Environmental Statement

Volume 2i: Scheme-wide Assessment

Chapter 16: Climate vulnerability

Contents

16. CLIMATE VULNERABILITY 16-3

Summary of principal findings 16-3

16.1 Introduction 16-4

16.2 Legislative and policy context 16-5

16.3 Assessment methodology 16-8

16.4 Baseline 16-12

16.5 Potential effects 16-13

16.6 Mitigation measures 16-30

16.7 Residual effects 16-30

16.8 Cumulative effects 16-30

Tables

Table 16-1 Receptor vulnerability 16-10
Table 16-2 Significance of climate vulnerability impacts 16-11
Table 16-3 CCR assessment: potential operational impacts on assets 16-19
Table 16-4 CCR assessment: potential operational impacts on end users (passengers and staff) 16-28
Table 16-5 ICCI assessment: potential operational impacts on the environment 16-29

Inserts

Insert 16-1 Delays associated with weather-related incidents across the network 2006 to 2018 16-13
Insert 16-2 Overview of Network Rail's operational weather management 16-15
Insert 16-3 Example of heat shield protection hoods for trackside signalling equipment 16-16
Insert 16-4 Network layout around Scheme 16-31

16. CLIMATE VULNERABILITY

Summary of principal findings

This chapter presents the assessment of climate vulnerability effects associated with the construction and operation of the Huddersfield to Westtown (Dewsbury) section of the Transpennine Route Upgrade (TRU) Programme. This chapter covers the assessment of the entirety of the Huddersfield to Westtown (Dewsbury) Route herein referred to as the 'Scheme').

The impact of future climatic conditions on the Scheme during construction and operation have been assessed.

The assessment of the vulnerability of the Scheme to climate change has shown that climate projections covering the study area show that it is likely climate will change in the future and that the Scheme will be vulnerable to the consequences of this change during its operation. However, the detailed assessment has found that none of these vulnerabilities are significant as embedded mitigation sufficiently adapts the design and operational processes to remove and reduce to acceptable levels all otherwise significant climate vulnerability impacts.

16.1 Introduction

16.1.1 This chapter presents the assessment of climate vulnerability effects associated with the construction and operation of the Huddersfield to Westtown (Dewsbury) section of the Transpennine Route Upgrade (TRU) Programme. This chapter covers the assessment of the entirety of the Huddersfield to Westtown (Dewsbury) Route (herein referred to as the 'Scheme'). No separate Route Section Assessments are included within Volume 2ii of this Environmental Statement (ES).

16.1.2 This chapter is set out as follows:

- Legislative and policy context – relevant international, national and local policy requirements, legal requirements and guidance which have been used to define the assessment approach are outlined;
- Assessment methodology – the methodology the assessment follows is defined including the justification for the study area and the approach for determining significance of effects;
- Baseline – a summary of the climate baseline within the study area is provided;
- Potential effects – the potential impacts and effects (both beneficial and adverse) during construction and operation are characterised;
- Mitigation measures – agreed avoidance, mitigation, compensation and enhancement measures are described;
- Residual effects – the significance of residual effects (both beneficial and adverse) following the implementation of mitigation measures are assessed; and
- Cumulative effects - the potential likely significant cumulative effects of the Scheme are described and assessed.

16.1.3 A detailed description of the Scheme is provided in Chapter 2 (Scheme description) in Volume 2 of the ES and all appendices and figures referred to in this chapter are provided in Volumes 3 and 4 of this ES respectively.

16.1.4 The Scheme has the potential to be affected itself by climate change and its indirect effects. For example, by future changes to rainfall as well as by associated changes to flood risk.

16.1.5 The climate vulnerability assessment approach reviews how climate change could affect the Scheme's assets and how it could affect, e.g. intensify, the potential environmental impacts identified in the other chapters of this assessment, i.e. how the Schemes climate vulnerabilities could impact environmental receptors.

16.1.6 The aim of the assessment is to ensure that climate change, and impacts associated with extreme weather, are considered during planning so that they can be avoided and, if that is not possible, mitigated during the construction and operation of the Scheme.

16.1.7 This chapter should be read in conjunction with Chapter 2 (Scheme description) of this ES and also the Scheme's Flood Risk Assessment (FRA) which can be found in Appendix 11-1.

Climate change glossary

16.1.8 Although the term climate vulnerability is seemingly straightforward its components are open to interpretation. In this environmental assessment climate vulnerability is the degree to which the Scheme and its environmental receptors are susceptible to the impacts of climate change (beneficial and adverse). These effects include slow onset trends in climate as well as projected changes to extreme weather. Key climate terms used in this environmental assessment and an explanation of them are as follows:

- A **climate hazard** is a weather or climate related event that has the potential to do harm to the Scheme or its environment. For example, extreme hot temperatures;
- A **climate impact** is any type of damage or interference to the Scheme or its environment (in construction or operation) caused by a climate hazard. For example, buckled rails;
- **Consequences** of climate impacts are the effects of climate impacts. For example, reduced performance (delays) and repair costs; and
- **Mitigation** is the adaptative actions taken to remove or reduce potential climate impacts and/or their associated consequences. It is noted that some receptors have a certain level of inert adaptive capacity, i.e. the ability to absorb and recover from the consequences of climate impacts themselves.

16.1.9 An assessment of the effects of the Scheme on climate, i.e. its emissions, is provided separately in Chapter 17 (Effects on climate) of this ES.

16.2 Legislative and policy context

National

Climate Change Act 2008

16.2.1 The UK passed legislation that introduced the world's first long term legally binding framework to tackle the risks posed by climate change. The Climate Change Act 2008[1] ("the Act") created a new approach to managing and responding to climate change in the UK by providing:

- Ambitious, legally binding reduction targets;
- Powers to help meet those targets;
- A stronger institutional framework;
- A mechanism to enhance the UK's ability to adapt to the impacts of climate change; and
- Clear and regular accountability to the UK Parliament and to the developed legislatures.

16.2.2 Key provisions of the Act in respect of climate change adaptation include a requirement for Government to report, at least every five years, on the risks to the UK of climate change, and to publish a programme setting out how these will be addressed. This Act also introduces powers for Government to require public bodies and statutory undertakers to carry out their own risk assessment and make plans to address those risks. The Adaptation Sub-Committee of the Committee on Climate Change will provide advice to, and scrutiny of, the Government's adaptation work.

EIA Regulations for Transport and Works Act Orders (TWAO)

16.2.3 Schedule 1 of the Transport and Works (Applications and Objections Procedure) (England and Wales) Rules 2006[2] requires consideration of climatic factors. These Rules, which revise the Transport and Works (Applications and Objections Procedure) (England and Wales) Rules 2000, are designed to:

- Make the process for considering Transport and Works Act 1992 Order applications, and objections to them, more efficient and effective; and
- Implement the amendments that have been made to the European Directive on EIA by EC Directive 2003/35/EC.

[1] http://www.legislation.gov.uk/ukpga/2008/27/contents
[2] https://www.legislation.gov.uk/uksi/2006/1466/contents/made

National Planning Policy Framework 2019

16.2.4 The National Planning Policy Framework (NPPF)[3] sets out the Government's planning policies for England and how these are expected to be applied. The NPPF develops a planning system that contributes to radical reductions in Green House Gas emissions, minimises vulnerability and improve resilience; encourages the reuse of existing resources, including the conversion of existing buildings; and supports renewable and low carbon energy and associated infrastructure. The NPPF sets out that new development should be planned for in ways that avoid increased vulnerability to the range of impacts arising from climate change. When new development is brought forward in areas which are vulnerable, care should be taken to ensure that risks can be managed through suitable adaptation measures, including through the planning of green infrastructure.

National Policy Statement for National Networks

16.2.5 The National Policy Statement for National Networks (NPS NN)[4] sets out the need for applicants in the development of long-term infrastructure to consider the impacts of climate change, using the latest available UK Climate Projections data. The Policy statement highlights the importance of doing this throughout the project's lifecycle – when planning location, during design, when selecting building techniques and when planning operational procedures. It is noted that this Scheme is to be consented via a TWAO and is not a nationally significant infrastructure project (NSIP), therefore, although it is not directly relevant, this Policy Statement still provides helpful guidance.

Local

Joint Strategic Needs Assessment for Kirklees – physical environment and climate change, 2013

16.2.6 This report[5] summarises disruption to the services provided by Kirklees Council prior to 2013, disruptive climate events described in the report include:

- 2010 and 2011 – snow and ice disrupted transport and resulted in cancelation of all routine and non-emergency appointments at Huddersfield Royal Infirmary;
- 2009 – storm damage;
- 2007 – 100mm of rain in 24 hours caused major flooding; and
- 2003 – heatwaves increased hospital admissions.

16.2.7 The report sets out that the council expects flooding, storm intensity, heat waves and drought to be the main future climate change risks. It also acknowledges that the council expects that a changing climate will affect all its communities and will have significant implications on some key individuals in Kirklees. The report concludes that the obvious short-term risks are to the health of vulnerable people, such as older people, people in poor housing conditions, people with long-term health conditions, and infants. The report states that these risks include heat stroke on hot days and cold related health conditions which may lead to excess winter deaths. Chronic obstructive pulmonary disorders, cardiovascular disease, mobility and falls, and mental health illness are all also mentioned in the report as being exacerbated by cold and damp housing. Additionally, Kirklees Council notes that the effects of flooding can have a major impact on people's lives, including the long-term dislocation of people, the need to re-home and deal with the aftermath of a flood, and consequently their health and wellbeing.

[3] https://www.gov.uk/government/publications/national-planning-policy-framework--2
[4] https://www.gov.uk/government/publications/national-policy-statement-for-national-networks
[5] https://www.kirklees.gov.uk/you-kmc/partners/health/jsna/pdf/KirkleesJSNAPhysicalenvironmentandclimatechange.pdf

16.2.8 Kirklees Council recognises that it needs to influence travel behaviour and promote more sustainable and active modes to reduce dependence on private cars and in particular single-occupancy car journeys. In parallel, work to address the cost barriers (perceived or actual) to using public transport needs to be undertaken, particularly for young people, job seekers and part-time workers.

Kirklees Strategic Flood Risk Assessment 2016

16.2.9 The Kirklees Strategic Flood Risk Assessment[6] identified and analysed current and future broad scale flooding issues, with consideration of climate change impacts, for key locations in Kirklees, including along the River Colne from Huddersfield to Dewsbury. The document provides support for further assessment of planning applications and proposed development allocations within those areas.

Technical guidance and standards

Network Rail Weather Resilience and Climate Change Adaptation Impact Assessment Guidance Note

16.2.10 This document[7] provides guidance on how to effectively carry out weather and climate change risk assessments for those involved in design, construction and maintenance projects and activities.

Network Rail's 2017-2019 Weather Resilience and Climate Change Adaptation Strategy (WRCCAS), 2017

16.2.11 This document[8] builds on Network Rail's overarching Climate Change Adaptation Report (2015) and the Route Climate Change Adaptation Plans (various publication dates).

16.2.12 The WRCCAS summarises progress in understanding the potential impacts of climate change on performance and safety of the rail network, and what is being done to increase resilience. This includes ensuring all projects going through the GRIP[9] process undertake a climate change risk assessment and design schemes to be resilient to future weather conditions and/or with a view to providing passive provision for future weather conditions. Progress on immediate actions are also highlighted and these include enhancements in operational weather management and better understanding of weather risks to assets and infrastructure.

Route Weather Resilience and Climate Change Adaptation Plans London North East (LNE) and East Midlands, 2016

16.2.13 This document forms a strategic adaption plan[10] for the region in which the Scheme is located. It is based on assessments of weather-related vulnerabilities, identification of root causes of historical performance impacts and an understanding of potential future impacts from regional climate change projections[11].

[6] https://www.kirklees.gov.uk/beta/planning-policy/strategic-flood-risk-assessment.aspx
[7] https://safety.networkrail.co.uk/wp-content/uploads/2018/06/Weather-resilience-climate-change-impact-assessment-Guidance-Note.pdf
[8] https://safety.networkrail.co.uk/wp-content/uploads/2017/02/NR-WRCCA-Strategy-2017-2019.pdf
[9] Governance for Railway Infrastructure Projects (GRIP) is a management and control process developed by Network Rail for delivering projects on the operational railway
[10] https://cdn.networkrail.co.uk/wp-content/uploads/2016/11/LNE-and-EM-Route-WRCCA-Plan.pdf
[11] https://cdn.networkrail.co.uk/wp-content/uploads/2016/11/LNE-and-EM-Route-WRCCA-Plan.pdf

16.2.14 The consequences of weather on the rail network can be monitored over time using performance data. Schedule 8 of the report presents the costs of compensation payments to train and freight operators for network disruption caused by different types of weather for the past eight financial years for the LNE and East Midlands areas. The analysis highlights that flooding and wind events have had the most significant weather impacts in the area.

16.3 Assessment methodology

Study area

16.3.1 The study area for the climate vulnerability assessment incorporates all the study areas used for the assessment of impacts for the environmental topics within this ES. This area therefore includes all land within the Scheme boundary and includes land up to a maximum distance of 10km from the railway.

Baseline data sources

16.3.2 Three main data sources are used to inform the baseline:

- The Met Office's standard average data tables are used to summarise the historic regional climate (Yorkshire and Humber administrative area[12]). These show historic sets of 30-year averages for several climate variables covering the period 1981-2010;
- Local data from the Bradford climate station which is the closest long running climate station to the Scheme[13]; and
- Climate change projections from UKCP18 (United Kingdom Climate Projections 2018[14]). These have been developed by the Met Office Hadley Centre Climate Programme which is supported by the Department of Business, Energy and Industrial Strategy (BEIS) and the Department for Environment, Food and Rural Affairs (Defra). They provide the most up-to-date assessment of how the climate in the of the UK may change over the 21st century.

Identifying receptors

16.3.3 Receptors which may be affected by climate change have been identified with consideration of both extreme weather events and gradual climatic changes in the study area over the Scheme's design life. The assessment considers impacts on the following receptors during the Scheme's construction and operational phases:

- Construction receptors – including site viability, plant and workforce health and safety;
- The assets and their operation, maintenance and refurbishment – including tracks, stations, structures, earthworks, drainage, power supply and technology (e.g. for signalling and communication);
- End-users (passengers and staff) – including health and safety, comfort and well-being; and
- Environmental receptors – including the water environment, landscaping and biodiversity.

Assessment criteria

16.3.4 The assessment is broken into two parts, specifically the In-Combination Climate Change Impacts (ICCI) assessment and the Climate Change Resilience (CCR) assessment.

[12] https://www.metoffice.gov.uk/research/climate/maps-and-data/uk-climate-averages
[13] https://www.metoffice.gov.uk/research/climate/maps-and-data/historic-station-data
[14] https://www.metoffice.gov.uk/research/approach/collaboration/ukcp/index

16.3.5 The ICCI assessment focusses on those effects of the Scheme identified by an environmental topic which will also be affected by climate change (for example a potential impact identified by the water topic which could be affected or intensified in the future by projected changes in rainfall).

16.3.6 The CCR assessment focusses on the resilience of the Scheme's assets to the projected effects of climate change.

16.3.7 The ICCI and CCR assessment follow the same multi staged method as set out below. It is undertaken separately for each potential climate vulnerability:

- Stage 1a – Assess the exposure of receptor to climate hazard;
- Stage 1b – Assess the sensitivity of the receptor to climate hazard;
- Stage 2 – Combine Stages 1a&b to define receptors climate vulnerability. If vulnerability is medium or high move to next stage otherwise the impact is classified not significant;
- Stage 3a – Assess the magnitude of consequence;
- Stage 3b – Assess the likelihood of consequence (frequency and duration); and
- Stage 4 – Combine 3a&b to define significance of climate risk.

Stage 1a – Assess the exposure of receptor to climate hazard

16.3.8 A climate hazard is a weather or climate related event that has the potential to do harm to the Scheme or its surrounding environment. These are identified based on professional judgement and a review of historic international experience.

16.3.9 The exposure of receptors to climate change hazards has been determined using available data (see Section 16.4) and professional judgement. The categories range from negligible through low and medium to high. When defining exposure, consideration has been given to the projected return periods of future events (where known), the confidence in the direction of projected changes as well as to the extent of that change relative to the baseline value.

Stage 1b – Assess the sensitivity of receptor to climate hazard

16.3.10 For each potential climate vulnerability, the sensitivity of the receptor to climate impacts is determined following consideration of the receptor's adaptive capacity. For Scheme assets (i.e. for the CCR assessment) this includes consideration of design adaptation measures (embedded mitigation). Four levels of sensitivity are used in the assessment, defined as:

- **High sensitivity** – the receptor is directly dependent on existing and/or prevailing climatic factors, and reliant on these specific existing climate conditions continuing in future (for example, river flows and groundwater level); or only able to tolerate a very limited variation in climate conditions;
- **Medium sensitivity** – the receptor is dependent on some aspects of the prevailing climate;
- **Low sensitivity** – the receptor is able to tolerate some extreme conditions; and
- **Negligible sensitivity** – climatic factors have very little or no influence on the receptor.

Stage 2 – Define receptors climate vulnerability

16.3.11 Table 16-1 shows how for each potential climate vulnerability the receptor exposure and sensitivity are combined to define climate vulnerability. This is done separately for each potential vulnerability rather than by receptor because receptors may be impacted by changes to multiple climate variables and could, for example, be more likely to be impacted by changes in precipitation than temperature.

Table 16-1 Receptor vulnerability

Receptor exposure	Receptor sensitivity			
	Negligible	Low	Medium	High
Negligible	Low	Low	Low	Low
Low	Low	Low	Medium	Medium
Medium	Low	Medium	Medium	High
High	Low	Medium	High	High

Stage 3a – Assessing consequence magnitude

16.3.12 Consequences are the effects of climate impacts. For railway schemes, the main consequences of climate vulnerabilities relate to financial costs, poor performance, safety risks and negative public perception. Consequence magnitude is primarily a gauge of the size of these effects. In addition to this, the assessment also considers the value of the receptor, for example its quality and importance. For environmental harm, for example, this may be represented by the receptors conservation status and for operational performance this could be based on how critical the failure of a particular performance metric is to the operation of a larger system. Assessing consequences in this way recognises that some receptors are more important than others. As such, where everything else is equal, important receptors are more likely to be significantly affected than those considered to be of low importance.

16.3.13 Consequences of climate change impacts have been defined as follows:

- High:
  - Consequences have very large economic cost or affect assets that are integral to critically important systems;
  - Consequences cause very large safety risks (long term injury/illness or risk of fatality) or very poor performance (>48 hours);
  - Consequences cause prolonged negative national reporting; and
  - Consequences cause very large environmental pollution or harm resulting in a major breach in compliance and prosecution or adversely affect internationally important species or habitat.
- Medium:
  - Consequences have a large economic cost or affect important systems;
  - Consequences cause large safety risks (short term injury or illness) or poor performance (<48 hours);
  - Consequences cause negative regional media; and
  - Consequences cause large environmental pollution or harm resulting in a regulatory non-compliance or affect nationally important species or habitat.
- Low:
  - Consequences have a moderate economic cost or affect systems or assets that can be replaced;
  - Consequences cause safety risks (minor harm or near miss) or slightly reduce performance (<1 hour);
  - Consequences cause negative local media or adverse local stakeholder reaction; and
  - Consequences cause moderate environmental pollution or harm that may cause non-compliance of regional or local policy or affecting locally important species or habitat.

- Negligible:
  - Consequences have little economic cost or affect individual assets and can be easily repaired or replaced;
  - Consequences cause very small or no safety risks or reduced performance;
  - Consequences have little or no public interest; and
  - Consequences have no statutory controls or cause negligible environmental pollution or harm to receptors of little or no importance.

16.3.14 All consequences are adverse unless explicitly stated as being low, medium or high beneficial. In this case significance would also be explicitly stated as being beneficial.

Stage 3b – Assess likelihood of consequence

16.3.15 Consequence occurrence gives consideration of the expected frequency and duration of consequences. It is rated from high (consequences occur many times during the life of the Scheme, e.g. could occur seasonally or last for more than six months), medium (more than once or lasting three to six months), low (once or lasting one to three months) to negligible (consequences unlikely to occur during Scheme's design life or lasts less than a month).

Stage 4 – Define significance of climate risk

16.3.16 Table 16-2 shows how for each potential climate vulnerability, the consequence magnitude and likelihood are combined to define the significance of the climate risk. Climate vulnerability risks assessed to be 'moderate' or 'major' (marked red in Table 16-2) are considered to be significant.

Table 16-2 Significance of climate vulnerability impacts

Consequence likelihood	Consequence magnitude			
	Negligible	Low	Medium	High
Negligible	Negligible	Negligible	Negligible	Minor
Low	Negligible	Minor	Minor	Minor
Medium	Negligible	Minor	Moderate	Moderate
High	Minor	Minor	Moderate	Major

Residual impact assessment

16.3.17 If further mitigation, known as additional mitigation, is identified, for example to reduce otherwise significant climate vulnerability risks, this is identified in the residual impact section along with a final assessment of the ultimate impact. This has been an iterative process throughout the Scheme's design to ensure that mitigation can be built into the design wherever possible with the objective of removing all significant residual risks at the design stage.

Consultation

16.3.18 In relation to flood risk and drainage design, NPPF planning requirements and Environment Agency design guidance relating to climate change apply. Therefore, a separate FRA has been undertaken for the Scheme which can be found in Appendix 11-1. This includes an assessment of climate change effects on flood risk and takes into account current Environment Agency climate change allowances for increases in peak river flow and rainfall intensity. Consultation with Kirklees Council, Environment Agency, and other relevant authorities (for example, Canal and River Trust) has been undertaken to inform the FRA.

Assumptions and limitations

16.3.19 The assessment of the potential impacts of climate change on the Scheme is based on professional judgement.

16.3.20 The UKCP18 projections do not provide a single precise prediction of how weather and climate will change years into the future. Instead UKCP18 provides ranges that aim to capture a spread of possible climate responses. This better represents the uncertainty of climate prediction science. It should be noted that the level of uncertainty of the projections is dependent on the climate variable, for example, there is greater confidence around changes in temperature than there is in wind. In this assessment this is considered when assessing the likelihood of impacts. Further details on the limitations of UKCP18 data can be found online[15].

16.4 Baseline

16.4.1 Climate is defined as the typical weather conditions experienced in a place over a period of time, conventionally expressed as average weather over a 30-year period.

16.4.2 The baseline for climate change vulnerability is presented in two parts:

- Current climate- an examination of the current climate baseline using the Meteorological (Met) Office's latest regional dataset of 30-year averages and data from the closest long running climate station; and
- Projected climate – a consideration of the projected future climate baseline.

16.4.3 It should be noted, however, that climate change is not only a challenge of the future. The UK climate is already observing changes, for example average temperatures have risen by approximately 1ºC over the last century.

16.4.4 The full climate vulnerability baseline is included in Appendix 16-1; a summary is provided as follows.

Current climate

16.4.5 The climate in the study area is one of relatively mild winters and warm summers. Monthly average and mean maximum temperatures are just above average for the UK (Appendix 16-1, Insert A-16-1 and A-16-2). Long-term average monthly rainfall is close to the lowest in the UK (Appendix 16-1, Insert A-16-7) and the study area receives fewer heavy rainfall days than is usual for the UK (Appendix 16-1, Insert A-16-10).

Projected future climate

16.4.6 The study area is likely to experience warmer (Appendix 16-2, Insert A-16-13) and wetter (Appendix 16-2, Insert A-16-16) winters and hotter (Appendix 16-2, Insert A-16-14) and drier (Appendix 16-2, Insert A-16-15) summers. Alongside these changes in the average conditions, it is possible, but less certain, that climate change will also increase the frequency and severity of extreme weather events, such as heavy rainfall, storms and heatwaves (Appendix 16-2).

[15] www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/research/ukcp/ukcp18-guidance---caveats-and-limitations.pdf

16.5 Potential effects

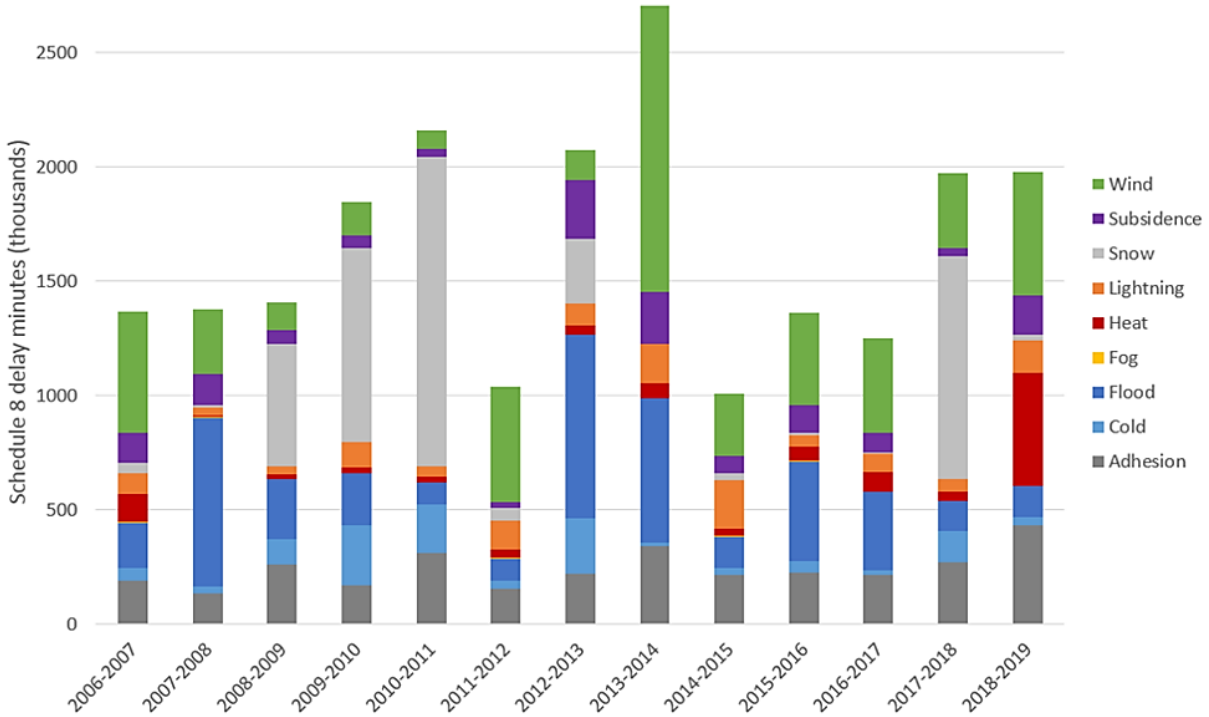
16.5.1 Long-term effective management of the impacts of weather and climate change is essential to the reliable and safe running of the railway. The main impacts of weather on railways are costs, poor performance (measured by Public Performance Measures) and safety risks. Each of these are expanded in this Section before a consideration of how each is relevant to this Scheme is presented.

Economic costs

16.5.2 Network Rail estimate that weather impacts cost them £50-£100m per year due to delays and cancellations[16].

Poor performance

16.5.3 Insert 16-1 shows the delays associated with weather-related incidents across the network for the past decade[16]. With regards to train delays, it gives an indication of which climate change variables could cause the greatest performance impacts on the Schemes operation.



Insert 16-1 Delays associated with weather-related incidents across the network 2006 to 2018

16.5.4 From 2008 to 2011, as well as in 2017-18, snowfall was a significant cause of train delays. Flooding is also an important factor although with regards to train delays, it is rarely the main cause of delays in any one year. Adhesion issues (inefficient acceleration and braking) is a fairly consistent factor year to year, whilst wind is highly variable with the potential to cause significant delays, as for example it did in 2013-2015. In this period the only year with notable delays due to heat was 2018-2019. These national findings agree with the regional data discussed in Section 16.2.14. It should be noted that some important weather impacts may affect performance but not cause train delays, and so their consequences may be underestimated in this graph.

[16] https://safety.networkrail.co.uk/home-2/environment-and-sustainable-development/wrcca/

Safety

16.5.5 The vulnerability of railways to weather related impacts was brought into sharp focus by the Stonehaven derailment, 12th August 2020. This accident caused three fatalities when a passenger train hit a landslip following heavy rain that occurred during an amber severe weather warning from the Met Office. The same stretch of railway had also been closed in October 2002 due to a landslide at Carmont, during torrential rain and gales. On 25th August, NR set up two new task forces, one aimed at improving its response to severe weather and the other aimed at better management of earthworks.

16.5.6 In September 2020 Network Rail produced an interim report on the 'Resilience of rail infrastructure following the derailment at Carmont, near Stonehaven' to the Secretary of State for Transport[17]. In it Network Rail acknowledged that the impact of climate change on its network "is an area that is accelerating faster than our assumptions". The report highlighted the need to deploy more technology across the network to predict failures and it said investment in better weather forecasting was needed to enable local decisions to be made in advance. Although climate change considerations are being embedded in Network Rail standards and planning the report also suggested that industry rules for reporting and responding to heavy rainfall is improved as this would help signallers to better manage services during bad weather.

16.5.7 It is noted that Stonehaven is in a remote location and that few railway upgrade works had been undertaken in the area. Works on the Scheme that is the focus of this report are not driven by the outcomes of the above-mentioned report but impacts associated with ground stability are still relevant and will still be addressed by the application of modern slope and drainage engineering standards.

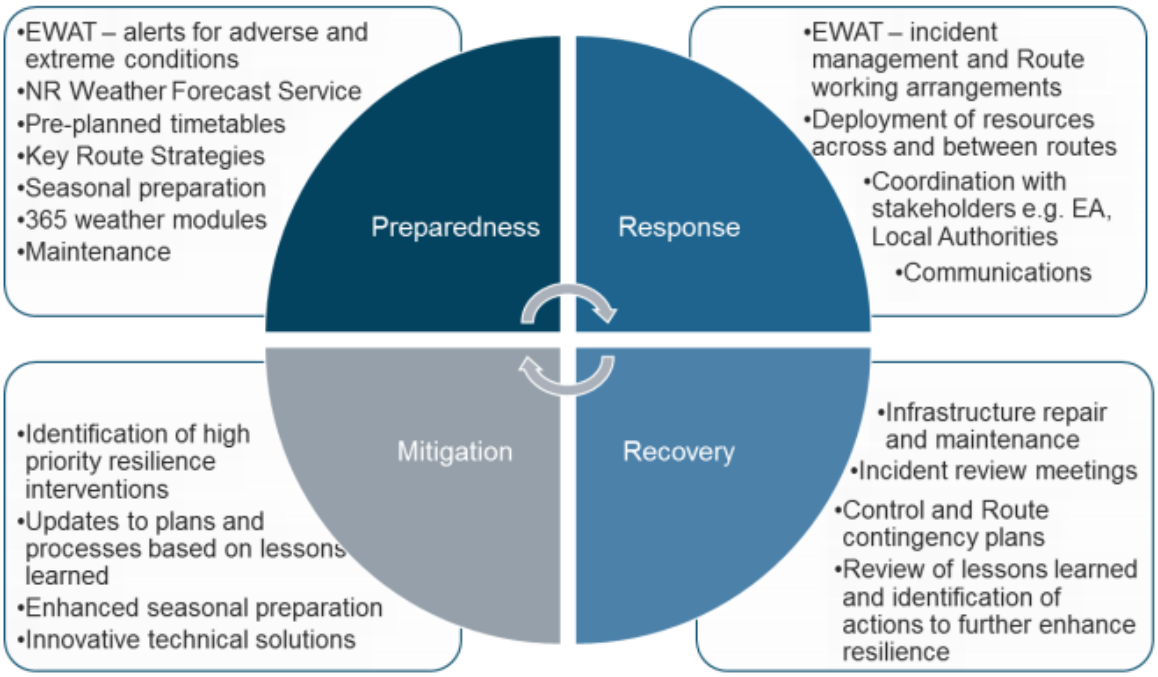
Identifying potential impacts on the Scheme

16.5.8 With regard to this Scheme, potential climate vulnerabilities are identified by considering whether the effects of the Scheme are likely to be different in the future because of projected change impacts. This is a qualitative process based on expert judgment, engagement with other EIA topic leads (for example Water Quality, Flood Risk and Landscape), design engineers, Scheme stakeholders and a review of the proposed design specification and relevant literature related to climate vulnerabilities in the UK and internationally. The process is supplemented with quantitative data and information where available. Most of the Scheme's climate vulnerability impacts relate to asset risks. For each vulnerability there is a climate hazard (e.g. hotter summers), an impact pathway (e.g. higher track temperatures), a failure (e.g. track buckling) and an effect (consequences such as delays and maintenance costs).

16.5.9 The potential climate vulnerability impacts assessed in this chapter (see Table 16-3 to Table 16-5) are summarised in paragraphs 16.5.14 onward. They are separated by broad receptor type.

[17] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/928593/resilience-of-rail-infrastructure-interim-report.pdf

16.5.10 The assessment of these impacts has been iterative. During the design process this has enabled the development of appropriate design adaptations, referred to as embedded mitigation. These remove the risk of climate vulnerability impacts and, where this is not possible, they reduce these risks and minimise the associated consequences to acceptable levels and have been included in the assessment of potential impacts and effects in Table 16-3. Many of Network Rail's operational weather management systems are also relevant to the mitigation of the Scheme's climate vulnerabilities. Although these are not specific to the Scheme, they are considered in the climate vulnerability assessment because they affect how the Scheme will be operated. A summary of Network Rail's operational weather management systems is provided in Insert 16-2. They include planning for seasonal variability, preparation for, response to, and recovery from adverse and extreme weather events, as well as activities to mitigate the impact of events occurring.



Insert 16-2 Overview of Network Rail's operational weather management[18]

16.5.11 An example of specific embedded mitigation is the protection of vulnerable signalling and telecommunications equipment from heat damage. Insert 16-3 provides an example of heat shield protection hoods for trackside signalling equipment. This is the preferred approach given that dependence on cooling of electronic equipment could make the system more vulnerable as well as themselves contributing to emissions of greenhouse gasses.

[18] https://safety.networkrail.co.uk/wp-content/uploads/2017/02/NR-WRCCA-Strategy-2017-2019.pdf

Insert 16-3 Example of heat shield protection hoods for trackside signalling equipment

16.5.12 In addition to the above, further mitigation measures, known as additional mitigation, have been selected to manage climate change vulnerabilities where it was not feasible or appropriate to embed sufficient mitigation into the design. These are detailed in the assessment tables and Section 16.6.

16.5.13 The climate vulnerability assessments presented in Table 16-3 to Table 16-5 have been undertaken with consideration of mitigation embedded into the design and Network Rail's operational weather management systems. A final assessment outcome, known as the residual significance, is also provided in these tables, which takes into account additional mitigation. The potential climate vulnerability impacts assessed in Table 16-3 to Table 16-5 are summarised in the following sections, they are separated by broad receptor type.

Operational impacts on assets

Tracks

16.5.14 The following potential climate vulnerability impacts that could affect tracks and track side assets are assessed in this chapter in Tables 16-3 to 16-5:

- Hot weather:
  - Track buckling;
  - Lineside or track fires; and
  - Adhesion issues (longer growing season leads to more "leaves on the line").
- Warmer winters:
  - Less cold weather incidents (snow blocked tracks, frozen points, electrical arcing etc.).
- Heavy rain:
  - Automatic signalling faults (train detection failure); and
  - Track bed subgrade washout.

- More extreme weather:
  - Fallen trees in storms.

Stations

16.5.15 The following potential climate vulnerability impacts that could affect assets within stations are assessed in this chapter in Tables 16-3 to 16-5:

- Hotter summers:
  - Heat impacts on materials (cracking, deformation, fading).
- More extreme weather:
  - Reduced platform maintenance (snow clearance and salting).

Structures

16.5.16 The following potential climate vulnerability impacts that could affect structures (including embankments) are assessed in this chapter in Tables 16-3 to 16-5:

- Hotter summers:
  - Reduced asset lives (overexpansion, failure of expansion joints etc).
- Drier summers:
  - Soil instability affecting structures including embankments and trees.
- Heavier rain:
  - Scour under bridges and excessive accumulation of debris under bridges.

Drainage infrastructure

16.5.17 The following potential climate vulnerability impacts that could affect drainage infrastructure are assessed in this chapter in Tables 16-3 to 16-5:

- Drier summers:
  - Increased soil erosion reducing drainage capacity; and
  - Reduced freeze thaw action on underground assets.
- Heavier rain:
  - Flooding.

Technology (signalling, communication, power and transmission)

16.5.18 The following potential climate vulnerability impacts that could affect technological assets are assessed in this chapter in Tables 16-3 to 16-5:

- Hotter summers:
  - Thermal loadings on electrical equipment;
  - Expansion and subsequent sagging of overhead lines;
  - Overvoltage damages from more regular lightning strikes; and
  - Storms damage overhead lines.

Potential operational impacts on end users – passengers and staff

Health and safety

16.5.19 The following potential climate vulnerability impacts that could affect health and safety are assessed in this chapter in Tables 16-3 to 16-5:

- Warmer winters:
  - Improved platform safety (slips trips and falls).
- Extreme weather:
  - Reduced safety of staff undertaking inspections.

Comfort and wellbeing

16.5.20 The following potential climate vulnerability impacts that could affect user comfort and wellbeing are assessed in this chapter in Tables 16-3 to 16-5:

- Hotter summers:
  - Uncomfortable temperatures at stations; and
  - Reduced opportunities for track maintenance.
- Warmer winters:
  - Operational benefits reduce delays and cancelations.

Potential operational impacts on the environment

Water environment

16.5.21 The following potential climate vulnerability impacts that could affect the water environment are assessed in this chapter in Tables 16-3 to 16-5:

- Hotter and drier summers:
  - Increased impacts from stormwater discharges to the environment.

Landscape and biodiversity

16.5.22 The following potential climate vulnerability impacts that could affect landscape and biodiversity are assessed in this chapter in Tables 16-3 to 16-5:

- Hotter drier summers:
  - Drought damage to landscaping and increased risks from invasive species.

Assessment of potential climate vulnerability effects

16.5.23 Table 16-3 to Table 16-5 assess the significance of potential climate vulnerability impacts specific to this Scheme. The assessments include consideration of receptors vulnerability to climate change, as well as the magnitude and likelihood of consequences. The CCR and ICCI assessments are presented separately.

16.5.24 The CCR assessment is presented in two tables, split out by broad receptor type:

- Assets – tracks, stations, structures, drainage infrastructure and technology (Table 16-3); and
- End-users (passengers and staff) – health and safety, comfort and wellbeing (Table 16-4).

16.5.25 The ICCI assessment is presented in Table 16-5. The table splits out potential climate vulnerabilities based on broad receptor types:

- Water environment;
- Landscaping; and
- Biodiversity.

Table 16-3 CCR assessment: potential operational impacts on assets

Climate trend	Potential impact	Embedded mitigation	Receptor vulnerability (exposure and sensitivity)	Climate risk (consequence and likelihood)	Significance (before additional mitigation)	Additional mitigation	Residual significance
Tracks							
Hotter summers	Extreme hot weather could buckle and break train tracks creating a derailment risk. NB – risk comes from variations in temperature, rather than constant heat.	The Scheme will use Continuous Welded Rail (CWR) rather than a jointed track design, which would be more susceptible to buckling. This will reduce but not remove the potential of track temperature impacts. Steel tracks are designed to operate in a narrow temperature range that is based on the temperature in which it is originally laid, known as the design neutral temperature[19]. When this temperature is exceeded, the ability of the track to support rail traffic begins to degrade. When rails are weakened, the downward and outward stress from the weight of the rail cars will push the rails out of alignment. Under extreme heat conditions even CWR tracks will buckle due to expanding metal. A typical welded length of 1800 feet of rail can expand up to 1 in. per ten degrees of temperature increase (Wolf, 2005[20]).	**High exposure:** Summer temperatures are projected to increase over the Scheme's lifetime. By 2071-89 summer mean daily maximum temperatures are expected to be +4.4ºC warmer (central estimate under emissions scenario RCP8.5). **Low sensitivity:** Low with embedded and additional mitigation. The track is able to tolerate some extreme conditions. Medium sensitivity without additional mitigation. **Medium receptor vulnerability** (high without additional mitigation).	**Low consequence:** Emergency repairs and more regular maintenance interventions may be required. These may reduce performance and have moderate associated economic costs. It is noted that under extreme temperature, certain maintenance activities may be required to be undertaken at night, thus incurring higher programme costs (e.g. labour and illumination) but causing less performance disruption. **Medium likelihood:** Consequences are expected to occur more than once during Scheme's design life.	Not significant (Minor adverse)	Options for additional mitigation will be investigated during detailed design. These will include using more resilient design specifications – improving the track-bed and subgrade, increasing the rigidity and weight of the superstructure of the track, using mono block concrete sleepers (and shortening the distance between them), using fixing systems that are resistant to lateral displacement and using high quality steel. Painting sections of the rail white to reflect the sunlight (shown to keep rail temperatures up to 5ºC lower in sunlight) and laying down new rail at times with higher temperatures will also be investigated during detailed design (noting however that the latter can reduce the tracks ability to contract during freezing spells creating tensile stress which is another pathway to failure). The residual risk will be managed by both reducing and slowing traffic during periods of high temperature. This is supported by a growing network of track temperature monitoring sensors to detect specific portions of rail that have met heat thresholds, which require slowing trains, so the tracks don't buckle. The intent of these practices is to reduce the stress on the weakened tracks during the highest temperature points during the day. The by-product is a delay in rail traffic as trains are forced to reduce speed or wait until temperatures return to a normal operating level.	**Not significant (Minor adverse)**
Hot summers	Line-side or track fires	Standard fire-resistant design of structures and in-built fire systems and safety equipment as required. Network Rail's standard operational weather management activities (see paragraph 16.5.10) include regular vegetation management that reduces the	**High exposure:** Summer temperatures are projected to increase over the Scheme's lifetime. By 2071-89 summer mean daily maximum temperatures are expected to be +4.4ºC warmer (central estimate under emissions scenario RCP8.5).	**Low consequence:** Trains may be delayed (<1hr) but services are unlikely to be cancelled. **High likelihood:** Low adhesion conditions could be	Not significant (Minor adverse)	None	**Not significant (Minor adverse)**

[19] https://www.sciencedirect.com/science/article/pii/S0967070X16308198
[20] Wolf, Gary, 2005. Preventing Track Buckles. Interface.

Climate trend	Potential impact	Embedded mitigation	Receptor vulnerability (exposure and sensitivity)	Climate risk (consequence and likelihood)	Significance (before additional mitigation)	Additional mitigation	Residual significance
		build-up of dry debris (see also mitigation to improve resilience to impacts from strong winds).	**Low sensitivity:** With embedded mitigation. The Scheme's assets can tolerate some extreme conditions. **Medium receptor vulnerability.**	experienced annually with increasing severity.			
Warmer winters	A reduction in the number of cold weather-related incidents: • Snow blocked tracks; • Frozen points; • Electrical arcing and power surges due to poor electrical contact; • Loss of power to rolling stock due to ice and snow build up and contact failure; • Damage to pantograph[21] from icicle build up; • Accidental vehicle incursion onto tracks at level crossings (due to icy roads); and • Conductivity failures around level crossings due to highway salting.	Although warmer winters will provide multiple benefits, recent data shows cold weather can currently create significant adverse effects (see Insert 16-1 Delays associated with weather-related incidents across the network 2006 to 2018). The Scheme therefore includes standard cold weather impact mitigation. Details will be confirmed during detailed design, it may, for example, include points insulation and covers and modular re-signalling to avoid use of mechanical signalling, which often fails in cold weather due to the number of moving parts.	**Medium exposure**: Mean winter temperatures are projected to increase over the Scheme's lifetime (high exposure). By 2071-89 mean winter temperatures are expected to be +2.9ºC warmer (central estimate under emissions scenario RCP8.5). However, projected changes to snowfall and the number of nights below freezing are less certain and so the exposure is found to be medium. **Medium sensitivity:** With embedded mitigation operation of the assets is dependent on climatic factors. **Medium receptor vulnerability.**	**Low beneficial consequence:** Reduced disruption to services. **Medium likelihood:** Potential for conditions to occur every winter but duration is usually short.	Not significant (Minor beneficial)	None	**Not significant (Minor beneficial)**
Heavier rain (cumulative impact with wetter winters)	Wetter weather may cause more track detection failures. Before a train is given authority to move along a section of line, it has to be proved to be clear of other traffic. This is a key enabler for automatic signalling, and hence modern train control. Heavier rain and wetter winters could cause certain types of track detection technology to fail.	The Scheme will be designed to Network Rail engineering standards that first comply with rail system requirements and operating a safe railway.	**Medium exposure:** Winter precipitation is projected to increase over the Scheme's lifetime. By 2071-89 winter precipitation is expected to increase by 0.5mm (central estimate under emissions scenario RCP8.5). These projections also show maximum daily rainfall could increase to between 42mm and 63mm. **Negligible sensitivity:** With embedded mitigation climate hazards should not impact track detection. **Low receptor vulnerability.**	N/A (low receptor vulnerability)	Not significant	The use of axle counters instead of track circuits will be used if appropriate – Track circuits are a train detection system that relies on electrical conductivity and can be negatively affected by wet weather. Axle counters will be installed if appropriate as they are more resilient to wet weather impacts. The requirement for axle counters will be confirmed during detailed design and secured (if appropriate) through implementation of Network Rail engineering standards.	**Not significant** (significance not quantified as receptor vulnerability is low)

[21] A device fitted to the roof of an electric train which is sprung upwards to make electrical contact with overhead wires and draw power.

Climate trend	Potential impact	Embedded mitigation	Receptor vulnerability (exposure and sensitivity)	Climate risk (consequence and likelihood)	Significance (before additional mitigation)	Additional mitigation	Residual significance
Heavier rain (and cumulative impact with wetter winters)	Track geometry faults caused by track-bed and subgrade washout	The Scheme will use conventional ballast.	**Medium exposure:** Winter precipitation is projected to increase over the Scheme's lifetime. By 2071-89 winter precipitation is expected to increase by 0.5mm (central estimate under emissions scenario RCP8.5). These projections also show maximum daily rainfall could increase to between 42mm and 63mm. **Negligible sensitivity:** With embedded mitigation climate hazards should not impact track geometry during assets design life. **Low receptor vulnerability.**	N/A (low receptor vulnerability)	Not significant	None	**Not significant** (significance not quantified as receptor vulnerability is low)
Extreme weather	Stormier weather may mean trees are uprooted more often. These could fall on the line and loose branches could be blown onto the track. Both causing delays. This is a cumulative effect with warmer summers which allow longer growing seasons and so increase the risk (more vegetation).	The landscape design will, as a minimum, comply with NR/L2/OTK/5201 – Lineside vegetation management manual (see Appendix 16-3). Existing large high-risk trees near the track will be removed. The Weather Resilience and Climate Change Adaptation Plan (WRCC) for the London North East and East Midlands (LNE&EM) area (in which the Scheme is located) is currently supporting the delivery of an enhanced vegetation management project with £10m of accelerated funding to address high-risk trees and mitigate the impact of both extreme winds and adhesion issues[22]. The WRCC LNE&EM also describes a proactive regime of tree felling and vegetation management has been undertaken throughout the route. All high-risk trees identified through the national lineside tree survey have been removed. It is noted that the establishment of completely tree-free zones around the	**Negligible exposure:** Climate projections show there is little certainty of how climate change will alter extreme weather in the future. **Medium sensitivity:** With embedded and additional mitigation operation of the assets is dependent on climatic factors. High sensitivity without additional mitigation. **Low receptor vulnerability** (also low without additional mitigation)**.**	N/A (low receptor vulnerability)	Not significant	An outline environmental mitigation plan is provided in Figure 2-3. A detailed landscape/ecological scheme will be prepared as part of the Landscape and Ecological Management Plan (LEMP) to be submitted to the local authority pursuant to a condition to be attached to the deemed planning permission[23] and this will include details on the landscape proposals and management of any replacement planting.	**Not significant** (significance not quantified as receptor vulnerability is low)

[22] https://cdn.networkrail.co.uk/wp-content/uploads/2016/11/LNE-and-EM-Route-WRCCA-Plan.pdf
[23] On making an order under the Transport and Works Act 1992, the Secretary of State may direct that planning permission shall be deemed to be granted, subject to such conditions (if any) as may be specified in the direction.

Climate trend	Potential impact	Embedded mitigation	Receptor vulnerability (exposure and sensitivity)	Climate risk (consequence and likelihood)	Significance (before additional mitigation)	Additional mitigation	Residual significance
		tracks could result in increased track vulnerability to heat and temperature variations by reducing shade. From an operational perspective when wind gusts of 60-69 mph are forecasted, trains slow down to allow drivers time to stop if they see an obstruction on the track. A revised timetable is set accordingly. Network Rail has made significant efforts to reduce risks from third party trees and other third-party debris, e.g. trampolines, that could blow onto tracks. In general, the Scheme will not alter the operational boundary in proximity to third party land. The primary exceptions to this to this are Heaton Lodge and Ravensthorpe through to Thornhill Road. Note – wind impacts on overhead lines are assessed separately later in this table.					
Stations							
Hotter summers	General impacts on exposed infrastructure from extreme heat including: • Heat softens and deforms bitumen in asphalt on platforms; • Wider temperature variations causing shrinkage and expansion that leads to cracking on platforms; and • Colour of materials and painted surfaces fades.	Best practice construction techniques and appropriate material quality standards will be followed to ensure the design lives specified can be met.	**High exposure**: Summer temperatures are projected to increase over the Scheme's lifetime. By 2071-89 summer mean daily maximum temperatures are expected to be +4.4ºC warmer (central estimate under emissions scenario RCP8.5). **Low sensitivity:** With embedded mitigation the Scheme's assets can tolerate some extreme conditions. **Medium receptor vulnerability.**	**Low consequence:** Damage usually identified before consequences occur. Planned repairs may have moderate economic cost. **Low likelihood:** Consequences may only occur once during the Scheme's design life.	Not significant (Minor adverse)	Since platform surfaces are susceptible to rutting in hot weather where required the detailed design process will consider the application of polymer modified bitumen for surface course.	**Not significant (Minor adverse)**

Climate trend	Potential impact	Embedded mitigation	Receptor vulnerability (exposure and sensitivity)	Climate risk (consequence and likelihood)	Significance (before additional mitigation)	Additional mitigation	Residual significance
Warmer winters	The projected increase in winter temperatures and decrease in snowfall suggests a reduction in the frequency of winter platform maintenance (salting).	NA	**Medium exposure**: Mean winter temperatures are projected to increase over the Scheme's lifetime (high exposure). By 2071-89 mean winter temperatures are expected to be +2.9ºC warmer (central estimate under emissions scenario RCP8.5). However, projected changes to snowfall and the number of nights below freezing are less certain and so the exposure is found to be medium. **Medium sensitivity:** With embedded mitigation, operation of the assets is dependent on climatic factors. **Medium receptor vulnerability.**	**Negligible beneficial consequence:** Small economic maintenance related saving and minor improvement in service. **Medium likelihood:** Potential for conditions to occur every winter but duration is usually short.	Not significant (Negligible beneficial)	None	**Not significant (Negligible beneficial)**
Structures (including embankments, earthworks and bridges)							
Hotter summers	Hotter summers could reduce the asset lives of structures, for example causing: • Over expansion and buckling (e.g. of culverts, bridges or kerbs); or • Failure of expansion joints.	The design will ensure structures can adapt to expected future variations in temperature. The bridges, subways and tunnels are designed as fully integral structures, meaning there are no bridge bearings, and no movement joints. Temperature effects on the structure will be taken into account through the soil and structure interaction in accordance with the appropriate standards. Structures will be routinely monitored by their operators throughout the life of the Scheme.	**High exposure**: Summer temperatures are projected to increase over the Scheme's lifetime. By 2071-89 summer mean daily maximum temperatures are expected to be +4.4ºC warmer (central estimate under emissions scenario RCP8.5). **Low sensitivity:** With embedded mitigation the Scheme's assets can tolerate some extreme conditions. **Medium receptor vulnerability.**	**Low consequence:** Damage usually identified before consequences occur. Planned repairs may cause slight adverse operational consequences and have moderate associated costs. **Low likelihood:** Consequences may only occur once during the Scheme's design life.	Not significant (Minor adverse)	None	**Not significant (Minor adverse)**
Drier summers	The expected reduction in summer average rainfall is likely to intensify and extend soil moisture deficits and impact groundwater levels. This could impact soil stability, for example, increasing earth pressures, affecting structures, including embankments. Natural structures, such as drought vulnerable tree	Risk will be managed by best practice design, for example, embankments will be designed from slope-stability analysis using site specific soil parameters collected from Ground Investigation and compacted and constructed in line with best practice. At present conservative 1 in 2 slopes are proposed where possible.	**Medium exposure:** Summers are projected to become drier. The central estimate of change in mean summer precipitation by 2071-89 is -21% under RCP 8.5. However, the variation in the extent of change between projections varies from -52% to -4% (represented by the 10th and 90th percentile respectively). **Low sensitivity:** With embedded mitigation the Scheme's assets	**Medium consequence:** Repairs may have large economic cost and large impact on performance. **Low likelihood:** Consequences may (worst case) only occur once during the	Not significant (Minor adverse)	None	**Not significant (Minor adverse)**

Climate trend	Potential impact	Embedded mitigation	Receptor vulnerability (exposure and sensitivity)	Climate risk (consequence and likelihood)	Significance (before additional mitigation)	Additional mitigation	Residual significance
	species, e.g. Beech, could also become unstable. All the above could have follow on impacts on track geometry and failures in supported lineside equipment.		can tolerate some extreme conditions. **Medium receptor vulnerability.**	Scheme's design life.			
Heavier rain (and cumulative impact with wetter winters)	Flooding could destabilise bridges by: • Scour of river bed material at bridge foundations due to hydraulic action (for example at Baker Viaduct); or • Accumulation of debris under structures	-	**Medium exposure:** Winter precipitation is projected to increase over the Scheme's lifetime. By 2071-89 winter precipitation is expected to increase by 0.5mm (central estimate under emissions scenario RCP8.5). These projections also show maximum daily rainfall could increase to between 42mm and 63mm. **Negligible sensitivity:** With embedded and additional mitigation the design will be resilient to extreme conditions. Medium sensitivity without additional mitigation. **Low receptor vulnerability** (medium without additional mitigation)**.**	N/A (low receptor vulnerability)	Moderate (significant) - Based on medium consequences (repairs may have large economic cost and large impact on performance) and high likelihood of consequences (potential for conditions to occur every winter).	Best practice environmental management measures will be implemented on site through application of the measures proposed within Chapter 11 (Water environment) and also the accompanying Flood Risk Assessment (Appendix 11-1).	**Not significant** (significance not quantified as receptor vulnerability is low)
Drainage infrastructure							
Drier summers	Drier summers combined with the projected increase in summer temperatures may increase erosion as soils and their substrates dry out allowing the mobilisation of more debris. This in turn could block or reduce the capacity of the Scheme's drainage infrastructure. NB – the assessed consequence of this impact is increased maintenance costs to maintain drainage capacity. Flood risk is assessed separately.	The design includes for all steep embankments to be planted and for topsoil retention systems to be used as required following investigation during detailed design. Additionally, the design will also include the following as required: • Sustainable drainage systems (SuDS) attenuation/treatment to allow sediment to settle out of the main flow; • Catch pits which have sumps where silt can be trapped. These will be accessible to assist regular clearing.	**Medium exposure:** Summers are projected to become drier. The central estimate of change in mean summer precipitation by 2071-89 is -21% under RCP 8.5. However, the variation in the extent of change between projections varies from -52% to -4% (represented by the 10th and 90th percentile respectively). **Negligible sensitivity:** With embedded and additional mitigation, climatic factors will have little influence on maintenance of the Scheme's drainage infrastructure. Low sensitivity without additional mitigation. **Low receptor vulnerability** (with and without additional mitigation)	N/A (low receptor vulnerability)	Not significant	Best practice environmental management measures will be implemented in accordance with the CoCP. A copy of Part A of the CoCP can be found at Appendix 2-1. Part B of the CoCP will include an Integrated Pollution Prevention Control Document. This Part B document will be submitted to the local authority pursuant to a condition to be attached to the deemed planning permission prior to construction works starting. Chapter 10 (Landscape, townscape and visual) includes proposals to reduce erosion by retaining existing trees and vegetation wherever possible. An outline environmental mitigation plan is provided at Figure 2-3. A LEMP will be submitted pursuant to a condition to be attached to the deemed planning permission and this will include details on the landscape proposals and management of any replacement planting.	**Not significant** (significance not quantified as receptor vulnerability is low)
Warmer winters	Milder winters will reduce freeze thaw erosion which	N/A – beneficial impact	**Medium exposure:** Mean winter temperatures are projected to increase over the Scheme's	**Low beneficial consequence:** Moderate	Not significant (Minor beneficial)	None	**Not significant (Minor beneficial)**

Climate trend	Potential impact	Embedded mitigation	Receptor vulnerability (exposure and sensitivity)	Climate risk (consequence and likelihood)	Significance (before additional mitigation)	Additional mitigation	Residual significance
	can damage underground assets.		lifetime. By 2071-89 mean winter temperatures are expected to be +2.9ºC warmer (central estimate under emissions scenario RCP8.5). However, projected changes to snowfall and the number of nights below freezing are less certain. **Low sensitivity:** The receptor is able to tolerate some extreme conditions. **Medium receptor vulnerability.**	economic maintenance related saving and small improvement in service. **High likelihood:** Potential for conditions to occur every winter.			
Wetter winters	The projected climate trend of increasing frequency and intensity of heavy rainfall events is likely to increase the risk of pluvial or surface flooding, as surface run-off inundates small catchments and the urban landscape. Furthermore, prolonged periods of excessive precipitation (e.g. wetter winters) saturates soil, increasing the risk of fluvial or river flooding. Above average precipitation for long periods can also lead to a raised water table, which can result in groundwater flooding in areas where the geological characteristics are favourable. Flooding could cause: • Line closure (track flooding); • Failure of lineside equipment (water inundation); • Reduced access to depots, stations and rail offices; • Power outage (substation inundation); and • Flashover of track side circuit breaker.	The principal mitigation for flooding will be the detailed drainage design. This will be in line with current standards. The Scheme's Flood Risk Assessment (see Appendix 11-1) sets out the climate change allowance that has been used for the surface water drainage design with adjustment factors in line with the latest information in the Planning Practice Guidance and Environment Agency and Lead Local Flood Authority requirements.	**Medium exposure:** Winter precipitation is projected to increase over the Scheme's lifetime. By 2071-89 winter precipitation is expected to increase by 0.5mm (central estimate under emissions scenario RCP8.5). These projections also show maximum daily rainfall could increase to between 42 to 63mm. **Negligible sensitivity:** With embedded and additional mitigation the design will be resilient to extreme conditions. Medium sensitivity without additional mitigation. **Low receptor vulnerability** (medium without additional mitigation).	N/A (low receptor vulnerability)	Moderate (significant) - Based on medium consequences (repairs may have large economic cost and large impact on performance) and high likelihood of consequences (potential for conditions to occur every winter).	Best practice environmental management measures will be implemented on site through application of the measures proposed within Chapter 11 (Water environment) and also the accompanying Flood Risk Assessment as well as measures set out in Part A of the CoCP. Other flood mitigations will be considered during detailed design. Where appropriate, the following which will be included in the Environmental Design Plan (Land Contamination and Hydrogeology) under Part B of the CoCP: • Designing out underground substations (included as additional mitigation as the current design does not account for this); • Real-time monitoring of water levels in key drainage assets; • Flood detection alarms in key locations to facilitate power system controller's judgment on whether a controlled manual shutdown would be required; • Flood gates and flood pumps for critical assets; and • A power supply system design that provides adequate redundancy.	**Not significant** (significance not quantified as receptor vulnerability is low)

Climate trend	Potential impact	Embedded mitigation	Receptor vulnerability (exposure and sensitivity)	Climate risk (consequence and likelihood)	Significance (before additional mitigation)	Additional mitigation	Residual significance
Technology – electrical control equipment (signalling), communication, power supply and transmission lines							
Hotter summers	Extreme hot temperatures increase thermal loadings on electrical equipment reducing their life. This could affect the future reliability of power supplies, signalling and telecoms	The design will seek to protect vulnerable signalling and telecommunications equipment from heat damage. Design options for this will be investigated during detailed design and may include heat reflective paint, siting assets in less vulnerable locations (i.e. shaded areas) and/or using heat shield hoods. Insert 16-3 provides an example of heat shield protection hoods for trackside signalling equipment. This is the preferred approach given that dependence on cooling of electronic equipment could make the system more vulnerable as well as themselves contributing to emissions of greenhouse gasses. Only in extreme cases, to be confirmed during detailed design, where design options do not provide sufficient heat protection for critical signalling and telecommunications equipment, fan assisted ventilation systems will be fitted to trackside cabinets and in larger equipment rooms air cooling systems may be fitted.	**High exposure:** Summer temperatures are projected to increase over the Scheme's lifetime. By 2071-89 summer mean daily maximum temperatures are expected to be +4.4ºC warmer (central estimate under emissions scenario RCP8.5). **Medium sensitivity:** The receptor is dependent on some aspects of the prevailing climate. **High receptor vulnerability.**	**Low consequence:** Repairs may have moderate economic cost or slightly reduce performance. **Low likelihood:** Consequences may (worst case) only occur once during the Scheme's design life.	Not significant (Minor adverse)	None	**Not significant (Minor adverse)**
Hotter summers	Expansion and sagging of overhead lines. This increases the risk of the pantograph losing contact with the overhead wire, known as dewirement.	By following standard best practice the detailed design will include mitigation for dewirement, this may include: • The design includes post-tensioned OLE instead of simple contact lines; • The design mechanically and electrically sections the overhead lines to minimise damage in the case of dewirement or wire breakage and to facilitate detection of faults; and Twelve standard portals and seven anchor portals are proposed for Huddersfield	**High exposure:** Summer temperatures are projected to increase over the Scheme's lifetime. By 2071-89 summer mean daily maximum temperatures are expected to be +4.4ºC warmer (central estimate under emissions scenario RCP8.5). **Medium sensitivity**: The receptor is dependent on some aspects of the prevailing climate. **High receptor vulnerability.**	**Low consequence:** Repairs may have moderate economic cost or slightly reduce performance. **Low likelihood:** Consequences may (worst case) only occur once during the Scheme's design life.	Not significant (Minor adverse)	None	**Not significant (Minor adverse)**

Climate trend	Potential impact	Embedded mitigation	Receptor vulnerability (exposure and sensitivity)	Climate risk (consequence and likelihood)	Significance (before additional mitigation)	Additional mitigation	Residual significance
		Viaduct. The distance between supports for overhead power lines will be reduced at any other locations prone to high winds that are identified during the detailed design. In these locations, as well as at Huddersfield Viaduct, the design utilises portals instead of head-spans. Head-spans can cause complete route closure after a single overhead line failure. The introduction of a portal isolates the damage to one line which can significantly reduce performance impact.					
Extreme weather	More regular and intense storms in the future could increase the regularity of lightning strikes on infrastructure which could cause overvoltage damages to electrical equipment. For example: • Flashover of insulator and sub-station; • Equipment • Breakdown of lightning arrester; and • Nuisance tripping of circuit breakers.	Where required the design protects electrical equipment against main electrical supply surge and lightning current by including surge protection devices such as varistors. Key electrical components will be regularly checked by their operators, and replacement cycles may be shortened if deterioration rates increase. Redundancy in power supply systems (i.e. UPS or Uninterrupted Power Supply) will be installed where required.	**Negligible exposure**: Climate projections show there is little certainty of how climate change will alter extreme weather in the future. **Medium sensitivity**: The receptor is dependent on some aspects of the prevailing climate. **Low receptor vulnerability.**	N/A (low receptor vulnerability)	Not significant	None	**Not significant** (significance not quantified as receptor vulnerability is low)
Extreme weather	High winds in more regular and intense storms could damage transmission lines and signals.	Mitigation measures include those mentioned above for hot weather impacts on overhead lines (i.e. post tensioning, reducing distance between supports and sectioning). When sustained periods of heavy winds are forecast operational procedures are implemented as previously outlined in the assessment of high winds increasing track impacts from falling trees.	**Negligible exposure** – Climate projections show there is little certainty of how climate change will alter extreme weather in the future. **Medium sensitivity:** The receptor is dependent on some aspects of the prevailing climate. **Low receptor vulnerability.**	N/A (low receptor vulnerability)	Not significant	None	**Not significant** (significance not quantified as receptor vulnerability is low)

Table 16-4 CCR assessment: potential operational impacts on end users (passengers and staff)

Climate trend	Potential impact	Embedded mitigation*	Receptor vulnerability (exposure and sensitivity)	Climate risk (consequence and likelihood)	Residual significance
Health and safety					
Warmer winters	Warmer winters will improve platform safety with a reduction in slip, trip and fall hazards for customers and staff.	Although climate change will reduce this impact the Scheme still includes mitigation for cold weather impacts at stations, these are being implemented like for like.	**Medium exposure:** Mean winter temperatures are projected to increase over the Scheme's lifetime. By 2071-89 mean winter temperatures are expected to be +2.9ºC warmer (central estimate under emissions scenario RCP8.5). However, projected changes to snowfall and the number of nights below freezing are less certain. **Medium sensitivity:** The receptor is dependent on some aspects of the prevailing climate. **Medium receptor vulnerability**	**Low beneficial consequence:** Impact will reduce occurrences of minor harm or near misses. **High likelihood:** Potential for conditions to occur every winter.	**Not significant (Minor beneficial)**
Extreme weather	Safety of staff undertaking inspections – e.g. at flooded sites or where landslip risk is high.	In conjunction with standard operational health and safety practices, the impact will be mitigated by best practice design that aligns with Network Rail's Asset Management Manual for structures, earthworks and drainage. For example, providing safe inspection access points with handrails and other health and safety design features.	**Negligible exposure:** Climate projections show there is little certainty of how climate change will alter extreme weather in the future. **Medium sensitivity:** The receptor is dependent on some aspects of the prevailing climate. **Low receptor vulnerability**	N/A (low receptor vulnerability)	**Not significant** (significance not quantified as receptor vulnerability is low)
Comfort and wellbeing					
Hotter summers	Increased exposure of customers and staff to uncomfortably high temperatures at stations (also implicitly considers shelter from cold and wet conditions)	The Scheme provides like for like replacement of station facilities including shelters. An exception to this is Huddersfield Station where the Scheme will increase shade and shelter provision on some platforms. At all other stations that are part of the Scheme (Deighton, Mirfield and Ravensthorpe) shelters will be provided in line with Network Rail's standards for provision based on passenger numbers.	**High exposure:** Summer temperatures are projected to increase over the Scheme's lifetime. By 2071-89 summer mean daily maximum temperatures are expected to be +4.4ºC warmer (central estimate under emissions scenario RCP8.5). **Medium sensitivity**: The receptor is dependent on some aspects of the prevailing climate. **High receptor vulnerability**	**Negligible consequence:** Consequences cause very small or no safety risks or reduced performance. **High likelihood:** Consequences could reoccur seasonally.	**Not significant (Minor adverse)**
Hotter summers	Reduced opportunities for track maintenance (increase the need for expensive night-time repair works when temperatures are lower)	None	**High exposure:** Summer temperatures are projected to increase over the Scheme's lifetime. By 2071-89 summer mean daily maximum temperatures are expected to be +4.4ºC warmer (central estimate under emissions scenario RCP8.5). **Medium sensitivity**: The receptor is dependent on some aspects of the prevailing climate. **High receptor vulnerability.**	**Low consequence:** Moderate economic cost or affect systems or assets that can be replaced. **High likelihood:** Consequences could reoccur seasonally.	**Not significant (Minor adverse)**

* No additional mitigation is required for potential operational impacts on end users

Table 16-5 ICCI assessment: potential operational impacts on the environment

Climate trend	Potential impact	Embedded mitigation	Receptor vulnerability (exposure and sensitivity)	Climate risk (consequence and likelihood)	Significance (before additional mitigation)	Additional mitigation	Residual significance
Water environment							
Drier summers	Drier, and hotter, summers will lower water levels in rivers. Impacts on the water environment caused by the Scheme's stormwater discharges to the environment could therefore increase as the capability of rivers to dilute discharges reduces over time.	The design will include sustainable drainage systems (SuDS). These are attenuation and treatment mechanisms that improve the quality of surface water runoff before it is discharged to the water environment.	**Medium exposure:** Summers are projected to become drier. The central estimate of change in mean summer precipitation by 2071-89 is -21% under RCP 8.5. However, the variation in the extent of change between projections varies from -52% to -4% (represented by the 10th and 90th percentile respectively). **Low sensitivity:** with embedded and additional mitigation the receptor is able to tolerate some extreme conditions. Medium sensitivity without additional mitigation. **Medium receptor vulnerability** (with and without additional mitigation).	**Low consequence:** Moderate environmental pollution or harm. **High likelihood:** Consequences could reoccur seasonally.	Not significant (Minor adverse)	Best practice environmental management measures will be implemented on site through application of the measures proposed within Chapter 11 (Water environment) as set out in Part A of the CoCP.	**Not significant (Minor adverse)**
Landscaping and biodiversity							
Drier summers	Drier and hotter summers will increase soil moisture deficits in the future, which could negatively impact the Scheme's landscaping. The landscaping has aesthetic benefits but also prevents excessive aeolian soil erosion and protects the Scheme from surface water runoff scour. Climate changes may also cause the Scheme to become increasingly vulnerable to incursion from invasive species with associated impacts on maintenance budgets.	The proposed landscape design will futureproof the Scheme in terms of climate change as well as in terms of pests/diseases by adhering to best practice. This will include diversifying planting species as much as possible, including drought tolerant species, whilst still having regard to the local character, and generally planting only native species. It will also adhere to best ecological practice.	**Medium exposure:** Summers are projected to become drier. The central estimate of change in mean summer precipitation by 2071-89 is -21% under RCP 8.5. However, the variation in the extent of change between projections varies from -52% to -4% (represented by the 10th and 90th percentile respectively). **Medium sensitivity:** With embedded and additional mitigation the receptor is dependent on some aspects of the prevailing climate. High sensitivity without additional mitigation. **Medium receptor vulnerability** (high without additional mitigation).	**Low consequence:** Moderate economic cost or affect systems or assets that can be replaced. **High likelihood:** Consequences could reoccur seasonally.	Not significant (Minor adverse)	An outline environmental mitigation plan is provided at Figure 2-3. A detailed landscape/ ecological scheme will be prepared as part of the LEMP and this will include details on the landscape proposals and management of any replacement planting.	**Not significant (Minor adverse)**

16.6 Mitigation measures

16.6.1 Mitigation measures (embedded and additional) are set out in Section 16.5. These are selected in accordance with the risk mitigation hierarchy these prioritise avoiding risks, reducing risks, rescuing or restoring the receptor, offsetting the impact and then compensation.

16.6.2 Although climate vulnerability impacts during construction have been scoped out of this assessment it is noted that the CoCP and construction risk assessments should set out how extreme weather risks during construction will be managed. For example, how extreme weather events are monitored and what the emergency chain of command and communication process is so that construction activities can be managed accordingly. This should also include emergency planning for disastrous weather impacts.

16.6.3 The embedded mitigation identified in Section 16.5 will be realised through the implementation of Network Rail engineering standards. The Scheme must comply with these standards to operate in a safe and reliable manner.

16.6.4 The additional mitigation identified in Section 16.5 will seek to reduce the vulnerability of the Scheme to climate change. However, it should be noted that the detailed design stage will be led by the operational and technical rail system requirements, to ensure that the final design results in a railway which operates safely. Once the principle of the design is confirmed as operationally acceptable, then the detailed design will seek to minimise the environmental effects.

16.6.5 In addition to the specific additional mitigation identified in Section 16.5 it is recommended that more general monitoring and evaluation of the Scheme's major assets resilience to climate shall be part of regular asset inspections to inform climate change adaptation decision-making in the future.

16.7 Residual effects

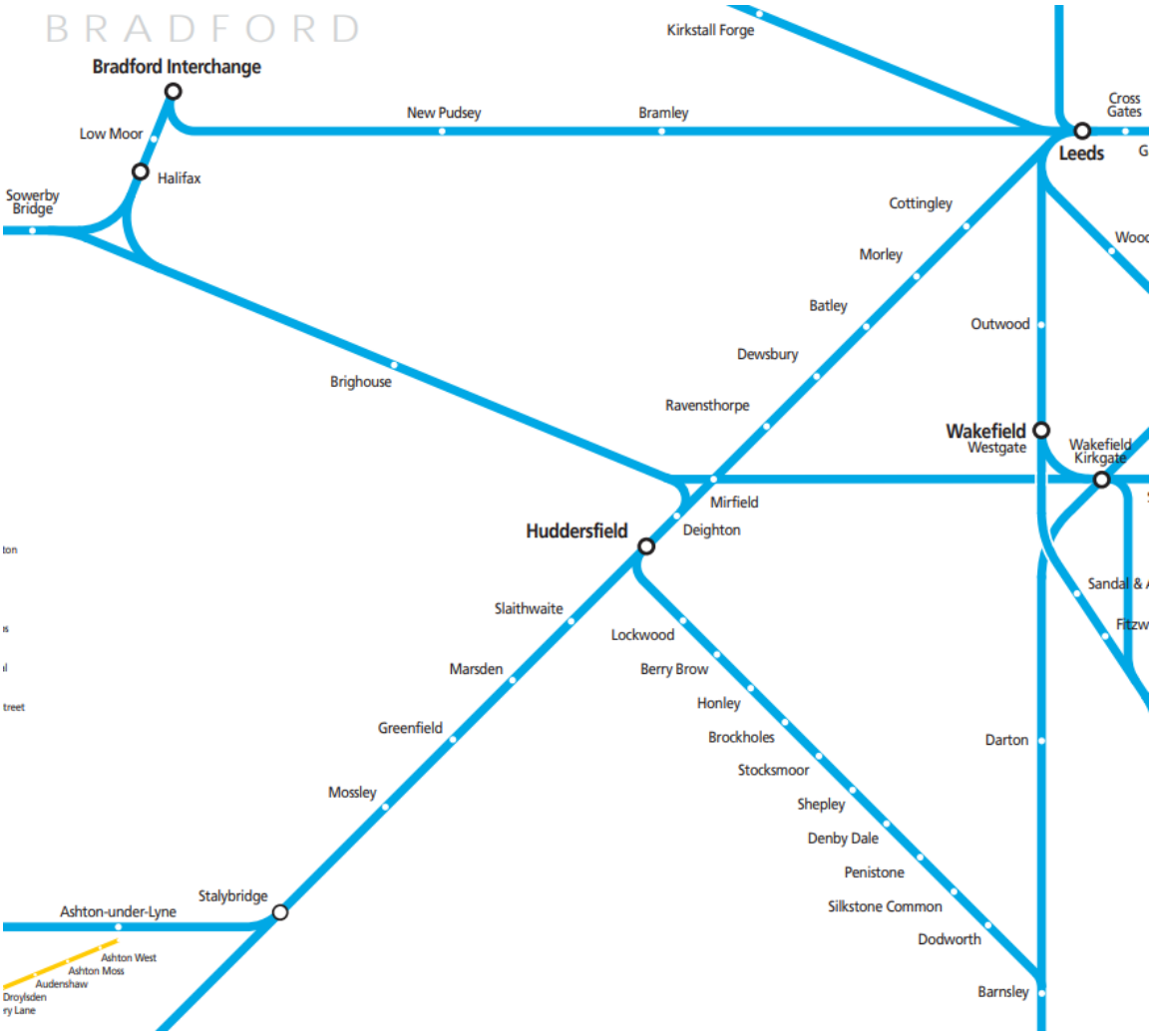
16.7.1 The climate vulnerability assessment presented in Section 16.5 has, after consideration of embedded and additional mitigation, not identified any significant adverse vulnerabilities of the Scheme to climate change.

16.8 Cumulative effects

16.8.1 Cumulative effects can be intra-Scheme, for example the combined impact of multiple effects on a single receptor and also inter- Scheme, where more than one scheme is under construction that has the potential to affect the same receptor. They are discussed further in Chapter 22 (Cumulative effects).

16.8.2 There are no inter-Scheme cumulative effects relevant to climate vulnerability. However, it is noted that there are important interdependencies with other types of infrastructure. Disturbances in the power supply from external networks directly influence the functionality of the railway transport system. Telecommunications and other transport systems are other central areas where the system is dependent on the functionality of external infrastructure.

16.8.3 Climate-related events often affect all of these systems at the same time. The layout of the rail network in the Scheme (Insert 16-4) area provides some redundancy by allowing route options[24], for example if the line was blocked by a flood at Brighouse it is still possible to access Bradford interchange from Huddersfield via Leeds. Similarly, if the line was blocked at Deighton it is still possible to access Wakefield from Huddersfield via Barnsley.



Insert 16-4 Network layout around Scheme

16.8.4 For climate vulnerability intra-Scheme effects occur where a single receptor is impacted by changes to more than one climate variable. Those assessed within this assessment are:

- Heavier peak rainfall and on average wetter winters;
- Drier summers and hotter summers; and
- Warmer winters (temperature change) and reduced snow (precipitation change).

16.8.5 The impact assessment, presented in Section 16.5, found that none of the potential intra-Scheme effects were significant adverse.

[24] https://www.nationalrail.co.uk/Blue%20route%20ASplusMetro%20map%20v16.pdf