NetworkRail

# Route Weather Resilience and Climate Change Adaptation Plans

## *Wessex*

# Contents



## Purpose of this document

This document sets out a Weather Resilience and Climate Change Adaptation (WRCCA) plan for Wessex Route supported by an evaluation of the resilience of rail infrastructure to historical weather events and an awareness of potential impacts from regional climate change projections. The resilience of rolling stock operating within the Route is not specifically assessed.

The approach taken is consistent across all Network Rail's Routes, and describes our current planned mitigations, how we intend to develop the plans further, and how we are improving the embedment of WRCCA across the business to deliver *a railway fit for the future*.

# Director Route Asset Management statement

Customers of the South West Trains Network Rail Wessex Alliance have suffered delays and disruption from the impacts of freezing winter weather, floods, lightning strikes and high winds in recent years. We need to improve the resilience of our infrastructure to weather events and to plan to meet the challenges presented by a changing climate.

Our Route manages specific vulnerabilities; in the west flooding and landslips risks, the response of clay embankments to wet and dry conditions in the east of the route, and train services are powered largely by conductor rail that can cause disruption in winter conditions.

We are committed to achieving improved resilience of our infrastructure through targeted investment and improved operational practices. We are investing in CP5 to increase resilience through improvements to weather forecasting, remote condition monitoring, and renewal and enhancement of our assets.

We need to improve our understanding of future weather risks from sea level rise on our assets in tidal flood zones and potential impacts from increases in temperature on service disruption from actions we take to manage track safety.

We are committed to better understand the risks posed by a changing climate so that we can plan to meet the challenges this presents, working with others such as the Environment Agency and local authorities to find solutions suitable for the communities we serve.

Stuart Kistruck
Director Route Asset Management
South West Trains, Network Rail Wessex Alliance
September 2014

# Executive summary

Weather events can cause significant disruption to the operation of train services and damage to rail infrastructure. A move to a warmer climate and a variance in the pattern of precipitation across the year, generally projected by the UK Climate Change Projections (UKCP09), could result in changes in the frequency and intensity of extreme weather events and seasonal patterns. A detailed understanding of the vulnerability of rail assets to weather events, and potential impacts from climate change, are therefore needed to maintain a resilient railway.

Wessex Route has developed a Weather Resilience and Climate Change Adaptation (WRCCA) plan based on assessments of weather-related vulnerabilities, identification of root causes of historical performance impacts and an understanding of potential future impacts from regional climate change projections.

Using this information, Wessex Route has determined whether previous investments have mitigated weather impact risks, if actions planned during Control Period 5 (CP5) (2014 to 2019) are addressing these vulnerabilities, and where additional actions could further enhance weather and climate change resilience.

An analysis of Schedule 8 performance costs (the compensation payments to train and freight operators for network disruption) during the period 2006/07-2013/14 clearly shows wind has generated the greatest performance impact, with flooding and cold also causing major disruption.

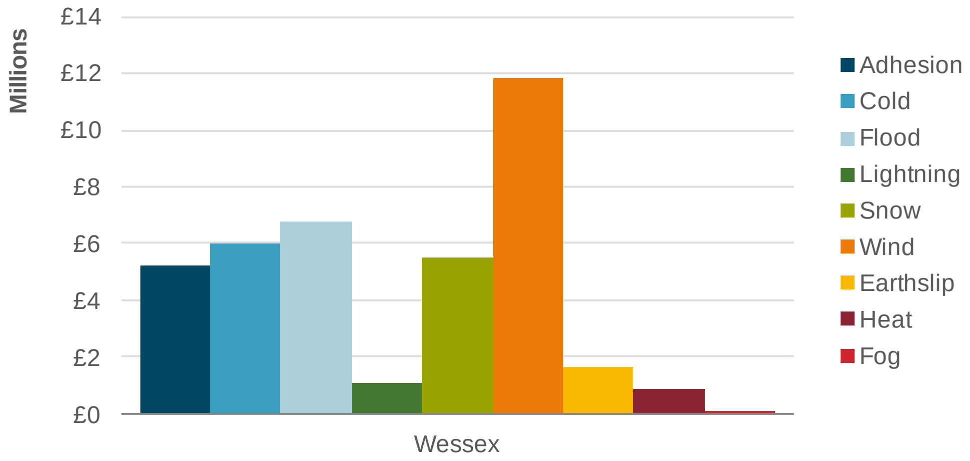


**Figure 1 Wessex Route weather attributed Schedule 8 costs 2006/07-2013/14**

Wessex Route is committed to supporting the delivery of improved weather and climate change resilience through Route-specific objectives:

- remove high-risk vegetation and replace with lowest whole cost lineside environment through development and implementation of a route wide vegetation management strategy.
- work with lineside neighbours to establish an environment beyond the boundary that does not negatively affect safety of the line or performance.
- remediate failed drainage and improve drainage to cope with climate change through the development and implementation of a route wide drainage management strategy.
- understand flood risk now and in response to climate change and ensure risks are mitigated where it is possible and cost effective to do so.
- ensure there are robust plans in place to remediate sites at high risk of earthslip, and appropriate mitigations and service recovery plans are in place until these improvements can be made.
- improve resilience to freezing conditions and snow through continuous improvement of winter operational practice and through targeted investment in points heating, conductor rail heating and remote condition monitoring.
- develop constructive relationships with Environment Agency area offices and Lead Local Flood Authorities at route level to identify opportunities to resolve flooding problems cooperatively where possible.
- undertake works on a risk basis to improve track and track support assets in areas where heat speeds have been imposed historically or where they are predicted to occur in the future, by establishing space for a compliant ballast shoulder and safe cess. This may take the form of track lowering or properly designed ballast retention systems for narrow embankments and over ballasted bridges.
- review the suitability of office, depot and operational accommodation as a working environment as temperatures increase, review control measures designed to ensure the safety and welfare of staff working on the infrastructure in hotter summers.

Wessex Route has identified actions planned in CP5 that will increase weather and climate change resilience including:

- increase in forecasting capability in order to predict flooding and earthwork failures at high-risk locations
- roll out of strategic programmes of Remote Condition Monitoring
- engage with wider industry to improve the resilience of rolling stock to extreme weather conditions to minimise delay impacts.

Wessex Route will deliver the WRCCA plan in a timely, cost-efficient and safe manner.

# Introduction

Weather events can be a cause of significant disruption to the railway network. Recent prolonged periods of rainfall and extreme storm events demonstrated much of the network is resilient; however, asset failures such as Botley embankment failure, the widespread tree fall following the St. Jude storm, and the loss of the morning peak service due to conductor rail icing in March 2013 reveal the vulnerability of the rail network and the severe impact these weaknesses in resilience have on train services and our resources.

The impact of weather on the rail network is monitored using performance data. Schedule 8 costs, the compensation payments to train and freight operators for network disruption, are used as a proxy for weather impacts due to greater granularity of root cause reporting. Weather-related costs can also be captured within Schedule 4 payments, compensation to train and freight operators for Network Rail's possession of the network, and capital expenditure required to reinstate the asset.

Over the past eight years (2006/07 to 2013/14) the average annual Schedule 8 cost attributed to weather for the whole network was over £50m. The data clearly includes the impacts on train performance from the severe weather events during 2007, 2012 and 2013 from rainfall, and 2009 and 2010 from snowfall, Figure 2. In terms of the proportion of delay minutes, weather and seasonal events on average caused 12% of all delays experienced during this eight-year period.

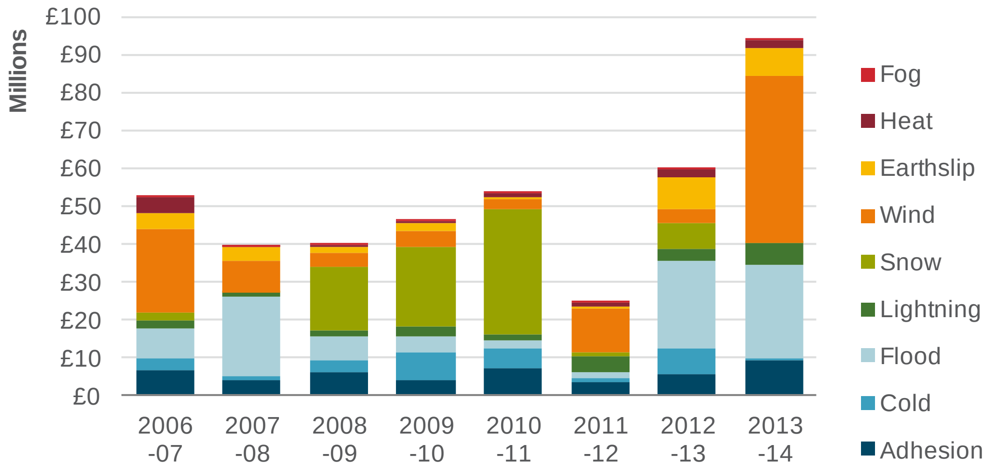


**Figure 2 Whole network weather attributed Schedule 8 delay costs, 2006/07 to 2013/14**

Following the recent increase in the rate of Schedule 8 compensation payments (by around 62 per cent), the equivalent payments in future years would be over £80m per annum.

These levels of performance cost, consequential costs of repairing the rail infrastructure, and wider socio-economic impacts in the UK, justify Network Rail's enhanced investments to increase weather resilience. The interdependencies within transport and infrastructure systems similarly justifies Network Rail's efforts to improve collaborative understanding of the wider impacts of weather-related events and our role in supporting regional and national resilience.

Potential escalation of these impacts from climate change supports the business case to increase weather resilience actions and presents a challenge to identify further actions to deliver a resilient rail network for the future.

Historical temperature records indicate that a significant relatively recent shift in climate has occurred. The Hadley Centre Central England Temperature (HadCET) dataset is the longest instrumental record of temperature in the world, Figure 3 and clearly shows a rising trend in temperature over the past century[1].

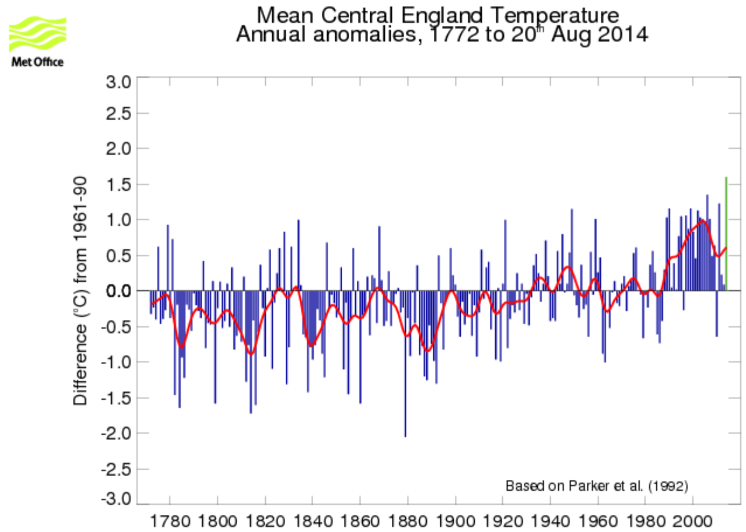


**Figure 3 Mean Central England temperature record**

[1] Parker, D.E., T.P. Legg, and C.K. Folland. 1992. A new daily Central England Temperature Series, *1772-1991. Int. J. Clim.,* ***Vol 12****, pp 317-342*

Future climate change projections for the UK have been developed by the Met Office Hadley Centre, UK Climate Projections 2009 (UKCP09). UKCP09 provides probabilistic sets of projections based on low, medium or high greenhouse gas emission scenarios, for climate periods of 30 years to the end of this century. For Network Rail, as a safety critical focused organisation and major UK infrastructure manager, the high emissions scenario is an appropriate benchmark on which to base evaluations and decisions.

UKCP09 projects an overall shift towards warmer climates with drier summers and wetter winters, Figure 4 and Figure 5, with regional variations.

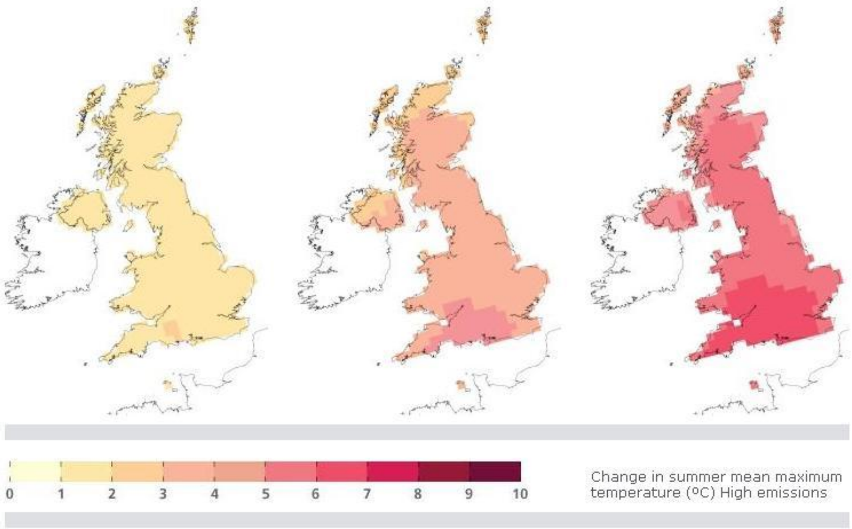


**Figure 4 Change in summer mean maximum temperature (left 2020s, middle 2050s, right 2080s) (© UK Climate Projections, 2009)**

It must be noted that climate change projections include inherent uncertainties, associated with natural climate variability, climate modelling and future emissions, and these uncertainties increase with downscaling to local levels. However, the projections can be used by Network Rail to provide a direction of where the UK climate is heading, and this Route Weather Resilience and Climate Change plan uses the projections to support the prioritisation of weather resilience actions.

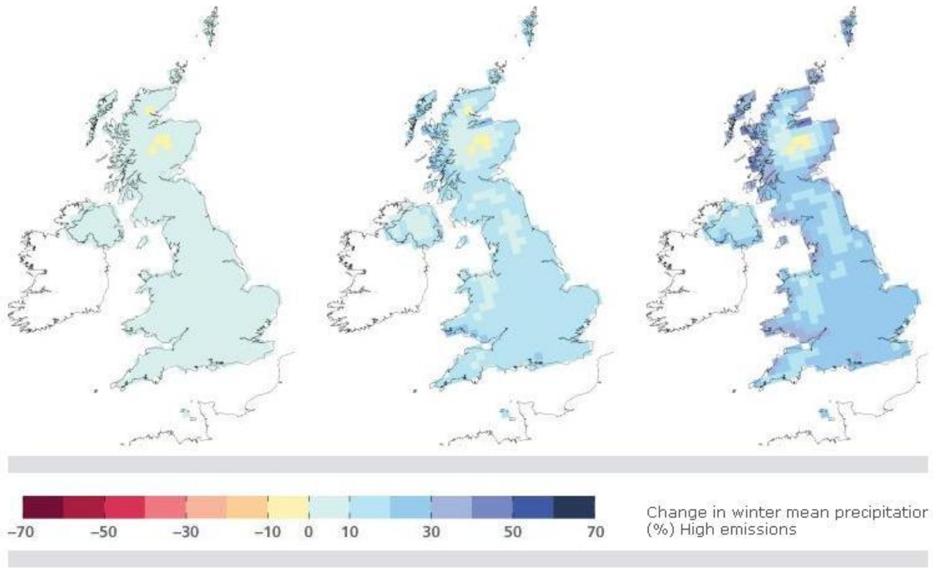


**Figure 5 Change in winter mean precipitation (left 2020s, middle 2050s, right 2080s) (© UK Climate Projections, 2009)**

To ensure weather resilience and climate change adaptation is approached consistently across Network Rail, an iterative framework provides key management stages: set strategy, assess vulnerability and impact, identify actions, and review, Figure 6. This framework has been applied to develop the Wessex Route WRCCA plan.


**Figure 6 Weather resilience and climate change adaptation framework**

Network Rail weather resilience and climate change adaptation actions will include a range of measures appropriate to the strength of evidence and level of risk:

- soft – changes to processes, standards and specifications, increasing knowledge and skill base
- hard – engineered solutions to increase resilience; e.g. raising of sea walls and increasing drainage capacity
- 'do nothing/minimum' – the option to 'do nothing' or 'do minimum' should be evaluated
- 'no regrets' – measures that increase the resilience of the assets to current and future impacts
- precautionary – investment into adaptation measures today in anticipation of risk in the future
- managed adaptive – a staged approach incorporating uncertainties in future risk and current investment funds, allowing assets to be retrofitted cost-effectively in the future.

The following sections provide findings from the Wessex Route vulnerability and impact assessments, and details of the WRCCA actions; both completed and planned in CP5, and potential additional actions, that aim to increase weather and climate change resilience.


**Figure 7 Earthslip at Botley following unusually wet winter of 2013/2014.**

# Wessex Route WRCCA strategy

The Network Rail Sustainable Development Strategy outlines our corporate weather resilience and climate change adaptation objectives, and commits the business to:

- 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.

These objectives will support the long-term management of a weather-resilient railway and are fundamental steps towards achieving Network Rail's sustainable development vision of a railway fit for the future.

## Wessex Route strategy

Wessex Route is committed to supporting the delivery of this strategy through Route-specific weather resilience and climate change adaptation objectives:

- remove high-risk vegetation and replace with lowest whole cost lineside environment through development and implementation of a route wide vegetation management strategy
- work with lineside neighbours to establish an environment beyond the boundary that does not negatively affect safety of the line or performance
- remediate failed drainage and improve drainage to cope with climate change through the development and implementation of a route wide drainage management strategy
- understand flood risk now and in response to climate change and ensure risks are mitigated where it is possible and cost effective to do so
- ensure there are robust plans in place to remediate sites at high-risk of earthslip, and appropriate mitigations and service recovery plans are in place until these improvements can be made
- improve resilience to freezing conditions and snow through continuous improvement of winter operational practice and through targeted investment in points heating, conductor rail heating and remote condition monitoring
- develop constructive relationships with Environment Agency area offices and Lead Local Flood Authorities at route level to identify opportunities to resolve flooding problems cooperatively where possible
- undertake works on a risk basis to improve track and track support assets in areas where heat speeds have been imposed historically or where they are predicted to occur in the future, by establishing space for a compliant ballast shoulder and safe cess. This may take the form of track lowering or properly designed ballast retention systems for narrow embankments and over ballasted bridges
- review the suitability of office, depot and operational accommodation as a working environment as temperatures increase, review control measures designed to ensure the safety and welfare of staff working on the infrastructure in hotter summers.

Through these objectives, Network Rail's corporate commitments are applied in the context of Wessex Route, supported by the opportunities to deal locally with challenges from a changing regional climate. Meeting these objectives will contribute to the long-term resilience and sustainability of Wessex Route and the whole railway network

# Wessex Route vulnerability assessment

This section provides the details of the general vulnerability of the rail network in Great Britain and Wessex Route's specific vulnerabilities to weather impacts, and regional climate change projections.

## Network-wide weather vulnerability

The challenge for Network Rail is to manage a complex and extensive portfolio of assets, with variations in geographic location, age, deterioration rates and vulnerability to weather impacts.

Continual analysis of the vulnerability of rail assets to weather, and identification of trends and characteristics of weather-triggered failures, improves our knowledge of the resilience of the rail network. An understanding of current weather impacts is an essential platform to implement cost-effective investments to adapt the network to future changes in climate.

The whole rail network is sensitive and exposed in some way to many primary climate drivers and secondary impacts, including:

- temperature
- rainfall
- wind gusts
- flooding
- landslips
- soil moisture
- sea level rise
- coastal erosion.

Network Rail has 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. Figure 8 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' change in incident rates (red). This deeper dive analysis is critical to understanding the resilience of operational assets today and potentially in future climates.

From this analysis it has been established that high temperatures have wider impacts across assets, earthworks are the predominant asset sensitive to rainfall and overhead line equipment (OLE) to wind gusts.

Rail asset and weather impact relationships are complex, as demonstrated in the case of OLE where many wind-related failures are a result of vegetation incursion and not direct wind gusts as the primary impact. Therefore any analysis of rail assets and weather vulnerability requires deeper understanding of root causes to identify cost effective resilience actions.

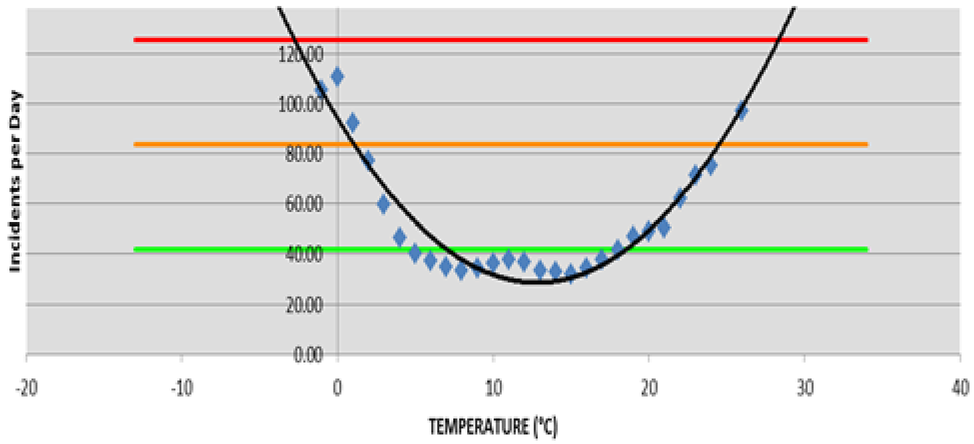


**Figure 8 Example of asset failure and weather analysis**

**Managing operational response to weather vulnerability**

Network Rail manages risks from weather-related impacts through a range of asset management tools, operational response standards and alert systems. Higher risk assets are prioritised for investment within asset policies and proactively managed through risk-based maintenance.

Defining 'normal', 'adverse' and 'extreme' weather conditions is fundamental to ensuring effective coordination across the rail-industry. Network Rail and the National Task Force (a senior rail cross-industry representative group) are currently reviewing weather thresholds and definitions to improve the Extreme Weather Action Team (EWAT) process which manages train services during extreme weather alerts.

Control rooms monitor and respond to real-time weather alerts through a range of action plans. Operational response to the risks posed by weather events includes; temporary speed restrictions (TSRs), deployment of staff to monitor the asset at risk, proactive management of the asset i.e. use of ice maiden trains to remove ice from OLE or protection of assets from flood water, and in some cases where the risk dictates, full closure of the line. Increasing the resilience of the infrastructure reduces the need for operational response however the range of weather events experienced today, potential changes in the future, and the prohibitive scale of investments required to mitigate all weather risks, means that operational response will always be a critical process for Routes to manage safety risks.

Network Rail seeks continuous improvement of weather-based decision support tools, including flood, temperature, wind speed and rainfall alerts. A trial aiming to significantly improve real-time weather forecasting has installed approximately 100 weather stations on the Scotland rail network, Figure 9. The pilot study is currently being evaluated to support a potential wider roll-out of this level of weather service.

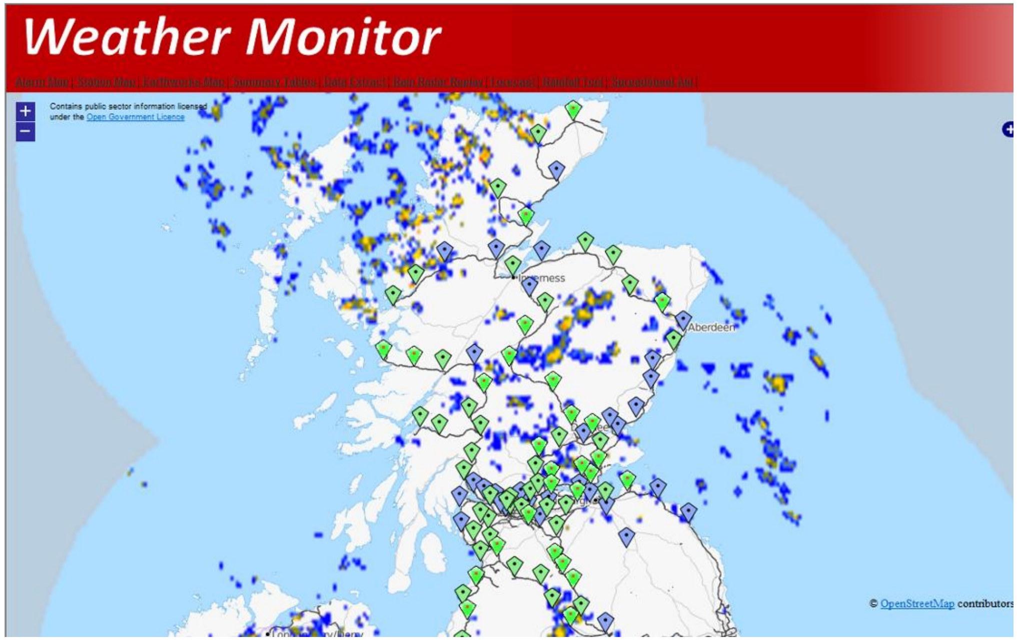


**Figure 9 Scotland Route real-time weather monitor**

For the management of operational flooding risk, Network Rail receives alerts through our Flood Warning Database based on warnings issued by the Environment Agency and the risk is translated to rail assets. In locations where no national flood warnings are available, Network Rail can arrange to receive alerts from bespoke river level monitoring equipment.

Longer-term flood risk management of rail assets is provided through geographic information system (GIS) decision support tools including flood datasets, such as Network Rail's Washout and Earthflow Risk Mapping tool (WERM). Transformative asset information programmes are currently aiming to improve weather-related hazard mapping in decision support tools.

**Improving our network wide resilience**

A Weather Resilience and Climate Change (WRCC) programme is at the centre of Network Rail's delivery plans. Its importance is underlined by the fact that it is one of the Company's top 15 business change projects. The programme was first identified in April 2013, but its priority and profile were heightened as a result of the extreme weather that was experienced between October 2013 and March 2014. The programme board and stakeholders include representatives from across the rail industry.

The WRCC programme is founded on a bow tie risk assessment of weather-related disruption, Figure 10 - this risk assessment methodology is used widely across Network Rail. The bow tie assessment provides a detailed understanding of the adequacy of the controls that are in place to reduce the causes of disruption and consequences and highlights those controls that need to be enhanced.

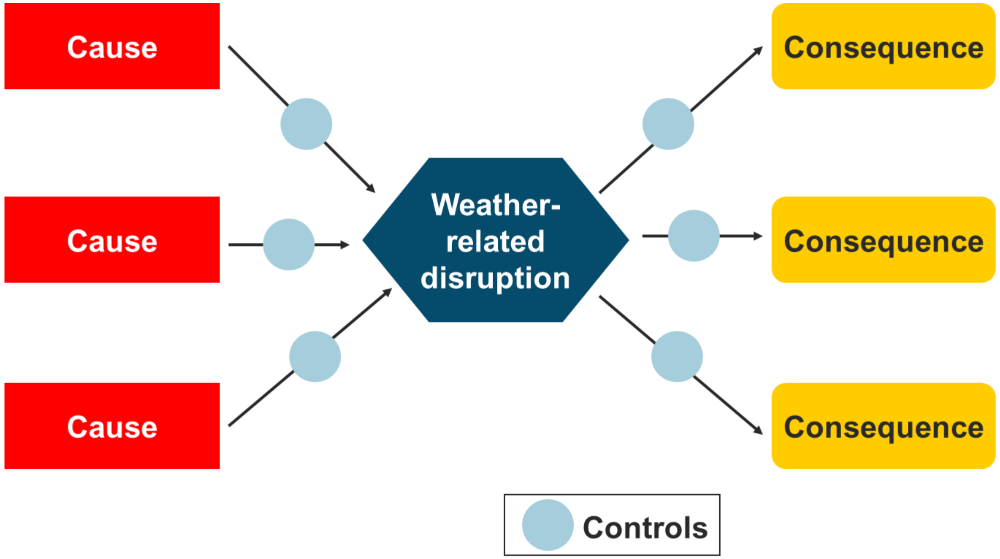


**Figure 10 Bow tie risk assessment**

The programme consists of six sub-programmes and their 23 constituent projects; these are described in Figure 11 below. Although the bulk of the outcomes that are currently defined expect to be delivered within the next 18 months, the programme is expected to extend throughout CP5.

It is important to emphasise the national-level programme supplements the work Routes are completing under their CP5 business plans.

**WWRCC Sub-Programmes**

**1 Infrastructure Resilience**

1. Year 1 Enhanced vegetation management strategy
2. Sustainable vegetation strategy
3. Identifying Highest Risk assets Enhanced resilience to effects of:
4. Flooding
5. Costal surge
6. Snow, Ice and extreme temperatures
7. High winds

**2 Cross-industry Resilience**

8. Property portfolio
9. Fleet
10. Timetabling-flexibility and contingency planning
11. Providing advice and communicating with customers

**3 Earthworks Integrity**

12. Improved Earthworks Knowledge
13. Improved Drainage Knowledge and Management
14. Improved Earthworks Monitoring
15. Improved Earthworks Management

**4 National Weather Event Response**

16. Weather Definitions and Thresholds
17. Weather Event Response
18. Weather Information and Decision Support systems
19. Strategic resource management

**5 Climate Change Adaptation**

20. Route Climate Change Adaptation Plans
21. Tomorrow’s Railway & Climate Change Adaptation project

**6 Information Exploitation**

22. Delivering supplementary information
23. Delivering Weather Resilience Intelligence

**Figure 11 The constituent components of Network Rail’s WRCC programme**

The WRCC programme is currently supporting 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: installation of up to 7,000 points heat insulation and covers 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: involving 250 high-risk sites across four Routes (Scotland, LNE, Wessex and Western) starting in December 2014
- improved drainage management: mobile works tools and drainage competency improvements by December 2014
- agreed weather thresholds and definitions
- an enhanced extreme weather action team process: this will be reviewed and the improved processes implemented into the first Route by end November 2014
- aerial surveys of infrastructure using the Light Detecting and Ranging (LIDAR) technique; This will be complete by December 2014
- enhanced weather forecast service which will be in use from April 2015.

## Route weather vulnerability

Wessex Route has some specific vulnerability to severe weather. The western parts of the Route pass through difficult topography requiring the original railway builders to use numerous deep cuttings, tunnels and large embankments to maintain acceptable gradients. To minimise construction costs the lines were routed down river valleys where possible, this has resulted in this part of the Route suffering from a high risk of earthslips and flooding in wet weather conditions. This risk is raised further by the effect the Blackdown hills has on locally increasing rainfall rates, and the east west orientation of route in this area means that storms tend to track along the line resulting in flooding in multiple locations. Roads in the area are also prone to flooding and earthslip often making it difficult for maintenance staff to access sites to quickly rectify problems on site.

In large areas at the eastern part of the Route the underlying geology is of London clay, this material is prone to softening and expanding in wet winter conditions and shrinking when desiccated, a risk in long dry summers. This results in an elevated risk of landslip in wet winters and difficulty in maintaining track geometry in late summer. The repeated seasonal expansion and contraction can also over long periods push over retaining walls and results in embankments becoming lower and wider over many years requiring maintenance to maintain track geometry.

Southern parts of Wessex Route pass through the tidal flood zone, this currently causes infrequent disruption at present, however future risk must be quantified so that appropriate plans can be made before the risk of tidal flooding becomes unacceptable.

Specific vulnerabilities on the Wessex Route to weather impacts include high-risk earthworks on the Salisbury to Exeter line. This area of the network passes through the Blackdown Hills which are prone to failure during periods of heavy rain due to very soft geology, over steep earthworks and ageing drainage. Honiton tunnel is a good example of the challenge in managing these assets, Figure 12. Similar conditions exist on parts of the Bristol to Weymouth line.

**Figure 12 Honiton tunnel earthwork failure**

Large sections of the Salisbury to Exeter line near Axminster run in the River Axe flood plain. Some of the embankments and up to nine river crossings in this area require modification to prevent flood damage. The embankment at Broom was strengthened with sheet piles to reduce the chance of washout at this location in the future, Figure 13.

**Figure 13 Track washing out at Broom near Axminster**

Several bridges within the Route are at higher risk to flood damage including those at Yetminster on the WEY line and at River Frome on the Bournemouth main line, Figure 14.


**Figure 11 Bridge prone to flood damage at Yetminster.**

Recent severe winters have exposed the route to significant flooding; the line at Datchet station closed for several days in early 2014 as a result of the River Thames experiencing the highest levels recorded for over 40 years, reminding all that significant parts of Greater London are at risk of flooding. The Environment Agency is now reviewing options to improve the flood performance of this section of the Thames and the Route is engaged.

Large parts of the route near the South Coast are vulnerable to sea level rise including sections of track near Poole Harbour and the Portsmouth line as it approaches and crosses Portcreek Viaduct, Figure 14. This viaduct will require replacement before mid-century as track level is currently predicted to be below flood levels at that time, and is below the crest level of the proposed new flood defences for Portsmouth.

**Figure 14 Portcreek viaduct at high tide.**

Parts of Wessex Route are built on London clay, this is a moisture-sensitive material and embankments constructed from it are prone both to conventional failure when saturated in winter but also to desiccation failure where track quality is very difficult to maintain in dry summer and autumn conditions. This affects several lines but is most pronounced on the BKE line between Reading and Basingstoke, this line forms part of the strategic freight network and there is no freight diversion due to restricted gauge on all alternatives. Significant works are required to improve resilience of the BKE line and in order for this work to take place a freight diversion is required.

Wessex Route is largely DC electrified, this technology although extremely resilient in most conditions is prone to icing, the worst effect occurs when rain falls on a conductor rail that is below freezing, this happens infrequently but the consequences are very disruptive. Conductor rail icing is likely to be a reducing problem in the future. DC electrification is also unreliable if flooding occurs, this is likely to increase in frequency unless significant improvements are made to the drainage asset.

Heat speeds are currently well managed, most jointed track has been removed from important parts of the route and work is programmed to minimise formation disturbance during the summer months. As average temperatures increase the window for maintenance will reduce as the season where critical rail temperatures are reached may lengthen. This will be a significant challenge for maintenance teams who do not have access to any additional maintenance shifts in winter.

As embankments weather they become narrower at the crest and most current track maintenance practices raise the track. This has resulted in parts of the route suffering from no safe cess and insufficient space to maintain a compliant ballast shoulder. As temperatures increase we must find a cost-effective way to either lower track, so it fits on the underline bridges and embankments, or undertake works to make space for the track formation on the narrow embankments. The lack of cess in places not only makes maintaining track difficult, it also increases the chance of failures impacting on the track support zone such as at Pinks Hill near Guildford which failed in July 2014 following a very wet winter, Figure 15.

**Figure 15 Pinks Hill track support failure**

One of the most significant weather-related safety and performance incidents in recent years was the St Jude storm, this brought down hundreds of trees across the Route. If storm intensity and frequency increases, the impact of such weather events will be significant unless the number of trees able to fall on the line, both Network Rail and third-party owned, is reduced.

## Future climate change vulnerability

The relationship between weather events and climate is complex; therefore it is understandable that climate change projections do not forecast future weather events. However, Network Rail can use the climate projections to understand potential risks and make informed strategic decisions to increase future weather resilience.

The UK Climate Change Projections (UKCP09) provides regional climate change projections across 13 administrative regions in Great Britain, Figure 16. Wessex Route spans across South East and South West England regions. Projections for these are considered to be representative of the future climate changes within the Route.


**Figure 16 UKCP09 administrative regions**

The following derived charts from UKCP09 data show the projected changes in temperature and precipitation for the high emissions scenario, 50th percentile (10th and 90th percentile data has been obtained). The projected changes are shown for future climate periods up to the 2080s (2070-2099) and are relative to the baseline climate of 1970s (1961 – 1990).

## Mean daily maximum temperature change

The mean daily maximum temperatures for both South West England and South East England are projected to increase throughout the year, with greater increases expected in the summer months.

In South West England the average maximum daily temperature in July is expected to increase by over 3°C, reaching 23.3°C by the 2050s, and by over 5°C, reaching 25.3°C by the 2080s. Average maximum daily temperature in January is expected to increase by 1.9°C, reaching 9°C by the 2050s, and by 2.9°C, reaching 10°C by the 2080s, Figure 17.

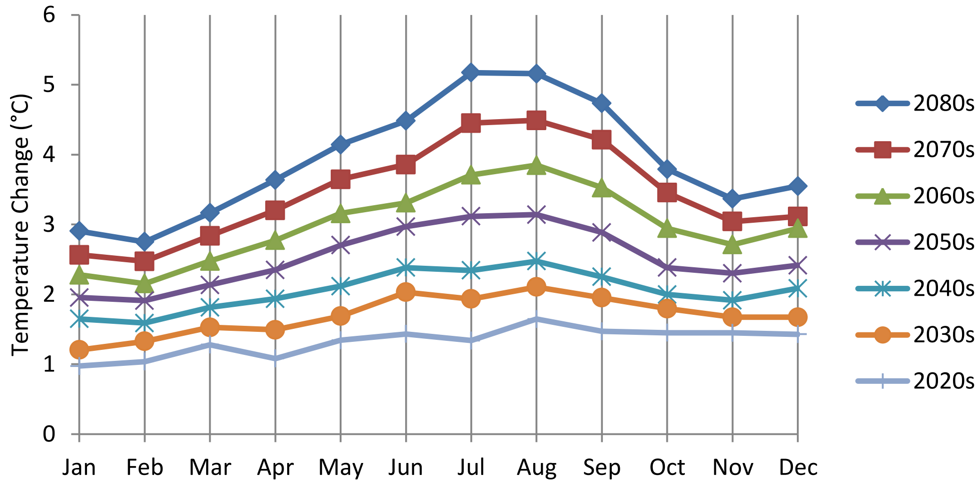


**Figure 17 South West England, mean maximum temperature change (50th percentile)**

The average maximum daily temperature in the in South East England in July is expected to increase by 3.1°C, reaching 24.3°C by the 2050s, and by over 5.1°C, reaching 26.3°C by the 2080s. Average maximum daily temperature in January is expected to increase by 2.2°C, reaching 8.7°C by the 2050s, and by 3.2°C, reaching 9.7°C by the 2080s, Figure 18.

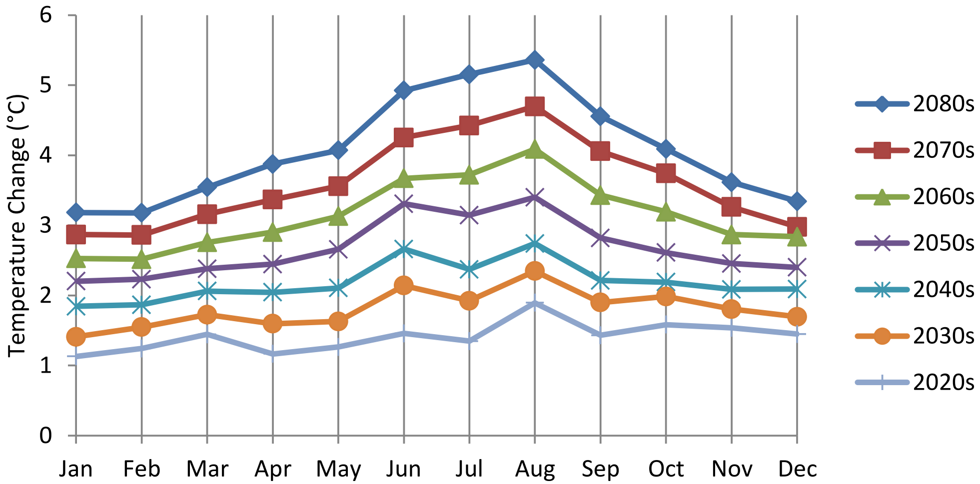


**Figure 18 South East England, mean maximum temperature change (50th percentile)**

## Mean daily minimum temperature change

The mean daily minimum temperatures in both South West England and South East England administrative regions are also projected to increase throughout the year.

In South West England the average minimum daily temperature in July is projected to increase by 2.7°C, reaching 14.5°C by 2050s, and by 4.4°C reaching 16.2°C by the 2080s. Average minimum daily temperature in January is projected to increase by 2.7°C, reaching 4.6°C by 2050s, and by 3.9°C, reaching 5.8°C by 2080s, Figure 19.

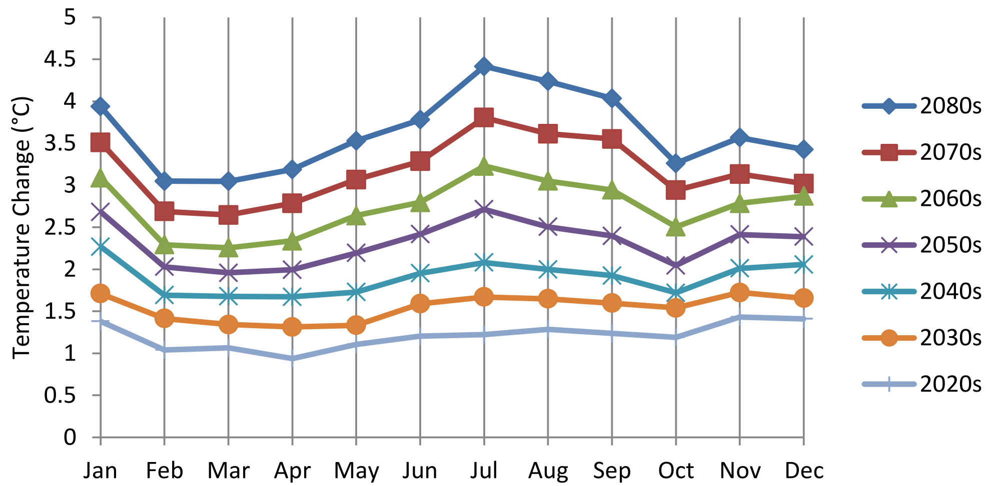


**Figure 19 South West England, mean minimum temperature change (50th percentile)**

In South East England the average minimum daily temperatures in July are projected to increase by 3°C, reaching 14.8°C by 2050s, and by 4.8°C reaching 16.6°C by the 2080s. Average minimum daily temperature in January is projected to increase by 2.9°C, reaching 4.3°C by 2050s, and by 4.2°C, reaching 5.6°C by 2080s, Figure 20.

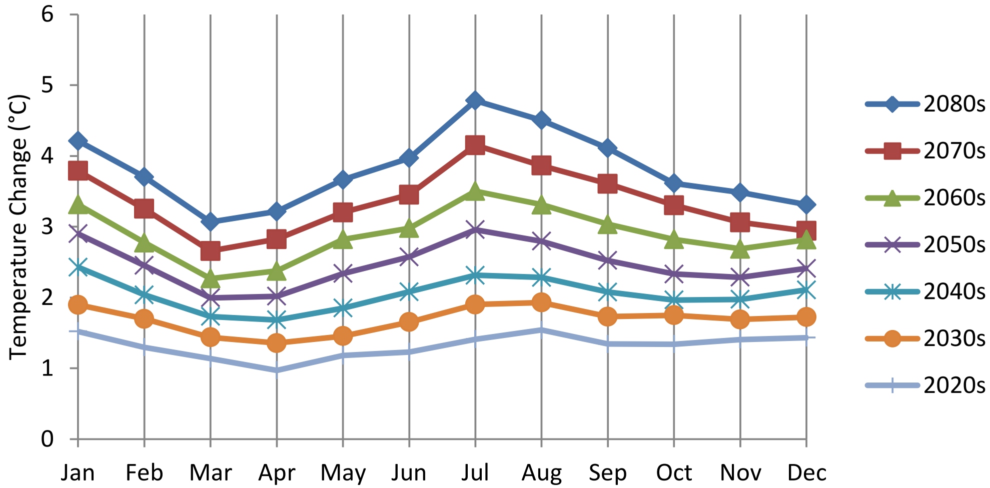


**Figure 20 South East England, mean minimum temperature change (50th percentile)**

### Mean daily precipitation

Projections for mean daily precipitation for both South West England and South East England administrative regions show a significant increase in the winter months and a decrease in summer months. Generally, the greatest increase is projected to occur in February, while the greatest decrease is expected to occur in August.

In South West England the increase in daily precipitation in February is projected to be 21 per cent, reaching 3.5mm per day by the 2050s, and 39 per cent, reaching 4.1mm per day by the 2080s. The mean daily precipitation in August is projected to decrease by 31 per cent by the 2050s, to 1.6mm per day, and by 48 per cent, to 1.2mm per day by the 2080s, Figure 21.

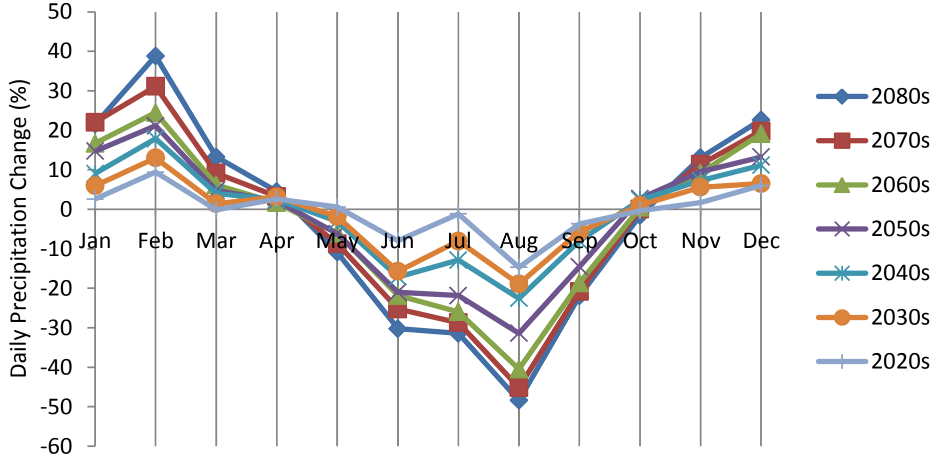


**Figure 21 South West England, mean daily precipitation change (50th percentile)**

In South East England the mean daily precipitation is projected to increase by 25 per cent, reaching 2.3mm per day by the 2050s, and by 42 per cent, reaching 2.6mm per day by the 2080s. Mean daily precipitation in August is projected to decrease by 20 per cent by the 2050s, to 1.4mm per day, and by 32 per cent, to 1.2mm per day by the 2080s, Figure 22.

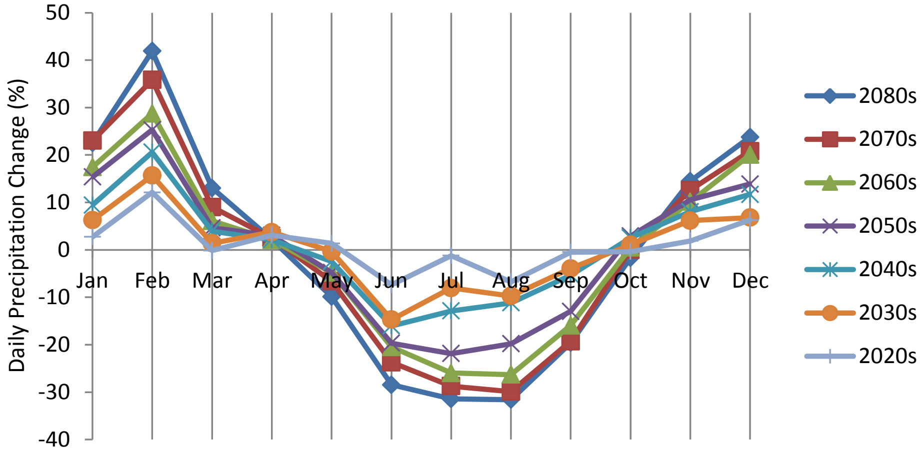


**Figure 22 South East England, mean daily precipitation change (50th percentile)**

## Sea level rise

Sea level rise for the Wessex Route coastal and estuarine assets can be represented by the projections for the Weymouth area. For the high emissions scenario, the projections for the 50th percentile for 2050 are 0.265m and 0.576m by the end of century (the rise is unlikely to be higher than 0.408m and 0.898m respectively), Figure 23.

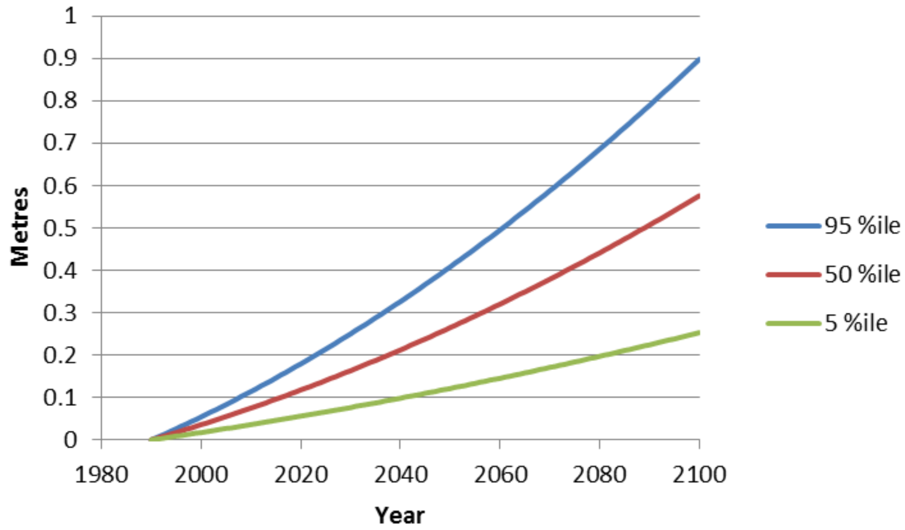


**Figure 23 UKCP09 sea level rise projections in m for Weymouth area**

The understanding of the vulnerability of Wessex Route rail assets to current weather and potential risks from future climate change is an important stage in developing WRCCA actions.

# Wessex Route impact assessment

This section provides the findings from the Wessex Route weather impact assessment, including annual performance impacts and mapping of high impact locations on the Route.

### Performance impacts

The impact of weather on the rail network can be monitored within rail performance data. Schedule 8 costs; the compensation payments to train and freight operators for network disruption, are used as a proxy for weather impacts due to greater granularity of root cause reporting.

Schedule 8 costs for the past eight financial years for Wessex Route have been analysed to provide an assessment of weather impacts, Figure 24.

- ‘flooding’ costs include delays due to a range of fluvial, pluvial, groundwater and tidal flooding of assets.
- ‘earthslip’ delays have been included due to internal analysis indicating primary triggers of earthworks failures are weather-related.
- ‘heat’ and ‘wind’ include direct impacts on assets and impacts on delay due to speed restrictions implemented as part of Network Rail’s operational response during weather events.

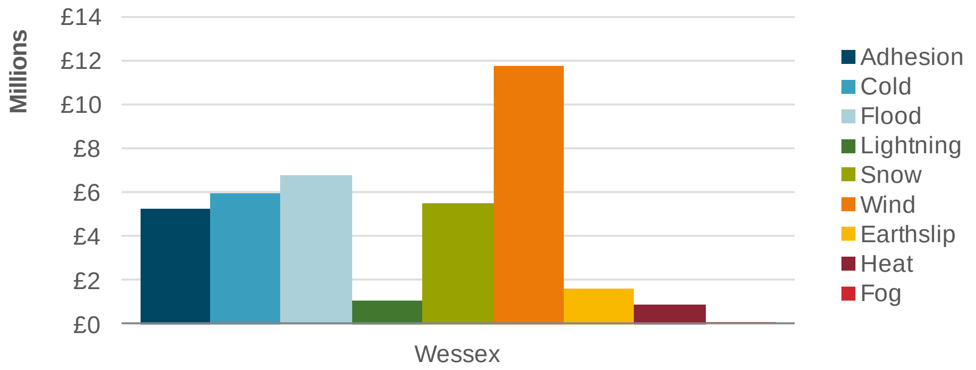


**Figure 24 Wessex Route weather attributed Schedule 8 costs 2006/07-2013/14**

The analysis shows that wind has been the most significant weather impact for the Route, with total Schedule 8 costs for under £12m during the period 2006/07-2013/14.

Climate modelling cannot provide strong projections for future changes to wind speeds, though, increased storminess is generally projected and may increase the risk of wind-related incidents on the Route

Snow-related delays have been significant but are projected to decrease in the future. However, extreme cold-related events are projected to continue to occur and actions to ensure resilience to cold-related weather impacts should continue to be factored in future seasonal preparedness and investment decisions.

The impacts of changes in winter and summer precipitation on flooding patterns are complex, however, it is expected that flooding events will increase in frequency and intensity, and presents increased risk to Wessex Route over the coming decades.

A combination of the assessment of historical weather impacts on Wessex Route and regional climate change vulnerability from UKCP09 can be used to prioritise weather resilience actions.

**Table 1 Prioritisation of weather-related impacts on Wessex Route**

| Weather-related impact | Schedule 8 costs[1] | Projected future impacts | Prioritisation |
|---|---|---|---|
| Wind | £1.69m | Wind changes difficult to project however generally projected to increase | High |
| Flooding | £0.97m | Up to 25 per cent increase in February mean daily precipitation2 | High |
| Adhesion | £0.74m | Complex relationship between adhesion issues and future climate change. | High |
| Cold | £0.85m | Up to 3°C increase in January mean daily minimum temperature2 | Medium |
| Snow | £0.79m | Up to 3°C increase in January mean daily minimum temperature2 | Medium |
| Sea level rise | Not recorded | 0.27m increase in sea level rise3 | Medium |
| Earthslips | £0.23m | Up to 25 per cent increase in February mean daily precipitation2 | High |
| Heat | £0.12m | Up to 3.1°C increase in July mean daily maximum temperature2 | Medium |
| Lightning | £0.15m | Storm changes difficult to project however generally projected to increase | Medium |
| Fog | £0.07k | Complex relationship; research suggests fog events may decrease | Low |

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

It is also worth noting the Schedule 8 cost per delay minute in CP5 will be on average 60 per cent higher, further reinforcing the importance of effective WRCCA actions.

### Identification of higher risk locations

A geographic information system (GIS) based decision support tool, METEX, has been developed to analyse gridded observed weather data and rail data, including the past eight years of delays attributed to weather.

Over recent years our network has experienced some of the most extreme weather on record and weaknesses in existing assets will be captured in performance impacts. Climate change is projected to impact the UK with more intense and frequent extreme weather events, so taking actions on our current weaknesses, and proactively managing future risks are important steps to increasing our future resilience.

Higher-risk locations have been identified by assessing METEX outputs for high-frequency/high-cost sites across the whole Route, and detailed assessment of key sections of the rail network. These locations have been assessed to determine:

- validity of the delay attribution to a weather impact
- root cause of the delay
- resilience actions that have been undertaken
- resilience actions that are currently planned
- identification and prioritisation of additional resilience actions.

In addition, Routes have identified potential future risks and resilience actions based on climate change projections and Route knowledge.

### Wind impact assessment

Based on 2006/07 to 2013/14 data, wind-related delays total 47,055 minutes per year on average, costing £1.69 million per year in Schedule 8 costs. This is 6.8 per cent of weather-related delay minutes.

Wind affects performance directly in that blanket speed restrictions are imposed when thresholds are reached. Wind also affects performance indirectly primarily as a result of damaging lineside trees which then fall, or drop branches on or near the line. Wind also moves other debris on to the line from the lineside environment. High winds can also lead to significant waves to form even in waters protected from the open sea, these can cause damage to the infrastructure, as evident at some of the coastal assets in Poole Harbour and to Ryde pier on the Island Line.

The primary operational risk mitigation to strong wind is to impose speed restrictions on the parts of the route forecast to be impacted, or in extreme conditions to suspend operations completely.

The primary longer term mitigation is to remove trees which are able to fall on to the line, Figure 25. Wessex has a 10 phase plan to clear a 6m strip of trees from adjacent to the track, and to remove dangerous trees beyond the 6m strip. There is also a significant risk associated with trees on third-party land, many are sufficiently tall to fall across the running lines, Wessex Route has sought funding to undertake works on high-risk third-party trees. Clearing trees in danger of falling on or near the line is an enormous undertaking with many sensitivities, some trees are protected and the trees form an important visual screen to our infrastructure. Wessex Route is committed to producing a Vegetation Management Strategy.

The impact of wind can be reduced by monitoring wind speed on site, allowing speed restrictions to be imposed and lifted when triggers are actually met rather than when high winds are forecast. Due to the complex nature of train planning this cannot be applied on too local a scale, the route needs to be operated in wind speed zones to allow train paths to be planned. There is also a difficulty in understanding the relevance of data from a wind speed recorder in a single location and how the information it provides relates to the chance of forecast conditions materialising particularly when strong gusts are forecast.

**Figure 25Staff using a Mobile Elevating Work Platform (MEWP) to reduce the height of a tree in danger of falling on to the line.**

## Flooding and earthslip impact assessment

Based on 2006/07 to 2013/14 data flood-related delays total 27,947 minutes per year on average costing £0.97m per year in Schedule 8 costs. This is 18.1 per cent of weather-related delay minutes. It should be noted that the winters of 2012 and of 2013 were far wetter than the long-term average. Earthslip-related delays total 6,517 minutes per year on average costing £0.23m per year in Schedule 8 costs. This is 4.2 per cent of weather-related delay minutes.

The climate is forecast to become warmer and wetter in the winter with an increasing number of storms of increasing ferocity. This will be a particular challenge to manage as drainage assets throughout the Route require investment and geotechnical assets are sensitive to intense storms, and the impacts of very heavy rain can result in significant damage to the asset. During the very wet winters of 2012/2013 and the winter of 2013/2014 Wessex Route experienced numerous landslides and delays resulting from track flooding. During and following the very wet winter of 2013/2014 repairs to geotechnical assets cost in the region of £12m. Two lines were closed for extended periods whilst repairs were undertaken and several other lines were closed for shorter periods and subject to speed restrictions as damage was assessed and made safe. Service was also suspended on a number of occasions, and speed restrictions imposed in order to mitigate against the risk of flooding damaging bridges or washing out the track at locations where the flood risk is high. Many other locations suffered from track flooding including a frequent suspension of traffic at Fulwell in South West London and at Datchet where the River Thames flooded large parts of the town and the rail line requiring service to be suspended for over two weeks.

**Figure 26 Undertaking repairs to the embankment at Botley following its collapse in the winter of 2013/2014.**

**Figure 27 Undertaking temporary repairs following an embankment failure near Yeovil in the winter of 2013/2014.**

Large parts of the Wessex infrastructure are built along the margins of floodplains as this was the alignment that allowed the railway builders both to maintain a consistent gradient and because communities have tended to develop along river corridors. As railways need to be as close as possible to straight and rivers tend to meander, the railways tend to cross and re-cross rivers numerous times, this is problematic as the entire river flow must be conveyed beneath the railway at each river crossing. Modern flood risk assessments were not carried out when the railways were built, and floodplains have generally accreted in the intervening 100 plus years; in addition increasing urbanisation and changing farming practices have increased run-off rates. These problems all combine to increase the vulnerability of the network to flooding, and this will worsen as winter storms intensify.

**Structures**

A programme of bridge scour protection is nearing completion; this will significantly reduce the risk of bridge failure due to scour at the footings. Over 25 significant bridges on Wessex route are currently at risk of flood waters affecting the bridge deck, one of the most vulnerable, a wheel timber structure in Yetminster on the WEY line had its deck displaced, damaging the abutment in 2012. One of the bridges in the Axe Valley had water flow over the top of the structure twice in 2012 washing ballast off the structure. Train services were stopped twice in 2013 to mitigate this risk, post-event analysis identified that water had reached to within 100mm of the top of the ballast shoulder meaning that a washout was imminent.

In order to mitigate against river flooding, Wessex Route use flood warnings data issued by the Environment Agency to slow or stop trains before damage occurs. In locations where no flood warning is available bespoke river level monitoring will be installed by Network Rail in 2014/2015.

In order to mitigate against increased peak flood flows that will result from higher rainfall intensities, some bridges may need to be replaced or raised, this is seldom simple. Portcreek viaduct, although at high risk of tidal flooding cannot be raised as there are overline bridges over the track at both ends. The bridge at Yetminster which has been damaged by flood several times cannot be easily raised as it is close to a level crossing on one side and a station platform on the other. The numerous bridges that may require raising in the Axe valley are not so constrained but large projects such as this require significant investment and multiple environmental constraints exist in areas at risk of flooding. In order to increase the resilience of the railway not only bridges will require raising but also the earthworks in areas where they are prone to overtopping, this would be very time consuming work requiring lines to be closed for extended periods. It may be necessary to undertake very significant works such as sheet piling in order that new larger embankments can be fitted within the existing rail corridor. Lines would need to be re-cabled and track relaid.

**Earthworks**

Intense rain and flooding can cause the failure of geotechnical assets via a number of mechanisms each with different mitigations:

- washout failure due to water flowing over the crest of cuttings, mitigated by increasing capacity of crest drainage and works to stabilise cutting slopes
- cutting failure due to saturation of face, face drainage and stabilisation
- cutting failure due to wet cutting toe, often accompanied with track quality problems, improved cutting and track drainage
- embankment failure due to saturation during rainfall events, very difficult to mitigate against, slope must be re-engineered to retain a factor of safety of greater than unity when saturated, requires assessment and engineering intervention, usually toe support such gabian walls or sheet piles. A regrade to reduce the steepness of the face is also frequently required
- embankment failure due to saturated toe, drainage of toe, many embankments are land locked and this is difficult to achieve in many cases, particularly in areas impacted by sea level rise, see sea level rise section
- embankment failure due to scour at the toe, this occurs where the toe of the embankment is adjacent to a river stream or drainage ditch which conveys water at high velocity during storm events, these failures can occur very quickly.

In all cases good water management is required and a co-ordinated drainage investment strategy is required to ensure that by solving one problem another is not created.

**Drainage**

Increasingly frequent and intense storms will overwhelm the existing track drainage networks which have suffered from insufficient maintenance in previous decades. This will lead to increasingly frequent traffic disruption and accelerated degradation of assets that depend on good drainage, particularly geotechnical assets and the track formation. The current drainage asset is currently beyond maintenance in parts of the route, it must in the first instance be brought back into use and a robust maintenance regime implemented and funded long term. In coming years the drainage assets should be assessed and where capacity is insufficient for predicted climatic conditions, improvements should be implemented. In future years it is likely that some locations, particularly in the coastal floodplain will no longer function as effective gravity drainage systems unless significantly greater system storage is constructed, if this is not practical pumped drainage will become increasingly necessary.

Drainage rehabilitation and renewal is taking place in line with a drainage policy compliant workbank. Improved drainage data resulting from improved drainage inspections will begin to become available from March 2015, this will allow the workbank to be better targeted as the condition of each element of the drainage network will be recorded. During the winter of 2014/2015 additional drainage survey will take place to improve the completeness of our drainage records, again this will allow more targeted drainage maintenance, rehabilitation and renewal, Figure 28.

**Figure 28 A typical drainage system in need of clearance and possibly replacement.**

In some parts of the network, such as at Datchet and the River Axe valley in Devon, it will be difficult for Network Rail to undertake works to improve the flood resilience of the railway in isolation from the community it serves. In these and similar locations funding may be more effectively invested in measures to make service recovery quicker by raising location cabinets and holding spares for items which it is reasonable to assume will get wet such as points motors. Some thought could be given to redesigning track layouts to remove mechanical plant such as Switches & Crossings from areas prone to flooding.

A detailed assessment of the vulnerability of the route to fluvial flooding will be commissioned so that appropriate investment decisions can be made in both short-term mitigation measures and longer-term investments so that infrastructure that can be relocated in an organised and prioritised way in line with or ahead of normal renewal timescales. This plan will complement the Coastal and Estuarine Asset Management Plan.

### Sea level rise impact assessment

There is some evidence that sea level rise recorded since the railway infrastructure was built has contributed to flooding delays, but no formal analysis has taken place to confirm this and it is likely that any impact is minor when compared to the impact of defects in the drainage asset.

Sea level increase will not have a day-to-day impact in the short to medium term, in practice it will only be notable as it increases the impact of coastal storm events in the short term, but in the longer term the impact will increase. Minor coastal storms will have an ever greater impact. Over time the proportion of the tidal cycle that coastal gravity drainage systems are able to discharge over will reduce, in the short term this will result in more tide locking and flooding only if rain falls over the high-tide period, longer-term drainage capacity will be utilised to discharge ‘normal’ flows leaving no capacity to deal with storm water. When combined with the increased storminess and more intense rainfall, the number of occasions when the capacity of surface water drainage systems in the coastal zone is exceeded will increase. Before that point is reached we must plan to manage water through the high tide period by increasing the system storage or pumping at high tide.

Over time ground levels in areas discharging into tidal rivers, coastal marsh and the floodplain of lowland river systems have increased as successive floods or tides have deposited silt. The rail infrastructure is a fixed point in this rising landscape and the maintenance of culverts, and associated approach ditches, which discharge on to neighbouring land, needs to manage these changes. The impact of these changes is difficult to quantify but the height of the railway above the floodplain will reduce with time increasing the chance of track flooding and infrastructure damage which is exacerbated by particular difficulties in maintaining drainage features. A secondary important impact is that with reducing drainage effectiveness embankments will sit in water for increasing periods of time or are permanently wet at the toe which significantly reduces the stability of the earthworks.

There are several sections of the route that pass through the tidal flood zone including;

- WPH2 –between Havant and Portsmouth including the Portsea viaduct
- SDP2 – Havant
- BML1 – Swathling and St Denys
- BML2 – Southampton, Christchurch and Poole
- BML3 – Weymouth.

Several of these areas currently suffer from poor drainage, including difficult to maintain outfalls, indicating that they will be increasingly difficult to maintain in the future.

Exposed sections of the Bournemouth mainline at Poole have been damaged by wave action in recent years. As sea levels rise damage of this nature will increase and will occur closer to track level. In the long term it may be required to build formal coastal defences or to raise sections of track in this area.

The Portsea Viaduct on the WPH2 is currently vulnerable to high tides, the bottom of the main girders and bearings are submerged on several tides per year, this causes a significant maintenance challenge. This structure is not viable in the very long term as it will fully submerge on storm tides by the end of the century. Portsmouth City Council have obtained funding to improve the city's flood defences, these new defences will have a crest level above current track level, the bridge and deck cannot easily be raised as there are overline bridges near both ends of the viaduct with limited headroom. This will probably require the replacement of the existing bridge with a new structure with solid parapets which can tie into the new flood defences to provide a continuous flood defence line to Portsmouth and prevent flood damage to the rail line during high tides. Network Rail are committed to working with Portsmouth City Council to find a solution to this problem before sea level rise causes the bridge to become a breach in the city defences.

Wessex Route is committed to producing a Coastal and Estuarine Asset Management Plan during CP5 to quantify the vulnerability of our coastal and estuarine assets and to inform future investments to mitigate this emerging risk.

## Heat impact assessment

Based on 2006/07 to 2013/14 data, heat-related delays total 2,934 per year on average costing £0.12m per year in Schedule 8 costs. This is 1.9 per cent of weather-related delay minutes.

### Track

The impact of high temperatures is largely a problem in the management of the track asset. Track maintenance teams put significant resource into managing the track asset in a way that limits the number and length of heat speeds required to manage safety, they are largely successful and the current impact is relatively small as a result. Capital investment in the track asset is also targeted in part in removing assets that perform poorly in high temperatures, to this end most jointed track has now been removed from the route and there are robust plans in place to remove the remaining jointed track in areas where a heat-related speed restriction would have a performance impact. Jointed rail will remain in sidings, depots, passing loops and freight only lines with low usage or low speed limits until it is life expired.

As temperatures rise there are several probable implications, firstly the number of days where the critical rail temperature are reached will increase, this will require speed restrictions to manage the safety risk of a track buckle to be imposed on a greater number of days per year over a longer summer season, and potentially for longer periods on those days when critical rail temperature is reached. This increase will have to be mitigated by concentrating track maintenance works that disturb the track formation into an ever smaller window during the winter. This is clearly mitigation with a natural limit in its practical application; the same amount of maintenance cannot be squeezed into an ever-shorter season without radical efficiency improvements or changes in methodology or a larger workforce with more access to the track in the winter period.

It is possible that track standards for rail stress may be modified as the climate warms to increase the maintainability but this can only take a number of forms and all have an impact, one mitigation would be to reduce sleeper spacing, this would require a significant capital investment, another may be to increase rail stress, but this would require a more significant ballast shoulder to prevent the rail slewing in towards the inside of curves in winter, a third may be to increase the ballast shoulder to prevent slewing off the outside of curves in summer. A more radical option may be to convert to a slab track system in high-risk areas.

The common complication with all options to increase the tracks resilience to stresses induced by temperature variation is that they will require a more robust track support system including more space on bridge decks and embankments for a more substantial formation. Wessex route suffers from historic asset management practices which have resulted in a higher track alignment that was originally designed to be accommodated leading to ballast loading to many underline bridge parapets and spandrels and to ballast retention problems on numerous embankments. To manage this problem, track lowering must be undertaken or significant engineering to increase the width of embankments and to retain ballast in an engineered way on underline bridges. Over-ballasting in cuttings is less difficult to manage but has resulted in drainage becoming unmaintainable as cess ditches are filled and catchpits are buried.

There are two potential none structural heat mitigations for track. The first is to use RCM to detect either rail temperature or rail stress at regular intervals; by using this data speed restrictions could be applied only where rail temperature or stress is actually causing a risk to safety, this could largely be automated. This would remove the need to apply the current controls which use a very conservative estimate of rail temperature based on a formula and a temperature forecast. This may also reduce or remove the need to place special restrictions in place following engineering works. The second mitigation is to paint the rails white; good results have been achieved by painting short lengths of rail in areas of high-risk of reaching critical rail temperature. This work is currently carried out by hand and with little control of application methodology or paint specification. There is scope to mechanise this process and to closely control specification which could lead to much more effective rail temperature reduction, reduced need to reapply the coating, and the potential to treat larger parts of the network.

Track is more likely to be affected by heat speeds if it is in direct sunlight. Works to significantly reduce the amount of tree cover to mitigate the risk of increasing wind and to reduce adhesion problems may significantly increase the proportion of the track asset that is un-shaded.

Increasing average temperature will have several other impacts with a need for appropriate mitigation:

- shorter periods of temperature close to freezing will increase the active growing season for many plant species and when combined with wetter winters will lead to more vigorous growth in the spring. Vegetation management will become more expensive as a result unless more efficient vegetation management practices are adopted
- plant species will may migrate north, this will result in existing plants, such as some broad leaved trees becoming stressed by drier summers and becoming dangerous, these species will have to be removed from the network where they pose a risk, this is likely to be a significant problem with off boundary trees over which network rail has less control
- new species which are likely to be more vigorous than those they displace will require new management practices
- during dryer summers the frequency and severity of lineside fires can be expected to increase, this can largely by mitigated be managing the lineside environment to be largely free of combustible materials, this will require a change in management practice as we currently leave most cut vegetation on the lineside either as cut material or as chipped material, both burn well when dry
- electrical equipment housed in both location cabinets and buildings will overheat if ventilation or air conditioning is insufficient. This may be a greater problem if tree cover, which currently shades many such installations, is removed
- hotter summers are also expected to be dryer, this is a risk for embankments constructed of moisture sensitive clays that shrink as they dry and expand when they are wet
- embankments of this type dominate on several lines within Wessex route most notably the BKE between Basingstoke and Reading. In dryer summers in the future these embankments will shrink more, resulting in significant track quality problems, the interventions required to repair the damage to the track caused by embankment shrinkage require speed restrictions to be imposed until they have consolidated, particularly in hot conditions thus increasing the impact of the track quality problems on performance
- station buildings designed in the Victorian era perform surprisingly well in hot weather, some more recent structures less so. As passenger densities and temperatures increase passenger comfort must be monitored and alterations made to buildings to improve ventilation and cooling as required
- staff accommodation must also be modified or replaced to deal with increasing temperatures. Staff, particularly those undertaking safety critical roles such as signallers and electrical control room staff share their work space with large electrical and electronic installations so must be provided with sufficient ventilation and air conditioning to maintain a safe working environment.

### Snow and cold impact assessment

Based on 2006/07 to 2013/14 data, snow-related delays total 22,711 minutes per year on average, costing £0.79m per year in Schedule 8 costs. This is 14.7 per cent of weather-related delay minutes. Cold-related delays total 24,115 minutes per year on average, costing £0.85m per year in Schedule 8 costs. This is 15.6 per cent of weather-related delay minutes.

Snow is infrequent in much of Wessex route, the very significant delay minutes are due to the widespread nature of this problem when it does occur. Snow can all but prevent trains from running if it stops them from drawing current from the conductor rail.

Cold weather without snow is largely managed in the same way as snow. Ice on the conductor rail causes the greatest disturbance to service. Ice and snow can cause points to freeze in position preventing trains from being correctly routed.

The primary mitigation for snow and cold is good forecasting allowing robust emergency timetables to be implemented including simplifying train movements to minimise the use of points. The targeted use of on track equipment to de-ice key routes is also essential. An increased robustness in these capabilities could improve preparation for well-forecast snow and freezing conditions and speed up recovery following ice or snow fall. Winter preparation is reviewed annually and processes to reduce the impact of the seasonal conditions are continuously improved.

Further mitigation to snow and ice in the form of points heating and conductor rail heating is also possible. Key points on the route are already fitted with points heating, its effectiveness is being improved in some places by the addition of insulation and its reliability and effectiveness is being improved by increased use of remote condition monitoring which monitors both rail temperature and the health of the heating system. Conductor rail heating to prevent accumulation of ice and snow is expensive and a large deployment of this technology is not practical. Very limited deployment of conductor rail heating to locations where icing is common and the impact on service is significant is being investigated.

Although the number of cold and snow fall events is likely to fall in future years, and the season where there is a snow risk is likely to shorten, there is some evidence to suggest that snow fall may increase in intensity.

Overall the risk of significant delays due to cold and snow is a reducing problem and significant investment in expensive mitigations should probably not be a priority, moderate investments in better procedures and relatively short-term investments such as more de-icing capacity should however be assessed as should limited targeted investment in points heating, rail temperature monitoring and possible very limited use of conductor rail heating.

### Lightning impact assessment

Based on 2006/07 to 2013/14 data, lightning-related delays total 3,932 minutes per year on average, costing £0.15m per year in Schedule 8 costs. This is 2.5 per cent of weather-related delay minutes.

Lightning strikes can happen anywhere on Wessex route and they can cause signalling systems to fail. Lightning does not usually generate large delays as normal business processes allow relatively quick recovery of service in most cases. Unfortunately the route does suffer the occasional lightning strike in the London area, due to the very congested nature of the network east of Woking any signal failure here can cause disruption to a significant number of services.

To mitigate the effect of lightning, certain signalling installations can retrofitted with power supply surge protection, this does not guarantee that lightning will not generate a failure but does significantly reduce the chance of that occurring. As signalling systems are replaced over time, new systems should be specified with a greater degree of resilience. Until this is possible a good stock of spare parts in danger of failure during a lightning strike should be retained to ensure service recovery is swift. Additionally systems in the Woking to Waterloo corridor should be reviewed for suitability for fitting with surge protection and this protection fitted if economic.

Lightning can generate fires in lineside vegetation. Good vegetation management can minimise this risk, Wessex route is committed to producing a vegetation management strategy.

### Adhesion impact assessment

Based on 2006/07 to 2013/14 data, adhesion-related delays total 19,372 minutes per year on average, costing £0.74m per year in Schedule 8 costs. This is 12.5 per cent of weather-related delay minutes.

Adhesion is extremely complex with many interlinked causes, both infrastructure and operational. Many cases of adhesion delays are attributed to a lack of appropriate rail head treatment. Frequently when adhesion problems are investigated the rail head is found to be clear of contamination indicating that operational improvements could generate significant reductions in delays.

The weather that causes the greatest adhesion problems is still cold mornings and evenings which promote heavy dew. If combined with leaf fall the rail head can become contaminated. This weather should become less common in the future.

The primary mitigation is tree removal in areas where the problem is persistent followed up with programme of rail head treatment including rail cleaning to remove contamination and application of adhesion gel. Increased MPV capacity could assist with both rail head treatments. Plans to reduce the vegetation cover on the route should improve matters also.

More modern rolling stock with wheel slip detection reduces the impact of rail head contamination, and good forecast and robust alternative timetables that build sufficient time in to allow trains to slow and accelerate gently when conditions are poor can also significantly reduce impact.

### Fog impact assessment

Based on 2006/07 to 2013/14 data, fog-related delays total 18 minutes of delay per year, costing £0.07k per year in Schedule 8 costs. This is 0.1 per cent of weather-related delay minutes.

Fog risk may increase slightly in the south as the climate changes although the relationship is complex. Current controls are considered adequate for future management of fog. Historic delays were frequently accrued in areas controlled by semaphore signals, these have now been phased out on Wessex Route, as the route migrates to the use of LED signal heads, which have greater visibility, the risk of fog-related delays reduces.

# Wessex Route WRCCA actions

Network-wide weather and climate change resilience will be driven predominately by Network Rail's Central functions through revision to asset policies and design standards, technology adoption and root cause analysis. The location specific nature of weather impacts will require analysis and response at Route level.

This section is a concise summary of Wessex Route actions planned in CP5, Table 2, beyond Business as Usual (BAU), and potential additional actions, Table 3, for consideration in CP5 and future Control Periods to increase weather and climate change resilience.

**Table 2 Planned actions in CP5**

| Vulnerability | Action to be taken | By when |
|---|---|---|
| **All Impacts** | | |
| Climatic conditions and specific weather-related risks are not clearly communicated to asset renewal and enhancement processes | Include clear requirements for climatic conditions and resilience levels in Route Requirements Documents | Ongoing |
| Risk to staff from extreme weather conditions | Staff supplied with appropriate PPE, offices and depots temperature controlled where required. | Ongoing |
| **Flooding** | | |
| Level of engagement with flood risk management authorities is not supporting effective discussions | Strengthen relationships with the Environment Agency through setting up of a Local Liaison Group on flood risk management to share information and resolve issues.<br><br>Engage with Local flood resilience forums | March 2015 |
| Flood risk in River Axe catchment not quantified. | Network Rail have jointly funded a flood risk study in the River Axe Catchment with the Environment Agency and Devon County Council. This study will allow all three parties to work together to improve flood risk to both rail assets and homes. | Phase 1 of study completed Autumn 2014, Phase 2 TBA. |
| Flood risk not well understood in most catchments. | Quantitative assessment of vulnerability of assets in fluvial flood plain to understand asset investment requirements. Undertake Fluvial Asset Management Plan. | By March 2018 to allow bidding for funding in CP6 |
| No trigger for flood mitigations at five known most vulnerable structures. | Install RCM and write procedures to manage risk. | March 2015 |
| Drainage not managed optimally. | Produce drainage management plan and review annually. | October 2014 and ongoing |
| Drainage systems not fully understood. | Undertake drainage survey in areas where records are incomplete. Improve drainage inspection through use of handheld data capture in the field. | Survey by March 2015 Improved inspections start March 2015 |
| Drainage in poor condition | Undertake Renewal, Rehab and Maintenance in line with Drainage Management Plan and drainage policy compliant workbank. | Ongoing |
| **Earthworks** | | |
| Procedures to mitigate against risk of earthwork failure not fully embedded. | B&C and control to work together to fully embed. | Nov 2014 |
| Systems supporting procedures to mitigate against risk of earthwork failure not fully supported by the business. | Work with centre to develop fully supported systems to mitigate against earth slip, flooding and heavy rain risk. | TBA |
| **High temperatures** | | |
| Impact of increased temperatures on current heat prep work back not understood. | Assess current heat prep work banks to quantify risk to delivery with shorter working season. | March 2018 |
| **Coastal and estuarine** | | |
| Coastal flood risk not well understood. | Quantitative assessment of vulnerability of assets in coastal flood plain to understand asset investment requirements. Undertake Coastal and Estuarine Asset Management Plan. | By March 2018 to allow bidding for funding in CP6 |
| No adequate triggers for mitigations for coastal storms. | Undertake assessment of hazard associated with storm on coast and develop triggers. | March 2016 |

| Vulnerability | Action to be taken | By when |
|---|---|---|
| **Wind** | | |
| Current condition and quantity of vegetation on route not fully understood. | Undertake tree survey including assessment of parts of route where trees are liable to fowl gauge if they are felled by wind. | March 2016 |
| No integrated vegetation management plan exists for route. | Produce an integrated vegetation management strategy for route meeting objectives of all departments. | March 2016 |
| Emergency timetable for wind splits route into several large blocks reducing flexibility if high winds forecast in small areas. | Continue to develop emergency timetables with more flexibility to allow restrictions to be imposed on smaller areas of route when required. | Ongoing. |
| **Cold and snow** | | |
| Benefits of limited deployment of conductor rail heating not fully understood. | Analyse requirement for targeted deployment of conductor rail heating. | March 2017 |
| Future requirement for rail head treatment not fully understood. | Continue to review performance of rail head treatment programme and modify in response to emerging trends. | Ongoing |
| **Adhesion** | | |
| Future requirement for rail head treatment not fully understood. | Continue to review performance of rail head treatment programme and modify in response to emerging trends. | Ongoing |
| Impact of Route vegetation management strategy not understood. | Make assessment of impact when route vegetation management strategy is published. | March 2017 |
| Better forecasting and rail temperature monitoring can allow more targeted treatment | New weather forecasting service currently being procured centrally. | TBA |
| **Lightning** | | |
| Scope for reducing impact of lightning strike through retrofitting surge protection not fully understood. | Undertake assessment for golden corridor assets in Woking to Waterloo area. | March 2017 |

In addition to the above actions in CP5, the following actions have been identified as potential enhanced WRCCA actions which will require business case evaluation and funding submission.

**Table 3 Potential additional WRCCA actions requiring further evaluation**

| Vulnerability | Action to be evaluated |
|---|---|
| **Weather information** | |
| Weather forecasting services do not provide adequate information | Following procurement of new weather forecasting service, all weather plans need to be reviewed to take advantage of higher-quality information. |
| **Flooding** | |
| Track near Axminster at risk of flood | Consider investing in raising the most vulnerable section of track to reduce frequency of flooding and improve resilience of service between Exeter and Salisbury. Work must tie in with a track renewal. |
| Fluvial flooding risks | Fluvial Asset Management Plan .Following production of the plan, schemes to manage risk can be assessed for cost effectiveness. |
| Portcreek Viaduct at risk of tidal flooding. | Ongoing liaison with Portsmouth City Council flood risk management team to continue. |
| **Earthworks** | |
| High-level investment plans to remediate known weak earthworks are currently unfunded. | Consider investing in enhanced remediation for geotechnical assets in 2016/2017 to 2018/2019. Once an indicative settlement is agreed detailed planning can begin. |
| **Coastal and estuarine** | |
| Coastal flood risk not well understood. | Following production of the CERD plan, assess schemes for cost effectiveness. |
| **Wind** | |
| Better forecasting and wind monitoring can allow more targeted mitigation | Wind recording equipment at key locations could be used to supplement weather forecasts to help inform when to use emergency timetable. Investigate locations for equipment and costs to install and maintain. |
| **Cold and snow** | |
| Benefits of limited deployment of conductor rail heating not fully understood. | If investigations show positive benefit expected through very limited deployment of conductor rail heating plan to deploy. Review and consider investing in if warranted. |
| **Lightning** | |
| Scope for reducing impact of lightning strike through retrofitting surge protection not fully understood. | Consider investing in retrofit signal power supply surge protection in line with vulnerability assessment. |

# Management and review

## Corporate management and review

Weather resilience and climate change adaptation will require long-term commitment to regular review and management across the business. The challenge for the industry, and for all organisations managing assets vulnerable to weather events, is to develop cost-effective strategies to accommodate climate change and implement these strategies in a timely manner to avoid an unacceptable increase in safety risk, reduction in system reliability or undeliverable downstream risk mitigation strategies.

Key actions being taken within corporate functions include:

- Safety, Technical and Engineering – Review of weather and climate change within asset policies and standards, and monitoring of WRCCA actions through the S&SD Integrated Plan
- Network Operations – Review of the Extreme Weather Action Team process and definition of 'normal, adverse and extreme' weather
- Group Strategy – Delivery of future weather resilience in the Long-Term Planning Process (LTPP)
- Infrastructure Projects – Review of weather and climate change within the Governance for Railway Investment Projects (GRIP).

The progress on WRCCA actions is reported through Network Rail's governance process to the Executive Committee as part of regular Strategic Theme business management updates.

## Wessex Route management and review

Wessex Route has identified embedment of this plan (and the severe weather management plan) as a change project. Progress on embedment will be tracked by the route change board to ensure that the work required is appropriately assigned and migrated into business as usual processes. Wessex route is committed to improving both safety and performance during periods of severe weather and making improvements to process and infrastructure to achieve this.

## Review of Route WRCCA plan actions

The actions within all eight Route WRCCA plans will be monitored through internal Network Rail governance processes.

Route WRCCA plan progress will be reported every six months through the S&SD Integrated Plan. The plan monitors the actions being taken across Network Rail delivering safety and sustainable development objectives. The whole plan is monitored monthly by the cross-functional S&SD Integration Group.

Enhancement of assets will be included in Network Rail workbanks and monitored through our asset management processes.

Network Rail will also look to engage with the wider rail industry, specifically Train Operating Companies and Freight Operating Companies, to discuss the Route WRCCA actions to identify opportunities for collaboration to facilitate effective increase of rail system resilience. We will also update the Office of Rail Regulation (ORR) on progress through regular bilateral meetings.

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