High winds</td>
<td>Overhead line equipment</td>
<td>Risk to rolling stock, staff and asset failure from falling trees and debris (plastic bags, sheds and trampolines)</td>
</tr>
<tr>
<td></td>
<td>and track</td>
<td></td>
</tr>
<tr>
<td>Sea level rise and storm surge</td>
<td>Coastal assets</td>
<td>Closure of track due to flooding. Structure or earthwork failure and risk to rolling stock and staff. Increased overtopping and sea water ingress into rolling stock and lineside equipment</td>
</tr>
<tr>
<td>Extreme weather</td>
<td>Staff</td>
<td>Poor working conditions for staff in extreme weather conditions</td>
</tr>
<tr>
<td>Seasonal changes</td>
<td>Vegetation</td>
<td>Changes in growth rates and impacts on maintenance budgets and leaf fall management. Changes in invasive species and impacts on maintenance budgets and risk based assessment</td>
</tr>
<tr>
<td>Lightning</td>
<td>Lineside equipment</td>
<td>Asset failure as a result of lightning strikes and electrical surges</td>
</tr>
</tbody>
</table>

Since our first adaptation report, we have made a step change in the way we assess risks across the organisation. The bow tie risk assessment methodology, provides a detailed understanding of the adequacy of the controls in place to manage the causes and consequences of a ‘top’ event, and highlights those controls that need to be enhanced. Network Rail has a strategic crisis management process to coordinate and aid rapid response to extreme weather events.
In 2014, bow tie risk assessments for each asset group were produced to provide comprehensive assessments of controls for a wide range of weather–related events, including design of new infrastructure, management of existing infrastructure, operational responses and third party actions. The risk assessments provided the foundation for the delivery of the Weather Resilience and Climate Change (WRCC) programme. This programme is now transitioning to business as usual.

The WRCC programme has supported the delivery of:

- An enhanced vegetation management project: £10m of accelerated funding to address high-risk trees and mitigate the impact of both extreme winds and adhesion issues.
- Points enhancements: in support of Key Route Strategy.
- Forensic investigation of earthworks failures in 2012/13 and 2013/14: the 261 failures that occurred during this two-year period have been investigated with deep dive analysis being undertaken on 89 of them.
- Earthworks remote condition monitoring pilot: involved c. 200 high-risk sites.
- Improved drainage management: mobile works tools and drainage competency improvements.
- Agreed weather thresholds and definitions.
- An enhanced Extreme Weather Action Team process.
- Aerial surveys of infrastructure using the Light Detecting and Ranging (LIDAR) technique.
- Enhanced Weather Forecast Service: the development of Route climate change adaptation plans meeting the challenge of the 2014 Transport Resilience Review.
- An enhanced Future Weather Service: delivered benefits to date include a central ‘one-stop-weather-shop’, and more granular and localised weather forecasts for user defined geographic areas across the railway network. The FWS has provided a solution that displays a summary of alert status for all Route hotspots on a geographical map; and centralised, localised weather stations to monitor high wind speed and rainfall.

The following areas were reviewed as part of the WRCC programme:

<table>
<thead>
<tr>
<th>WRCC Sub-Programmes</th>
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<tbody>
<tr>
<td><strong>Infrastructure Resilience</strong></td>
</tr>
<tr>
<td>1. Year 1 Enhanced vegetation management strategy</td>
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<tr>
<td>2. Sustainable vegetation strategy</td>
</tr>
<tr>
<td>3. Identifying Highest Risk assets Enhanced resilience to effects of:</td>
</tr>
<tr>
<td>4. Flooding</td>
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<tr>
<td>5. Coastal surge</td>
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<tr>
<td>6. Snow, ice and extreme temperatures</td>
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<tr>
<td>7. High winds</td>
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<tr>
<td><strong>Cross-industry Resilience</strong></td>
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<tr>
<td>8. Property portfolio</td>
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<tr>
<td>9. Fleet</td>
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<tr>
<td>10. Timetabling-flexibility and contingency planning</td>
</tr>
<tr>
<td>11. Providing advice and communicating with customers</td>
</tr>
<tr>
<td><strong>Earthworks integrity</strong></td>
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<tr>
<td>12. Improved Earthworks Knowledge</td>
</tr>
<tr>
<td>13. Improved Drainage Knowledge and Management</td>
</tr>
<tr>
<td>14. Improved Earthworks Monitoring</td>
</tr>
<tr>
<td>15. Improved Earthworks Management</td>
</tr>
<tr>
<td><strong>National Weather Event Response</strong></td>
</tr>
<tr>
<td>16. Weather Definitions and Thresholds</td>
</tr>
<tr>
<td>17. Weather Event Response</td>
</tr>
<tr>
<td>18. Weather Information and Support systems</td>
</tr>
<tr>
<td>19. Strategic resource management</td>
</tr>
<tr>
<td><strong>Climate Change Adaptation</strong></td>
</tr>
<tr>
<td>20. Route Climate Change Adaptation Plans</td>
</tr>
<tr>
<td>21. Tomorrow’s Railway &amp; Climate Change Adaptation project</td>
</tr>
<tr>
<td><strong>Information Exploitation</strong></td>
</tr>
<tr>
<td>22. Delivering supplementary information</td>
</tr>
<tr>
<td>23. Delivering Weather Resilience Intelligence</td>
</tr>
</tbody>
</table>
Safety risks

The safety of passengers and staff is the priority for Network Rail. Safety risk is modelled using the RSSB Safety Risk Model (SRM), and weather-related incidents contribute to around 4.5% of the underlying total safety risks (SRM v8.1). The largest precursor where weather is a factor is passenger slip, trip or falls in a station.

The Precursor Indicator Model (PIM) supports the rail industry to better understand the risks arising from potentially higher-risk train accidents, and currently the PIM indicates that the highest such risk which can be affected directly by extreme weather arises from cutting failures.

Performance risks

Schedule 8 costs, the compensation payments to train and freight operators for network disruption, are used as a proxy for weather resilience due to greater granularity of root cause reporting.

Detailed analysis of Schedule 8 data, gridded weather data and performance data provides greater confidence in weather being a contributing factor to disruption. The analysis provides the ability to highlight disruption across the whole network, and across each Route.

Over the last nine years (2006/07 to 2014/15), the average annual Schedule 8 cost attributed to weather for the whole network was over £50m. The data clearly indicates the impacts on train performance from the severe weather events during 2007, 2012 and 2013 from rainfall, and 2009 and 2010 from snowfall. In terms of the proportion of delay minutes, weather and seasonal events on average caused 12% of all delays experienced during this period.

Total Schedule 8 costs attributed to weather 2006/7 to 2014/15
The analysis was the platform for the eight Route Weather Resilience and Climate Change Adaptation Plans, published on 30 September 2014. The plans can be accessed from our website: [http://www.networkrail.co.uk/](http://www.networkrail.co.uk/)

In combination with regional climate change projections from UKCP09 and asset safety risks, the performance analysis supported the prioritisation of WRCC actions in our Routes. The Western Route prioritisation is provided as an example.

**Western Route prioritisation of WRCC actions**

<table>
<thead>
<tr>
<th>Weather-related impact</th>
<th>Schedule 8 costs(^1)</th>
<th>Projected future impacts for South West and South East England</th>
<th>Prioritisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flooding</td>
<td>£4.3m</td>
<td>21-25 per cent increase in February mean daily precipitation(^2)</td>
<td>High</td>
</tr>
<tr>
<td>Earthslips</td>
<td>£0.9m</td>
<td>21-25 per cent increase in February mean daily precipitation(^2)</td>
<td>High</td>
</tr>
<tr>
<td>Heat</td>
<td>£0.3m</td>
<td>&gt;3°C increase in July mean daily maximum temperature(^2)</td>
<td>Medium</td>
</tr>
<tr>
<td>Sea level rise</td>
<td>Not recorded</td>
<td>0.27m increase in sea level rise(^3)</td>
<td>Medium</td>
</tr>
<tr>
<td>Wind</td>
<td>£1.1m</td>
<td>Wind changes difficult to project however generally projected to increase</td>
<td>High</td>
</tr>
<tr>
<td>Snow</td>
<td>£0.7m</td>
<td>2.7°C increase in January mean daily minimum temperature(^2)</td>
<td>Low</td>
</tr>
<tr>
<td>Cold</td>
<td>£0.1m</td>
<td>2.7°C increase in January mean daily minimum temperature(^2)</td>
<td>Low</td>
</tr>
<tr>
<td>Adhesion</td>
<td>£0.7m</td>
<td>Complex relationship between adhesion issues and future climate change.</td>
<td>Medium</td>
</tr>
<tr>
<td>Lightning</td>
<td>£0.5m</td>
<td>Storm changes difficult to project however generally projected to increase</td>
<td>Low</td>
</tr>
<tr>
<td>Fog</td>
<td>£10k</td>
<td>Complex relationship, however research suggests fog events may decrease</td>
<td>Low</td>
</tr>
</tbody>
</table>

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1 Annual average 2006/07 to 2013/14.  
2 UKCP09 projection, 2050 High emissions scenario, 50th percentile, against 1970s baseline  
3 UKCP09 projection, 2050s High emissions scenario, 50th percentile, against 1990 baseline
Identifying thresholds

Detailed asset analysis supports better understanding of root causes of failure and performance disruption attributed to weather events to provide justification for implementation of resilience actions.

We have moved from subjective and expert review-based knowledge of weather and climate change risks to more detailed internal analysis of asset failure and weather data to understand thresholds at which failure rates significantly change.

The figure below provides an illustrative example of the analysis identifying assets with higher sensitivity to weather impacts. The horizontal lines are thresholds where there is ‘no significant’ (green), ‘significant’ (amber) or ‘very significant’ (red) change in incident rates. This deeper dive analysis is critical to understanding the resilience of operational assets to improve the understanding of how they may operate in future climate conditions.

There is a clear difference between operational thresholds and design standards. Operational thresholds are often much lower, due to legacy equipment and other factors affecting operation. We have reviewed and updated operational thresholds based on analysis of asset failure rates and train service disruptions. This enables us to focus on investment on the asset types which are the most vulnerable to adverse weather and have the most impact on performance.

The analysis has also supported the definition of ‘normal, adverse, extreme’ operational weather thresholds for rail infrastructure, approved by the rail industry’s National Task Force in September 2014.

Since the first adaptation report, we have gained a better understanding of the effect rapid changes in temperature and humidity can have on certain assets such as signalling. For example a diurnal change of greater than 12°C increases both failure incident rates and Schedule 8 costs significantly.

The threshold analysis has supported the development of vulnerability matrices to provide an overview of the rail infrastructure system and its weather sensitivities.

Example of asset failure rates varying with temperature
Evidence and research

It is important our operational responses and investment decisions are based on robust evidence. A priority is to improve our current weather services and our understanding of asset vulnerability, to better inform risk assessments and target actions to improve long term resilience.

We have commissioned, and are supporting, research to better understand the potential implications of climate change, and the actions we can take to mitigate future risks.

Meteorological data

Network Rail receives various types of weather information, forecasts and alerts, through Central and Route contracts with meteorological organisations. Currently, we are procuring a new weather services contract which will aim to deliver an extended range of services including:

- 24-hour availability of expert weather forecasters.
- A geographic information system that displays location of critical rail infrastructure.
- Display of high resolution weather forecast and live weather data.
- Display of flood forecasts and river level data.
- Early warnings that are triggered when forecast or live weather data increases the risk to vulnerable or critical assets.
- The system will be available on a range of mobile devices to disseminate information and support the management of the operational response.

We own weather stations that provide local real-time information. This enables us to improve our operational response and reduce delays, for example through better decisions on when to place speed restrictions in high wind conditions. The stations will also provide additional local observations that can be utilised within the national weather services system.

Since 2010, we have increased the resolution of weather data used in our asset analysis. Initially nine weather stations were used to provide historic weather information. We now have key weather variables for 25km square grids across the network for the past seven years, and last year received 12.5km square grids of weather data.

This provides a much more detailed representation of weather conditions. This information is combined with information on the network using a decision support tool developed for Network Rail, called METEX. METEX is a GIS tool used to assess asset and system vulnerability to weather. Statistics can be produced for all the UK, by route or for a single maintenance delivery unit.
Analysis of historic data helps each Route understand local weather conditions. In particular it has enabled us to establish definitions of adverse and extreme weather in terms of asset performance, and explore the frequency that these are experienced. This information has allowed us to establish correlations between weather conditions, failures and associated delays of different asset groups. In some incidents there are clear links, for example between temperature and point operating equipment, with other assets there is no clear influence of weather conditions on failure rates. Weather thresholds have been established for those assets where there is correlation.

The analysis has provided us with a better understanding of the types of weather which cause failure of different assets, and the consequences in terms of delay. The use of adverse and extreme weather definitions are used to trigger operational procedures to help reduce the risk associated with weather. Combining this with UKCP09 climate projection data continues to enable us to identify the assets most likely to be affected by climate change. (See table, Key climate change risks to rail infrastructure p.6)

Coastal alert system

Wales Route have improved their coastal asset management by implementing a warning service to support safer operation. The service forecasts coastal flooding, wave overtopping and toe scour up to 36 hours in advance. The alerts can be used to direct and inform incident management before and during a coastal storm event; either to give early warnings to mobilise staff, or to trigger actions to send out patrols for at-risk locations during a storm event.

The alerts are received in four ways:

- A summary SMS to ask the user to check their email.
- A summary email.
- Online through a link.
- Online through the Network Rail Flood Warning Database.
Asset data

We have been improving our asset data, which can be used to better understand the vulnerability of each asset type to climate impacts. Our asset information is held in a number of differing systems supported by a range of data maintenance and assurance procedures. Offering Rail Better Information Services (ORBIS), is a £325m programme to improve the collection, storage and use of asset information. The ORBIS programme has been created to deliver:

- Tools to capture, maintain and access high-quality asset data.
- The ability to join and view asset data in collaborative environments.
- Decision support tools to better manage the asset.
- Geo viewer and location data improvement to visualise the railway using image-capture techniques such as LIDAR, bird’s eye and oblique photogrammetry.

This capability will provide data stewards with a new perspective of the railway that will highlight instances of inaccurate data previously not easily visible.

Our entire network has now been surveyed using LIDAR, and will provide detailed information of our assets, including the characteristics of lineside trees to inform vegetation management. Data will be available to support the reduction of risk of trees causing a derailment and causing damage to infrastructure in high winds; and reduce leaf fall impacts during autumn.

Example of how the new information services could be used to risk assess
Climate change adaptation research

We support internal and external research projects focused on specific climate change risks. Research projects include:

- **EngD research on bridge scour and climate change (University of Surrey and Network Rail)** – The research aims to develop a flexible climate change adaptation methodology, capable of in-depth assessment and management of bridge scour risk within Network Rail, through the following tasks:
  - Assess the potential effects of climate change on bridge scour.
  - Assess the adequacy of current scour management procedures.
  - Make recommendations for changes in Network Rail scour management procedures and workbank prioritisation based on whole-lifecycle value.

- **Infrastructure slopes Sustainable Management And Resilience Assessment (iSMART)** – An EPSRC funded project using a combination of field measurements, laboratory tests and modelling to better understand the interactions between earthworks, vegetation and climate. This project includes road and rail partners, and is being led by the University of Newcastle: [http://www.ismartproject.org/](http://www.ismartproject.org/)

- **UK Infrastructure Transitions Research Consortium** – ITRC is developing a new generation of infrastructure system simulation models and tools to inform the analysis, planning and design of National Infrastructure: [www.itrc.org.uk/](http://www.itrc.org.uk/)

- **The assessment of anemometer-based wind alert systems for implementation in GB: Operational context and requirements** – An RSSB funded project to capture and model wind speeds in order to inform a localised wind alert system. This was to support more localised safety speed restrictions, rather than broad forecasts, reducing delays. The research project supported the installation of trackside anemometers, and the implementation of a wind alert system.

**Earthworks Remote Monitoring Pilot**

As part of a pilot study, we are installing remote monitoring on c. 250 earthworks assets to improve the detection of failure before there is a safety risk to train operations. The technology will include an array of proven tilt sensors to detect movement of the earthwork asset towards the track. In addition each installation will include an infrared camera to validate alerts and alarms from the tilt sensor array before further action is taken.

When movement is detected the alarm will be sent in email format to Route control centres to allow validation and any further action.

This work is enhancing our capability at high risk sites to detect incidents and the onset of failure before there is a risk to train operations.

The project will be implemented before the winter weather conditions which typically are a factor in earthworks failures.
**Natural Environment Research Council (NERC) Environmental Risks to Infrastructure Innovation funding**

– Co-creating railway flood resilience: applying the science of blue-green-grey infrastructure (University of the West of England).

– Dynamic heat risk management to reduce the costs of propagating hot weather delays on the rail network (University of Birmingham).


– FoRUM – Flood risk: Building Infrastructure Resilience through better Understanding and Management choices University of Oxford.

**FUTURENET** – An EPSRC project on future resilient transport networks led by the University of Birmingham. This project developed a methodology for determining the resilience of a multi-modal transport corridor under different climate scenarios. A suite of models were produced for different infrastructure failure mechanisms, for example landslides and the cascade of delays across the network was demonstrated.

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**Tomorrow’s Railway and Climate Change Adaptation research programme (T1009)**

The Tomorrow’s Railway and Climate Change Adaptation research programme is RSSB funded and designed to support the rail industry to adapt to climate change. Network Rail is contributing to the project with the provision of technical expertise and data. It is a cross-industry project, with a wide steering group.

The T1009 programme builds on the previous T925 project described in our first adaptation report. T1009 is divided into two work packages; the first produced a compendium of current research which has been shared with the industry through the RSSB Spark platform, and carried out a knowledge gap analysis. The second work package builds on this knowledge by carrying out specific research and developing tools in the following areas:

- The economics of climate change adaptation
- Overseas analogies
- Metrics
- System modelling
- Spatial decision tools
- Funding sources
- Research priorities

The major challenge of T1009 is maintaining a whole system approach which balances the needs of the rail industry, and integrates the different topics addressed within the project. The co-ordinated approach and identification of independencies will support the industry to adapt to climate change more efficiently and to prioritise resources.

The project findings will be widely disseminated to the industry to inform adaptation activities.

T1009 details can be accessed on the RSSB website page:

http://www.rssb.co.uk/research-development-and-innovation/research-and-development/research-project-catalogue/t1009
Understanding uncertainties

Identifying uncertainties

There are a number of different types of uncertainties that need to be taken into account when assessing the impacts of climate change on the railway:

**Climate science** – Uncertainties are inherent in the projections of future climate, especially further into the future, 2050 onwards. It is not possible to know exactly when and where extreme weather events will occur, and changes in certain variables such as wind are more difficult to project than others. Climate scientists are working on reducing and clarifying these uncertainties, and knowledge on climate change is advancing all the time. We have been making use of UKCP09 to understand these uncertainties and utilise the data available.

**Asset knowledge** – There are also uncertainties in how assets react to different weather conditions. Failure mechanisms can be complex, with many interacting risk factors. We have been improving asset data, and supporting research on the vulnerability of key assets such as bridges and earthworks to better understand these.

**Social** – There are also socio-economic uncertainties. How people will use the railway and their expectations in terms of performance and services changes over time. Network Rail as an organisation also undergoes changes over time (as seen recently). These types of uncertainty can also impact on how climate change is addressed.

**Funding** – Despite the advantages of the control period system, no-one can predict future control periods, both in the total value and the investments it will be allocated to.

These uncertainties are not new, but our understanding of their implications on adapting the railway to climate change and how to deal with them has improved. For example we have been focusing on increasing our adaptive capacity and maintaining a flexible approach to cope with future uncertainties, rather than solely on physical adaptation actions. We have also added climate change allowances to standards to manage the uncertainty over climate projections, e.g. adding 20% to estimated requirements for drainage capacity.

Addressing information gaps

The success of our progress is based on activities to reduce uncertainty and this is inherent in all actions:

- Reviews for Executive groups to be clear on our actions and future requirements.
- Detailed weather analysis to refine knowledge of root cause of incidents.
- Liaison with external stakeholders to clarify strategic and operational plans.
- Supporting research projects.

Assumptions

The following assumptions are made when committing to managing future climate change impacts and risks:

- Network Rail will be able to fund the requirements of climate change adaptation.
- Performance data is a good proxy for the impact of weather on the network.
- Third party flood risk management assets will be maintained.
- No significant change to land use around rail assets, where there is change Network Rail would be informed and consulted.
Although we are able to make many changes to our organisation and network to adapt to climate change, some actions are effected by external factors or involve actions that need to be carried out by others. Since the last adaptation report we have a better understanding of these interdependencies, and are working with a number of different organisations on climate change adaptation.

Our critical dependencies for the safe, efficient and reliable operation of rail assets include:

- Clear national transport strategies and availability of funding.
- Robust utility supplies; specifically electricity and telecommunications and water management.
- Long term strategic planning of third party flood risk asset management.
- Informed third party land management.
- Support for research and innovation.

A significant amount of weather related impacts on the railways are as a result of, or influenced by, third parties. For example, many of the trees that fall on the network are from land adjacent to ours. These external risks can be more difficult to manage due to difficulties obtaining access to land, lack of data on third party assets, and difficulties determining who is responsible for assets (e.g. drainage).

However, local liaison with environment agencies and national liaison with other sectors through the National Infrastructure Owners Adaptation Forum can help us to work with other parties to address risks to the railway.

We are aware of the influence our operations can have on others. We work with other organisations, such as local authorities, flood groups and local landowners to implement the best solution for the local area as well as the railway.

The overtopping of an aqueduct demonstrates the importance of understanding surrounding water systems.
There is great benefit from working more closely with other organisations on climate change adaptation issues, specifically the sharing of knowledge and information when facing similar issues and sharing resources when commissioning studies.

Flooding from multiple sources is a high priority climate change risk, and we continue to have strong engagement with the Environment Agency, Scottish Environment Protection Agency and Natural Resources Wales.

In 2014, a Memorandum of Understanding (MoU) between us and the Environment Agency was approved by respective CEO’s, Mark Carne and Paul Leinster. The MoU includes three operational annexes; Environmental Protection, Flood and Coastal Risk Management, and Communications and Access.

The MoU provides clarity on how we can work together to improve strategic flood risk planning, day-to-day flood risk management and communication.

The MoU is based on communication through local liaison groups, between our Route teams and EA local areas, and a national strategic liaison group. A local liaison group in the South West of England which has been engaging for over 18 months, has been successful in identifying issues and opportunities at flood risk locations, sharing information and improving processes. This year, the group are jointly supporting the appointment of a liaison officer to facilitate the management of shared flood risk issues in the South West.

Good liaison with the Environment Agency supported the solution for the Teignmouth landslip.
SEPA’s approach to Flood Risk Management Planning is underpinned by the National Flood Risk Assessment, and identified 243 areas, called Potentially Vulnerable Areas (PVAs), which contain the greatest risks from flooding in Scotland. Scotland Route has railway in 131 of these PVAs and will undertake a study of each PVA to determine the risk to the railway. The 131 PVAs are being ranked based on the level of risk to support long-term strategic flood resilience actions.

In Wales, we are engaged with NRW at both the operational level, through good communication directly with our asset engineers, and also at the strategic level discussing the long-term impacts of climate change in Wales. Coastal risk, and impacts from sea level rise, is a priority risk for Wales Route as it manages 34 miles of asset that is vulnerable to overtopping, coastal erosion and storm surges.
The main barriers to climate change adaptation are:

- Funding, balancing short-term delivery of benefits with investment in long-term resilience.
- Uncertainties of long-term climate change impacts.
- Limited redundancy in the system.
- Competing priorities, e.g. biodiversity and environmental targets versus vegetation removal and safety impacts.
- Short-term reactive nature of media to individual extreme events.
- Regulations and legislation.
- Lack of information on some impacts such as rates of change and extreme events.

No new barriers have been identified since our first adaptation report in 2011.

Addressing barriers:

- Routes have applied for and received additional funding for specific resilience measures.
- Research to reduce uncertainties.
- Embedding in organisational policy and regular reviews so can react to new information, not just ad hoc one-off actions.
- Improve relationships with key stakeholders such as Environment Agency, Natural Resources Wales, Scottish Environment Protection Agency.
- Share activity and research with other infrastructure owners; National Grid, Highways England, water companies, HS2, Transport for London.
The Periodic Review process is initiated by the Initial Industry Plan (IIP). In 2011, the IIPs for England & Wales, and Scotland set out how the industry could deliver a more efficient and better value railway. The plans provided options for funders in specifying future outputs and the level of funding required, and included a specific section on climate change adaptation.

In 2012, informed by the options within the IIPs, the Government published its vision for the railway in the High Level Output Specification (HLOS), in addition to the Statement of Funds Available (SoFA). The HLOS for CP5 included a requirement for climate change adaptation:

“Climate adaptation: The Secretary of State requires the industry to confirm how decision-making processes and investment plans will take appropriate account of the risks and opportunities from anticipated climate change.”

In response to the HLOS, we produced our CP5 Strategic Business Plan which stated:

“We will amend our asset policies and investment processes to enable account to be taken of climate change projects. This will protect the value of our assets in future and will be an essential component of whole-life costing.”

The Final Determination illustrates the progress made in embedding CCA into the regulatory process, supported by improved evidence and discussion.
Climate change and resilience

8.323 An overarching consideration in our assessment of Network Rail’s maintenance and renewal plans has been the extent to which they have addressed climate change and resilience of the network both in the short- and long-term.

8.324 Network Rail, in conjunction with RSSB, has undertaken extensive research to understand likely future climate change scenarios and has led the industry’s initial response to the Climate Change Act 2008.

8.325 Whilst it is clear that Network Rail has developed its understanding of the impact of climate change on some elements of its infrastructure it is imperative that this understanding is developed further for all assets and, in particular, for earthworks and drainage.

8.326 The CP5 asset policies generally contain improved consideration of climate change. However we have not seen evidence that these elements have been embedded in Network Rail’s standards and specifications. Specific consideration needs to be given to:

(a) specification of new components / equipment / systems to provide robust performance for anticipated climate scenarios over the design life. For example, Network Rail might consider including projected climatic ranges in the specification of new systems such as overhead line, track and structures.

(b) evaluation of existing systems to identify and justify interventions to improve resilience to projected climate change. For example, Network Rail might consider increasing tension in overhead line systems to reduce the likelihood of dewirement due to high wind speeds, or improvements to sea defences to mitigate changes in tidal reach.

(c) review and amendment of existing operating and maintenance practices to improve mitigation of the impact of climate change. For example, Network Rail might review its maintenance practices to improve management of climate driven failure modes or alter its stressing ranges for running rails.

8.327 In our draft determination we stated a requirement for Network Rail to update its Climate and Weather Resilience document to include a strategic review of the key nodes in its network. We required the updated document to demonstrate how Network Rail has assessed the risk associated with climate change at those key nodes and how it has assessed the need for measures to improve their resilience. In its response to our draft determination Network Rail provided an update to its Climate Change and Weather Resilience document which set out its approach to the strategic review of key nodes. It clarified what was embedded in the SBP through its asset policies and practices and provided examples of relevant projects. It also provided an example of a climate change and weather resilience plan at route level (for Western) and committed to developing plans for all other routes by end of September 2014. We will review these plans and monitor progress against the milestones in each route.”
Corporate strategy

In 2013, we published our first Sustainable Development Strategy to achieve the vision of ‘a railway for the future’, which outlines our corporate climate change adaptation objectives:

- Understand our current weather resilience, and seek to optimise resilience and enhance adaptation capability.
- Develop a thorough understanding of the potential impacts of climate change in terms of infrastructure performance, safety risks and costs.
- Embed climate change adaptation within our asset policies and investment decisions.
- Communicate the role that the rail network plays in supporting weather and climate resilience across Great Britain, and support efforts to increase national resilience.

Our Sustainability updates provide evidence of our progress in achieving our objectives. This year our sustainability update will be included in our Annual Report.

Our current Asset Management Strategy explicitly includes weather and climate change, and the benchmarking tool, Asset Management Excellence Model, AMEM, monitors the progress as part of ‘Risk and Review’.
Our Technical Strategy, published in June 2013, outlines the research and development (R&D) opportunities that we believe can unlock significant benefits for our organisation and the wider rail industry over the next thirty years. Its development has been driven by a need to focus R&D investment on meeting our key outcomes: safety, performance, customer experience, capacity, cost-efficiency and sustainability. Climate change adaptation is embedded in the whole system approach:

“The impact of extreme weather remains an ongoing challenge to railway transport today and we need to prepare for further potential changes in climate. By developing our understanding of the impact of weather, the potential impacts of climate change can be assessed and effective adaptation strategies put in place for the future.”

Asset policies

Our Asset Management Policy is based on a set of policy statements aligned to corporate objectives, which includes:

“4. Assets, systems and networks shall be managed in accordance with sustainable development principles, including due consideration of long-term financial, societal and environmental impacts.”

Climate change resilience is explicitly included in our Asset Management Policy as a core principle to deliver the policy statements:

“4e. Define resilience requirements to a specified range of weather conditions, taking account of emerging knowledge of climate change.”
Our Asset Management Improvement Programme (AMIP) is accountable for revising our CP5 asset management policies and preparing for CP6. Our current asset policies include a specific section on ‘asset resilience’ to provide explicit reference to how the assets are vulnerable and what actions can be taken to improve resilience.

**Design standards and guidance**

We include climate change explicitly in some of our standards where it is appropriate; our drainage design manual has included climate change factors since 2011 and is currently undergoing review as part of the Business Critical Rules (BCR) programme.

The Business Critical Rules programme will reduce the complexity of our working regime (i.e. standards, competence and business processes) by implementing a new control framework across the company. This framework will replace the current Network Rail standards framework with a reduced number of rules applicable to all staff and suppliers complemented by new integrated management systems. Compliance with the rules will be supported by changes to our competence arrangements and by better provision of information.

**Governance**

Programmes and projects delivering improvements in resilience are sponsored by senior leaders and governed by programme boards, and steering groups such as the National Safety Health Environment Review Group (NSHERG). These provide strong direction to achieve successful outcomes from the investment.

Our progress on weather resilience and climate change has been regularly reviewed, and challenged where necessary, by our Executive Committee and Board.

**Corporate risk register**

In 2013, weather resilience and climate change adaptation was added to our corporate risk register, which is owned by an Executive Committee member, and reviewed every three months. The risk assessment is based on the bow tie assessment methodology with climate change as the top event, and identifies and evaluates the controls in place to mitigate the impact from climate change risks and also reduce the scale of any consequences. The assessment sets accountability across the business for delivering actions to support effective risk controls. Critical controls, and early warnings indicators are identified.
Long term planning

Our long term planning process (LTPP) is designed to facilitate the strategic planning of the rail network in a way which is flexible enough to take into account the views of the rail industry, funders, specifiers and customers on the requirements to develop the network to meet future demand through market studies, cross-boundary analysis and route studies. The process takes the views of local stakeholders into account and incorporates their views on how the rail industry can drive and support economic growth, as well as giving passenger and freight operators the confidence they need to take their own strategic decisions in planning the future of their services. This process also fulfils our licence obligations to plan the future capability of the network.

In March 2015, the Welsh Route study was released for consultation, and is a good example of how the Route Weather Resilience and Climate Change Adaptation plan is linked to the long term strategic plan:

“The WRCCA plan for Wales sets out the plans, policies and actions that are in place to address resilience in the Welsh Route Study area. At this stage of the resilience planning process there are no proposals to consider alternative line scenarios in Wales. However, it is reviewed regularly and this subject area will be updated as appropriate in future strategic plans for Wales”.

Diversionary route studies may need to be developed in locations where climate change impacts are projected to severely disrupt train services.
In July 2014, the West of Exeter Route Resilience Study was published and summarised the findings of our high-level study into the options the West of England main line through Exeter and Newton Abbot. The current main line provides the only railway link between the South West peninsula and the rest of the country and loss of the route, even temporarily, without a viable alternative has ramifications for the economy and for mobility and connectivity across the region.

Capability

Many roles within Network Rail deliver programmes and actions to increase resilience, and to achieve the required improvements we have enhanced our internal capability.

Operational response management is supported by a National Weather Specialist and Route Seasons Delivery Specialists. In 2012, to support improved strategic planning, the Sustainable Strategy Business team appointed a Climate Change Adaptation Specialist. The Central team also supports an EngD student researching bridge scour and climate change impacts who is located within our business.

In addition to these specific roles, the Weather Resilience and Climate Change programme currently engages a management team dedicated to improving resilience across the Routes.

Monitoring progress

We believe our efforts have been effective in increasing the awareness of climate change impacts across the business, and our capacity to adapt.

Our Sustainable Development Integration Plan monitors the delivery of key climate change adaptation projects to ensure they deliver the expected benefits to achieve our objectives in our sustainable development strategy. The plan is governed by the Safety, Technical and Engineering Integration Group.

Our annual Sustainability update communicates a summary of the progress made on climate change adaptation.
The increase in organisational awareness of impacts from extreme weather events and climate change projections has created opportunities. Additional resources have been allocated to:

- Identify priority risks.
- Deliver projects to increase resilience of groups of assets, such as earthworks.
- Deliver location specific programmes of work such as the Western Route flood resilience projects.

However, from an infrastructure perspective the opportunities presented by climate change are limited when compared to increases in risks to performance and safety. For example, with projections of fewer cold days there would be an expectation of reductions in future risks associated with cold weather and subsequent decrease in funding allocated to mitigate those risks; including slips, trips and falls, and winter maintenance costs.

However, commitment to long term investment is still required to prepare the rail network for cold weather events to maintain very high levels of service, for example procurement of snow ploughs and maintenance of ice maiden trains, and the construction of safe station environments.

As in the case of managing increased risks, the realisation of benefits from climate change requires a detailed understanding of the vulnerabilities of the asset and good evidence of potential change to justify revisions to risk controls.
Implemented actions

We have implemented many actions to increase resilience to weather and extreme events; including the renewal of our drainage assets, scour protection of bridges, the installation of high specification overhead line equipment.

This section provides details of key milestones in our progress since our last report in 2011; specifically in our governance, strategy, asset management processes and investments.

<table>
<thead>
<tr>
<th>Action</th>
<th>Delivered</th>
<th>Timescale of delivery</th>
<th>Risks addressed by action</th>
<th>Benefits delivered</th>
<th>Challenges experienced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual weather analysis reports</td>
<td>Sept 2012</td>
<td>6 months</td>
<td>All (excl. lightning and fog)</td>
<td>Detailed asset failure analysis; Prioritisation of higher risk assets</td>
<td>Data granularity and quality; Procurement of weather data</td>
</tr>
<tr>
<td>Climate change adaptation objectives in Sustainable Development strategy</td>
<td>Jan 2013</td>
<td>6 months</td>
<td>All</td>
<td>Sets clear objectives for climate change adaptation; Assures external stakeholders of commitment</td>
<td>Executive approval</td>
</tr>
<tr>
<td>Strategic Business Plan</td>
<td>Jan 2013</td>
<td>12 months</td>
<td>All</td>
<td>Clarity of approach</td>
<td>Consistent level of assessment across all assets</td>
</tr>
<tr>
<td>Western Route Geo-environmental resilience study</td>
<td>Apr 2013</td>
<td>6 months</td>
<td>Flooding</td>
<td>Detailed analysis of root causes of flooding risks and costs of potential resilience actions</td>
<td>Data quality; Cost/benefit analysis</td>
</tr>
<tr>
<td>Climate change adaptation included in corporate risk register</td>
<td>Dec 2013</td>
<td>2 months</td>
<td>All</td>
<td>Executive awareness of risks; Accountability at senior levels</td>
<td>Detailed assessment of all controls</td>
</tr>
<tr>
<td>Integrated drainage management plans</td>
<td>March 2014</td>
<td>12 months</td>
<td>Rainfall</td>
<td>Risk based prioritisation of workbank</td>
<td>Detailed asset data</td>
</tr>
<tr>
<td>West of Exeter Route resilience study</td>
<td>July 2015</td>
<td>3 months</td>
<td>Coastal</td>
<td>Options identified and evaluated; Consultation with local stakeholders</td>
<td>Timescale to deliver study; Cost/benefit analysis</td>
</tr>
<tr>
<td>Route Weather Resilience and Climate Change Adaptation plans</td>
<td>Sept 2014</td>
<td>18 months</td>
<td>All</td>
<td>Increased awareness across business; Additional resilience measures identified</td>
<td>Cross business buy-in; Resources to deliver</td>
</tr>
<tr>
<td>Environment Agency Memorandum of Understanding</td>
<td>Dec 2014</td>
<td>12 months</td>
<td>All</td>
<td>Increased knowledge of third party long-term strategy; Resolution of issues and identification of opportunities</td>
<td>Shared agreement of objectives; Funding barriers and constraints</td>
</tr>
<tr>
<td>Coastal and estuarine asset management plans</td>
<td>March 2015</td>
<td>18 months</td>
<td>Coastal erosion and tidal flooding</td>
<td>Detailed risk based prioritisation of future investments; Long-term planning of high risk assets</td>
<td>Resources for detailed asset assessments</td>
</tr>
<tr>
<td>Enhanced year 1 vegetation management</td>
<td>March 2015</td>
<td>12 months</td>
<td>Wind</td>
<td>65% uplift in vegetation management funding</td>
<td>Coordination across all Routes</td>
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</table>
Planned actions

The Route Weather Resilience and Climate Change Adaptation plans provide details of planned actions across the whole network and can be found on our website: http://www.networkrail.co.uk/ in ‘Publications’.

In addition to Route actions, Central business units will lead actions to increase weather resilience, embed climate change resilience in critical processes, plan for control period 6, and present strategic options for long term plans for the rail network.

<table>
<thead>
<tr>
<th>Action</th>
<th>Risk addressed by action</th>
<th>When</th>
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</thead>
<tbody>
<tr>
<td>Develop and publish long term Route studies</td>
<td>All</td>
<td>2015/16</td>
</tr>
<tr>
<td>Develop CP6 asset policies</td>
<td>All</td>
<td>2016</td>
</tr>
<tr>
<td>Publish CP6 Strategic Business Plan</td>
<td>All</td>
<td>2018</td>
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