2019 – 2024

WALES

Route CP6 Weather Resilience and Climate Change Adaptation Plan

Contents

Purpose of this document

This document; defines the Wales Route Weather Resilience and Climate Change Adaptation (WRCCA) Plan for CP6 and reviews progress against the WRCCA Plan published for CP5. This is 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 the rolling stock operating within the Route is not specifically assessed.

Wales Route Weather Resilience and Climate Change Adaptation Plan – Version 3 – May 2020.

Director of Route Asset Management statement

The railway network, over recent years, has been significantly affected by severe weather conditions.

In recent memory; The Beast from the East, Summers of 2017 and 2018, and Storm Callum. These events have brought wind, snow, rainfall, lightning, and prolonged periods of high temperatures.

Figure 1
Storm Gareth, Conwy Valley Line – 15th March 2019

These extremes can lead to asset system failure, degraded operation capability and ultimately, delays to our train services. CP5 was overall quieter in terms of individual weather events than CP4 which saw severe damage to Barmouth Bridge due to severe storm patterns aligning with other factors to produce frequent and extreme weather.

To address the continually evolving weather resilience challenges on the Wales Route, we are committed to identifying new and innovative ways of improving our infrastructure resilience during periods of severe weather conditions.

It is challenging to accurately predict individual changes in weather, but UKCP18 datasets give a solid indication of climate change risks which will affect the vulnerability of the Wales Route asset portfolio in the future. This dataset is the basis of risk profiling for the Wales Route for CP6. The findings of this process are that the infrastructure reliability will be tested by climate change and more frequent severe weather events. Wales Route, and many other Routes, will see these events being driven by increases in average and maximum daily temperatures and changes in seasonal rainfall patterns, with significantly drier Summers, and wetter Winters – already experienced in the 2017 and 2018.

We will continue to work with all stakeholders involved in facing the challenge that climate change poses to the Wales Route. Principle stakeholders we are currently working closely with include Natural Resources Wales (NRW), Transport for Wales, MetDesk, the Environment Agency (EA) and other lineside stakeholders.

Wales & Boarders Route is experiencing significant investment over the next five-year control period (Control Period 6); we will spend £1.34 billion in enhancing, renewing, maintaining and operating the infrastructure. The level of investment reflects the growth in the demand for rail travel and the economic significance of the railway in Wales. Connecting many of the Southern valley lines to major urban areas such as Newport, Swansea and Cardiff, we also directly link Swansea to London Paddington and Cardiff to Shrewsbury, Birmingham, Nottingham and Manchester. With links to so many networks it is important for the holistic network resilience that we make these improvements – and in this document we will outline how we will go about that challenge.

Tom Stanley
Director of Route Asset Management

Executive summary

Current weather events can cause significant disruption to the operation of train services and damage to rail infrastructure.

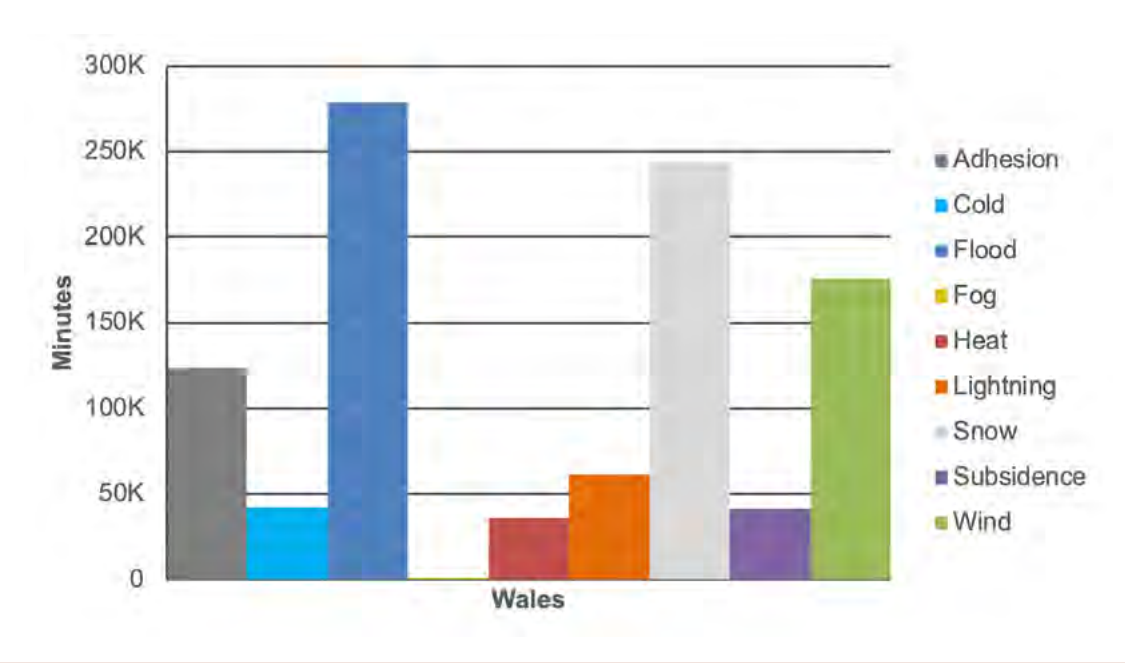
The UK Climate Change Projections 2018 (UKCP18) indicate that there will be a shift to a warmer climate with significant changes in sea level and the pattern and intensity of precipitation across the year.

Changes in the frequency and intensity of extreme weather events and seasonal patterns as a result of this could alter the likelihood and severity of weather event impacts. 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.

Wales Route is committed to supporting the improvement of weather and climate change resilience through the delivery of the Route-specific objectives. We have developed an understanding of our risks by; assessing our weather-related vulnerabilities (for example Figure 2), identifying root causes of historical performance impacts and using UKCP18 regional climate change projections.

Our 2014 Route WRCCA Plan set out our Route WRCCA Strategy, summarised the findings of our Route vulnerability and impact assessments, detailed the CP5 investments and actions that we would take to mitigate these and highlighted future considerations.

Figure 2
Wales Route weather attributed delay minutes –2006/07 to 2018/19



This updated plan reports our CP5 progress, sets out our plan for CP6 and beyond and updates our vulnerability and impact assessments to account for changes in the Network Rail WRCCA Strategy and guidance. Key highlights include:

- In 2017 the Network Rail guidance on the climate change projections to be used for impact assessment and planning was reviewed. This recommended using the UKCP09 Medium scenario, 90th percentile probability. With the release of the UKCP18 data this has been updated to the UKCP18 Representative Concentration Pathway (RCP) 6.0 scenario, 90th percentile[1],
- Development of a Weather Resilience and Climate Change Hub (currently on a SharpCloud interface) which integrates Operations, Route Asset Management and Maintenance in a singly accessed area,
- Highlighting high risk asset areas and using foresight to make reasonable judgements using the UKCP18 dataset,
- Replacing failed assets with increased resilience, replacing like for better instead of like for like,
- Implemented Remote Condition Monitoring (RCM) systems e.g. CCTV at high-risk asset sites – trialled at Black Bridge,
- Electrical heating of key switches on the network, increasing resilience to snow and cold weather, and
- Drainage funding combined with track, lineside and earthworks and delivered as combined drainage solutions maximising benefit to railway infrastructure.

Although the actions taken in CP5 improved aspects of our resilience, weather events continue to impact our operations. Wales Route is committed to addressing the risks through the timely, cost efficient and safe delivery of this Route WRCCA Plan.

[1]Previous recommendation used in the 2014 Route WRCCA Plans was UKCP09 High scenario, 50th percentile probability.

Introduction

The railway routinely operates in a wide range of weather conditions, however adverse and extreme weather can still cause significant disruption to our network.

Current weather events such as extreme rainfall, snow and high temperatures can cause delays, raise operating costs and increase safety risks. Recent examples include:

- The landslip at Porth, leading to 4 days of closures on the affected line,
- 16th March – low-pressure system, closing the Conwy Valley Line for up to several weeks,
- The Beast from the East, which saw widespread network disruption, and
- Storm Callum which saw the trackbed being washed away at Pontarddulais and Llandeilo, requiring around 300 tonnes of ballast being replaced on the line in addition to damaging 21 of Transport for Wales's fleet.

We monitor the impact of weather events on the performance of our network by using delay minutes and Schedule 8 delay compensation costs[2]. Incidents are recorded under 9 categories as follows:

- Adhesion – line contamination leading to traction loss, e.g. leaf fall, moisture, oils,
- Cold – e.g. ice accumulations on conductor rails, points and in tunnels,
- Flooding – standing or flowing water leading to asset damage or preventing trains from accessing the track,
- Fog – reduced visibility obscuring signals,
- Heat – high temperature impacts e.g. rail buckles, Temporary Speed Restrictions (TSRs), overheated electrical components,
- Lightning strike – e.g. track circuit and signalling damage or power system failure,
- Snow – e.g. blocked lines and points failures,
- Subsidence – the impacts of landslips, rockfalls and sinkholes, and
- Wind – e.g. trees and other items blown onto the track and into the Overhead Line Equipment (OLE) TSRs.

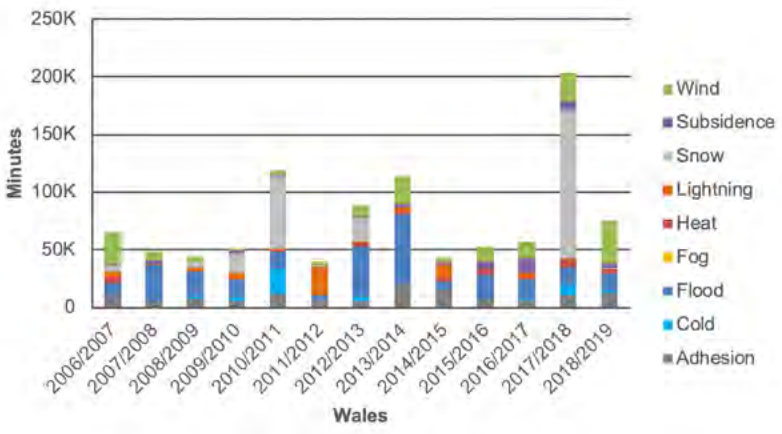
As these data include the duration and location of each disruption, and attribute cause, they give a high degree of granularity for use in analysing weather impacts and trends.

In the past 13 years (2006/07 to 2018/19) the average annual number of delay minutes attributed to weather for the Wales network was 77.1k. This represents 15.3 % of the total number of delay minutes for all cases over that period and equates to an average annual cost of £1.56m.

The impacts of severe weather events on the Wales Route can be clearly seen in Figure 3, for example:

- Snowfalls of 2009 through to 2011, 2012/13 and 2017/18,
- Wind in a number of years, but particularly 2006/07, 2013/14 and 2017/18,
- Flooding in all years, but particularly 2007/08, 2012/13 and 2013/14, and
- Lightning in 2011/12.

Figure 3
Wales Route weather attributed delay minutes by year – 2006/07 to 2018/19



[2]The compensation payments to passenger and freight train operators for network disruption.

Weather related costs can also be captured in Schedule 4[3] payments and the capital expenditure required for reinstating damaged assets.

The costs of weather attributed Schedule 8 and 4 payments and the wider socio-economic impacts of rail disruption on the UK justify continued investments to increase current weather resilience. Network Rail's collaborative approach to understanding weather impacts in the increasingly interdependent infrastructure, societal and environmental systems is key to identifying appropriate resilience responses that support our role in developing regional and national resilience.

Trends in the UK climate, and the UKCP18 data, indicate that there has, and will continue to be, a shift to a warmer climate. Figure 4 illustrates the changes in frequency and severity of Atlantic Winter storms and Figure 5 shows observed increases in the Central England Temperature record.

Figure 4
Intensity and frequency of high latitude Atlantic Winter storms[4]

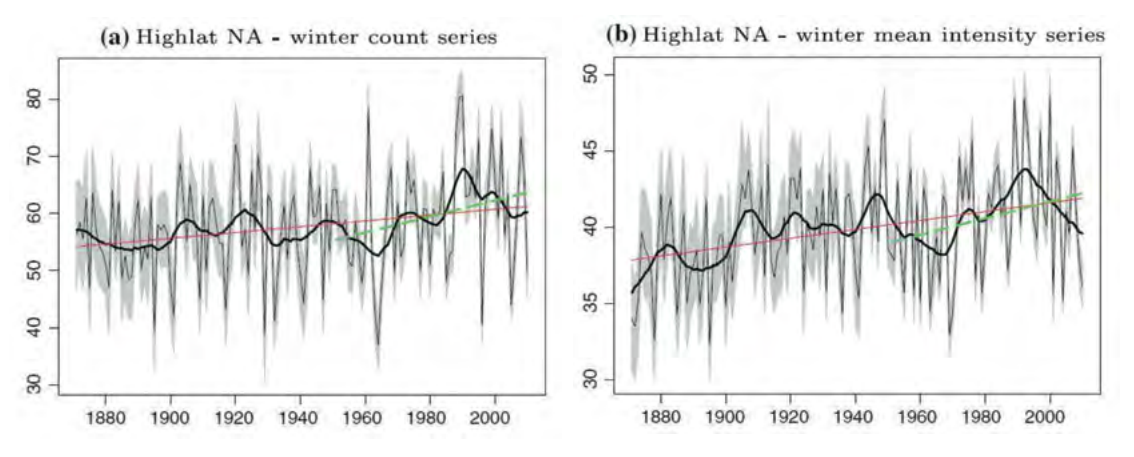
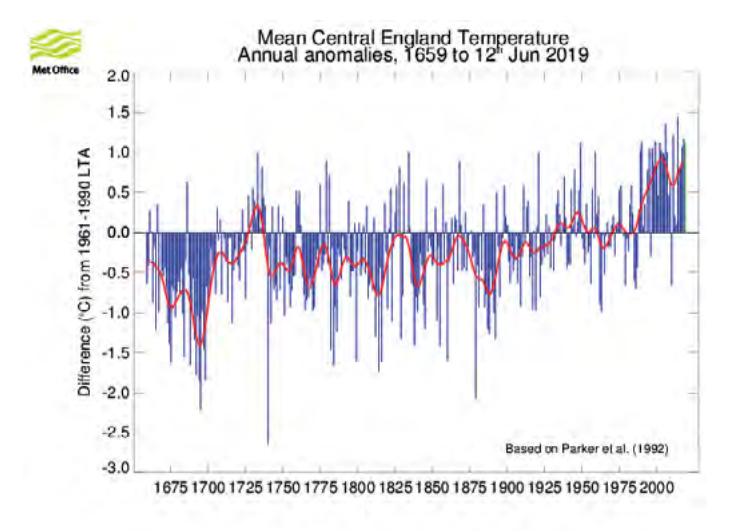


Figure 5
Mean Central England Temperature record[5]



[3]Compensation payments to passenger and freight train operators for Network Rail's possession of the network.
[4]Xiaolan L. Wang, Y. Feng, G.P. Compo, V.R. Swail, F.W. Zwiers, R.J. Allan, P.D. Sardeshmukh. 2012. Trends and low frequency variability of extra-tropical cyclone activity in the ensemble of twentieth century.
[5]Parker, D.E., T.P. Legg and C.K. Folland. 1992. A new daily Central England Temperature Series, 1772-1992. Int. J. Clim., Vol12, pp 317-342 reanalysis.

Introduction continued

UKCP18 projects an overall shift towards warmer climates with drier Summers and wetter Winters for the whole of the UK, although the level of change will vary across the regions.

Examples of the changes are shown in Figure 6 for the mean maximum Summer temperature and Figure 7 for Winter precipitation.

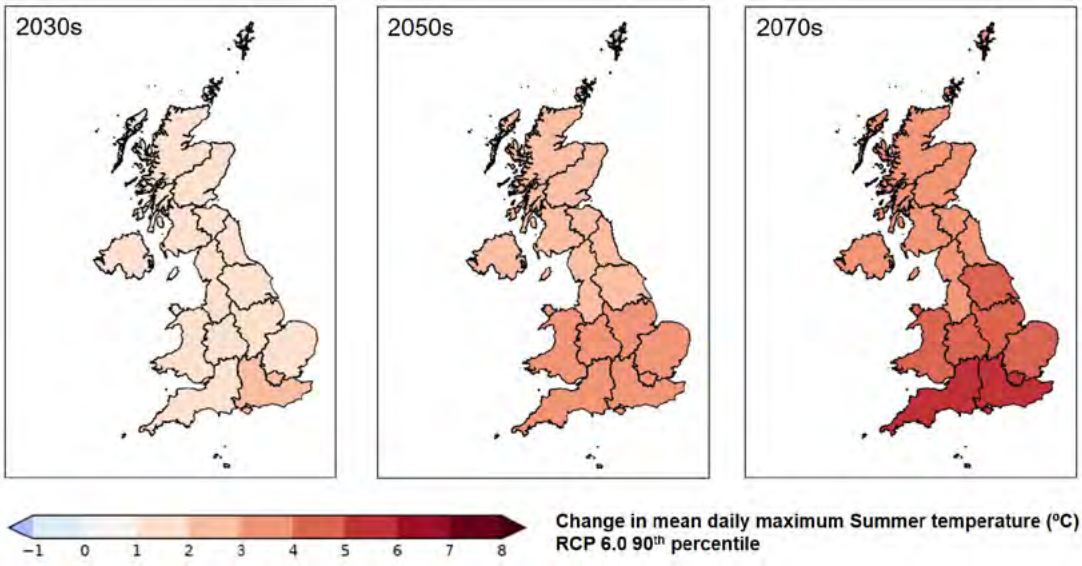


Figure 6
Change in mean daily maximum Summer temperature (˚C) (left to right; 2030s, 2050s and 2070s) based on a 1981-2000 baseline[6]

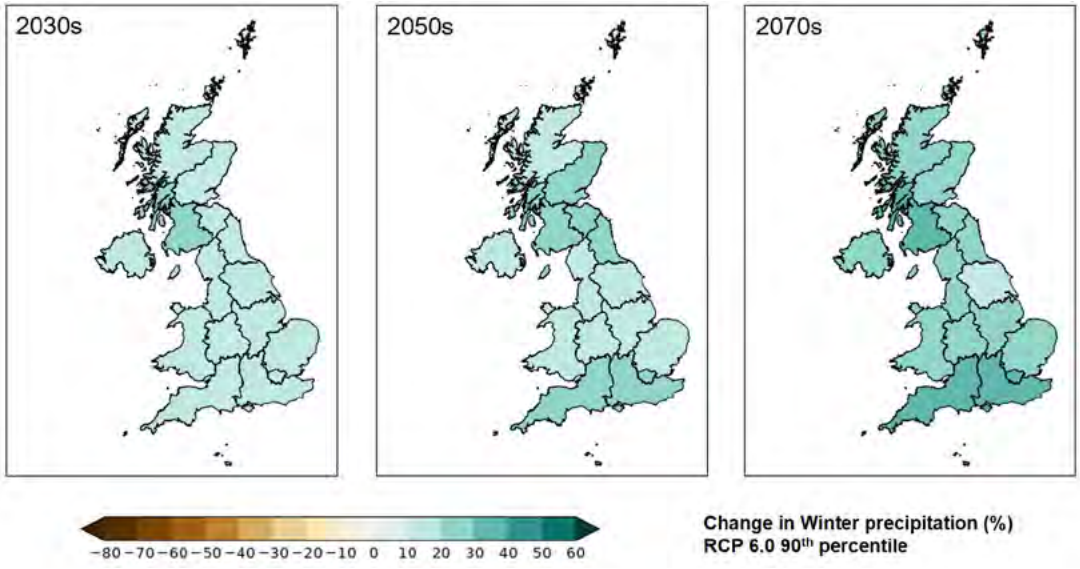


Figure 7
Change in Winter precipitation (%) (left to right; 2030s, 2050s and 2070s) based on a 1981-2000 baseline[7]

[6] © UK Climate Projections, 2018.
[7] © UK Climate Projections, 2018.

The potential increases in weather impacts due to climate change support the business case for enhancing weather resilience action and identifying actions that will deliver a railway that is safe and more resilient to the effects of weather, now and in the future.

The 2015 Paris Agreement unites nearly every nation in a common cause to undertake ambitious efforts to combat climate change and adapt to its effects. The central aim is for a strong global response to the threat that keeps the global temperature rise this century to well below 2˚C above pre-industrial levels and to pursue efforts to limit it to 1.5˚C.

The Department for the Environment, Food and Rural Affairs (Defra) and the Welsh Government provide climate change guidance in a number of ways to enable the assessment of future climate risks and the planning of adaptation actions to maintain and improve resilience. Most important to Network Rail and the Wales Route are:

- The UK Climate Projection data sets which are produced by the Met Office Hadley Centre, and
- Wales' Climate Change Adaptation Plan (Wales' CCAP) – 'Prosperity for All: A Climate Conscious Wales'[8].

The UK Climate Projection data sets are produced for use in assessing the future risk and impacts of the possible climate projections for the UK. They are used by government to conduct the 5 yearly UK Climate Change Risk Assessment (UKCCRA) and by individual organisations to understand and plan for their specific risks.

For the 2014 Route WRCCA Plans Network Rail's national guidance was to use the then current UKCP09 High scenario, 50th percentile probability projections as an appropriate benchmark on which to base evaluations and decisions. In 2017 Network Rail commissioned a review of its guidance taking into account the Paris Agreement, advances in climate science, additional years of climate observations and the then pending release of the UKCP18 projections dataset.

The conclusions of the review[9] were that as a safety critical focused organisation and major UK infrastructure manager the most appropriate UKCP projections to use are:

- UKCP18 – RCP 6.0 90th percentile probability as the baseline scenario for evaluations and decisions, and
- RCP 8.5 90th percentile as the sensitivity test on assets with a lifespan beyond 2050.

Analysis in this report has been updated using the UKCP18 projections where available. It should be noted that some UKCP09 parameters have not been updated in UKCP18. Where this is the case, the UKCP09 data has been used and this is clearly indicated in the report.

[8]The most current version of the document should be consulted on the www.gov.wales/climate-change pages.

[9]Identifying a climate change planning scenario, JBA Consulting 22/02/18.

Introduction continued

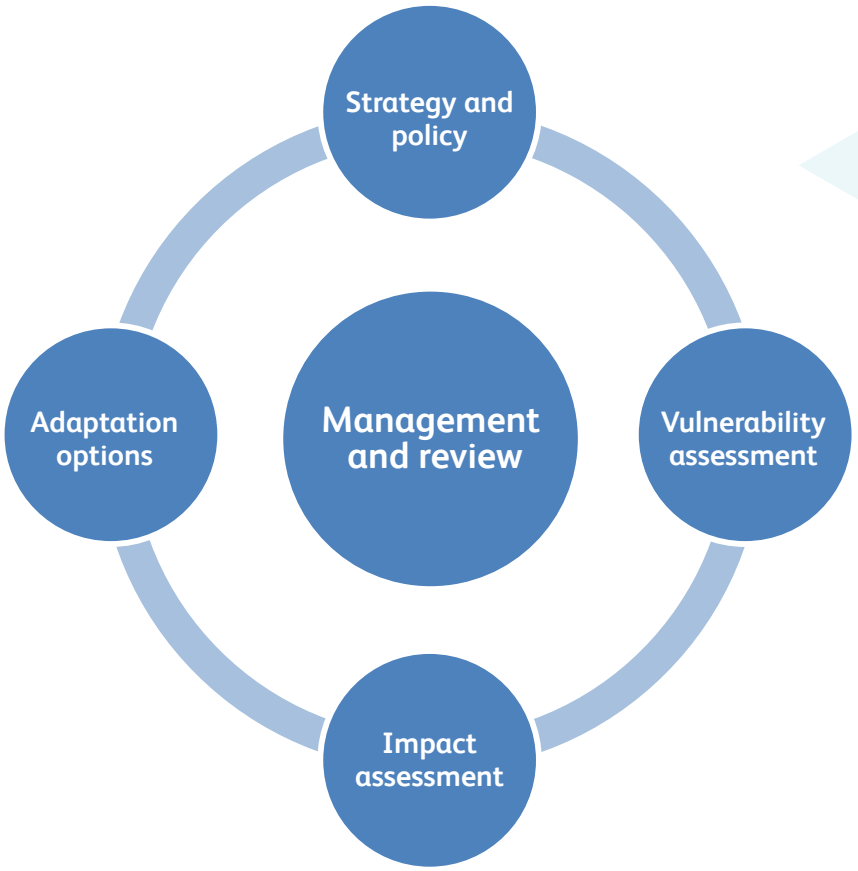
Wales' CCAP is based upon the UK Climate Change Risk Assessment which is published by Defra every 5 years.

It contains a summary of the impacts expected for each sector of the Welsh economy and tables detailing adaptation actions that the Welsh Government requires those sectors to undertake to ensure the continuing resilience of the Welsh Economy.

The sectorial actions are apportioned to key stakeholders such as regulators and national infrastructure operators. Details of the Transport Sector actions in Wales' CCAP that are apportioned to Network Rail and hence the Wales Route are included in Table 5 in the Wales Route WRCCA Actions section of this Plan.

Although climate change projections include uncertainties, associated with natural climate variability, climate modelling and future emissions, they and the actions from Wales' CCAP can be used to provide guidance on the direction that the UK climate may take. Wales Route has therefore used the projections in the creation of this WRCCA Plan.

Figure 8
Weather resilience and climate change adaptation framework



To ensure a consistent approach to WRCCA consideration and action across Network Rail an iterative framework of key management stages is used (see Figure 9). The same framework has been applied to develop this Route WRCCA plan.

Network Rail will take a range of soft (changes to processes, standards, specifications and knowledge and skill base) and hard (engineered solutions to increase resilience) WRCCA actions tailored to the level of risk and the strength of evidence for it. Examples include:

- Do nothing/minimum – the option to do nothing/minimum and the risks should be evaluated,
- No regrets – increasing current and future resilience without compromising future flexibility,
- Precautionary – investment in adaptation now in anticipation of future risk, and
- Adaptation pathways – staged adaptation balancing future risk and current investment funds through phased investment enabling assets to be retrofitted cost-effectively in the future.

The following sections provide findings from the updated Wales Route vulnerability and impact assessments, and detail: progress on the CP5 resilience actions, actions planned for CP6 and additional actions for future consideration.

Figure 9
Tree on the line, Blaenau Festiniog, Storm Callum – 21st October 2018

Wales Route WRCCA Plan

Network Rail's WRCCA Policy sets out the approach to achieving our company's vision of 'A better railway for a better Britain' by creating a railway that is safer and more resilient to weather impacts now and in the future.

It commits the business to seeking to apply the following key principles:

- Including current and future weather impacts in our risk analysis and investment decision making and embedding climate change specifications into policies, procedures and standards,
- Adapting at construction and at asset renewal, designing schemes to be resilient in the most cost-effective manner to and/or with passive provision for future weather conditions,
- In the event of catastrophic asset failure replacing on a like for better basis rather than like for like, considering the whole life cost and the best strategy for managing the railway,
- Identifying high priority locations for proactive resilience interventions and working to identify funding sources for projects not included within agreed Control Period funding, and
- Working with stakeholders to identify opportunities to enhance our preparation for, response to and recovery from adverse/extreme weather events.

Figure 10
Landslip at Dina Powys in late 2018 – Storm Callum

Wales Route Plan

The Wales Route is committed to supporting the delivery of this strategy through Route-specific WRCCA objectives:

- Improve understanding of climate change impacts and cost-effective resilience measures,
- Predict the impacts of weather and use weather forecasting and asset monitoring to manage locations vulnerable to adverse weather,
- Establish a coastal and estuarine asset management strategy to identify future weather risks and develop a plan to mitigate against sea level rise,
- Develop and manage a Route WRCCA plan to inform current and future Control Period investment plans and work banks,
- Maintain and improve relationships with external organisations, including NRW and the EA, for improved weather resilience and environmental awareness,
- Continue to monitor and improve operational flood plans and weather alerts,
- Improve asset records, inspection, and maintenance regimes in order to support the replacement and/or maintenance of high-risk or poorly performing assets, and
- Work towards reducing the carbon footprint of our operations in accordance with the Energy Act (2011).

Through these objectives, Network Rail's corporate commitments are applied in the context of Wales 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 Wales Route and the whole railway network.

Wales Route vulnerability assessment

In the 2014 Route WRCCA Plan this section provided details of the general vulnerability of the national rail network and Wales Route's specific vulnerabilities to current weather impacts, and regional climate change projections.

This Plan updates the vulnerability assessment taking account of:

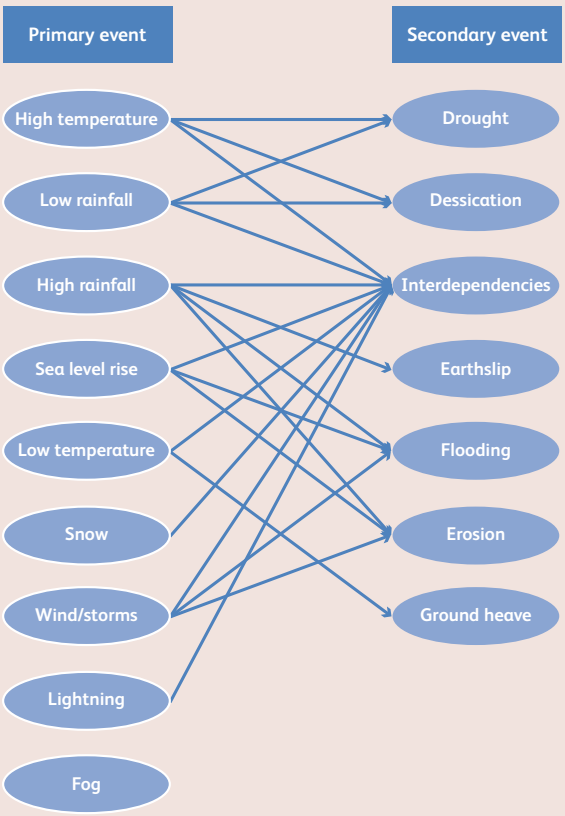
- Advances in climate science,
- Improvements in our understanding of the impacts of weather and future climate, and
- Changes in Network Rail's climate change policy and guidance since the last plan was published.

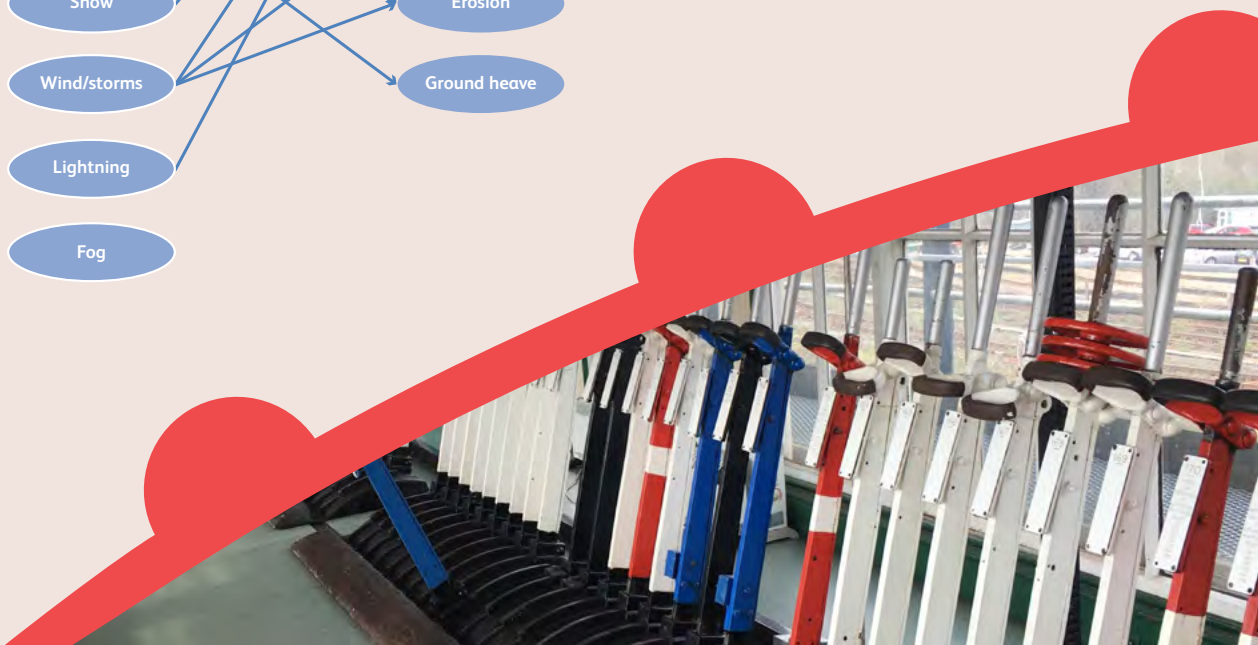
Network-wide weather vulnerability

The rail network and its component assets are sensitive to the effects of a number of weather types. These manifest as either primary events (one weather type) or secondary events which are the result of these and/or a combination of weather types. It should be noted that these are the mechanisms by which impacts are felt, not the actual impacts themselves. Figure 11 illustrates the primary event types and their related secondary event types.

Managing a complex array of assets with varying ages, condition and weather vulnerabilities across a wide range of bio-geographic regions in a variety of climates is a complex challenge. Interdependencies with other sectors of the economy, for example power, telecoms and water infrastructure add to this.

Figure 11
Examples of primary and secondary events





Wales Route vulnerability assessment continued

Understanding current weather impacts is essential for assessing the probable effects of climate change and for the planning and implementation of appropriate cost-effective resilience investments to adapt the network to the future impacts.

The 2014 Plan outlined how we monitor the impact of weather on the performance of our network by using Schedule 8 delay compensation costs and the process we used to carry out a detailed analysis of this data to understand:

- The characteristics of weather events that trigger failures,
- The thresholds at which failure rates change, and
- Trends in the failures of assets and the performance of the network.

The key findings of this work were that earthworks were the asset most affected by rainfall, OLE was most sensitive to wind and that temperature impacted the widest range of assets. These and the detailed outputs behind them have been disseminated to Network Rail's national asset function teams and the Routes for use in asset maintenance and investment planning.

As the above work was based upon current data the changes to Network Rail's national guidance for the climate change planning projections have not changed the conclusions.

We continue to monitor and analyse this data and we now have a 13-year series increasing our capacity to discern trends in failures and performance. We have now made the raw data available and we are continuing to look at how we can improve its use including through trend and performance reporting on a period, quarter and annual basis.

Route weather vulnerability

The Wales Route manages a large percentage of Network Rail's coastal assets; 34 miles are vulnerable to overtopping, coastal erosion and storm surges. In CP5 earthworks saw the brunt of weather-related vulnerability.

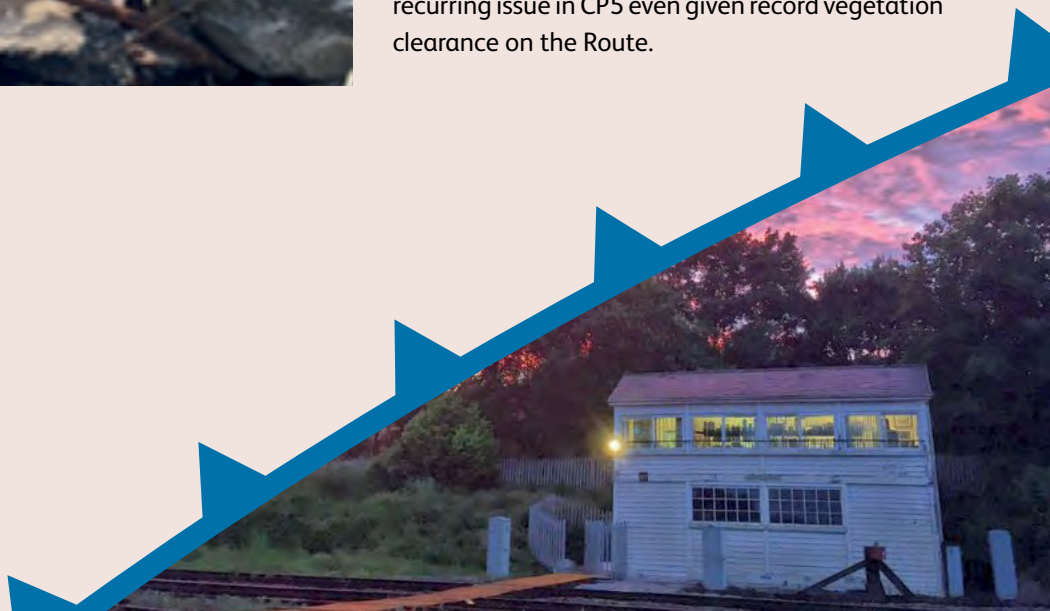
Several landslips occurred in October 2018 as a result of Storm Callum, in addition to several cases of falling vegetation on the line due to the same storm system. The persistent, prolonged and heavy rainfall increased the impact of high winds to Earthwork assets. Following the trend for increased storm intensity and frequency, isolated heavy rainfall events have occurred on the Wales and Boarders Route, for example Storm Eric, flooding and closing the HNL line near Nant-y-Derry, and most recently, 16th March – low-pressure system causing multiple asset failure at Conwy Valley Lines (Figure 12).

Figure 12
Low-pressure system – 16th March 2019

Sections of the earthworks in South Wales failed in extreme rainfall brought about by Storm Callum, see Figure 13.

Figure 13
Landslip at Dinas, BRY – October 2018

Many of the adhesion-related incidents relate to the 'leaf fall season' and are a result of leaves on the railhead. Wales Route has a relatively high level of vegetation and removing lineside trees can reduce disruption. In the past vegetation management has been specifically focused on this, however, within Wales, this is not always entirely effective as 'third-party leaves' also contribute to railhead contamination. This continued to be a recurring issue in CP5 even given record vegetation clearance on the Route.



Wales Route vulnerability assessment continued

Future climate change vulnerability

The complexity of the relationship between weather events and climate means that the UKCP18 data set cannot forecast future weather events. It projects modelled probabilistic trends that can be used to understand the potential future risks associated with certain climates and the likely changes in weather events/parameters. Network Rail therefore uses projections from the UKCP18 data set as a future baseline to understand potential risks and for making informed strategic decisions to increase future weather resilience.

UKCP18 provides regional projections across 13 administrative regions in Great Britain (Figure 14). Projections that cover the Wales Route are provided by the Wales region.

In the 2014 Plan charts were generated using the UKCP09 High emissions 50th percentile probability scenario for the three regions to show the projected changes in temperature and precipitation from the 2020s to the 2080s relative to the baseline climate of the 1970s (1961-1990).

For this report the charts and text have been updated in line with the current Network Rail climate change guidance which uses the current UKCP18 climate projections where available. Replacing the UKCP09 emissions scenario used in the 2014 report with the UKCP18 emissions scenarios noted in the introduction has involved a number of changes to the data used. These include:

- Using a new baseline period of 1981-2000,
- Moving from projection time periods of 30 years (2020, 2050, 2080) to shorter 20 year periods (2030, 2050, 2070), and
- The use of UKCP18 RCP 4.5 95th percentile data for sea level rise as a proxy for RCP 6.0 data (UKCP18 did not model RCP 6.0 for sea level rise).

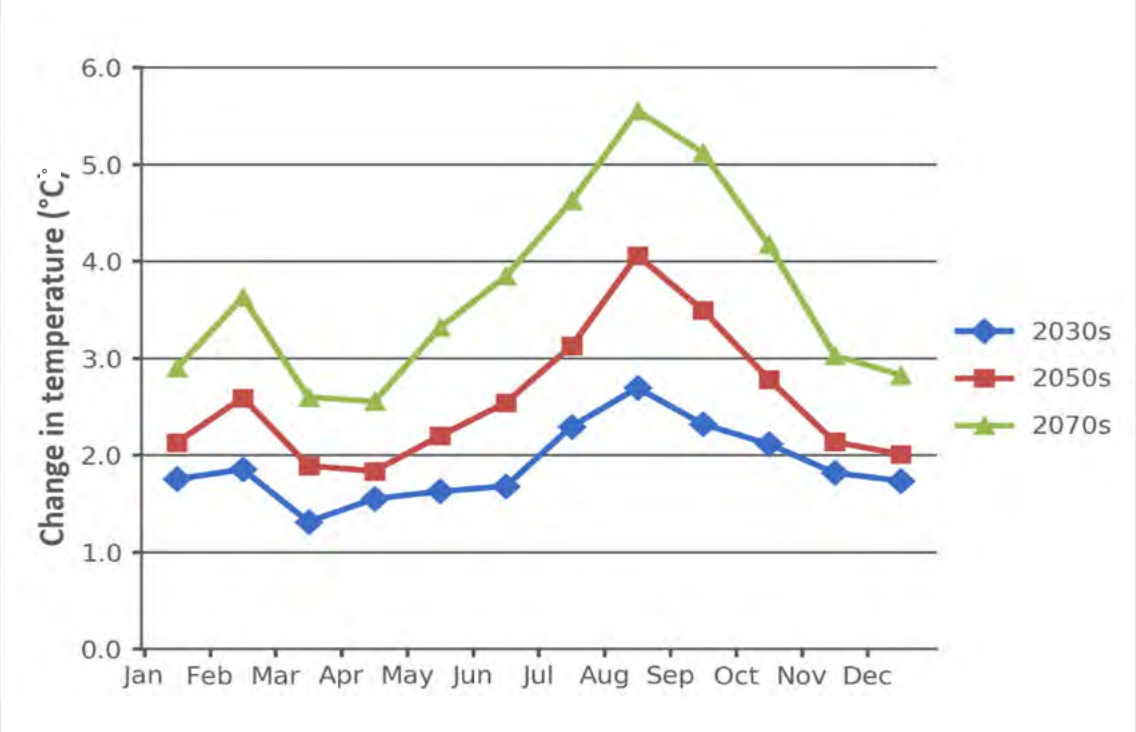
Figure 14
Map of UK administration regions used in UKCP18[10]

[10]Source: Met Office © Crown Copyright 2019 [available from UKCP18 Guidance: Data availability, access and formats: https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/research/ukcp/ukcp18-guidance-data-availability-access-and-formats.pdf]

Mean Daily Maximum Temperature change

The highest mean Summer temperatures are expected to be in August for both the 2050s and 2070s, with increases of 4.1˚C to 23˚C and 5.6˚C to 24.5˚C respectively. In Winter the highest mean temperatures will be seen in December with increases of 2.0˚C to 9.3˚C for the 2050s and February for the 2070s with increases of 3.6˚C to 10.3˚C.

Figure 15
Wales, mean daily maximum temperature change (˚C) (RCP 6.0 90th percentile



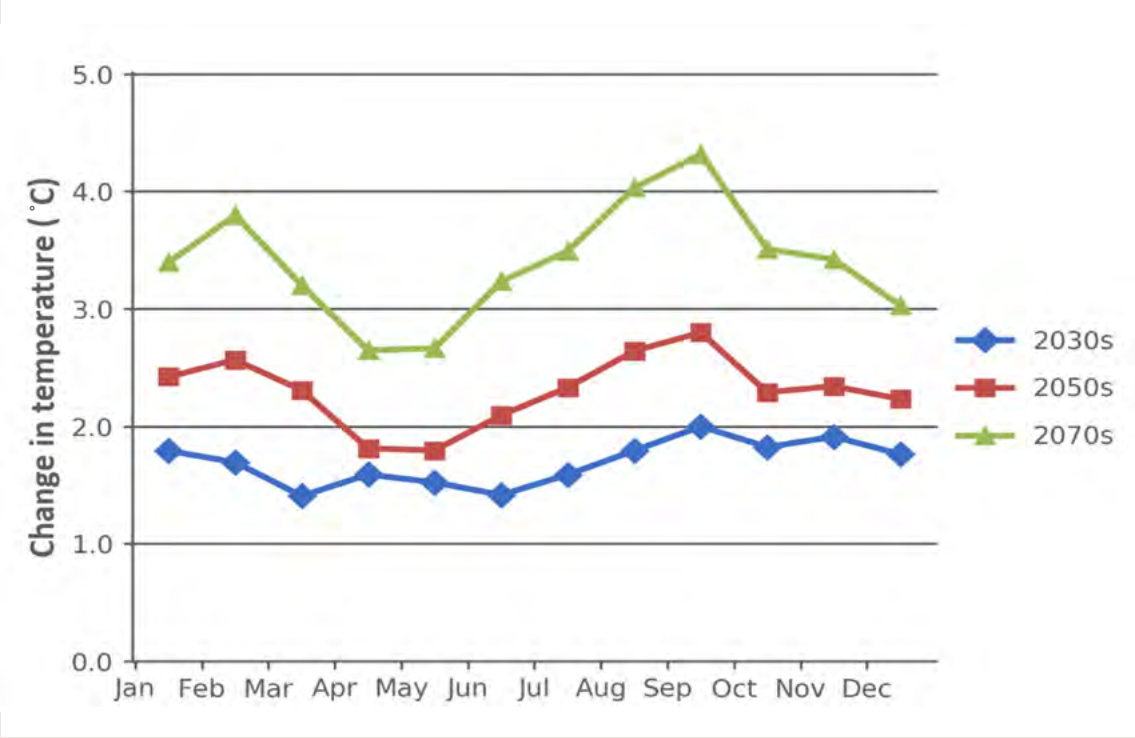
Wales Route vulnerability assessment continued

Mean Daily Minimum Temperature change

The highest mean minimum temperatures for Summer are expected to be in August, with increases of 2.6˚C to 13.5˚C by the 2050s and 4.0˚C to 14.9˚C by the 2070s.

The lowest mean minimum temperatures will occur in February with expected increases of 2.6˚C to 3.7˚C by the 2050s and January for the 2070s with increases of 3.4˚C to 4.7˚C.

Figure 16
Wales, mean daily minimum temperature change (˚C) (RCP 6.0 90th percentile)



Mean daily precipitation

The UKCP18 narrative for mean daily precipitation in Wales is of significantly wetter Winters and drier Summers. Network Rail's chosen climate change planning scenario (RCP 6.0 90th percentile) shows the upper range of Winter rainfall increases, but does not illustrate the highest potential Summer rainfall reductions. These are best represented by the RCP 6.0 10th percentile projections.

Figure 17 therefore plots the RCP 6.0 50th percentile projections with error bars that indicate the wider range of change associated with the 10th and the 90th percentiles.

In the 2050s and 2070s, November and December will be the wettest months with mean daily rainfall increases of 37.7% and 22.4% respectively to 7.2mm/day for both. The driest month will be July showing decreases of 41.6% to 1.5mm/day by the 2050s and 49.0% to 1.3mm/day by the 2070s.

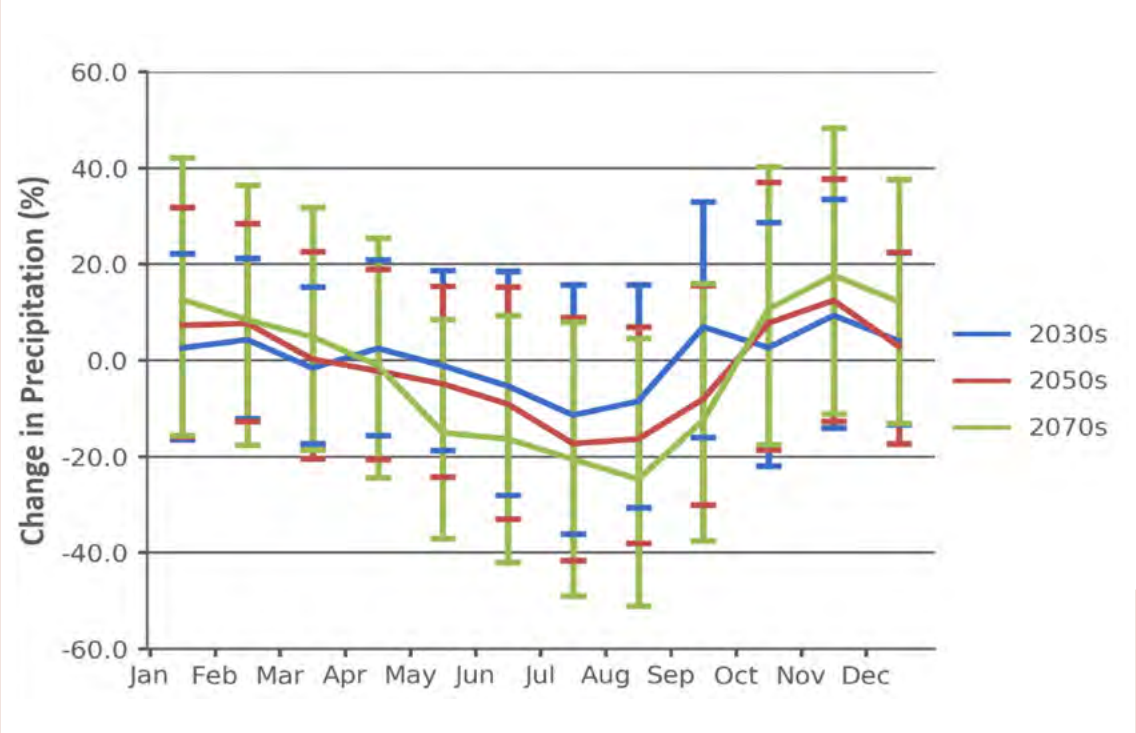


Figure 17
Wales, mean daily precipitation change (%) (RCP 6.0 50th percentile with the wider range showing the 10th and 90th percentiles)

Wales Route vulnerability assessment continued

Storm intensity and river flows

In addition to changes in total rainfall, climate change is also expected to increase the frequency and severity of river flooding events and individual rainstorm events, Summer rainstorms will show the largest increases.

NRW do not currently produce guidance on climate change uplifts to rain storm intensity, so the only guidance available is that provided by the EA. This uses the UKCP09 Medium emissions scenario and recommends that rain-storm intensities should be increased by 10 % for the 2050s and 20 % for the 2080s.

This guidance is currently being updated to use UKCP18 but presently uses the older climate projections UKCP09.

NRW does provide guidance on uplifts for river flows in all of the Welsh catchments, however the scenarios modelled do not match the Network Rail planning scenario. NRW modelling is the only source of guidance available for the Western Wales catchment, but for Dee and Severn catchments EA data also exists. Table 1 summarises the guidance and indicates the sources used.

Table 1
River flow uplifts (UKCP09)

River basin	2050s uplift	2080s uplift
Severn[11]	25 %	35 %
Western Wales[12]	25 % or 40 %	30 % or 75 %
Dee[13]	20 %	25 %

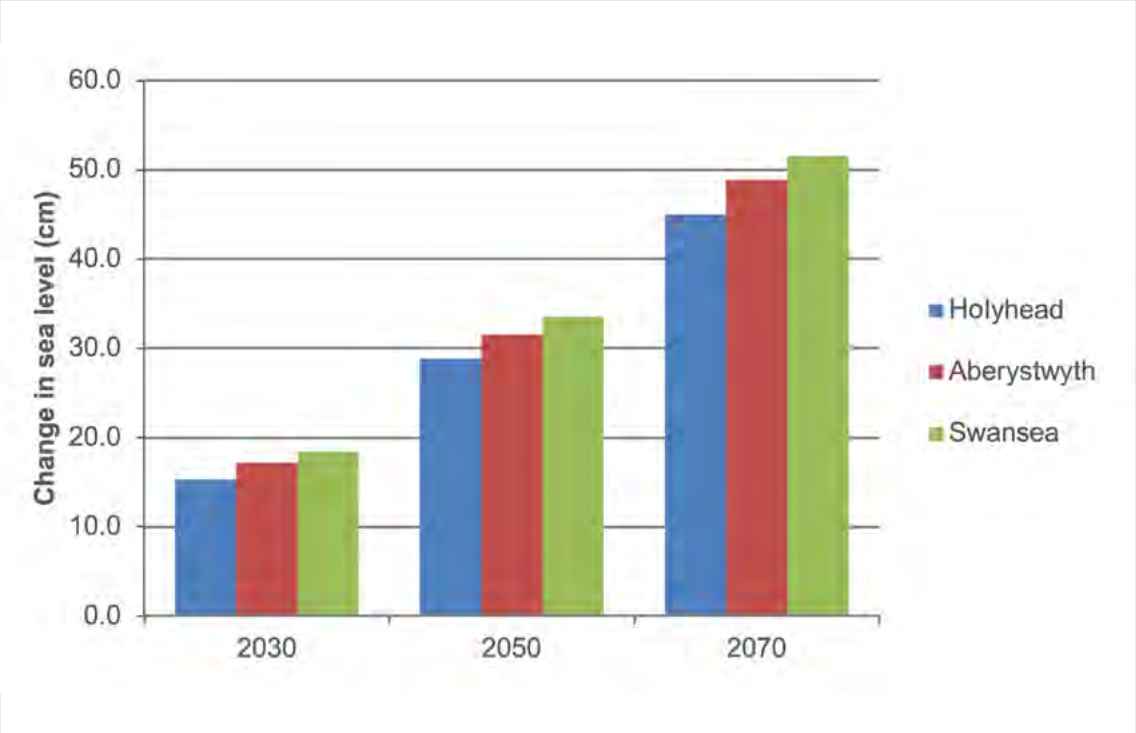
[11]EA Higher Central uplifts used – compatible with Network Rail planning scenario.
[12]NRW Central or Upper end uplifts used – lower or higher than Network Rail planning scenario.
[13]EA Higher Central uplifts used – compatible with Network Rail planning scenario. Sea level rise data in UKCP18 is not available for RCP 6.0, instead RCP 4.5 is used as a proxy on the recommendation of the Met Office. This is the most compatible with the Network Rail Primary planning scenario.

Sea level rise

Sea level varies around the coast due to differences in coastal morphology and isostatic rebound since the last ice age. As this also affects the degree of sea level rise, projections have been obtained for 3 coastal locations in the administrative region covered by the Wales Route[14].

Swansea will see the highest rise by 2050 and 2070 of 33.6cm and 51.6cm respectively and Holyhead will see the lowest at 28.8cm and 45.1cm.

Figure 18
Sea level rise projections for Wales (cm), RCP 4.5 95th percentile



[14]Sea level rise data in UKCP18 is not available for RCP 6.0, instead RCP 4.5 is used as a proxy on the recommendation of the Met Office. This is the most compatible with the Network Rail Primary planning scenario.

Wales Route impact assessment

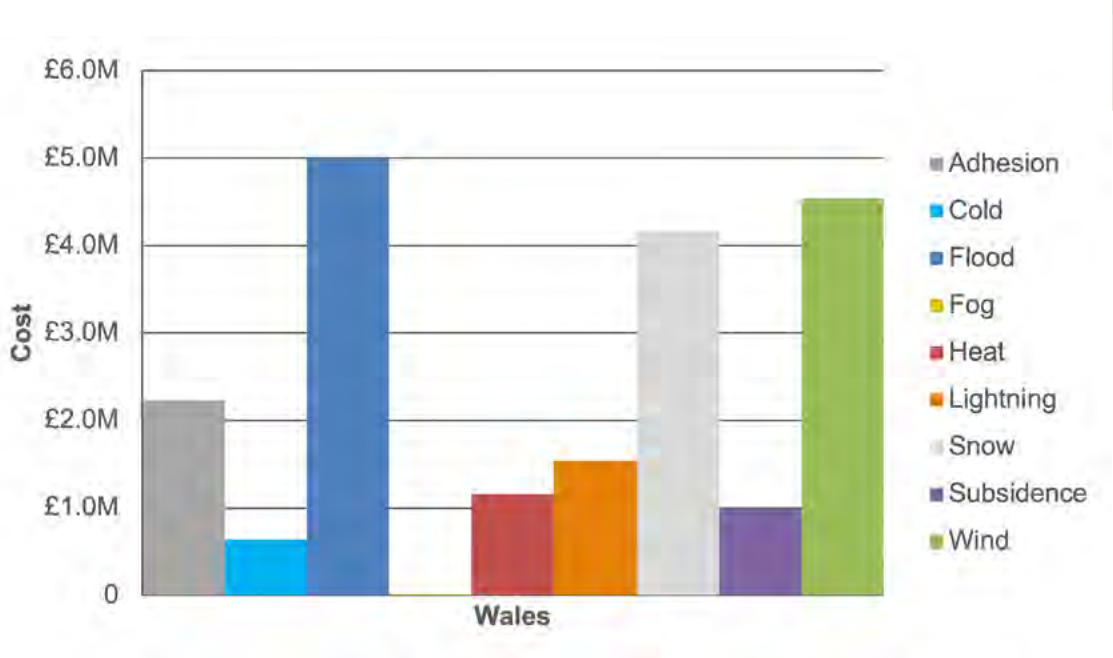
This section provides an update of the Wales Route weather impact assessment findings published in the 2014 Wales Route WRCCA Plan, including annual performance impacts and identification of higher impact locations on the Route.

Performance impacts

The impact of weather events on our network's performance is monitored using delay minutes and Schedule 8 delay compensation costs as proxies. As these data include the duration and location of each disruption, and attributes cause, they give a high degree of granularity for use in analysing weather impacts and trends.

In the 2014 plan eight financial years of Schedule 8 data were analysed to give an assessment of the weather impacts for the Wales Route. This Plan updates that assessment using additional data from the past 5 years, see Figure 19.

Figure 19
Wales Route weather attributed Schedule 8 costs – 2006/07 to 2018/19



The updated analysis shows that whilst flooding continues to be the most significant weather impact costing a total of £5.0m in the last 13 years, the cost impacts of snow and wind have increased markedly. These now significantly exceed the costs of the remaining impacts, with both having roughly doubled. Wind is now the more costly of the two at £4.5m (snow is £4.2m) over the same period.

Climate modelling cannot provide future weather forecasts, but it does give us projections for the trends in future weather patterns. Combining these trends with our analysis of current weather impacts allows us to understand the future vulnerability and possible impacts upon the Wales Route.

There is a high degree of confidence in the UKCP18 projections for temperature, rainfall and sea level rise, but lower levels for wind, lightning and snow fall. Planning for the latter parameters should still be undertaken, but outputs should be more flexible to acknowledge the higher possibility of alternative climate outcomes.

The findings from the combined analysis of current weather impacts and UKCP data (UKCP09 for wind, lightning and snow and UKCP18 for temperature, precipitation and sea level rise) will be used in the prioritisation of resilience actions as summarised in Table 2 below.

Table 2
Prioritisation of weather-related impacts on Wales Route

Impact	Schedule 8 Cost per year[15]	Climate projection[16]	Prioritisation
Wind	Average £0.35m Highest £1.09m	Changes difficult to project, however generally expected to increase	High
Adhesion	Average £0.17m Highest £0.42m	Complex relationship between multiple causes and their climate projections	Medium
Snow	Average £0.32m Highest £2.85m	Changes difficult to project, but increases in Autumn, Winter and Spring minimum temperatures suggest reduced snow days	Medium
Lightning	Average £0.12m Highest £0.57m	Changes in storms difficult to project, however generally expected to increase	Medium
Cold	Average £0.05m Highest £0.26m	Increases in mean daily minimum temperatures in Autumn, Winter and Spring ranging from 1.8˚C in April and May to 2.8˚C in September for the 2050s and 2.6˚C in April to 4.3˚C in September for the 2070s	Low
Subsidence	Average £0.08m Highest £0.38m	Increases in mean daily rainfall across late Autumn, Winter and early Spring months, for example; 18.9 % in April and 37.7 % in November by the 2050s becoming 25.4 % in April and 48.2 % in November for the 2070s. Increased frequency and intensity of Winter and Summer storms. Decreases in mean daily rainfall for late Spring through to early Autumn, for example: 24.2 % in May and 41.6 % in July by the 2050s becoming 37.1 % in May and 51.1 % in August by the 2070s	High
Heat	Average £0.09m Highest £0.46m	Increases in mean daily maximum temperatures range from 2.0˚C to 2.6˚C (Winter) and 2.5˚C to 4.1˚C (Summer) by the 2050s. In the 2070s this becomes 2.8˚C to 3.6˚C and 3.8˚C to 5.6˚C respectively	Medium
Flooding	Average £0.38m Highest £0.68m	Increases in mean daily rainfall for late Autumn through to early Spring and increased intensity and frequency of Winter and Summer storms (see subsidence)	High
Fog	Average <£0.01m Highest <£0.01m	This is a complex picture with low confidence[17], however possible seasonal changes for the 2080s have been indicated as: Winter -27 %, Spring -52 %, Summer -57 % and Autumn -27 %	Low

It should be noted that the rate charged for Schedule 8 delays increased in 2015 and that this will have been responsible for some of the increase in delay costs. However, this affected all weather-related delays equally and does not affect their relative impact rankings.

[15]Based on Schedule 8 costs per year over the last 13 years from 2006/07 to 2018/19.
[16]UKCP09 projections still used for wind, snow, lightning and fog as UKCP18 does not contain updates.
[17]Probabilistic data is not available from the UKCP09 data sets, this has been sourced from a supplementary UKCP09 report and represents the average of 11 models run using the medium emissions scenario.

Wales Route impact assessment continued

Identification of higher risk locations

Since the publication of the last Plan the Wales Route network has continued to experience extreme weather events that have challenged weaknesses in our assets and operations. Climate change projects more frequent and intense extreme weather events, so understanding the impacts of current and future events is critical to investment decision making.

The impacts of weather on our Route are captured via the delay minute and Schedule 8 cost data and input into our METEX GIS system along with gridded observed weather data. The outputs of this allow high impact frequency/cost sites to be identified and targeted for detailed assessment to:

- Verify the attribution of the delay(s) to a weather impact(s),
- Determine the root cause of the delay,
- Identify if resilience action has been taken in the past or is already planned, and
- Generate and prioritise appropriate resilience actions.

In addition to the above assessments Wales Route has also identified potential future risks and resilience actions based on climate change projections and Route knowledge.

Combining these findings allows us to proactively identify potential investments that would address current weaknesses and mitigate and/or enable the mitigation of future risks. This approach is critical in creating a railway that is safer and more resilient to weather impacts now and in the future.

Adhesion impact assessment

Between 2006/07 and 2018/19 adhesion related incidents accounted for an average of 9,513 delay minutes and £0.17m in Schedule 8 costs per year. This is 12.3 % of Wales' annual average weather-related delay minutes and 11.1 % of the annual average cost.

In the Autumn of 2018/19 there was particularly poor performance considering that there was a record amount of de-vegetation work, Rail Head Treatment Train usage and adhesion inspections on the Wales Route. Between 2006/07 and 2018/19 adhesion accounted for 123,675 minutes of Schedule 8 delays, the fourth highest related impact overall. The trends relating to changing climate become difficult to apply to adhesion as the changing temperatures, severity of storms, and season lengths will all play factors in leaf fall and vegetation growth. One important area relating to adhesion is working with Transport for Wales in introducing new fleet that will include anti-slip technology which works year-round. This will combat the changing season lengths, shifting leaf-fall patterns and general wheel-slip performance.

Figure 20
Rail Head Treatment Train

Fog impact assessment

Between 2006/07 and 2018/19 fog related incidents accounted for an average of 28 delay minutes and less than £0.01m in Schedule 8 costs per year. This is less than 0.1 % of Wales' annual average weather-related delay minutes and less than 0.1 % of the annual average cost.

Buildings

Buildings are in a unique position when considering assets on the Wales Route. The principal risk when taking UKCP18 projections into account is that of flooding. Although average rainfall is expected to decrease in the Summers and increase slightly in the Winters up to 2050, there is an overall increase in flood risk to buildings in Wales. There is an increase of 25-170 % in the risk of river or tidal flooding to non-residential buildings in Wales, and 40-240 % for all properties in Wales. This will likely impact our building assets on the Wales Route. The flood risk does not come from an overall increase in mean precipitation values, rather increased frequency and severity of isolated rainfall events when taking UKCP18 projections into account.

Although flooding may affect buildings, the costs associated with flooding of buildings, except stations, is less likely to impact Schedule 8 costs, than flooding on the line and surrounding areas.

Similar to flooding, the increase in frequency and severity of isolated rainfall events correlates with the potential for more frequent and intense wind events due to the increase in overall energy in the troposphere. This impact could lead to current building assets being put at risk and as a result in these conditions, closed, due to increasing sheer wind speeds. The Route is looking at implementing stringent requirements to the design of station canopies to take the increased risks of wind and rain will bring to the Route. Implementing the requirements to build-in resilience to station canopies will likely incur cost but will be recovered through reduction or avoidance in Schedule 8 costs as an offset. This applies to the entire Wales Route and asset infrastructure as certain bridges, station canopies, structures and lines can see reduced line speed, and even closures to extreme wind events.

The risks associated with wind and flooding are likely to increase overall towards 2050 and by extension, 2070. The closure of stations and other building assets due to these factors will likely increase, and potentially see a rise in Schedule 8 costs relating to these events. Something not noted is the non-Schedule 8 delay minute costings, e.g. damage to building assets on the Route due to flooding and/or high winds. Creating resilience on current building assets is a key factor to creating and keeping Wales Route resilient to climate change across Control Periods.

The last major WRCCA factor which has a high probability of impacting building assets is **heat**. The current UKCP18 projections predict an increase in heatwave occurrence, severity, and length in addition to higher mean average daily temperatures. These all have to be taken into account as buildings in the UK are not currently designed with frequent, high temperatures in mind. The comfort to both workers, passengers and other stakeholders that have access to our buildings is a key factor to monitor and alleviate before these extremes in weather become the norm.

To mitigate climate change going forward all franchised buildings within the Route are currently being assessed for Energy Performance in accordance with the Energy Act (2011). Work has been completed to meet minimum performance requirements will be developed to increase the efficiency of the franchised portfolio within the Route.

CP6 climate change mitigation and resilience actions

Looking forward to CP6 there are several targets set to mitigate the Route's impact on climate change. These are in the form of reductions to Route-wide energy usage, and as a result, reduction in CO2 emissions:

- Energy reduction of 18% by the end of CP6, against baseline CP5 exit baseline figure, and
- CO2e reduction of 25% by the end of CP6, against the CP5 exit baseline figure.

These targets will be achieved thorough several methods including replacing the platform lighting at around 65-70 stations. LED replacements have been shown to significantly reduce energy consumption, where lighting is often the single largest energy use. Further mitigation will be in implementing new building design for CP6, where sustainability will be considered from the outset. This has been particularly relevant for our new depot designs, where we are working towards self-sufficiency from an energy perspective, including using a variety of novel technologies to support this vision.

In the CP6 scheme planning mentioned above future resilience of assets and energy efficiency has been considered. This can be in terms of new assets or retrofitting measures to existing assets to meet the changing and evolving WRCCA risks discussed in this Plan. An example of this will be the use of passive cooling delivering significant energy savings and providing extra resilience by preventing asset failure in the higher extremes of Summer temperatures that will occur.

In addition to the plans already in place for CP6 there is potential to attract third-party funding to deliver renewable energy generation on unused land currently under Network Rail ownership. These schemes will involve reselling the renewable energy to the Route which would lead to a reduction in risk and costs associated with the volatile energy trading market. An added benefit to Network Rail and Wales Route is that of providing the Route with zero carbon electricity, generated on our own land assets.

Overall benefits of the CP6 Energy work-bank are currently costed at around £6m for capex. Through the delivery of the schemes listed above, including novel energy recovery systems, use of photovoltaic arrays and introducing energy efficient lighting there should be a delivery of around £900k annual savings, in addition to a reduction to CO2 emissions and integrated resilience for the building asset portfolio.

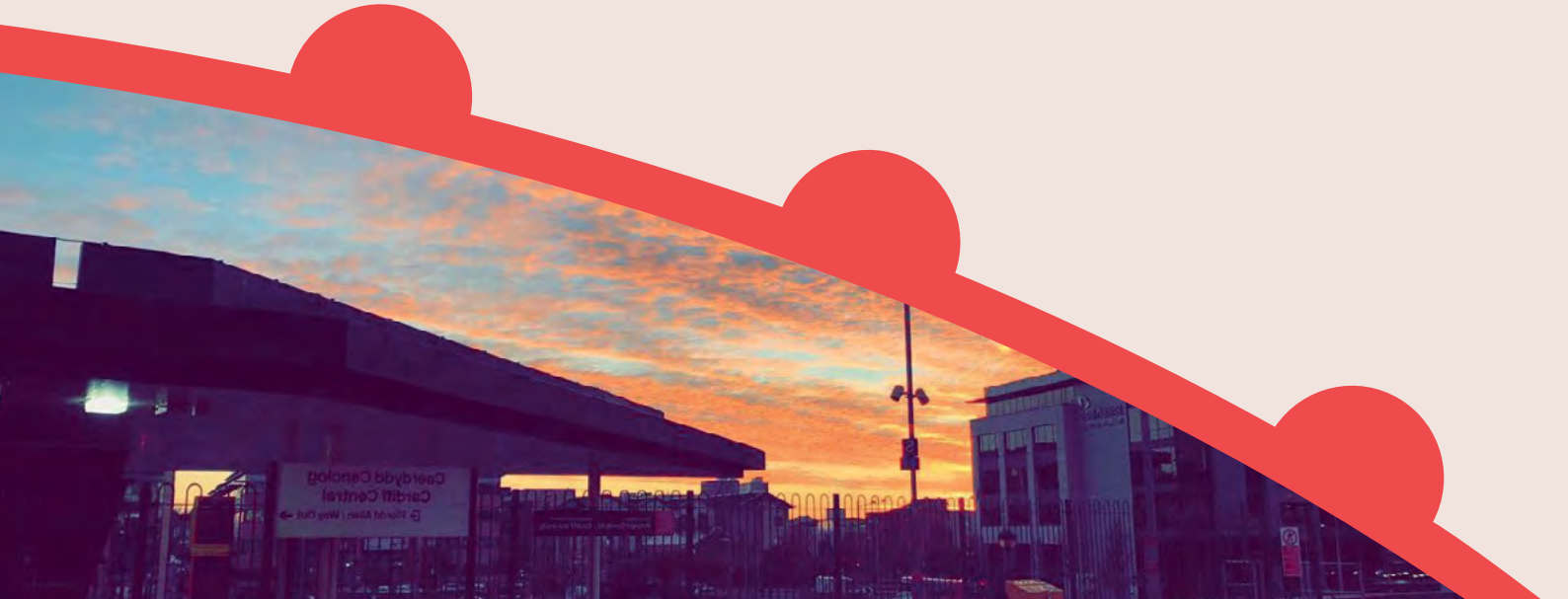
Wales Route impact assessment continued

Drainage

The key risk when focusing on Drainage assets when considering WRCCA impact is that associated with **flooding. Flooding** caused 278,387 total delay minutes between 2006/07 and 2018/19. This is one of the largest portions of schedule 8 costs per year and the highest of any weather-related factor. As stated in the Buildings section, there is an increase in overall risk for flooding for Wales as a region when looking at current UKCP18 data towards 2050. The risk is not attributed to an overall increase in yearly average rainfall, but rather an increase in the frequency and severity of adverse and extreme weather events. The fluctuations in seasonal rainfall, decreases in Summer and increases in Winter will cause its own problems to current drainage assets e.g.; reduced Summer rainfall meaning that self-cleansing assets do not cleanse in the Summer leading to asset failures and consequently delay minutes. The projected changes mean that planning for future Control Periods will have to take into account higher intensity and frequency of storms in both Summer and Winter. This will mean that drainage assets at high risk sites can be improved to cope with the added dynamic risk that changing climate poses to Wales Route and its drainage assets.

A principal factor for mitigating this risk is a thorough maintenance schedule for drainage assets. This is particularly key at sites on the Route which are already classified as high risk due to their proximity to rivers and other hydrological features. Working closely with maintenance to carry out pre-emptive cleanses of these drainage assets when extreme weather events have been predicted will continue to be pursued in CP6 and beyond.

Even though there are mitigation activities we already undertake, there are factors that influence flood risk which are harder to predict and mitigate. Changes in land use on adjacent land, conditions of adjoining boundaries and environments can all impact on the status and reliability of drainage assets. The impacts of climate change on the surrounding areas could greatly impact the our future asset status and lead to asset failure.



Earthworks and Geotechnics

Geotechnics sees a unique set of impacts relating to weather in CP5. The main WRCCA risks that affect earthworks and geotech are wind and rainfall. Rainfall and flooding are responsible for the largest proportion of weather-related delay minutes at 27.8 % between 2006/07 and 2018/19, with snow being the second averaging 24.3 %. These risks go hand in hand and are attributable to several asset failures which occurred during CP5.

One example is an extended period of heavy rain leading up to Sunday 21st January 2018. This caused a landslip with approximately 150 tonnes of mud and rock sweeping across the track at Dinas Rhondda, on the line between Porth and Treherbert. This closed the line for over 4 days, leading to significant delay minutes attributed to the accident. As a result, this location has seen significant work to stabilise the lineside cuttings to prevent potential future occurrences. Failed assets have been replaced with a better standard, instead of replacing like for like.

Figure 21
Dinas Rhondda landslip remediation – 21st January 2018

Lineside

During periods of hot weather, relay rooms, equipment rooms, location cabinets and signalling centres can be at risk of overheating. If this occurs the Signalling and Telecommunications (S&T) equipment may fail. This risk can be further increased if additional S&T equipment is added to location cabinets over time, putting extra strain on any existing cooling systems.

Heat related delay minutes on Wales Route totalled 35,503 delay minutes between 2006/07 and 2018/19. This accounts for around 3.5 % of total attributed delay minutes for the Route. This amount is likely to increase without mitigation put in place e.g. extra fans, shading and air conditioning for current and future lineside equipment.

Electrification and Plant (E&P)

Electrification and Plant will see a changing risk portfolio in the transition from CP5 to CP6 with electrification of the South Wales mainline up to Cardiff. This gives another area of OLE vulnerability to take into account. OLE on other Route's has been particularly vulnerable to adverse and extreme weather events and given the capital costs of implementing and maintaining the asset, the costs associated with weather related asset failure could be potentially substantial. Fortunately, the areas of electrification on Wales Route (Cardiff to Severn Tunnel) are currently at low risk from vegetation fall due to the local geography, land use and raised track level. With continued vegetation management, continued collaboration with lineside stakeholders and enhanced monitoring there should be limited risk to OLE going into CP6 and beyond. The Route also benefits from the fact that the vast majority of traffic is Bi-mode so weather-related impact on OLE equipment can be mitigated by switching to diesel operation.

The key WRCCA impact area to electrification and plant is that of lightning. Lightning currently contributes on average 6.1 % of all weather-related delay minutes. Between 2006/07 and 2018/19 there was a total of 61,029 delay minutes attributed to lightning. Due to UKCP18 data indicating that the frequency and severity of Winter and Summer storms is to increase, it is highly likely that delay minutes attributed to lightning strikes could see an increase, especially given the increase in electrification assets on the Route. Accurately predicting lightning risk to specific locations is not plausible but creating resilience and plans to mitigate the impact lightning currently has on the network will be key to monitor in CP6 onwards.

The increase in average Winter rainfall and greater occurrence of extreme weather events will lead to greater stress on lineside drainage pumping systems. This will be mitigated in some way by the introduction of new pumps into the network to increase the system capacity and availability.

Wales Route impact assessment continued

Signalling

For signalling assets there are several small areas of current weather-related impact. For all Routes the projections regarding fog conditions indicate that there will be an overall reduction in fog days, although it should be noted that there is relatively low confidence in these projections. This should decrease costs over the long term, and although a risk not leading directly to asset failure, it still incurs a cost to the Route. The overall delay minutes related to fog are only 364 between 2006/07 and 2018/19. This is the smallest impact of any of the WRCCA risks.

More extreme weather events increase the risk of both coastal and inland flooding which may impact on signalling location cases, track circuit equipment and cables. Projects are reminded that location cases should be installed on raised platforms in known risk areas whilst conversion to axle counter systems overcomes some of the issues associated with flooded tracks to allow faster recovery from events.

An increase in rainfall may lead to an increased risk of landslip which could damage signalling equipment either by material being washed down a cutting or land moving down a slope. If there is subsidence which moves track, ballast, or surrounding earthworks, there is likely to be an impact on signalling equipment used by that section of the railway. This will particularly affect cables and location cases. This means that areas currently at high risk of subsidence, with the potential to see increases according to the UKCP18 data, need to be monitored

Telecoms

The main risks associated with telecoms assets and services are subsidence, landslip, flooding, wind and lightning. This is due to the immense amount of telecoms fibre and copper cabling that is contained in trackside cable troughing at risk from subsidence, landslip and flooding. These cables carry important operational signalling, telecoms and E&P services and are critical to the operation of trains on the Route. If there is subsidence which moves track, ballast, or surrounding earthworks or flooding, there is likely be an impact on the cables associated with the telecoms systems used by that section of railway. This means that areas at high risk of subsidence and flooding, with the potential to see increases according to UKCP18 data, need to be monitored.

The risk from flooding, wind and lightning is mainly where there are telecoms Fixed Telephone Network Relocatable Electrical Buildings and GSMR mast sites. Current tolerances to wind are well within the increased risk boundaries however when extreme and adverse wind events occur in, for example, coastal areas there is an increased risk of structural failures. Radio masts attract lightning, so this risk is increased due to a rise in atmospheric entropy and energy, leading to more frequent and intense storms.

Track, Switches and Crossings

Track is an asset that sees a wider range of weather-related risks when compared with other asset areas of Wales Route's infrastructure. Track is vulnerable due to a variety of different factors, its working tolerances are slim and the potential consequences of not maintaining them are high. The issues raised by UKCP18 data on existing track infrastructure do not just impact the operations of the railway, but also need to be considered during renewal and enhancement work.

Between 2006/07 and 2018/19 there was a total of 35,503 delay minutes attributed to heat related incidents. This represented 3.5% of the Route weather-related delay minutes and 5.7% of weather-related costs.

The projected increases in mean daily temperatures, particularly during the Summer months, will increase the risk of track buckling incidents and other rail defects. Without any mitigating actions it is likely that the number of delay minutes attributed to heat related incidents will increase.

As a number of the traditional mitigation activities can themselves be a factor in raising the risk of track defects occurring during high temperatures it is also likely that rising temperatures will limit the timeframe in which these activities can be

completed. Maintenance may be prevented from undertaking specific activities which affect the track stability such as tamping, correcting geometry faults and wet bed eradication. This could lead to additional risks for the operational railway. For renewals the increase in temperature will not prevent the works being undertaken but careful scheduling would be required to prevent speed restrictions or the cessation of trains. Improvements in planning will be required in CP6 and beyond to account for these changing dynamics in weather patterns.

Cold weather and snow account for 28.5 % of the annual weather-related delay minutes and 23.7 % of the costs. The current UKCP18 projections indicate that Winters will be shorter and milder reducing the risks associated with cold weather-related incidents when looking forward through the century. Track assets are therefore likely to see a reduction in cold weather-related costs. It should however be noted that although the frequency is projected to fall the current extreme Winter events will still be possible.

A caveat to future Schedule 8 payments for Wales Route in CP6 is the increase in the expected number of services This increased load on the Route means that even if current asset failure rates are maintained, Schedule 8 costs would increase regardless as a consequence of having a more congested network.

Structures

Structures on the Wales Route face an ever changing and dynamic environment, likely to become more dynamic given the risks associated with WRCCA. Coastal assets cover a length of 34 miles across the Wales Route and carry a risk of overtopping. We have already experienced increases in sea level and the UKCP18 data projects further marked increases. The Welsh coast will see an average increase of around 28.8cm from pre-industrial levels by 2050, and 49cm by 2070. The current Structure assets saw a relatively quiet and calm CP5 in comparison to previous Control Periods e.g. Barmouth Bridge and other weather-related asset impacts prior to 2015.

When taking into account the sea-level increases and the increase in the intensity and frequency of storms in the Summer and Winter, it seems that structures will be at the front line of weather resilience and climate change. Working with third parties to come to a resolution between hold the line policies for sea-fronted structures, and managed retreat for the more vulnerable parts of the asset area is key of focus at present. Attributing costs for this area is a contentious issue and we are currently working closely with NRW to find a solution which is mutually beneficial.

With respect to Coastal, Estuarine and River Defences (CERDs), the Route objectives are to:

- Use an established coastal weather forecasting system and asset monitoring to manage locations vulnerable to adverse weather,
- Build upon the existing coastal and estuarine asset management strategy to identify and develop plans to mitigate future weather risks across the CERD portfolio,
- Develop and implement work banks using Planned Preventative Maintenance (PPM) approach to intervene and repair low to medium risk defects before they adversely impact upon the performance of the asset. This approach will reduce the need for replacement and/or large-scale maintenance of high risk or poorly performing assets, and
- Improve our asset knowledge and develop new inspection and maintenance regimes in order to support the long-term strategic approach to managing climate change and sea level rise including the enhancement of the assets to meet this challenge to CERD assets.

Wales Route WRCCA actions

As the impacts of weather events are location specific Wales Route will be responsible for identifying and carrying out the WRCCA investments necessary to deliver the continued and improved resilience of their assets and operations.

Network Rail's central functions will assist and enable the Wales Route in this by providing asset policies and design standards that have weather resilience and climate change considerations embedded within them, by carrying out root cause analysis of national weather and asset data and through the review and adoption of appropriate new technologies.

The first two tables in this section summarise the WRCCA actions undertaken by the Wales Route in CP5 (Table 3) and those that we have planned for CP6 (Table 4).

The final table details actions that have been apportioned to Network Rail, and hence the Wales Route, in Wales' CCAP. Some of these will align with CP6 planned and funded actions and Table 4 cross references with Table 5 to indicate the relationship between the Wales Route actions and the delivery of Wales' CCAP actions.

Table 3
2014 WRCCA Plan
CP5 actions review

Action name	Target completion date	Actual completion date	Comments
All Impacts			
Climatic conditions and specific weather-related risks are not clearly communicated to asset renewal and enhancement process	Ongoing	Ongoing	Continued briefing on weather-related risks. Due to be updated with UKCP18 dataset (amended UKCP09)
Flooding			
Holistic management	Ongoing	Ongoing	Relationship with NRW is ongoing – with liaison groups and meetings to manage flood risk management and ecological impact
Scour management programme	2019	2019	Level 2 scour assessments for bridges were funded which allowed the intrusive checking of structure's foundation depths – adding to current condition reports
Scour	2019	2019	Implemented approx. 25 scour work items during CP5 including; • Cegin viaduct, • Bodorgan viaduct, • River Towy viaduct, • Severn viaduct, and • Gelli (River Eastern Cleddau).
General flooding	Ongoing	Ongoing	Subscription to MetDesk (forecasting data) and also receives data from NRW and EA for fluvial flood warning data to trigger adverse weather plans for Operations Control and Maintenance
Aged drainage infrastructure	30/04/2019	02/03/2018	Implemented improved drainage investment for capital schemes including; • Caerphilly tunnel North Portal, • Llysfaen, • Talerddig cutting, cess drain renewal, • Severn tunnel Eastern Portal, new drain/repair (6ft), • Bangor tunnel, failed pipes and catch pits, and • Gaer.
Earthworks			
Earthworks assets sensitive to extreme or severe weather events	System established	System established	Subscription to bespoke weather-warning triggers, which provide advance warnings based on rainfall per hour and soil moisture saturation (extended rainfall events). This allows the Route to mitigate risks by the use of speed restrictions at particular at-risk asset sites.
Implement approx. 35 earthworks renewals	CP5	CP5	Implemented approximately 35 earthworks renewals schemes during CP5 including; • Llys Faen, • Trehafod, • Station Road Dinas Rhondda, • Radyr, • Birthdir, • Cwm Garnet, • Naas Lane Phase 2, • Gelli, and • Saltmoor.
Coastal and Estuarine			
Flood warning management	October 2014	October 2014	JBA 5 day warning – Forecoast, connected to flood warning database
Coastal management strategy	CP5	CP5	Developed Assetcoast – Asset management tool for estuarine assets. Provides resilience factor in real-time
Coastal flooding; • Deganwy, rock armour to pitching, • Llanfairfechan sea wall, refurbish, • Tal-Y-Cafn, pitching, • Lord Vivian's embankment, refurbish, • LJT sea wall, pitching and defences, • Old Colwyn sea wall, extensive repointing. • Ferryside sea wall improvements and rock armour protection, • Penmaenbach West sea wall, • Penmaenmawr armour stone, and • Mostyn sea wall.	30/04/2019	CP5	Completed works for refurbishing the sea/coastal defences in CP5 following proposed works. Reduced risk of asset failure and increased asset life. All structure asset information is input into Assetcoast to provide a real-time asset condition of each asset
Wind			
Fallen trees obstructing the line	CP5	Ongoing	Speed restriction mitigation warning 50mph blanked during adverse and extreme weather events, location dependent. Targeted removal of high-risk vegetation
Cold and snow			
Camarthen gas points heating	2019	CP5	Completed – increasing resilience for cold weather and EWAT events
Electric point heating	30/04/2019	CP5	Completed – increasing resilience for cold weather and EWAT events

Table 4
Planned WRCCA investment for CP6 (2019 to 2024)

Vulnerability	Location	Action to be taken	Cost of action	Expected benefit	Target completion date	Resilience change	Wales' CCAP reference
Flooding	Route-wide Black Bridge (initial site)	Increase amount of RCM sites	Dependent on test initiative	Reduce risk to workers assessing assets in adverse and extreme weather. Reduce risk to customers with real-time updates	CP6 Rollout dependent on RCM trial	Increase real-time asset information for weather-related impact and risk assessment	NRWCCAP3
Landslips	Little Hagloe Afon Llan River Tawe Cwmbargoed	Continue monitoring at risk sites	Costing due	Real-time monitoring of high risk sites	Completed by end of CP6	In-place sensors to provide alerts to any movement or landslip activity	NRWCCAP2
Slope Stabilisation	Route-wide	Increased spend on tunnel portal and cutting crest drainage schemes	Adjustment per scheme	Improved drainage and tunnel portal access	CP6 Dependent on tunnel schemes	Improve drainage to tunnels and cuttings against prolonged and high precipitation events	NRWCCAP2
Ongoing Engagement with Academia	Cardiff	2 MSc Students per year	~£20k/year	MSc related to geotechnical and drainage issues	CP6 2 students – 31/03/2020 6 students – 31/03/2022 10 students – 31/03/2024	Increasing academic engagement and knowledge for climate change and weather resilience	NRWCCAP1
Vegetation Management	Route-wide	Targeted removal of high-risk vegetation	–	Mitigate impact to PPM that falling vegetation has in high wind/ precipitation events	CP6 20 % – 31/03/2020 40 % – 31/03/2021 60 % – 31/03/2022 80 % – 31/03/2023 100 % – 31/03/2024	Decreasing risk profile for vegetation fall in extreme and adverse wind events	NRWCCAP2
Coastal Flooding	Tywyn Llanaber Afonnwen Old Colywyn Sudbrook Pumping Station Pwll Llanwrda	Refurbishment of CERD assets in CP6	~£8.0m over CP6	Increase lifetime of assets, protect assets from weather related degradation	CP6 Site Completion 25 % – 31/09/2021 50 % – 31/06/2022 100 % – 31/03/2024	Continue to refurbish existing structural assets in key risk sites	NRWCCAP2
Mitigation of further Climate Change	Route-wide	Energy and carbon reduction schemes	£6.1m	Reduce energy use and carbon produced by the Route to mitigate climate change	CP6 100 % spend by 31/03/2024	Mitigate the impact Wales and Boarders Route has on climate change	-
Barmouth Bridge Future	Barmouth Bridge	Refurbishment	£20.4m (Proposed)	Provide extended asset life	Proposed end of CP6	Provide a refurbished asset which can deliver a reliable and resilient service even in adverse weather conditions	NRWCCAP2 + 3
Flood Warning Management	Key Route Structures	Continue use of Assetcoast	–	Build on current use of Assetcoast (JBA consulting) providing up to date resilience data on estuarine assets.	Implemented	Continue to build data and more accurate asset information using Assetcoast platform	-
Coastal Management Strategy	Key Coastal Sites on Wales and Borders Route	Continue use of Forecast	–	To continue to provide a 5-day warning for coastal flooding – linking directly to operations	Implemented	Continue to develop and use the platform, integrating with maintenance and operations	NRWCCAP2
Structures	Route-wide	Planned Preventative Maintenance (PPM)	£1.6m Per Anum for CP6	To prevent asset failure by using PPM to pickup and predict failures in structural assets in CP6	100 % spend per year up to CP6	Resilient structures and assets throughout that life of the asset, taking into account changes in condition	-

Table 5
Wales' CCAP

Objective	Action	Timing	NR Wales' CCAP Reference	Monitoring and metrics
Improve understanding of the risks from climate change to transport infrastructure in Wales	Welsh Government to ensure Wales is comprehensively catered for within research undertaken for transport to enable the development of appropriate support	Not set	NRWCCAP1	To be confirmed
	Review of transport sector case studies to share best practice in adapting to transport related climate change risks in Wales	Not set	NRWCCAP2	
Raise awareness of the level of risk to bridges and pipelines from climate change, and address research gaps to help inform mitigation	Improve understanding of the level of risk to bridges and pipelines across Wales, the bridge owners involved, and the action being taken	Not set	NRWCCAP3	

Management and review

Corporate management and review

Successfully implementing WRCCA across the whole of Network Rail requires a long-term commitment to the regular review and management of the process at all levels of the business. This will ensure the timely delivery of the technical and cultural changes necessary to develop cost-effective WRCCA strategies and actions which will avoid unacceptable increases in safety risk, system unreliability or the compromising of downstream risk mitigation strategies.

Network Rail is committed to ensuring that we will appropriately govern and assure implementation of these plans. Although we are going through a reorganisation in 2019/ 2020 and the future governance structure is unclear, the Route WRCCA Plans are owned by the respective Director of Route Asset Management and the Office of Rail and Road (ORR – Network Rail's regulator) will monitor each Route's progress in implementation during CP6.

Effective governance of the wider WRCCA programme including Route WRCCA Plans will be embedded within the new governance structure. Based on existing structures, the following high-level management, review and reporting will be undertaken:

- Routes will provide updates on implementation of their WRCCA Plans to ORR and the central WRCCA Team twice a year (at the end of Periods 6 and 13),
- A report combining progress from all Routes will be presented to the National Asset Management Review Group and Quality, Health, Safety and Environment Integration Group (or future equivalents) twice a year,
- Progress in implementing milestones will be included in regular WRCCA reviews by the Network Rail Executive Leadership Team and the National Safety, Health and Environment Periodic Report (or future equivalent),
- Route WRCCA Plans form a key control in managing Network Rail's Enterprise Risk relating to weather related impacts on the railway which is managed through Route and National level Business Assurance Committees (or future equivalent),
- The WRCCA Working Group will review progress and identify any improvements which would be approved by the National Asset Management Review Group and Quality, Health, Safety and Environment Integration Group (or future equivalents) or Executive Leadership Team as appropriate,
- The central WRCCA Team will use the information in the Route Reports to inform the next National Climate Change Risk Assessment being compiled by the Committee on Climate Change and as part of its Adaptation Report under the Climate Change Act which is due to be submitted to Defra by 2021.

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.

Wales Route management and review

Wales Route is committed to continue understanding the implications of weather resilience and climate change. This is of continued importance for our coastal sites which will see and increasing risk profile in the coming control periods. Continual review and management of the shoreline management programme with NRW will play a significant role in the shoreline management strategy going forward, in terms of; funding, sustainability, impact to the network, and to the environment.

We have and will continue to instigate a proactive management programme of works of our drainage assets which has continued to improve the resilience of our drainage systems at previous sites across the Wales Route. We will continue to assess sites of weakness as the threat from climate change evolves and adapt our assets to match these changes, to continue operating a resilient and reliable rail network.

Wales Route will continue to work with its external partners, including NRW, the EA, local authorities, Transport for Wales, and others to develop and implement holistic plans for weather resilience.

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