2019 – 2024

Scotland's Railway

CP6 Weather Resilience and Climate Change Adaptation Plans

Part of

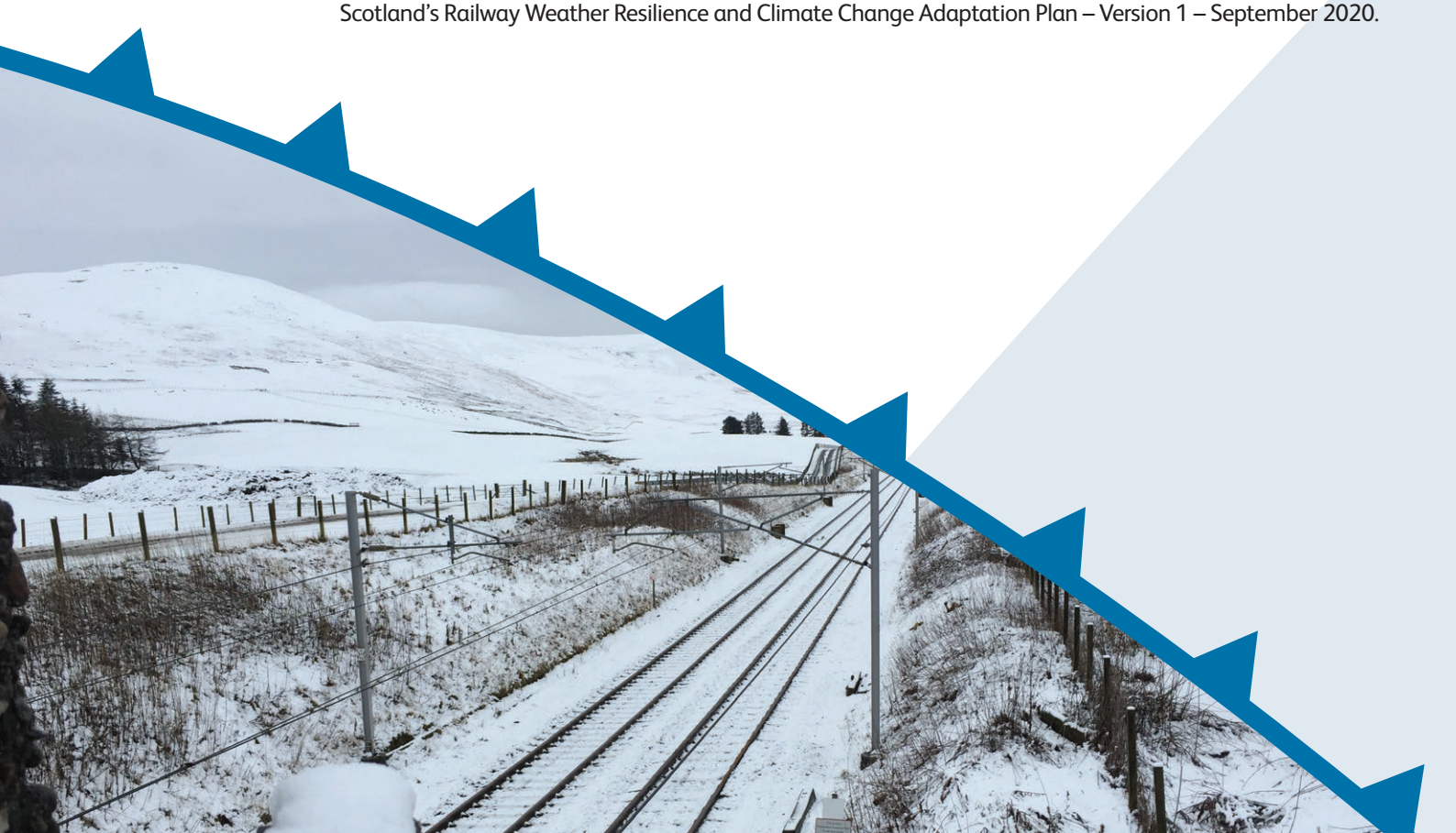
SCOTLAND'S RAILWAY
BETTER IN THE MAKING

Contents

Purpose of this document

This document; defines Scotland's Railway Weather Resilience and Climate Change Adaptation (WRCCA) Plan for Control Period 6 (2019-2024) 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.

Scotland's Railway Weather Resilience and Climate Change Adaptation Plan – Version 1 – September 2020.



Director of Engineering and Asset Management Statement

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

Scotland's Railway has recently faced the tragic consequences of extreme weather. In August 2020, following a period of intense rainfall, a train derailment near Stonehaven led to the death of two railway colleagues and one passenger. We will never forget those who lost their lives in this awful incident, those who were injured or the many people who have been affected and we will work with the investigating bodies to understand what happened and learn from it.

Scotland's changing weather patterns present challenges to our delivery for our passengers and freight customers. Recent challenges include events such as the 2015/16 winter storms, the infamous Beast from the East in 2018 and near record breaking rainfall in February 2020 (Storm Ciara) and of course the weather events in August 2020.

Figure 1
Flooding at Lockerbie (WCM1) August 2019

Climate change projections suggest we are entering a period of increasing average and maximum daily temperatures, drier summers, wetter winters, higher sea levels and more storms. This will increase the risk of weather-related events such as, floods, landslips, coastal storm surges, track buckles and obstructions on the track. While snow and cold weather will be less frequent, they will still freeze points and block routes. We in Scotland's Railway must address these operational challenges.

We have made significant progress in managing these risks. This includes investment to cut the number of geotechnical assets susceptible to bad weather, targeted schemes to combat storm surges and localised flooding, the creation of a high-risk tree asset database and improved autumn plans to manage the effects of leaf fall. This is an ongoing and dynamic process.

Throughout Control Period 6 (2019-2024), we will do more to meet this challenge. Scotland's Railway is investing record funding to tackle these incidents. We are working with our rail industry partners to reinforce close working relationships to help reduce the effects and improve the recovery from extreme weather. We are working collaboratively with external stakeholders to learn from their experiences.

This document outlines how Scotland's Railway is facing the Weather Resilience and Climate Change Adaptation challenge.

Alan Ross
Director of Engineering and Asset Management

Executive summary

Bad weather significantly disrupts our passengers and freight users, and damages our rail infrastructure.

The UK Climate Change Projections 2018 (UKCP18) show 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, and seasonal patterns as a result of this, will alter the likelihood and severity of its impact on the railway.

To maintain a resilient railway, we need a detailed understanding of how our railway may be impacted by weather, and the potential impact from climate change.

Scotland's Railway is committed to improving its weather and climate change resilience. We have identified our risks by assessing our weather-related vulnerabilities (for example Figure 2), identified root causes of previous incidents and have used UKCP18 climate change projections. This is a dynamic and evolving process.

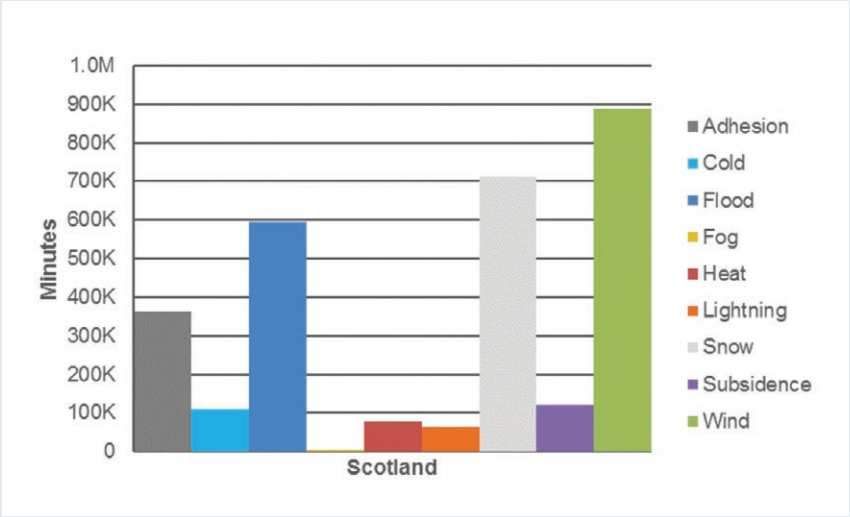
Our 2014 Route WRCCA Plan set out our strategy, summarised the findings of our vulnerability and impact assessments, explained where we would invest and take action and highlighted future considerations.

This CP6 plan reports our progress to date, explains our next plans for the future and updates our vulnerability and impact assessments to account for changes in Network Rail's WRCCA Strategy and guidance. Key highlights include:

- In 2017 the Network Rail guidance used the UKCP09 medium scenario, 90th percentile probability[1]. With the release of UKCP18 data this has been updated to the UKCP18 Representative Concentration Pathway (RCP) 6.0 scenario, 90th percentile,
- Commitment to further investment to reduce the effects of extreme weather on Scotland's railway infrastructure,
- Further targeting of earthworks assets, to reduce the number deemed susceptible to failure during adverse weather. This will include rolling out more remote condition monitoring to help mitigate the associated risks at identified sites,
- Investment in sites we know are prone to flooding,
- Investment where we know sites have a high-risk of structural scour,
- Further investment and acceleration of our vegetation management programme,
- Extra investment in remote condition monitoring technology, and
- Using data to drive our seasonal preparations and learning from incidents to adjust annual plans.

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

Figure 2
Scotland's Railway weather attributed delay minutes – 2006/07 to 2018/19



[1]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.

Extreme rainfall, snow and high temperatures can cause delays, raise operating costs and increase safety risks.

Recent examples in Scotland include:

- The Beast from the East in early 2018,
- Substantial closures of the West Coast Mainline in 2015/16 after storms damaged Lamington Viaduct,
- Severe restrictions between Glasgow and Edinburgh when Winchburgh Tunnel flooded in 2019,
- Significant closures on the West Highland Line in 2019 after storms triggered landslips and scoured bridges,
- Significant washout of track at Lochailort in 2020 after extreme rainfall overwhelmed a nearby watercourse,
- Finally, the tragic deaths of three people when a train derailed on a landslip at Carmont after extreme rainfall in August 2020.

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 – leaf fall, moisture or oils contaminating the railhead leading to traction loss,
- Cold – ice accumulations on overhead line equipment, rails, points and in tunnels,
- Flooding – standing or flowing water preventing trains running or damaging assets,
- Fog – reduced visibility obscuring signals,
- Heat – potential for metal rails to buckle resulting in the need for speed restrictions to be introduced on a temporary basis. Potential for electrical equipment to overheat,
- Lightning strikes – track circuit and signalling damage or power system failure,
- Snow – blocked lines and points failures,
- Subsidence – landslips, rockfalls and sinkholes, and
- Wind – trees and other items blown onto the track and into the Overhead Line Equipment (OLE) or Temporary Speed Restrictions (TSRs).

Our data includes the duration and location of each disruption and attributable cause, so it gives good detail that allows us to analyse weather impacts and trends. We will regularly report and discuss with Transport Scotland and the Office of Rail and Road our Moving Annual Average (MAA) performance KPI's during adverse and extreme weather days.

In the past 13 years (2006/07 to 2018/19) the average annual number of delay minutes attributed to weather for the Scotland network was 226k.

This represents 22.1% of the total number of Schedule 8 delay minutes for all causes over that period and equates to an average annual cost of £6m.

The impacts of extreme weather events on Scotland's Railway can be clearly seen in Figure 3, for example:

- Snow in 2009/10, 2010/2011 and 2017/18,
- Wind in several years, but particularly 2011/12, 2013/14 to 2014/15 and 2018/19,
- Flooding in all years, but less so in 2013/14 and 2016/17, and
- Heat in the summer of 2018/19.

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

Introduction continued

We can also capture weather related costs in Schedule 4[3] payments and the capital expenditure to repair damage.

The weather costs of Schedule 8 and 4 payments and the wider socio-economic impacts of rail disruption justify continued investment to increase weather resilience. We believe our collaborative approach to understanding how weather affects increasingly interdependent infrastructure, societal and environmental systems is key to finding the best way to increase 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.

[3]Compensation payments to passenger and freight train operators for Network Rail's possession of the network.

Figure 3
Scotland's Railway weather attributed delay minutes by year 2006/07 to 2018/19

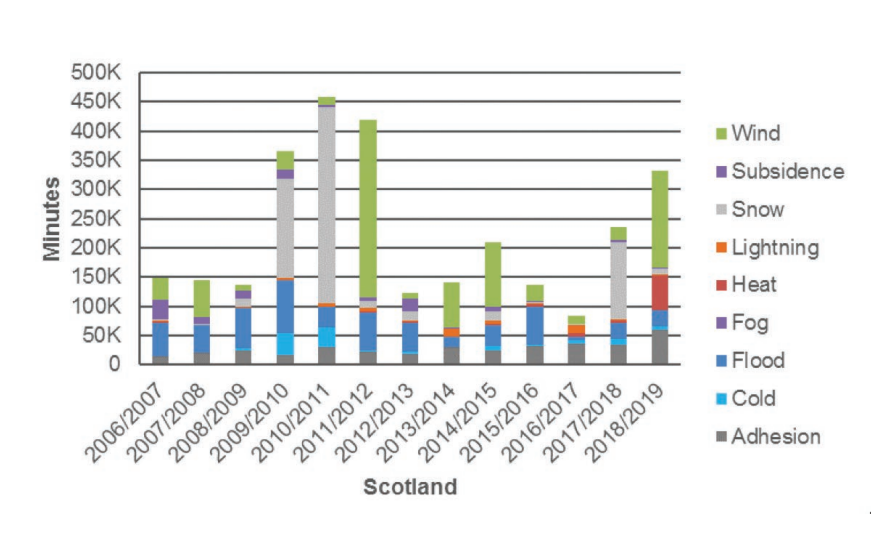


Figure 4
Intensity and frequency of high latitude Atlantic winter storms[4]

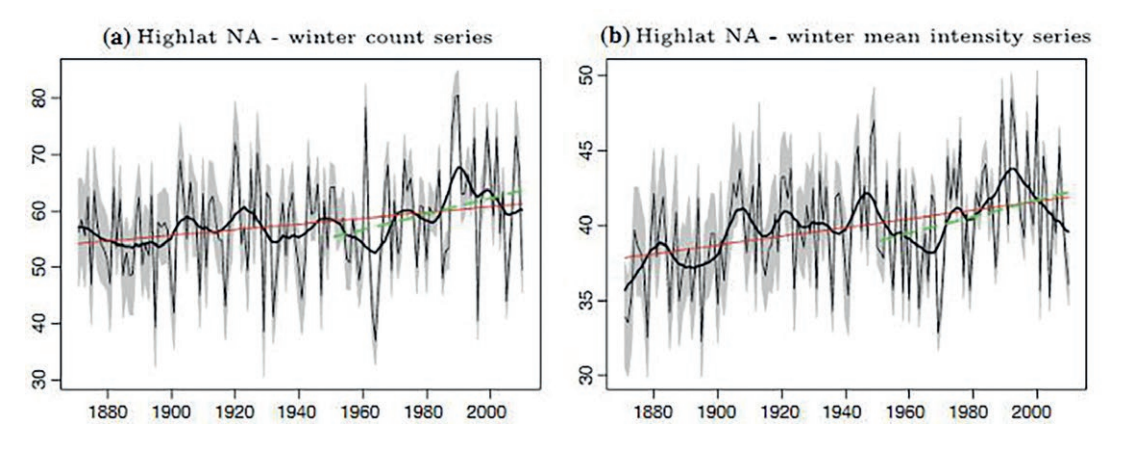
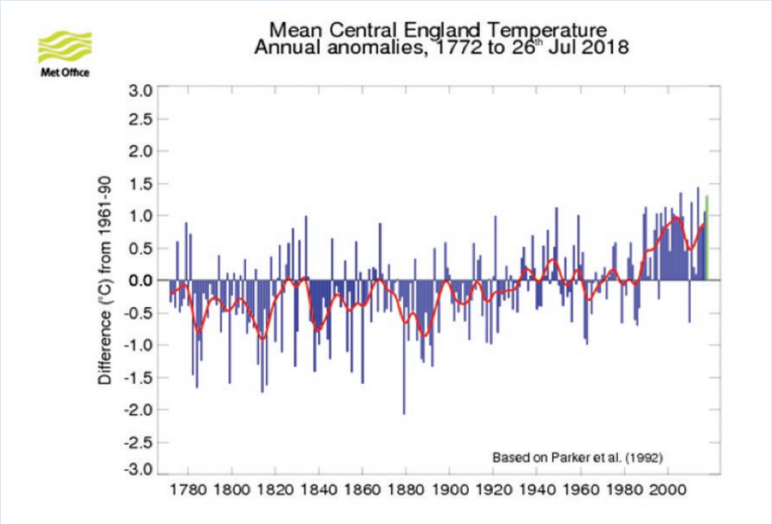


Figure 5
Mean Central England Temperature record[5]



[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 reanalysis.

[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.

Introduction continued

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

Examples of the changes are shown in Figure 6 for the mean daily 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) from a 1981 - 2000 baseline[6]

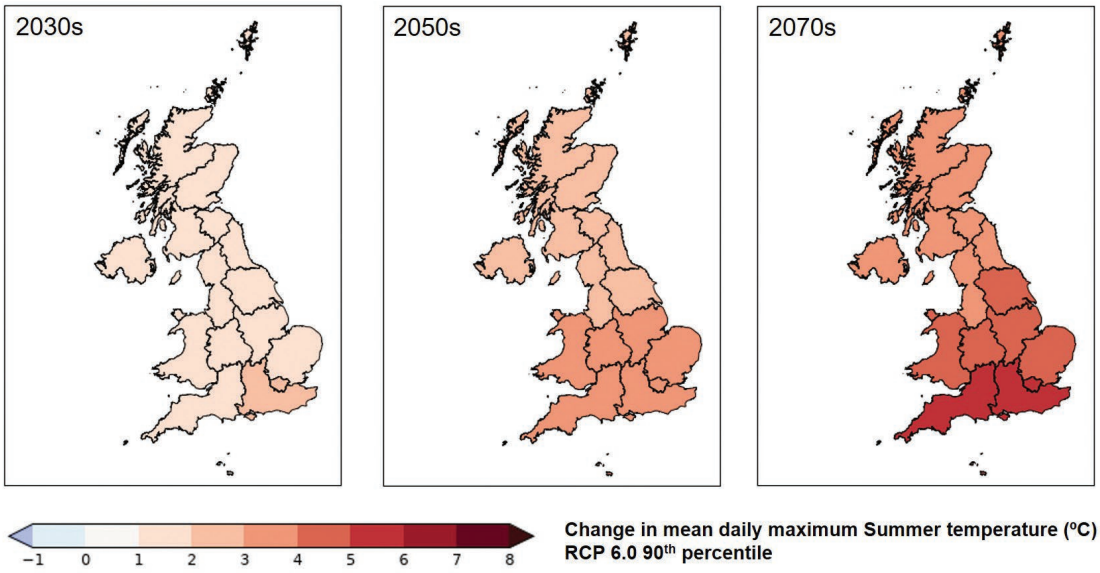
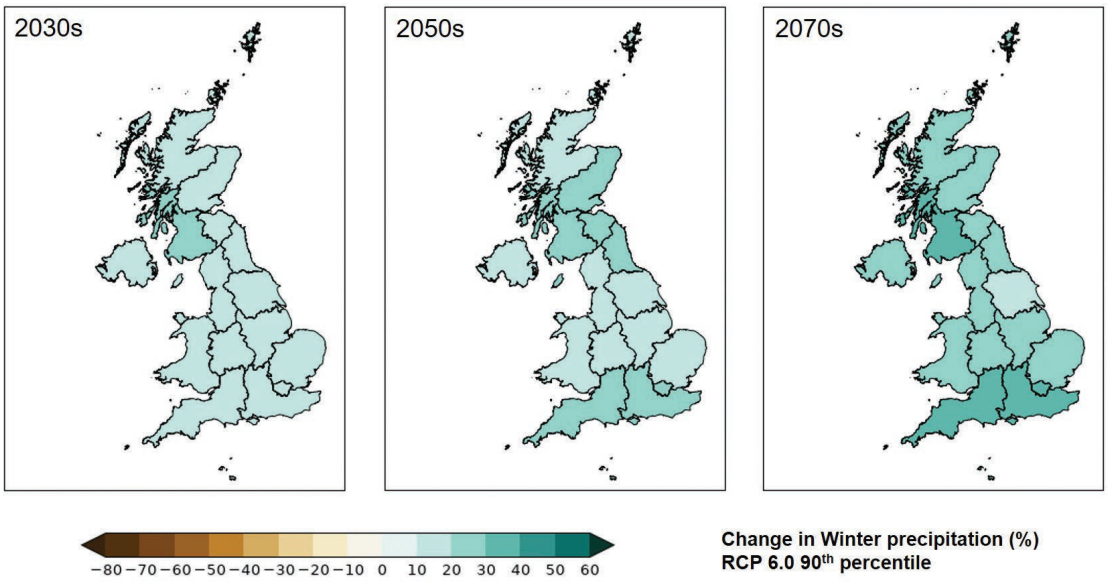


Figure 7
Change in winter precipitation (%) (left to right, 2030s, 2050s and 2070s) from a 1981 – 2000 baseline[7]



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

The potential increases in weather impacts support the business case for enhancing weather resilience and identifying actions to make our railway safer and more resilient.

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 UK and Scottish Governments provide climate change guidance in several ways to enable organisations like Network Rail to assess their future climate risks and create plans to maintain and improve resilience. Most relevant to Network Rail and Scotland's Railway are:

- The UK Climate Projection data sets which are produced by the Met Office Hadley Centre, and
- Scottish Government's Energy and Climate Change Directorate publication – Climate Ready Scotland: climate change adaptation programme 2019-2024.

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. Government uses them to conduct its 5-yearly UK Climate Change Risk Assessments. Individual organisations use them to understand and plan for their specific risks. In addition, in 2011 the UK Adaptation Sub-Committee published the report How well is Scotland Preparing for Climate Change?

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

- UKCP18 – RCP6.0 90th percentile probability as the baseline scenario for evaluation and decisions, and
- RCP8.5 90th percentile as the sensitivity test on assets with a lifespan beyond 2050.

[8]Identifying a climate change planning scenario, JBA Consulting 2/02/18.

Introduction continued

Analysis in this report uses UKCP18 projections where available, noting that some UKCP09 parameters have not been updated in UKCP18. Where this is the case, we have used UKCP09 data and indicated this clearly in the report.

The Climate Ready Scotland: climate change adaptation programme 2019-2024 is based upon the UK Climate Change Risk Assessment published by Defra every 5 years and it sets out the Scottish Government's five year Programme for climate change adaptation.

The programme contains seven outcomes and sets out current policies, proposals and research to increase the capacity of Scotland's communities, businesses and natural environment to adapt to a changing climate. The seven are:

- Communities,
- Climate Justice (including Health),
- Economy,
- Supporting Systems,
- Natural Environment,
- Coastal and Marine Environment, and
- International Networks.

Of these, Supporting Systems is the outcome to which Scotland's Railway can make the greatest contribution through its adaptation and resilience activities. The outcome has identified the UK Climate Change Risk Assessment risks that it seeks to address and we lay out in Table 5 those that are most relevant to Scotland's Railway.

Although climate change projections include uncertainties, associated with natural climate variability, climate modelling and future emissions, they and the actions from Climate Ready Scotland provide guidance on the direction that Scotland's climate may take. Scotland's Railway used them to create this WRCCA Plan.

To ensure a consistent approach across Network Rail, we have used an iterative framework of key management stages (see Figure 8) to develop this WRCCA plan.

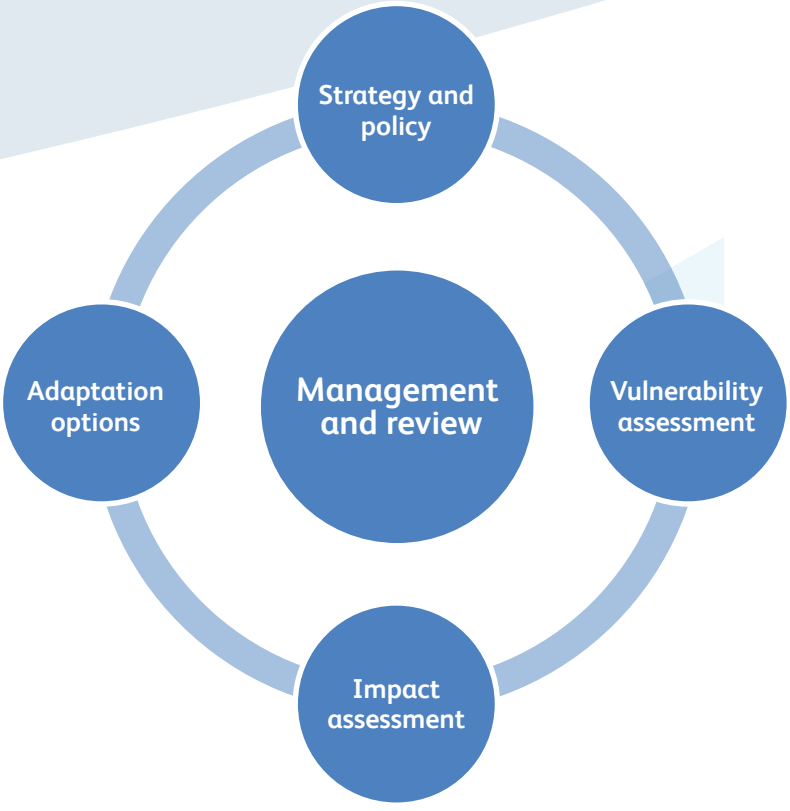


Figure 8
Weather resilience and climate change adaptation framework

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:

- The evaluation of risks to determine the level of investment required.
- Increasing current and future resilience without compromising future flexibility,
- Investment in adaptation now in anticipation of future risk, and
- 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 our updated vulnerability and impact assessments, detail progress to date on resilience actions and explain our future actions.

Figure 9
Impact of wind event – Kirknewton Level Crossing (September 2018)

Scotland's Railway WRCCA Plan

Network Rail's WRCCA Policy sets out the approach to achieve its vision of 'A better railway for a better Britain' by creating a railway for passengers and freight customers that is safer and more resilient to weather 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 and providing 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 active resilience interventions and finding funding 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 extreme weather.

Scotland's Railway Plan

Scotland's Railway is committed to supporting the delivery of this strategy through specific WRCCA objectives, such as

- Focus on weather resilience,
- Improve safety and performance through better operational controls (updated adverse weather plans) and physical resilience through: scour-risk reduction, removal of vulnerable earthworks, increased use of telemetry, accelerated vegetation management and strengthened off-track maintenance,
- Deliver increased resilience to extreme weather by enhancing lineside maintenance and targeted renewals, and
- Target standalone drainage and scour protection works to improve resilience to flooding. Maintenance activities including vegetation and drainage management have been enhanced.

This WRCCA plan does not consider works to decarbonise Scotland's Railway or our biodiversity and sustainable land use policies, which are covered under separate documentation.

Figure 10
Resilience works on geotechnical assets at Bishopton East.

Scotland's Railway Vulnerability Assessment

This section provides details of the general vulnerability of the national rail network and Scotland Railway's specific vulnerabilities to current weather impacts, and regional climate change projections.

This Plan updates our understanding of 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.

Figure 11
Examples of primary and secondary events

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 within a changing climate is a complex challenge. Interdependencies with other sectors of the economy, for example power, telecoms and water infrastructure add to this.

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.

Scotland's Railway Vulnerability Assessment continued

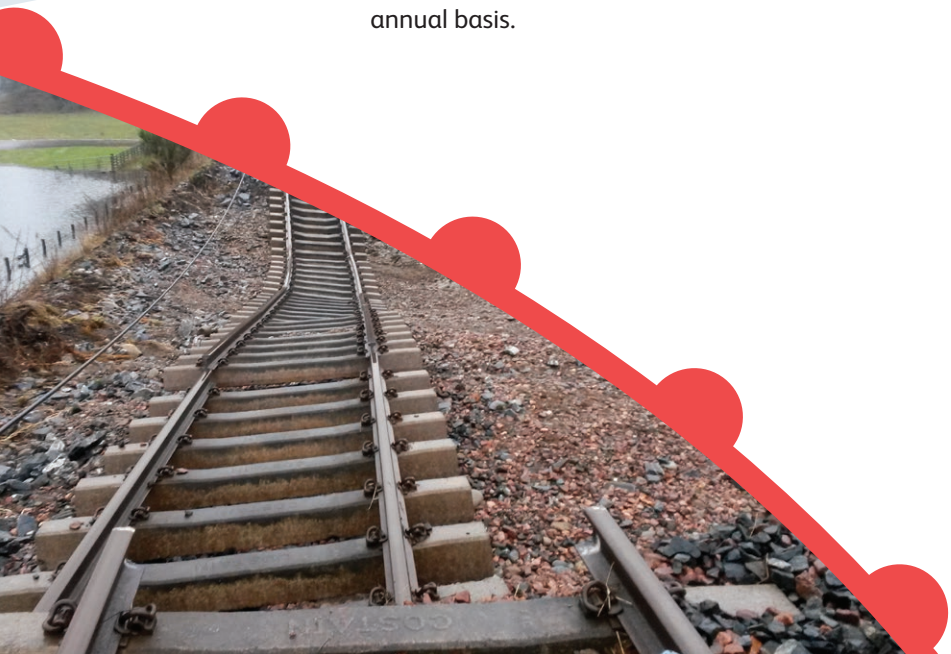
The 2014 Plan outlined how we monitor the impact of weather on the performance of our network by using Schedule 8 delay compensation costs and the process we used to carry out a detailed analysis of this data to understand:

- 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 regional teams 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.



Regional weather vulnerability

The geography of Scotland is highly varied, from rural lowlands to barren uplands and from large cities to rural communities. The topography of Scotland is distinguished by the Highland Boundary Fault which traverses the Scottish mainland.

This fault line separates two distinctively different regions: namely the Highlands to the north and west and the lowlands to the south and east. The more rugged Highland region contains the majority of Scotland's mountainous terrain, in which the management of a large and exposed railway network is complex. Couple this with the extreme rainfall events we receive in Scotland and it makes for a challenging environment.

Wind remains the primary vulnerability within the Region, accounting for 30% of weather-related delay costs during 2006/07 to 2018/19. Most wind-related delay incidents are not from gusts affecting the OLE but more often than not from objects being blown on to the line and in some cases objects coming into contact with the OLE.

In recent years we have had to deal with multiple third-party intrusions onto OLE during windy weather. Objects blown on to the line including trampolines, balloons, polythene sheets and garden sheds.

As Scotland plans for more electrification wind will continue to be a key priority in our mitigation of predicted future climactic changes.

Scotland's Railway is Scotland's is significantly vulnerable to heavy rain, with flooding accounting for 20.3%of delay minutes between 2006/07 and 2018/19. Furthermore the effect of rain in triggering landslips in Scotland, including from land beyond the railway boundary is significant.

Scotland's Railway has established plans to mitigate the effects of bad weather and continues to work proactively to further improve resilience.

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 probable trends that we can use to understand the potential future risks associated with certain climates and the likely changes in weather events and 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 12), Scotland's Railway covers 3 of these regions; Northern Scotland, Eastern Scotland and Western Scotland. These regions are therefore considered as representative of the Route for the purposes of analysing future climate projections.

In the 2014 Plan charts were generated using the UKCP09 High emission 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 has involved a number of changes to the data used including:

- Using a new baseline period of 1981-2000,
- Moving from projection time periods of 30 years (2020, 2050 and 2080) to shorter 20-year periods (2030, 2050 and 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 12
Map of UK Administrative regions used in UKCP18[9]

[9]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]

Scotland's Railway Vulnerability Assessment continued

Mean Daily Maximum Temperature change

The mean daily maximum temperature for all regions is projected to increase in every month of the year, with the greatest increases expected in the summer months. This increase becomes larger across the century.

Northern Scotland

The highest mean daily summer temperatures are expected to be in August for both the 2050s and 70s, with increases of 2.7˚C to 18.7˚C and 4˚C to 20˚C respectively. In winter the highest mean temperatures will be seen in February, with increases of 2.2˚C to 7.5˚C and 3.2˚C 8.4˚C respectively.

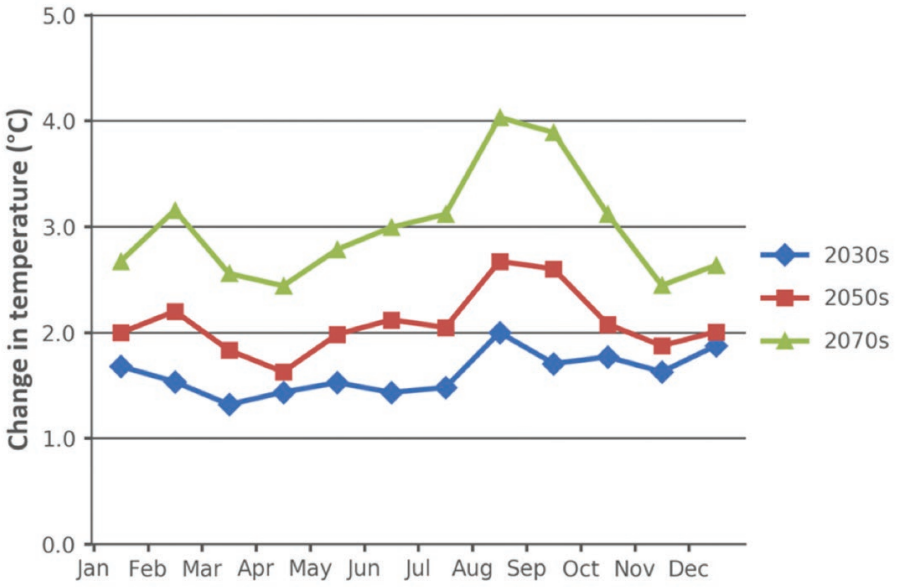


Figure 13
Northern Scotland, mean daily maximum temperature change (˚C) (RCP6.0 90th percentile)

Eastern Scotland

The highest mean daily summer temperatures are expected to be in August for both the 2050s and 70s, with increases of 3.1˚C to 20.5˚C and 4.9˚C to 22.2˚C respectively. In winter the highest mean temperatures will be seen in February for both periods, with increases of 2.3˚C to 7.4˚C and 3.3˚C to 8.4˚C respectively.

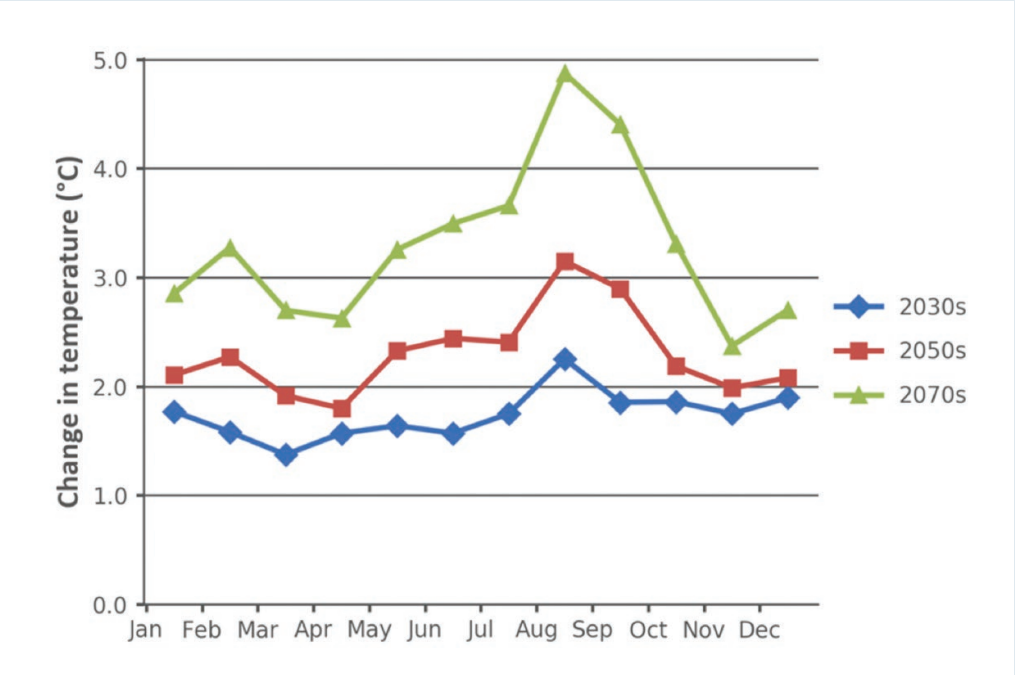


Figure 14
Eastern Scotland, mean daily maximum temperature change (˚C) (RCP6.0 90th percentile)

Scotland's Railway Vulnerability Assessment continued

Western Scotland

The highest mean daily summer temperatures are expected to be in August for both the 2050s and 70s, with increases of 3.4˚C to 20.6˚C and 4.4˚C to 21.6˚C respectively. In winter the highest mean temperatures will be seen in February for both periods, with increases of 2.4˚C to 8.3˚C and 3.5˚C 9.4˚C respectively.

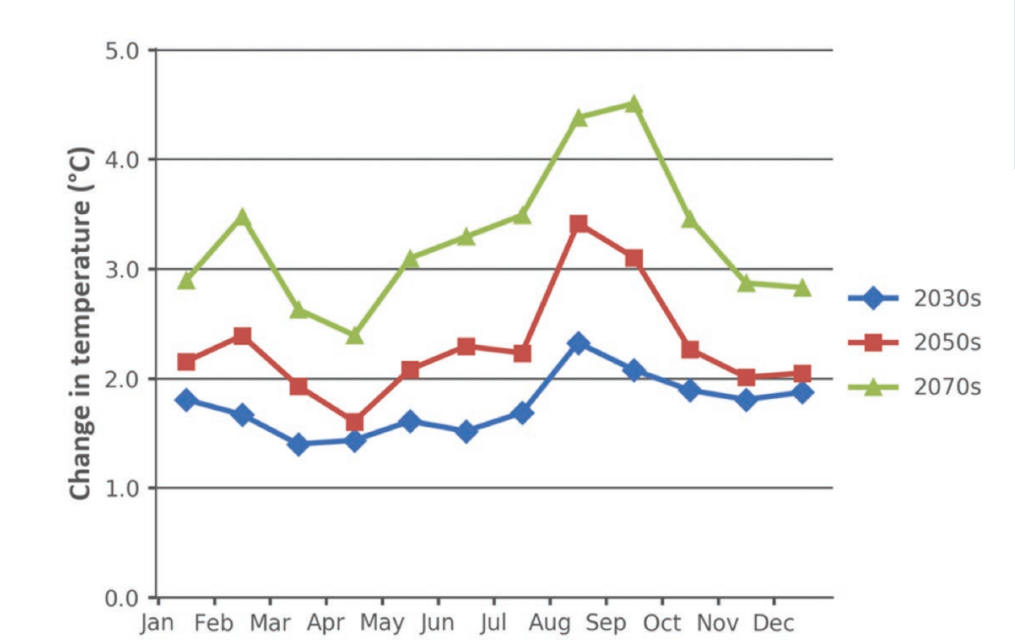


Figure 15
Western Scotland, mean daily maximum temperature change (˚C) (RCP6.0 90th percentile)

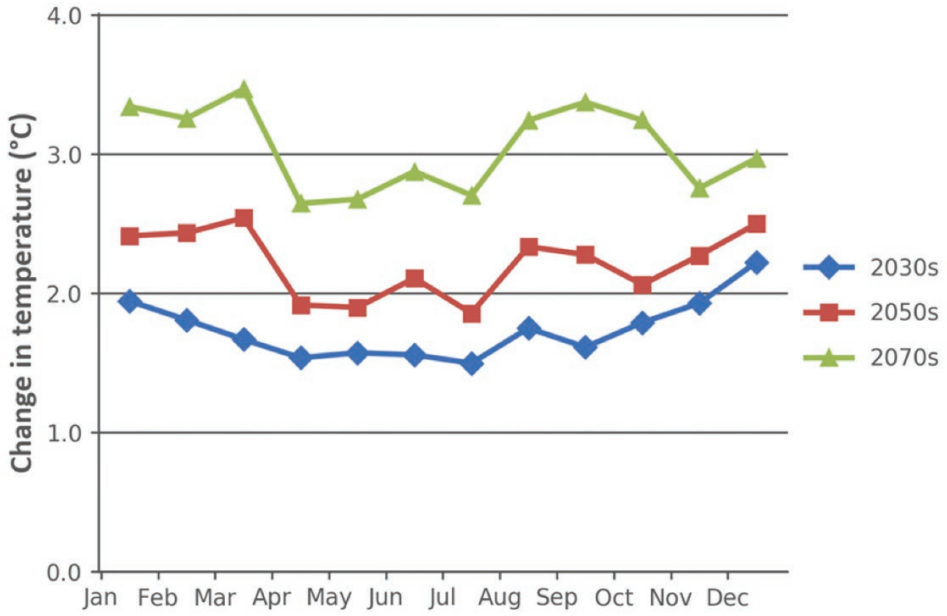
Mean Daily Minimum Temperature change

The mean daily minimum temperature for the regions is also projected to show increases throughout the year with the highest in summer and autumn. The level of increase is expected to become higher across the century.

Northern Scotland

The highest mean daily minimum temperatures for summer are expected to be in August, with increases of 2.3˚C to 11.4˚C by the 2050s and 3.2˚C to 12.3˚C by the 2070s. The lowest mean minimum temperatures in the 2050s will occur in January and February with the expected increase being 2.4˚C to 2.3˚C. In the 2070s it will be February and December with both expected to see increases of 3.3˚C and 3.0˚C respectively to 3.1˚C.

Figure 16
Northern Scotland, mean daily minimum temperature change (˚C) (RCP6.0 90th percentile)

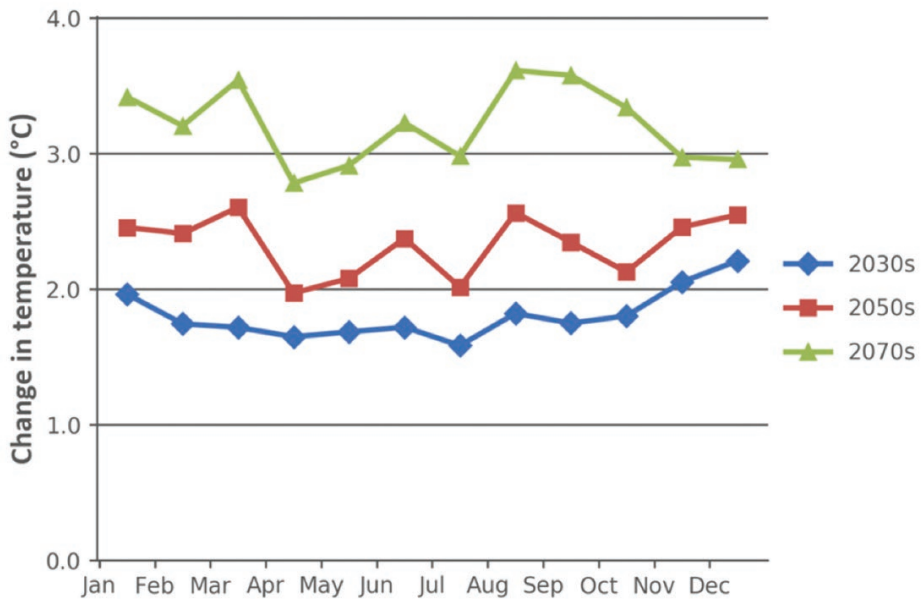


Scotland's Railway Vulnerability Assessment continued

Eastern Scotland

The highest mean daily minimum temperatures for summer are expected to be in August, with increases of 2.6˚C to 11.6˚C by the 2050s and 3.6˚C to 12.7˚C by the 2070s. The lowest mean daily minimum temperatures will now occur in January with expected increases being 2.5˚C by the 2050s to 1.9˚C, and 3.4˚C by the 2070s to 2.8˚C.

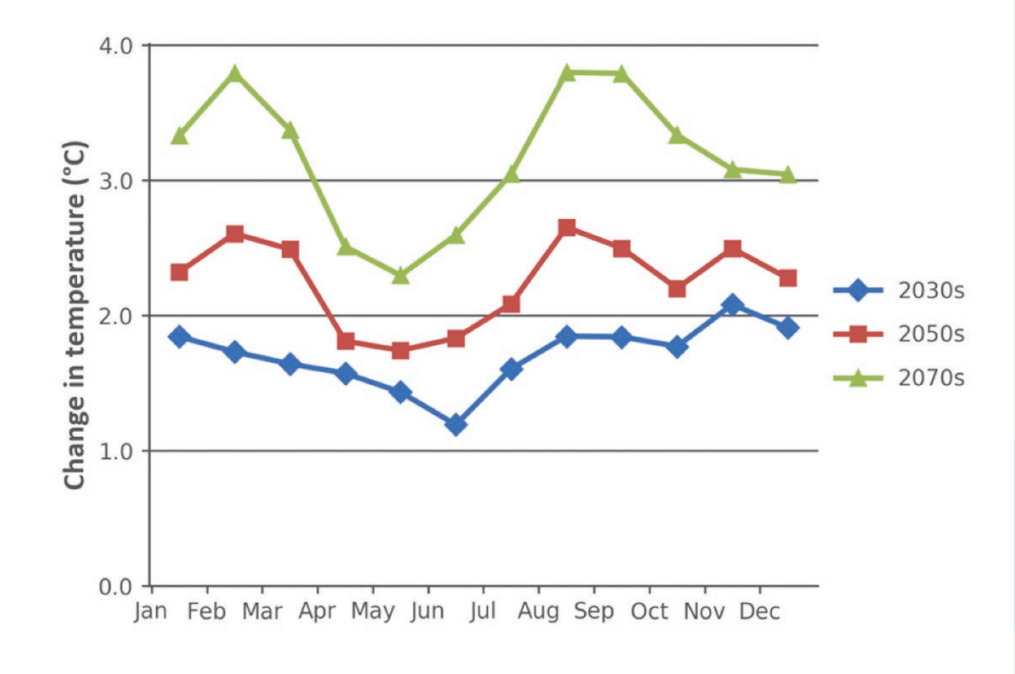
Figure 17
Eastern Scotland, mean daily minimum temperature change (˚C) (RCP6.0 90th percentile)



Western Scotland

The highest mean daily minimum temperatures for summer are expected to be in August, with increases of 2.7˚C to 12.5˚C by the 2050s and 3.8˚C to 13.7˚C by the 2070s. The lowest mean daily minimum temperatures will now occur in January with expected increases being 2.3˚C by the 2050s to 3˚C, and 3.3˚C by the 2070s to 4˚C.

Figure 18
Western Scotland, mean minimum temperature change (˚C) (RCP6.0 90th percentile)



Scotland's Railway Vulnerability Assessment continued

Mean daily precipitation

The UKCP18 narrative for mean daily precipitation in the regions suggest significantly wetter winters and drier summers. Network Rail's chosen climate change planning scenario (RCP6.0 90th percentile) shows the upper range of winter rainfall increases, but it does not illustrate the highest potential summer rainfall reductions. These are best represented by the RCP6.0 10th percentile projections. Figures 19, 20 and 21 therefore plot the RCP6.0 50th percentile projections with error bars that indicate the wider range of change associated with the 10th and 90th percentiles.

Northern Scotland

In the 2050s and 70s January will be the wettest month with daily increases of 27.5% to 8.6mm/day and 41.1% to 9.6mm/day respectively. The driest month will be July showing decreases of 29.2% to 2.3mm/day by the 2050s and 34% to 2.1mm/day by the 2070s.

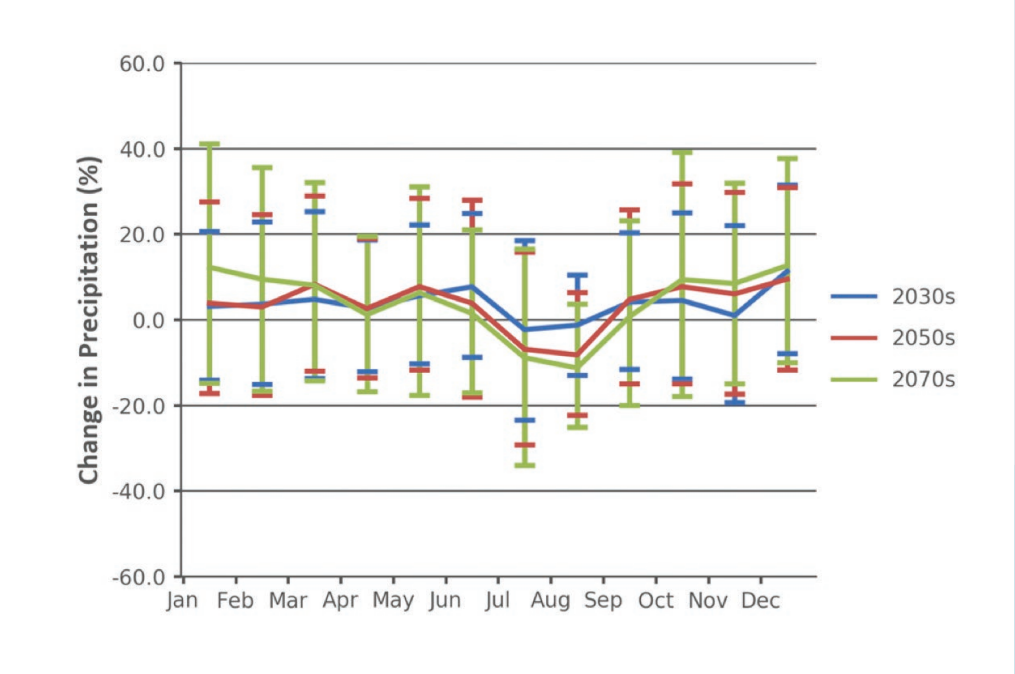


Figure 19
Northern Scotland, mean daily precipitation change (%) (RCP6.0 50th percentile with the wider 10th and 90th percentiles)

Eastern Scotland

In the 2050s and 70s January will be the wettest month with daily increases of 39.2 % to 6mm/day and 43.3 % to 6.2mm/day respectively. The driest month will be July showing decreases of 33.5 % to 1.6mm/day by the 2050s and 41.5 % to 1.4mm/day by the 2070s.

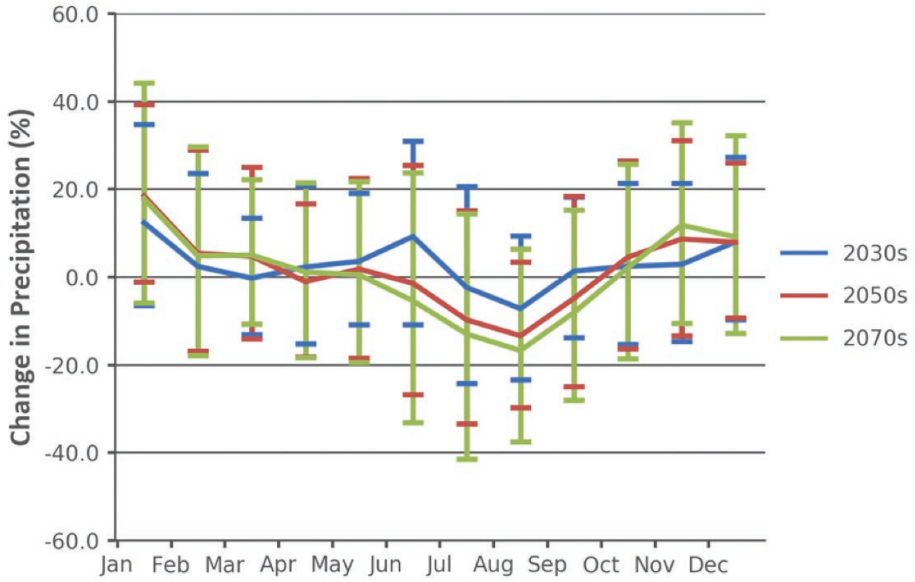


Figure 20
Eastern Scotland, mean daily precipitation change (%) (RCP6.0 50th percentile with the wider 10th and 90th percentiles)

Scotland's Railway Vulnerability Assessment continued

Western Scotland

In the 2050s and 70s October will be the wettest month with daily increases of 38 % to 9.1mm/day and 44.3 % to 9.5mm/day respectively. The driest month will be June showing decreases of 22.3 % to 2.3mm/day by the 2050s and 26.6 % to 2.1mm/day by the 2070s.

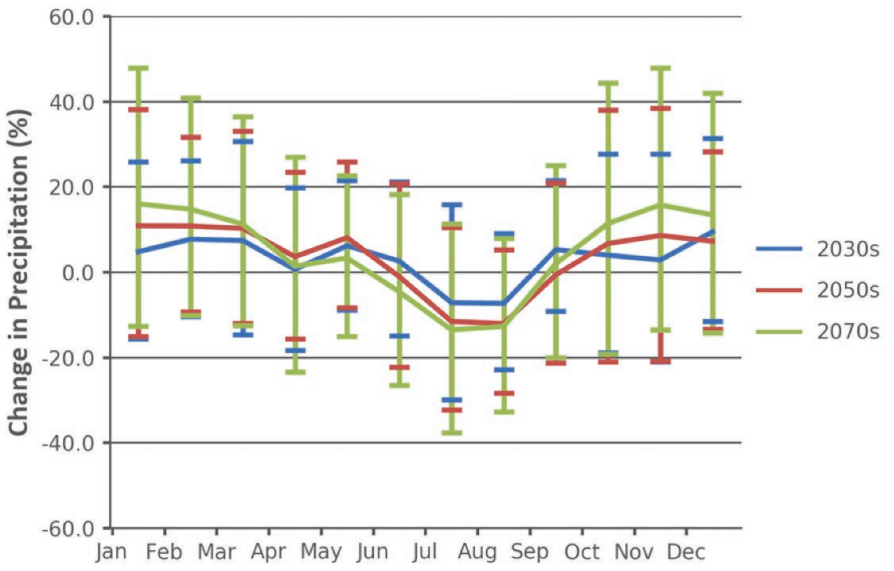


Figure 21
Western Scotland, mean daily precipitation change (%) (RCP6.0 50th percentile with the wider 10th and 90th percentiles)

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 and individual rainstorms with summer rainstorms show the largest increases.

The Scottish Environment Protection Agency (SEPA) updated their guidance on climate change uplifts to rainstorm intensity in April 2019. This guidance applied a peak rainfall intensity allowance to be applied relative to two specific regions, East and West Scotland. The definition of these regions can be found in SEPA publication Climate Change Allowances for Flood Risk Assessment in Land Use Planning, April 2019.

The same holds true for SEPA and EA climate uplifts to river flows. These are provided by river basin and those relevant to the Region are shown in Table 1.

Table 1
River flow uplifts

River basin[10]	2050s uplift	Year 2100
Tweed	20 %	33 %
Forth	–	40 %
Tay	–	35 %
North East Scotland	–	24 %
North Highland	–	37 %
West Highland	–	56 %
Argyll	–	56 %
Clyde	–	44 %
Solway	25 %	44 %

[10]SEPA modelling has provided uplifts for the Scottish river basins in the 2080s only. EA modelled outputs for both the 2050s and the 2080s are available for the two river basins that also cover England. This figure uses the SEPA uplifts for the 2080s and the EA uplifts for the 2050s where applicable.

Scotland's Railway Vulnerability Assessment continued

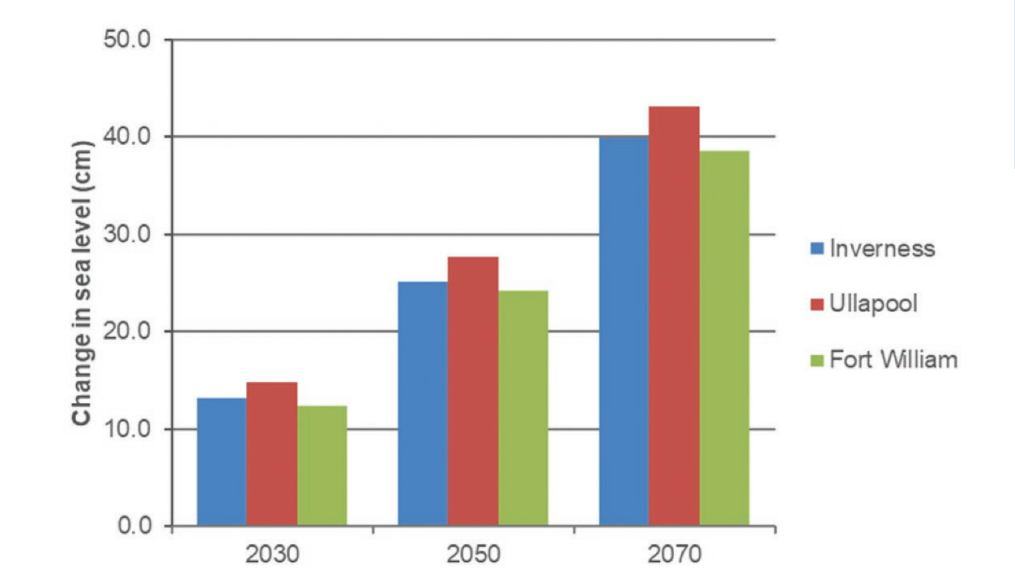
Sea level rise

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, UKCP18 projections have been obtained for 3 coastal locations in each of the administrative regions covered by the Scotland's Railway[11].

Northern Scotland

Ullapool, near Kyle of Lochalsh, will see the highest rises by 2050 and 2070 of 27.7cm and 43.2cm respectively and Fort William will see the lowest at 24.1cm and 38.5cm.

Figure 22
Sea level rise projections for Northern Scotland (cm) (RCP4.5 95th percentile)

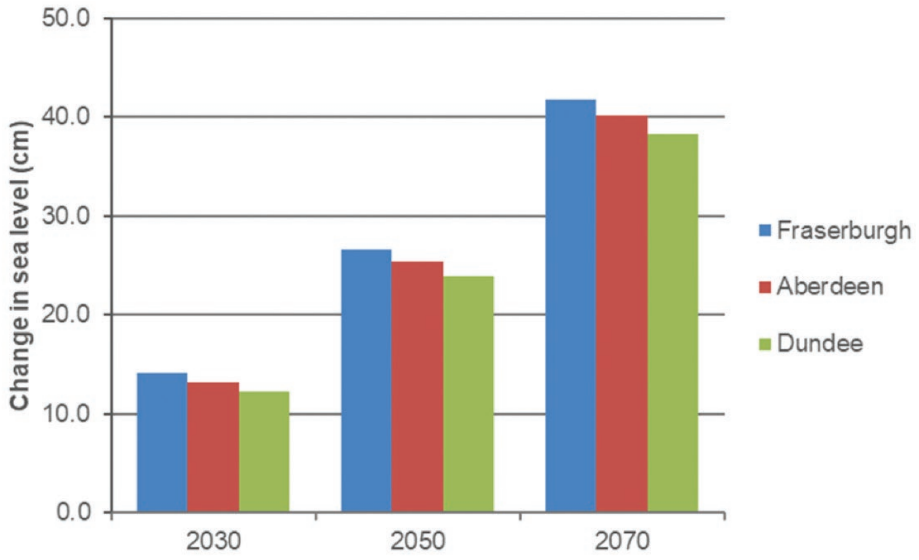


[11]Sea level rise data in UKCP18 is not available for RCP 6.0, instead RCP 4.5 is used as a proxy on the recommendation of the Met Office. This is the most compatible with the Network Rail Primary planning scenario.

Eastern Scotland

Fraserburgh, near Aberdeen, will see the highest rises by 2050 and 2070 of 26.6cm and 41.8cm respectively and Dundee will see the lowest at 24cm and 38.3cm.

Figure 23
Sea level rise projections for Eastern Scotland (cm) (RCP4.5 95th percentile)



Scotland's Railway Vulnerability Assessment continued

Western Scotland

Port Patrick, near Stranraer, will see the highest rises by 2050 and 2070 of 24.6cm and 39.4cm respectively and Ayr will see the lowest at 23.4cm and 37.6cm.

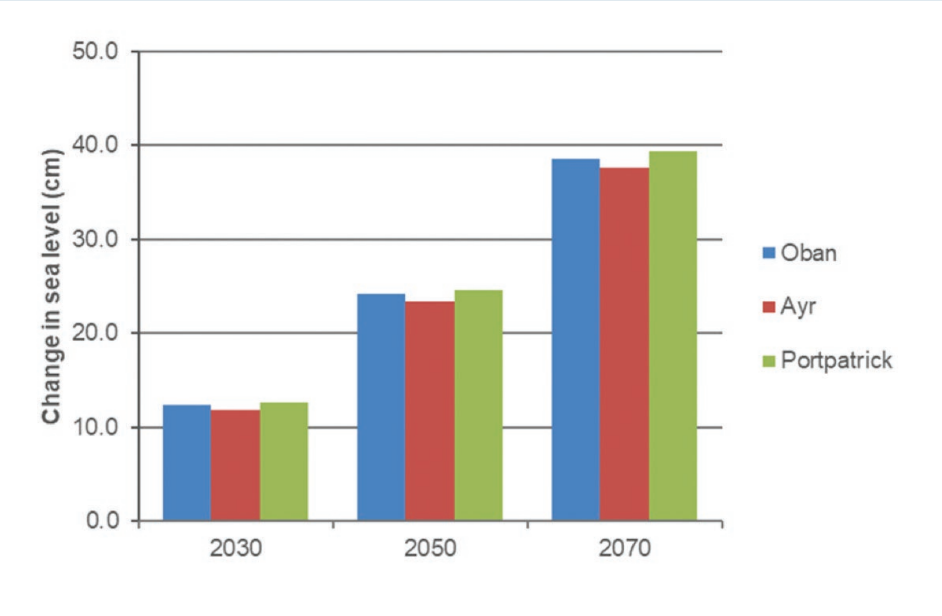


Figure 24
Sea level rise projections for Western Scotland (cm) (RCP4.5 95th percentile)

Scotland's Railway Impact Assessment

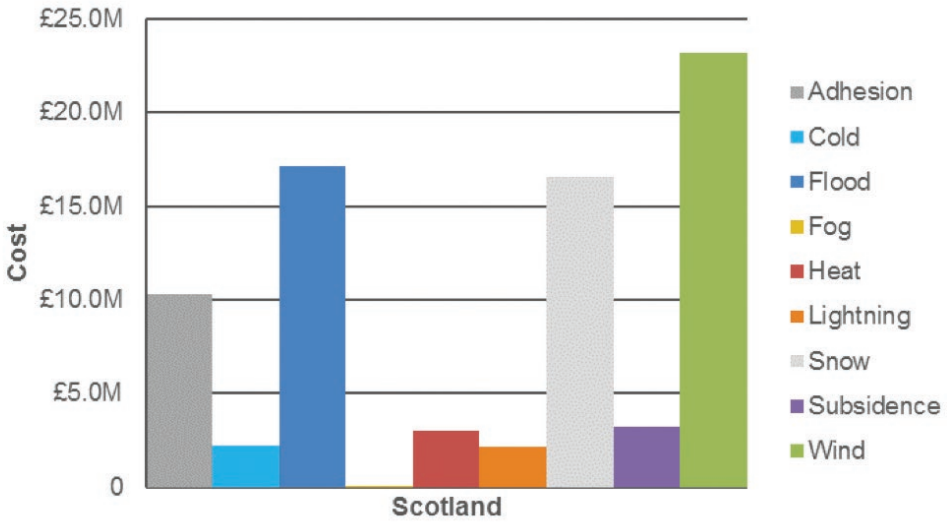
This section provides an updated Scotland's Railway weather impact assessment. This includes annual performance impacts and identification of higher impact locations on the Region.

Performance impacts

We monitor the impact of weather events on our network's performance using delay minutes and Schedule 8 delay compensation costs. As this includes 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 2014 plan, we analysed eight financial years of Schedule 8 data to give an assessment of the weather impacts for the Scotland Route. This Plan updates that assessment using additional data from the past 5 years, see Figure 25.

Figure 25
Scotland's Railway weather attributed Schedule 8 costs 2006/07-2018/19



The updated analysis shows that wind, flood and snow related incidents remain the most significant weather impacts for Scotland's Railway. Over the last 13 years these have cost a total of £23.2m, £17.2m and £16.6m respectively. The cost of wind delays is more than double the cost of rail adhesion related incidents at £10.3m 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 region.

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 UKCP09 projections (for wind, lightning and snow) and UKCP18 (for updated temperature, precipitation and sea level rise) will be used in the prioritisation of resilience actions as summarised in Table 2 below.

Scotland's Railway Impact Assessment continued

Table 2
Prioritisation of weather-related impacts on Scotland's Railway

Impact	Schedule 8 cost per year[12]	Climate projections[13]	Prioritisation
Wind	Average £1.78m Highest £5.12m	Changes difficult to project, however generally expected to increase	High
Subsidence (Landslip)	Average £0.25m Highest £0.78m	Increases in mean daily rainfall across the regions for late autumn, winter and early spring months, for example; 18.9 % in April and 38.4 % in November by the 2050s becoming 19.5 % in April and 47.8 % in February by 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; 11.7 % in May and 22.3 % in June by the 2050s, becoming 20 % in September and 26.6 % in June 2070s	High
Flooding	Average £1.32m Highest £3.31m	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
Adhesion	Average £0.79m Highest £2.17m	Complex relationship between multiple causes and their climate projections	Medium
Snow	Average £1.27m Highest £5.86m	Changes difficult to project, but increases in autumn, winter and spring minimum temperatures suggest reduced snow days	Medium
Heat	Average £0.23m Highest £2.24m	Increases in mean maximum daily temperatures across the regions range from 2.0˚C to 2.4˚C (winter) and 2.0˚C to 3.4˚C (summer) by the 2050s. In the 2070s this becomes 2.6˚C to 3.5˚C and 3˚C to 4.9˚C respectively	Medium
Lightning	Average £0.17m Highest £0.74m	Changes in storms difficult to project, however generally expected to increase	Medium
Cold	Average £0.17m Highest £0.62m	Increases in mean minimum daily temperatures across the regions in autumn, winter and spring ranging from 1.9˚C in April and May to 2.6˚C in March for the 2050s (lowest to highest) and 2.9˚C in May to 3.8˚C in August and September for the 2070s	Low
Fog	Average <£0.01m Highest <£0.01m	This is a complex picture with low confidence[14], however possible seasonal changes across the regions for the 2080s have been indicated as: winter -31 % to -55 %, spring -45 % to -57 %, summer -35 % to -43 % and autumn -28 % to -41 %	Low

[12]Based on the range of Schedule 8 costs over the last 13 years from 2008/09 to 2018/19

[13]UKCP09 2050s Medium emissions scenario 90th percentile, UKCP18 2050s RCP6.0 90th percentile except sea level rise

[14]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

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.

Identification of higher risk locations

Since the publication of the last Plan, Scotland's Railway has continued to see extreme weather that has exposed 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 are analysed via train delay minutes and Schedule 8 cost data. This allows 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, Scotland's Railway has also identified potential future risks and resilience actions based on climate change projections and local knowledge.

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

Heat impact assessment

Between 2006/07 and 2018/19 heat related incidents accounted for an average of 6,100 delay minutes and £0.23m in Schedule 8 costs per year. This is 2.7% of Scotland's annual average weather-related annual delay minutes and 3.9% of the annual average cost.

The year will become hotter on average in all seasons. Spring will move earlier, and autumn will move later. Winter will be shorter. Average and daily maximum temperatures will increase, and heatwaves will become more frequent, longer and more severe (see climate data). Growing seasons will lengthen, droughts will become more common.

Many railway assets are affected by heat, with signalling and track assets being the most prominent.

Signalling assets suffer from overheating of equipment and require insulation, cooling equipment or manual intervention to help reduce the effects of heat. Using remote condition monitoring and working with signalling equipment manufacturers to consider the effects of heat from the outset shall help to overcome some of this risk. We will carry out retrospective works to existing signalling equipment.

Increases in mean daily temperatures will increase the risk of track buckling and other rail defects.

Cold and snow impact assessment

Between 2006/07 and 2018/19 cold related incidents accounted for an average of 8,429 delay minutes and £0.17m in Schedule 8 costs per year. This is 3.7% of Scotland's annual average weather-related delay minutes and 2.9% of the annual average cost. Over the same period snow related delays averaged 54,857 delay minutes and £1.27m in Schedule 8 costs per year. This is 24.3% of the annual average weather-related delay minutes and 21.3% of the annual average cost.

Scotland's Railway have adopted specific winter working arrangements to manage the risks associated with extreme low temperatures and snow. Some of the actions detailed in these arrangements are:

Scotland's Railway Impact Assessment continued

- We will use snow ploughs and snow trains to alleviate the build-up of snow on the tracks and to melt snow in/around points machines,
- We will adopt bespoke working practices to manage the risks of icicles forming within tunnels (detailed in our Tunnel Icing Risk Strategy, Section X, Adverse and Extreme Weather Plan), and
- We will review our list of earthworks that are vulnerable to adverse weather to assess how snow melt might affect them.

Over and above these winter working arrangements, our Buildings team will deliver significant works to improve resilience within our station portfolio. For example, we now specify tactile studs on platforms rather than concrete tactile slabs following frost heave incidents on platforms in 2011. New platforms should also be of cross wall construction or similar in preference to mass fill.

We will use remote condition monitoring to ensure that points heating equipment is working as designed and highlight anomalies for checking and repair before asset failure.

Heavy snow can cause trees normally clear of railway assets to sag and become foul of the railway corridor or overhead electrification assets. Driving snow, especially with high sustained wind speeds can cause trees to fail and topple due to excessive loading of the crown area.

Flooding and sea level rise impact assessment

Between 2006/07 and 2018/19 inland and coastal flood related incidents accounted for an average of 45,884 delay minutes and £1.32m in Schedule 8 costs per year. In combination these represent 20.3 % of Scotland's annual average weather-related delay minutes and 22.1 % of the annual average cost.

Flooding

Flooding includes river, groundwater and surface water flooding (sea flooding is dealt with later). We expect winters to become significantly wetter on average with more frequent and intense storms. Summers will become significantly drier, but the intensity and frequency of summer storms is expected to increase markedly. Summer storm rainfall will be more severe than in winter. Intense summer rainfall after droughts/dry periods will increase the surface/flash flood risk and peak river flows will increase (see Table 1).

We saw the effects of extreme flash flooding in Central Scotland during August 2019, where substantial flooding occurred at Winchburgh Tunnel on the Edinburgh to Glasgow mainline, West Highland and Oban Lines. In 2020, we have had significant flood damage at Lochailort and at Whitecross near Polmont on the Edinburgh to Glasgow line, where a breach in the nearby Union Canal caused nearly a mile of damage.

Through 2019-2024, we allocated circa £10M of funding to alleviate or reduce the effects of flooding at sites we know have flooded before. We plan to renew several culverts and underbridges which have a history of flooding.

Following on from previous works, we will see the remediation of all remaining high bridge scour risk sites and remove minor scour defects at other sites.

We have identified funding to increase our planned underwater examinations, following on from a post incident review of Lamington failure in 2015. This includes provision to check underwater and Coastal, Estuarine and River Defences (CERDs) after adverse weather.

Sea level rise

Sea level will rise along the Scotland Route coast with small variations depending on the location (see climate data). Storm intensity and frequency will increase. The risk of coastal erosion and defence overtopping will increase. Discharges to estuaries and the coast will become more difficult.

We plan significant repairs at 10 locations before April 2024.

Subsidence (Landslip) Impact Assessment

Between 2006/07 and 2018/19 subsidence (landslip) related incidents accounted for an average of 9,437 delay minutes and £0.25m in Schedule 8 costs per year. This is 4.2 % of Scotland's annual average weather-related delay minutes and 4.1 % of the annual average cost.

We expect winters to become significantly wetter on average with more frequent and intense storms. Summers will become significantly drier but also come with markedly more frequent and intense storms. Summer storm rainfall will be more severe than in winter (see climate data).

We have targeted investment on a risk-based approach and have introduced our own in-house teams aimed at maintaining our earthwork drainage assets.

Network Rail in Scotland plans a record high capital investment (20 % higher than CP5) in our geotechnical assets. We will continue works on our highest risk assets and continue to reduce the number of geotechnical assets deemed susceptible to failure during adverse weather. We have adopted operational procedures during spells of adverse weather to reduce the effects of earthwork failure on train operations. These procedures include visual inspections of assets and/or slowing the speed of trains and are detailed in our Adverse and Extreme Weather Plan.

We will continue to roll out remote condition monitoring on our geotechnical assets to identify their performance during extreme weather. This technology will allow teams to identify the condition of assets without putting teams 'on the ground' during extreme weather and reduce the adverse effects on train performance.

Wind impact assessment

Between 2006/07 and 2018/19 wind related incidents accounted for an average of 68,375 delay minutes and £1.78m in Schedule 8 costs per year. This is 30.3 % of Scotland's annual average weather-related-delay minutes and 29.8 % of the annual average cost.

Wind is difficult to model into the future, so there are no projection figures, however the expected trend is for increased gust speeds and increases in the frequency and intensity of storms. In CP6, we have accelerated vegetation management programmes and enhanced risk based maintenance at some coastal locations to tackle this.

Vegetation

Tree failures can be caused by or be more likely in high winds. Failure might be a branch or limb falling, or the whole tree toppling. These failures can block railway traffic and (where present) interfere with/damage OLE assets.

They can damage, immobilise or derail trains. In most cases they delay trains and disrupt passenger and freight customers.

Scotland's Railway Impact Assessment continued

Trees inside and outside Network Rail's boundary can potentially fail onto the railway. In specific circumstances, even healthy trees can fail.

We will take action to reduce these risks, including:

- Improvements to the weather forecasting service and operation controls implemented due to these forecasts,
- Targeted clearing and management of trees within toppling range of track and OLE. We will spend circa £22.3m on clearing trees and maintaining the lineside,
- Specialist arboricultural foot surveys to identify potentially hazardous trees (between 2019-2022), to supply information for our review teams,
- Working with third party landowners to help them to reduce the risks of their trees failing onto Network Rail land, and
- Trials using decision support tools that incorporate LiDAR and railway asset data sets to identify high consequence locations for tree failures.

Adhesion impact assessment

Between 2006/07 and 2018/19 adhesion related incidents accounted for an average of 27,851 delay minutes and £0.79m in Schedule 8 costs per year. This is 12.3% of Scotland's annual average weather-related delay minutes and 13.2% of the annual average cost.

Changes in the rainfall and temperature patterns will make the growing season longer and delay autumn's onset. Increased storminess may remove leaves at additional times of year. Overall, we expect the pattern of leaf-fall to change. We have an all year round vegetation management programme to tackle this.

Seasonal leaf fall can delay trains, passengers and disrupt freight deliveries:

- Poor wheel/rail adhesion will impede braking distances and train acceleration,
- Point switches can become clogged with leaves that restrict full operation, and
- Train detection failures due to leaf mulch, insulating train wheels from track circuits are a rare but particularly serious loss of signalling equipment detection.

We expect that annual leaf burden and growth rates of trees will increase if climatic trends continue to warmer wetter weather for Scotland.

We have several actions to mitigate the effects of autumn leaf fall across the network:

- Detailed daily leaf fall forecasts to allow train operations and resources to be managed to best effect,
- High pressure water jetting and application of wheel friction modifier paste from a fleet of trains and other vehicles that operate throughout the season,
- Static wheel friction modifier applicators sited at locations of ongoing poor performance.
- Rapid response teams to target emerging issues "real time" and manually inspect and treat hotspots,
- Risk assessment at recorded locations of leaf fall problems, with targeted trees removed before the next autumn where this is possible and appropriate,
- Working with third party landowners to reduce the source of leaves that their trees shed each year, and
- Trials of emerging technologies for rail head treatment that utilise microwaves or cryogenics to supplement existing options.

Lightning impact assessment

Between 2006/07 and 2018/19 lightning related incidents accounted for an average of 4,888 delay minutes and £0.17m in Schedule 8 costs per year. This is 2.2% of Scotland's annual average weather-related delay minutes and 2.8% of the annual average cost.

Lightning can have a serious effect on our signalling assets, and it can take extensive works to recover the asset following lightning strike. Works to improve the resilience of our signalling systems are planned between Blair Atholl and Dalwhinnie to lessen the impacts of lightning strikes.

Scotland's Railway WRCCA actions

As the impact of weather can be very localised, Scotland Region will be responsible for identifying and carrying out the investments necessary to continue improving the railway's resilience in its assets and operations.

Network Rail's central functions will help the Scotland Region 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 by reviewing and adopting appropriate new technologies.

This section summarises the WRCCA actions undertaken by Scotland's Railway between 2014-2019 and those that we have planned for 2019-2024. The first two tables in this section show the:

- Network Rail Progress against CP5 WRCCA actions identified in the 2014 Plan (Table 3),
- Network Rail WRCCA actions planned for CP6 (Table 4), and

Table 5 details actions that have been apportioned to Network Rail Scotland in the Climate Ready Scotland: climate change adaptation programme 2019-2024. Some of these will align with CP6 planned and funded actions (Table 4), and others will require further consideration in CP6 and beyond.

Table 4 cross references with Table 5 to indicate the relationship between the Scotland's Railway actions and the delivery of the Climate Ready Scotland: climate change adaptation programme 2019-2024 actions.

Table 3 – 2014 WRCCA Plan CP5 actions review[15]

Action name	Target completion date	Actual completion date	Comments
All Impacts			
Climate Conditions and specific weather-related risks are not clearly communicated to asset renewal and enhancement processes	2019	2019	Route Scotland has now completed a comprehensive Route Adverse and Extreme Weather Plan. This brings together all asset adverse weather procedures into a single controlled document
Risk to staff from extreme weather conditions	2019	2019	Route Scotland has specific working arrangements for seasonal working, which considers steps that staff must take when working in extreme weathers
Weather Information			
The provision of only cyclical forecasts (e.g. daily general forecasts) limits the prediction of weather impacts on vulnerable assets	2015	2018	Route Weather Provider transferred to METDESK. This will allow for increased accuracy and targeted reporting At Risk "Adverse Weather" earthwork locations identified and receive bespoke forecast Route Scotland has now completed a comprehensive Route Adverse and Extreme Weather Plan. This brings together all asset adverse weather procedures into a single controlled document
Flooding			
Safety risk to staff responding to flooding sites and assessing the condition of the railway	2019	2019	Route Scotland has specific working arrangements for seasonal working, which considers steps that staff must take when working in extreme weathers
Level of engagement with Flood Risk Management Authorities	2019	2019	Network Rail has regular meetings with other statutory authorities. This includes collaborative working with councils on localised flood issues
Major repeat flood sites	2019	2019	Flood Risk Assessments have been carried out at several at-risk locations on Scotland Route. Detailed business plan put forward for CP6 remediation
New flood sites	2019	2019	Ongoing review of Water Management Group sites, including new flood sites added. Overall reduction in number of active sites part of Water Management Group
Potentially Vulnerable Areas (PVAs)	2019	2019	The review of PVA's and the effects on railway assets is a live process and is considered as part of our Business Plan development
Coastal and Estuarine			
Saltcoats Sea Wall	2017	2017	Works Complete
Other route sections at increased risk of flooding following sea level rise due to climate change	2019	2019	All Route CERD assets have been allocated to regional groupings and had individual current condition reviews and work items raised for current defects. Route overtopping risk monitoring service provided by HR Wallingford/Met Office
Earthworks			
A number of high-risk earthworks presently require proactive safety management in heavy rainfall	2019	2019	Adverse Weather Procedure in place following minimum Amber alert from Met Office Rainfall Data. Adverse Weather list updated bi-annually CP5 Business Plan Complete and consideration given to most vulnerable assets based on Adverse Weather
Failure precursors at earthworks sites are not directly monitored	2019	2024	Remote condition monitoring installed at 49 sites, target of 100 by end of CP6
Residual risk sites which require remediation	2019	2019	Additional funding secured in Years 3-5 workbank based on reduction of Adverse Weather site risk
Wind			
Detailed tree asset knowledge (location, size) is limited	2016	2016	LIDAR data analysis released to Scotland Route in December 2016
On electrified routes, 'tree on line' incidents will cause greater disruption than non-electrified routes	2018	2018	Vegetation Specification under normal circumstances mandates stricter management of trees (on Network Rail land) that are within falling distance of the track/OLE
Edinburgh to Glasgow Main Line electrified in 2017	2017	2017	Vegetation profile will continue to be maintained for new electrification
Adhesion			
Continued vegetation growth increases the volume of leaf fall and worsens adhesion	2019	2019	Vegetation management programmes are (and have been) principally working on high criticality, high consequence ELRs, especially where (or planned to be) OLE equipped. Such vegetation management works will improve adhesion issues that are due to leaf fall
Adhesion issues continue to cause a number of delay minutes	2019	2019	Network Rail Seasons Delivery Specialist continue to co-ordinate and manage the implementation of the Scotland Route Autumn Plan
Cold and Snow			
Only a limited number of points operating equipment have internal heating	2019	2024	Rollout Ongoing through CP6
System failure occurs when points heating strips become detached, but this is not detected by remote condition monitoring (which monitors the electrical properties of the points heating)	2014	2019	Automated train mounted inspection and monitoring systems in place to detect any detached heating strips
Overhead line and tunnel icicles can form, affecting performance of the first trains each day	2019	2019	Winter working arrangements processes identified to manage this risk
Heat			
Speed restrictions are imposed earlier than required, as actual site conditions are not known. Remote condition monitoring is not widespread	2015	2019	All local maintenance teams (based in Perth, Glasgow, Motherwell and Edinburgh) have remote condition monitoring installed at high risk sites
Lightning			
The railway between Perth and Inverness is particularly vulnerable to lightning strikes due to its geology	2018	2019	Significant works carried out between Dunkeld and Blair Atholl (Pitlochry Resignalling) and between Kincraig and Carrbridge (Aviemore Resignalling) in CP5

[15] References to Route Scotland were correct at the publication of the 2014 WRCCA plan. This has been subsequently superceded in 2019 as Network Rail have now adopted a regional structure, in Scotland known as Scotland's Railway.

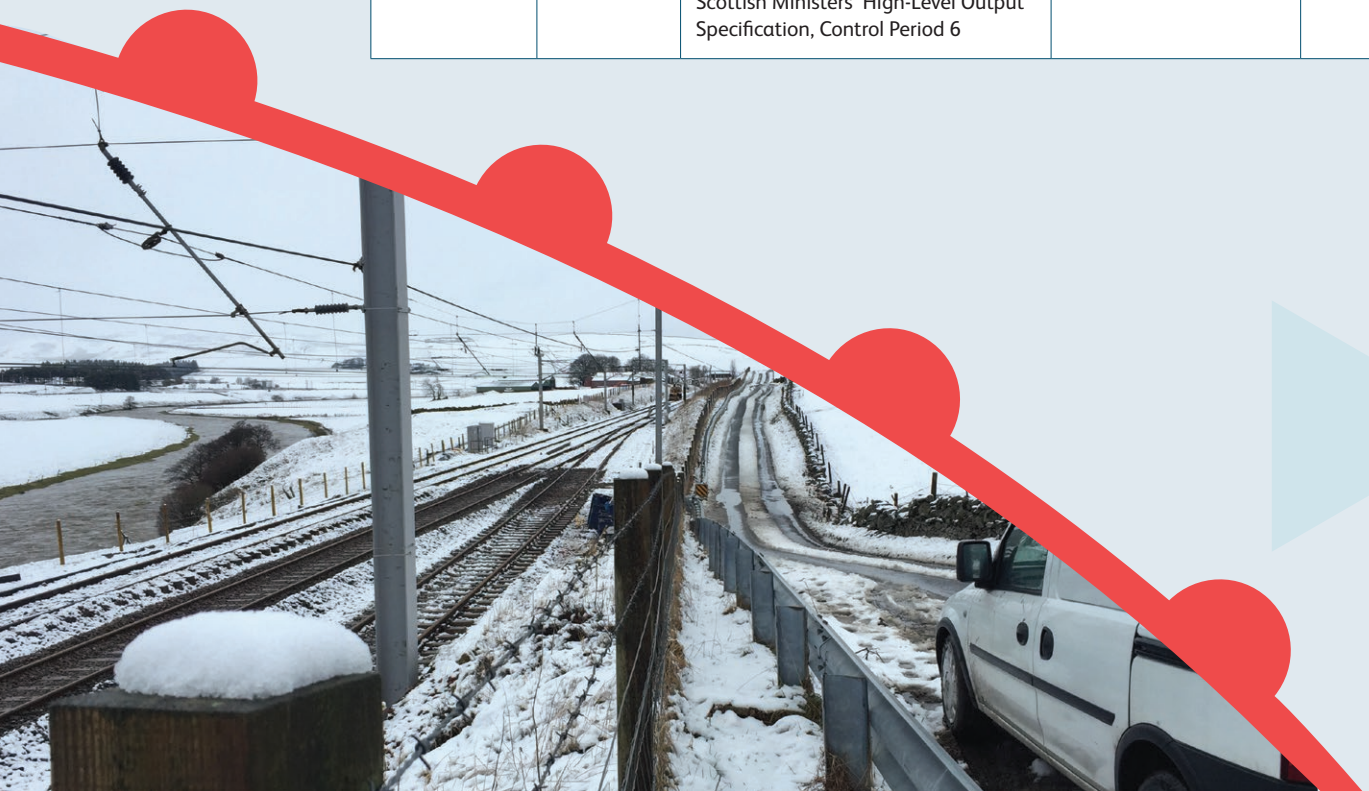
Table 4 – Planned Network Rail WRCCA investments for CP6 (2019-2024)

Vulnerability	Location (Parliamentary Region)	Action to be taken	Cost of action in Control Period 6	Expected benefit	Target completion date	Resilience change	Climate Ready Scotland action reference (see Table 5)
High Rainfall - Landslip	National	Reduce the overall number of earthworks susceptible to failure as a result of extreme rainfall. This will be achieved by investing £32m by 2024 on interventions at various locations across Scotland's Railway to improve the drainage and earthworks (D&E) on slopes that are in a poor condition The Asset Investment will extend across Scotland's rail network with focus on areas higher risk assets. Examples Include **South Scotland** Improving Slopes susceptible to adverse weather: – Glasgow & South West (GSW) line between Kilmarnock and Dumfries – Investment: circa £7m before April 2022 **Highlands and Islands** Improving weather resilience: – Highland Mainline – Far North Lines (Wick and Kyle lines) **Central Scotland** Improving Drainage: – Scottish Central Mainline – Investment: circa £4.6m before April 2023	£30m+ £7m £6.3m £5m £4.6m	Reduce failures to improve safety and performance	 2022 2024 2022 2023	Reduction in earthwork failures during adverse weather	NRCRS3 NRCRS5
High Rainfall - Landslip	National	Reduce the potential impact of a landslip on the operational railway by introducing remote condition monitoring to detect landslips and provide early warnings. This will be achieved by undertaking a trial of Landslip Detection Monitoring at 26 trial sites across Scotland by 2021. If trials are successful further roll out is planned **National** Landslip detection trial: – Across Scotland – 19 trial sites are operational increasing to 26 by the end of 2021 Landslip detection implementation: – Across Scotland – An additional 100 sites planned for delivery between 2021 and 2024	£2.0m £0.4m £1.6m	Proactive interventions reducing performance and safety consequences as well as driving more efficient focused expenditure	 2021 2029	Improved landslip detection	NRCRS1
High Rainfall - Flooding	National	Reduce the potential impact of flooding on the operational railway by undertaking targeted interventions at locations with a history of flooding. This will be achieved by undertaking discrete site-specific interventions at 32 sites on the rail network across Scotland **West of Scotland** Flood mitigation – 13 locations **South of Scotland** Flood mitigation – 7 locations **Lothians** Flood mitigation – 2 locations **Mid Scotland and Fife** Flood mitigation – 1 location **Highlands and Islands** Flood mitigation – 4 locations **North East Scotland** Flood mitigation – 2 locations **Central Scotland** Flood mitigation – 3 locations	£13m+ £4m £3m £0.75m £0.25m £3.5m £0.5m £0.7m	Reduce the likelihood of known repeat flood sites reoccurring	 2024 2022 2023 2021 2022 2022 2024	Targeting repeat flood sites	NRCRS3 NRCRS5
High Rainfall - Flooding	Niddrie Burn (Lothians)	Reduce the potential impact of flooding on culverts and underbridges where there has been evidence of previous incidents. This will be achieved by renewing assets to increase their resilience to flooding **Lothians** Asset resilience to flooding: – Niddrie Burn – 1no Underbridge renewal and 2no Culvert Renewals	£2m	Reduced flooding and reduction in performance risk	2024	Improved localised performance during floods	NRCRS5
High Rainfall - Flooding & landslip	West Highland Line (West of Scotland)	Reduce the impact of flooding and landslips where existing culverts assets struggle to cope with high rainfall events. This will be achieved by delivering the replacement of culverts **West of Scotland** Culvert Replacement – 33 culverts on the West Highland line	£4m	Reduced flooding and reduction in performance risk	2024	Improved asset resilience	
High Rainfall - Erosion	Scour Sites (National)	Reduce the potential impact of scour on the civils assets. This will be achieved by undertaking remediation work on the assets that have a high risk of scour as well as other assets will minor scour defects present **West of Scotland** Scour remediation – 11 locations **South of Scotland** Scour remediation – 7 locations **Lothians** Scour remediation – 2 locations **Mid Scotland and Fife** Scour remediation – 7 locations **Highlands and Islands** Scour remediation – 12 locations **North East Scotland** Scour remediation – 10 locations **Central Scotland** Scour remediation – 12 locations	£41m £5m £5m £2m £5m £9m £8m £7m	Reduced flooding and reduction in performance risk	Rolling programme of sites due to complete in 2024	Improved asset knowledge	NRCRS3

Vulnerability	Location (Parliamentary Region)	Action to be taken	Cost of action in Control Period 6	Expected benefit	Target completion date	Resilience change	Climate Ready Scotland action reference (see Table 5)
High Rainfall - Erosion	Scour Sites (National)	Reduce the potential impact of scour on assets by understanding the asset condition after a significant weather event. This will be achieved by increasing the number of post weather incident underwater examinations. This action resulted from a post incident review of the Lamington structure failure **National** Under water examinations following adverse weather events – includes reactive underwater and coastal & estuarial defence (CERD) examinations	£0.8m	Reduction in safety risk	2024	Improved asset knowledge	NRCRS3
Seal Level Rise - Erosion	Coastal Defences	Reduce the potential impact of sea level rises on coastal & estuarial location that are at risk of erosion due to degradation of the asset. This will be achieved by delivering repair interventions **National** Coastal and Estuarial defence (CERD) – Repairs to 10 Coastal and Estuarial defence locations. CERDs, where current rate of degradation requires intervention in CP6	£12m	Reduced risk of washout of the line and line closure during coastal storms	2024	Improved asset resilience	NRCRS3
Wind	National	Reduce the potential impact of vegetation and trees obstructing the operational railway as a consequence of high winds. This will be achieved by clearing lineside vegetation to reduce the likelihood of line blockages and train performance impacts **National** Vegetation Management – Lineside Vegetation clearance	£25m (£5m per annum)	Reduction in safety and performance risks	2029	Improved performance impact	NRCRS3
Wind	National	Reduce the potential impact of service affecting failures relating to overhead lines equipment due to contamination in coastal areas from high winds. This be achieved by additional and targeted maintenance regimes at high risk weather sites through the application of risk-based maintenance **National** Overhead line – targeted maintenance at high risk weather sites – Locations across Scotland e.g. Saltcoats	Implemented as Business As Usual	Recognition that high risks sites deteriorate at a faster rate than normal. Increased maintenance activity enables asset condition and integrity to be kept at appropriate levels to minimise the risk of incidents occurring	Ongoing	Improved asset resilience	NRCRS3
Wind	National	Reduce the potential impact of service affecting failures relating to electrical Principal Supply Points (PSPs). Rollout of remote condition monitoring for Principal Supply Points will enable remote supervision and control of critical plant assets which will be of key importance during periods of adverse weather and will allow PSPs to be controlled without the need to attend site **National** Principal Supply Points – Remote Condition Monitoring – Locations across Scotland	£0.5m	Extreme weather events often impact on the DNO network and can result in power outages across parts of the country. Fitment of Remote Condition Monitoring offers a functionality to enable key assets to remain operational during power outages	2024	Improved asset resilience	NRCRS2
Cold	National	Reduce the impact of frost heave uplifting the platform surfaces and coping stones due to the expansion of ground water on freezing during cold weather. This will be achieved by specifying tactile studs or using integrated tactile copers on the platforms in preference to concrete tactile slabs. In addition, new platforms will be constructed with a cross wall and or precast constructed mass infill in preference to traditional mass fill (constructed using brick or block). This action resulted from a post incident review from a widespread frost heave events in 2011 which affected 90% of Scotland's Station Platforms **National** Station Platform renewals – 12 station platforms across Scotland	£11m	Long term benefit as both cross-wall construction and tactile studs will perform better in any future frost heave event	Rolling programme of sites due to complete in 2024.	Improved asset resilience	NRCRS3
Lightning	Blair Athol to Dalwhinnie (Highlands and Islands)	Reduce the likelihood of lightning strikes due to the removal of assets that conduct electricity. Lightning strikes are a risk due to the remote location with little other conductive infrastructure in the vicinity **Highlands and Islands** Highland Mainline - Blair Athol to Dalwhinnie Aster track circuits conversion to axel counter and recovery of lineside cables	£15m	Susceptibility to lightning damage reduced	2024	Improved asset resilience	NRCRS3
Various	National	Reduce the impact of cracking and disintegration of glazing systems at stations canopies as a consequence of ultraviolet radiation from sunlight exposure. This will be achieved by installing polycarbonate glazing systems to station train shed as part of major refurbishment / renewal where permitted by planning consent **National** Glazing System renewals – Aberdeen Station train shed – Inverness Station	 £1.3m £1m	Robust material resistant to impact damage and UV degradation during periods of inclement weather	 2019 2020	Improved asset performance	NRCRS3

Table 5
Climate Ready Scotland Programme - Outcome 4 Our society's supporting systems are resilient to climate change – Policies and linked risks relevant to Scotland's Railway

Sub-outcomes		Policies	Progress monitoring themes	Network Rail Climate Ready Scotland action reference
4.1 Scotland's reserved supporting systems are resilient to climate change	4.1.4 Transport	The Infrastructure Investment Plan The Infrastructure Commission for Scotland The Infrastructure Investment Board Stakeholder Impact Assessments The National Transport Strategy 2 Dynamic Coast National Flood Risk Assessment 2018	Improving monitoring to inform assessment and prioritisation	NRCRS1
			Ensuring strategies are in place and the system has the flexibility and capacity to respond	NRCRS2
4.2 Scotland's devolved supporting systems are resilient to climate change	4.2.3 Transport	The Infrastructure Investment Plan The Infrastructure Commission for Scotland The Infrastructure Investment Board Stakeholder Impact Assessments The National Transport Strategy 2 Dynamic Coast National Flood Risk Assessment 2018 Strategic Transport Projects Review 2 Scour Management Strategy and Flood Risk Emergency Plan Landscape Management Preparing for Severe Weather Events Scottish Ministers' High-Level Output Specification, Control Period 6	Improving maintenance and reliability	NRCRS3
			Improving sustainability of resources and services	NRCRS4
			Futureproofing and building for climate resilience	NRCRS5
			Improving knowledge exchange and communication	NRCRS6
			Identifying interdependencies	NRCRS7



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. Scotland's Director of Engineering and Asset Management owns Scotland's WRCCA Plans and the Office of Rail and Road will monitor progress in implementation during CP6.

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

- Regions 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 regions 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),
- Regional 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 Regional 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, and
- The central WRCCA Team will use the information in the Regional 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 WRCCA actions to identify opportunities for collaboration to facilitate effective increase of rail system resilience.

Scotland's Railway management and review

Scotland's Weather Resilience and Climate Change Adaptation Plan will be reviewed annually by the Director of Engineering and Asset Management (DEAM) team and may be updated following significant weather events. The next large-scale review of the document will be carried out prior to CP7 (2024).

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