1 Purpose

This document provides data on projected changes in weather conditions due to climate change and guidance on how to select the data for use in risk assessments and asset/project design. Understanding these changes and their impacts will allow us to enhance our resilience to extreme weather and climate change and keep the railway running to expected levels of performance and safety in the future.

To meet the challenges of future weather changes caused by climate change, we need to adapt how we design, operate and maintain the railway. Failing to do this will result in greater exposure to weather related risks in the future, increasing safety and performance impacts and whole life costs.

The information presented in this document will enable engineers, designers, economic analysts and others to understand the future climate impacts on their projects or activities and to take appropriate actions to account for them in asset designs and activity planning. This document should be used in conjunction with the Weather Resilience & Climate Change Impact Assessment guidance note (NR/GN/ESD11).

2 Background

2.1 Climate impacts overview

Climate change will cause existing weather patterns to shift, changing the severity, frequency and impact of events across the seasons. General trends observed in the data in this document can be used to inform the initial thinking on how climate change may affect an activity, asset or project.

In the summer there is high confidence that; daytime and night-time minimum and maximum temperatures will increase, the frequency and intensity of summer storms, droughts and heatwaves will increase, and that overall rainfall will decrease. Low confidence projections suggest that lightning may show increases due to changes in summer storms, that humidity will increase and that fog days will decrease. The projections for wind speeds are mixed, but it is likely that they will show increases in the second half of the century.

In the winter, high confidence projections are that daytime and night-time maximum temperatures will increase and that the frequency and severity of snowfall will decrease. However, current snowfall severity and minimum temperatures will still be possible. Confidence is also high that the total volume of rain and the frequency and intensity of winter storms will increase. Low confidence projections suggest that; humidity will increase and that increases in storms may lead to increases in wind speeds. Fog days show reductions in the South and East changing to increases and the north and west and the confidence in the lightning and wind modelling outputs is so low that no trend is available.

It should be noted that the reductions in Summer rainfall and the increases in Winter rainfall are expected to balance out leading to almost no change in the total volume of rainfall across the year.

Sea level will rise significantly across the whole UK coast, increasing as you move south across the UK due to the land level changing after the last ice age. These rises combined with the changes in storm intensity and frequency increase the risk of storm surges around the whole coast.

Such changes increase the challenge of maintaining and improving our resilience and mean that we cannot rely on past weather data to inform future operational and investment decisions. Using the data in this document will increase our understanding of the changing risks enabling us to plan appropriate responses.

2.2 Climate scenarios

In 2018 we commissioned a review that enabled us to select the two climate scenarios modelled by the UK government that are most appropriate for adapting the railway (see *Table 1*). Guidance on how to choose and use the correct scenario for an impact assessment is included in Section *4 Using this document*.

Table 1 **Network Rail climate change planning scenarios**

Scenario name	UK Climate Projections 2009 (UKCP09)	UK Climate Projections 2018 (UKCP18)
Primary Scenario	Medium Emission Scenario 90% probability	RCP* 6.0 90th percentile⁺
Higher Scenario	High Emissions Scenario 90% probability	RCP* 8.5 90th percentile⁺

* Representative Concentration Pathway[1]

⁺ 90th percentile is used for the majority of UKCP18 climate data in this guidance (exceptions are noted in the relevant sections).

This document is based on the latest UKCP data and subsequent regulator guidance derived from it[2]. As such it presents a mixture of data sources which draw from the UKCP18 data set and derived products, where available, but continues to include UKCP09 data and derived products where these are still the most current. As a live document, its content will continue to be updated to reflect changes in national climate modelling and guidance as appropriate, for example the release of further relevant UKCP18 climate variables or the update of regulator guidance documents. The most current version of the document, the one available on Safety Central, should be used (see *Appendix 2* for version control).

If content changes occur after significant project/activity milestones have passed it will only be necessary to review decisions based on previous versions if there are significant concerns. For projects following the GRIP process, the decision to review projects should be taken in line with the current GRIP guidance.

3 Data sources

The majority of the quantitative data in this document is directly extracted as raw data from the UKCP18 or UKCP09 datasets as appropriate. This includes precipitation[3], sea level rise, relative humidity, fog and several temperature parameters (*4.1 Data sets*).

Other quantitative data sets have been produced from the analysis of UKCP data by the Environment Agency (EA), the Scottish Environment Protection Agency (SEPA) and Natural Resources Wales (NRW) to provide national guidance. These include, peak river flows, rainfall intensity and sea level rise.

Incomplete understanding of the processes driving some weather parameters means that modelled quantitative data is not available for them. In these cases, UKCP09 reports and guidance, and updated UKCP18 factsheets, were used to provide qualitative guidance on general change trends. This covers wind, lightning and snowfall.

[1] RCPs are the latest agreed pathways used internationally for climate modelling, and they replace the previous Medium and High Special Report on Emissions Scenarios (SRES). RCPs are used in UKCP18.

[2] E.g. Environment Agency, Scottish Environmental Protection Agency and Natural Resources Wales peak river flow guidance.

[3] All precipitation is expressed as mm of liquid. No quantitative data is given on snow depth or frequency.

4 Using this document

This section summarises the information available in the datasets and provides a flow chart to support your identification of the most appropriate information to use. Introductory text for each table provides detail on the data, its source, units, any use/limitations advice and any general trends.

As this document uses technical terminology and acronyms specific to the climate change subject a *Glossary* has been included to provide additional information and definitions to aid the user.

4.1 Data sets

The data tables and qualitative guidance used in this document have been grouped into the following sections:

5 Temperature
6 Precipitation (including sleet, hail and snow)
7 Flooding
8 Sea Level Rise
9 Humidity
10 Fog
11 Wind
12 Lightning
13 Event frequencies

4.2 Data types

4.2.1 Quantitative data

The UKCP data is presented as tables of average values for the 13 UK administrative regions, see *Figure 1*.

Figure 1 **UK Administrative regions**[4]

[4] Met Office © Crown Copyright 2019

Depending on the dataset used the tables contain columns of projected Primary and Higher scenario change values and where available baseline values[5] for the relevant parameter as follows:

- UKCP09 – 2020s, 2050s and 2080s (30-year averages against a 1961-1990 baseline,
- UKCP18 – 2030s, 2050s and 2070s (20-year averages against a 1981-2000 baseline or
- UKCP18 sea level rise – by 2030, 2050 and 2070 against a 1981-2000 baseline.

Where a baseline is provided future change values for the chosen parameter and time period can be derived by **calculation method 1**. For tables without baseline data **calculation method 2** should be followed.

Calculation method 1 – baseline data available:

- Select the baseline value for the chosen parameter, and
- Add/subtract the projected change (as appropriate) for the relevant time period.

Worked example: 1

Primary scenario, mean daily July rainfall for an earthwork with a 30-year maintenance period, Northern Scotland.

UK Administrative Region	Climate change scenario	June				July				August			
		Baseline	2030s	2050s	2070s	Baseline	2030s	2050s	2070s	Baseline	2030s	2050s	2070s
North Scotland	Primary	2.9	-8.7	-18.1	-17.1	3.2	-23.5	-29.2	-34.0	4.0	-13.0	-22.3	-25.1
	Higher		-10.0	-21.0	-24.2		-23.6	-34.2	-43.6		-14.6	-26.5	-32.6

1. Use the July baseline value (3.2mm), and
2. Subtract the 2050s primary value (-29.2%) from the baseline; 3.2 – 29.2% = 2.3mm

Calculation method 2 – no baseline data available:

- Replace the 2020s (UKCP09) or 2030s (UKCP18) change value for the desired weather parameter with the current observed value (data to be obtained from the Network Rail Weather Service *www.nrws.co.uk*,
- If a 2050s or 2070S/80s (UKCP09 or UKCP18) change value is be used, subtract the 2020s (or 2030s) change value from it, and
- Add/subtract the result to/from the current observed value.

Worked example: 2

Primary scenario summer warmest day temperature for a SCADA system with a 30-year life span, Northern Scotland.

UK Administrative Region	Climate change scenario	Winter				Spring				Summer				Autumn			
		Baseline	2020s	2050s	2080s	Baseline	2020s	2050s	2080s	Baseline	2020s	2050s	2080s	Baseline	2020s	2050s	2080s
North Scotland	Primary		1.7	2.5	3.3		3.1	4.9	6.4		4.0	6.6	9.4		3.1	5.0	7.2
	Higher		1.8	2.8	4.2		3.5	5.8	7.8		4.1	8.0	11.8		3.5	5.5	8.9

1. Replace Primary 2020s change value (+4°C) with current observed warmest summer day temperature (32.9°C),
2. Subtract the 2020s value from the 2050s Summer Primary value (+6.6°C); 6.6 – 4 = 2.6, and
3. Add the result to the current observed value: 2.6 + 32.9 = 35.4°C

[5] This is the average value for the given parameter from the 1961 to 1990 period as used by UKCP09 and from the 1981 to 2000 period as used by UKCP18.

The climate projections are provided as monthly or seasonal values for Winter, Spring, Summer and Autumn as defined in the *Glossary*. The one exception is sea level rise, as the degree of change is not affected by season. Cumulative change values are provided for the annual change (*8.1 Regulator guidance for sea level rise allowances*) and the time periods selected for this guidance (*8.2 UKCP18 sea level projections*).

Tables of data from the EA, SEPA and NRW show two projections for multiple time periods by geographical area. Baseline values are included where possible. The geographical footprints, projection names, climate scenarios and parameters used in external data show some differences from our planning scenarios. In all cases, best fit data has been obtained and methods for accommodating residual differences are provided in the relevant sections.

4.2.2 Qualitative data

For those weather parameters that affect our assets, but for which there is no quantitative UKCP09 or 18 or derived data sets, text has been provided that summarises the UKCP09 or 18 qualitative guidance. This includes information on its source, any use/limitations advice and any general trends.

4.3 How do I use the quantitative data?

The flow chart in *Figure 2* aims to guide you through the decision process to identify which quantitative data to use. When determining what lifespan to use for an asset or activity you should follow the guidance in *CIV/003/F1990*. The text box below contains a worked example to illustrate the approach.

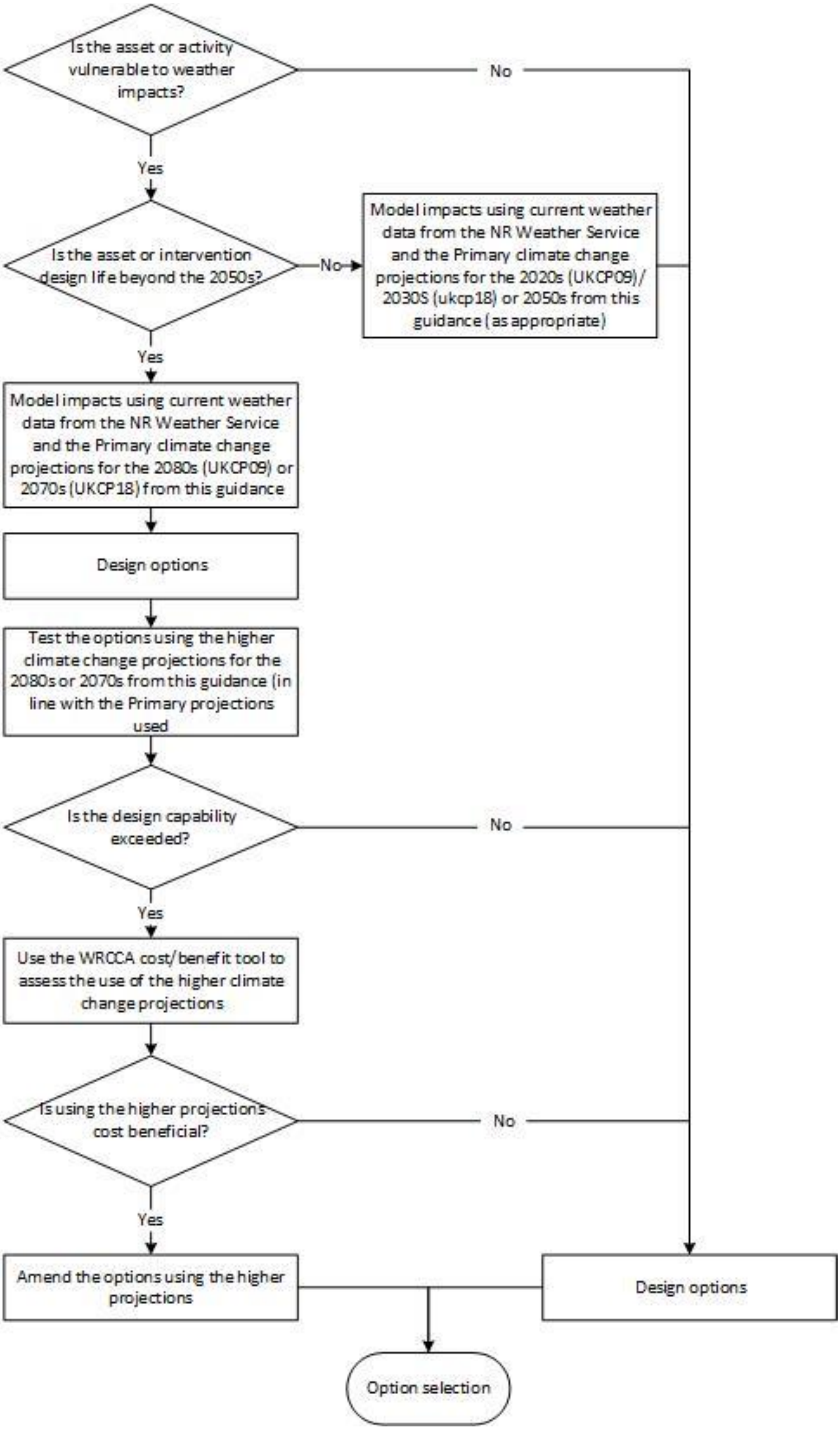
Worked example: 3

Renewing an electrical panel inside a flood-prone building would proceed in the following way:

1. Is the asset or activity vulnerable to weather impacts?
   Electrical panels are vulnerable to high temperatures and flooding. Follow the Yes arrow.
2. Is the asset or intervention design life beyond the 2050s?
   It is assumed that the electrical panel's design life is over 30 years, so follow the Yes arrow and the next 3 steps;
   a. Model the flood risk and the temperature impacts on the electrical panel using current weather data and the Primary climate change projections for the 2070s* or 2080s*.
   b. Produce new design options to minimise the impacts on the electrical panel.
   c. Test options using the Higher climate change projections for the 2070s* or 2080s* as a worst-case sensitivity test.
3. Is the design capability exceeded?
   If it is, follow the Yes Arrow.
4. Is using the Higher projections cost beneficial? This can be assessed using the WRCCA Cost/Benefit Tool.
   If not follow the No arrow and finalise the design using the Primary projections for the 2070s* or 2080s*. If it is, follow the Yes arrow and amend the design using the Higher projections for the 2070s* or 2080s*.
5. Select the option for construction, e.g. waterproof cabinet, floodproofed building, raising equipment height, reducing solar gain or incorporate low carbon climate control.

*2070s for UKCP18 datasets and 2080s for UKCP09 datasets

Figure 2 **Climate projection data selection process**



5 Temperature

The maximum, average and minimum temperatures are projected to rise in all months of the year across the UK. This will lead to more frequent and severe heatwaves in the summer months, and fewer snow and frost days in the winter months. Although current extremes of winter weather will be less frequent, they will still be possible.

This section contains tables of quantitative UKCP18 or UKCP09 projections for the following temperature parameters:

UKCP09

5.1 Change in temperature of the warmest day
5.2 Change in temperature of the coldest night

UKCP18

5.3 Change in mean daily maximum temperature
5.4 Change in mean daily minimum temperature

These projections are regional averages, so local effects may need to be considered depending on the sensitivity of the asset and the accuracy of the assessment that is required. For example, an air temperature of 30˚C may not represent the actual temperature experienced by an asset. Examples of factors to consider include; microclimate (wind chill, prevailing cloud cover, shade etc.), topology and asset characteristics (orientation, material, colour, ventilation, frequency/nature of use etc.).

In *5.1 Change in temperature of the warmest day* and *5.2 Change in temperature of the coldest night* values are the 99th percentile point from 30 years of daily maximum or minimum air temperature projections for each season (as defined in *4.2.1 Quantitative data*). The units are °C and for measurements taken 1.5 meters above ground level.

In *5.3 Change in mean daily maximum temperature* and *5.4 Change in mean daily minimum temperature* each monthly value is the average change in the average daily maximum or minimum temperature for each month from 20 years of modelled data. The baseline is the modelled average daily maximum or minimum temperature for each month between 1981 and 2000. The units are °C for measurements 1.5 metres above ground level.

5.1 Change in temperature of the warmest day

The general trend for the warmest day across all seasons and regions is for projected increases. Whilst the Summer will show the largest projected increases the degree of change will vary across the regions. The smallest projected changes will be seen in North Scotland and Yorkshire & Humberside and the greatest changes will be in North East and North West England.

Projections for this parameter are in *Table 2*. No baseline data is available for this parameter and this should be accounted for by following calculation method 2 in *4.2.1 Quantitative data*.

Table 2 **Change in temperature of the warmest day (°C) (UKCP09)**

UK Administrative Region	Climate change scenario	Winter				Spring				Summer				Autumn			
		Baseline	2020s	2050s	2080s	Baseline	2020s	2050s	2080s	Baseline	2020s	2050s	2080s	Baseline	2020s	2050s	2080s
North Scotland	Primary		1.7	2.5	3.3		3.1	4.9	6.4		4.0	6.6	9.4		3.1	5.0	7.2
	Higher		1.8	2.8	4.2		3.5	5.8	7.8		4.1	8.0	11.8		3.5	5.5	8.9
West Scotland	Primary		1.6	2.7	3.6		3.3	5.4	7.1		4.7	7.5	10.7		4.2	5.8	8.2
	Higher		1.6	2.9	5.9		3.8	6.3	8.7		5.0	9.2	13.7		4.3	6.4	9.6
East Scotland	Primary		1.7	2.5	3.4		3.4	5.2	6.8		4.8	7.5	10.7		3.5	5.9	8.4
	Higher		1.8	2.8	4.2		3.9	6.2	8.2		4.8	9.1	13.2		4.1	6.5	10.5
North East England	Primary		1.8	2.9	3.9		3.1	5.0	6.4		5.0	8.1	11.6		4.3	6.1	9.0
	Higher		1.7	3.1	4.9		3.6	5.8	7.8		5.4	10.0	14.6		4.4	6.9	10.7
Yorkshire and Humberside	Primary		1.9	3.0	4.1		3.2	5.6	6.9		4.1	6.5	9.0		3.9	6.1	8.5
	Higher		1.9	3.4	5.4		3.5	5.5	8.1		4.5	7.6	10.7		3.9	6.6	10.0
North West England	Primary		1.8	2.9	3.9		3.3	5.5	7.2		5.2	8.2	11.7		4.4	6.2	9.0
	Higher		1.8	3.1	4.9		3.9	6.3	8.7		5.4	9.9	14.8		4.4	6.9	10.6
Wales	Primary		1.8	3.0	4.1		3.3	6.4	8.2		4.4	7.1	9.5		4.0	5.8	8.0
	Higher		1.8	3.3	5.3		3.7	6.9	9.7		4.8	8.3	11.8		4.3	6.5	9.8
West Midlands	Primary		1.8	2.9	4.0		3.2	6.2	8.1		4.8	7.6	10.4		3.9	5.8	8.1
	Higher		1.8	3.3	5.2		3.6	6.8	9.5		5.2	9.0	12.8		4.2	6.5	9.8
East Midlands	Primary		1.9	3.0	4.0		3.4	5.9	7.4		4.6	7.3	9.9		4.1	6.5	9.0
	Higher		1.9	3.3	5.3		3.7	6.0	8.7		5.0	8.5	12.2		4.1	7.1	10.5
East of England	Primary		1.9	3.0	4.0		3.3	5.8	7.2		4.4	7.0	9.7		4.1	6.5	8.9
	Higher		1.8	3.3	5.3		3.5	5.8	8.5		4.6	8.2	11.8		4.1	7.1	10.6
London	Primary		1.9	3.0	4.0		3.4	6.1	7.5		4.7	7.5	10.0		4.4	6.8	9.4
	Higher		1.9	3.3	5.3		3.7	6.1	8.8		5.0	8.5	12.4		4.4	7.4	11.1
South East England	Primary		1.9	3.0	4.1		3.4	6.1	7.6		4.6	7.5	10.2		4.5	6.9	9.5
	Higher		1.9	3.3	5.3		3.7	6.1	8.9		4.9	8.6	12.6		4.5	7.6	11.3
South West England	Primary		1.8	2.9	4.0		3.2	6.3	8.1		4.9	7.8	10.7		4.4	6.4	9.4
	Higher		1.8	3.3	5.2		3.7	6.8	9.6		5.3	9.2	13.2		4.7	7.2	10.9

Baseline = 1961 to 1990

5.2 Change in temperature of the coldest night

Although Winter will remain the coldest season the general trend is for projected increases in the temperature of the coldest night across all seasons and regions. Across these months, South West England and North Scotland show the lowest projected increases and Yorkshire & Humberside and the East Midlands the highest.

Projections for this parameter are in *Table 3*. No baseline data is available for this parameter and this should be accounted for by following the calculation method 2 in *4.2.1 Quantitative data*.

Table 3 **Change in temperature of the coldest night (°C) (UKCP09)**

UK Administrative Region	Climate change scenario	Winter				Spring				Summer				Autumn			
		Baseline	2020s	2050s	2080s	Baseline	2020s	2050s	2080s	Baseline	2020s	2050s	2080s	Baseline	2020s	2050s	2080s
North Scotland	Primary		3.4	4.9	5.8		3.1	3.8	4.0		2.0	3.2	4.4		2.3	3.1	3.7
	Higher		3.4	5.4	6.9		3.1	3.6	4.2		2.1	3.6	5.4		2.5	3.2	4.0
West Scotland	Primary		3.8	5.6	6.3		2.6	4.5	6.4		1.9	2.9	4.1		3.1	4.6	6.1
	Higher		3.8	5.7	7.1		2.6	4.6	7.4		1.9	3.2	5.0		3.3	4.9	7.2
East Scotland	Primary		3.4	4.9	5.8		3.1	3.8	4.0		2.0	3.2	4.4		2.3	3.1	3.7
	Higher		3.4	5.4	6.9		3.1	3.6	4.2		2.1	3.6	5.4		2.5	3.2	4.0
North East England	Primary		3.3	4.8	5.8		2.5	4.3	6.1		2.0	3.0	4.3		3.1	4.5	6.0
	Higher		3.5	5.4	6.9		2.6	4.5	7.2		2.0	3.4	5.2		3.3	4.8	7.0
Yorkshire and Humberside	Primary		3.7	5.4	6.8		2.0	3.3	4.7		2.3	3.8	5.0		2.5	4.3	5.9
	Higher		3.7	5.9	7.8		2.1	3.5	5.6		2.4	4.1	6.3		2.6	4.6	7.4
North West England	Primary		3.6	5.2	5.9		2.1	3.7	5.4		1.9	2.9	4.0		2.9	4.2	5.6
	Higher		3.6	5.4	6.6		2.2	3.9	6.4		1.9	3.3	5.1		3.0	4.5	6.6
Wales	Primary		3.5	4.8	5.9		2.5	4.2	5.9		2.2	3.3	4.5		2.9	4.8	6.4
	Higher		3.7	5.2	6.6		2.4	4.5	7.5		2.2	3.7	5.5		3.0	5.1	8.1
West Midlands	Primary		3.9	5.3	6.4		2.3	4.0	5.5		2.2	3.4	4.6		2.6	4.4	5.8
	Higher		4.0	5.8	7.2		2.2	4.2	7.1		2.3	3.7	5.6		2.7	4.6	7.4
East Midlands	Primary		3.6	5.3	6.5		2.0	3.4	4.7		2.3	3.8	5.0		2.7	4.5	6.2
	Higher		3.6	5.7	7.6		2.0	3.5	5.7		2.4	4.1	6.3		2.6	4.8	7.8
East of England	Primary		3.2	4.6	5.8		2.2	3.7	5.2		2.3	3.8	5.1		3.0	5.0	6.9
	Higher		3.2	5.0	6.6		2.2	3.8	6.3		2.4	4.2	6.4		3.0	5.3	8.6
London	Primary		3.5	5.1	6.3		2.2	3.7	5.1		2.4	4.0	5.3		2.9	4.9	6.7
	Higher		3.6	5.5	7.2		2.2	3.8	6.2		2.5	4.3	6.6		2.9	5.1	8.4
South East England	Primary		3.5	5.0	6.4		2.2	3.7	5.2		2.4	4.0	5.2		3.0	5.0	6.9
	Higher		3.5	5.5	7.2		2.2	3.9	6.3		2.5	4.3	6.6		2.9	5.3	8.7
South West England	Primary		2.9	4.0	4.8		2.3	4.5	6.3		2.2	3.4	4.7		3.2	5.3	7.1
	Higher		3.0	4.4	5.4		2.6	4.8	8.0		2.3	3.9	5.7		3.3	5.6	9.0

Baseline = 1961 to 1990

5.3 Change in mean daily maximum temperature

The general trend for the mean daily maximum temperature across all months and regions is for projected increases. July and August will continue to be the hottest months with August seeing the highest projected increases. South East and South West England will see the largest projected increases in Summer and North and East Scotland will see the lowest.

Projections for this parameter can be found in *Table 4.* Baseline data is available for this parameter and it should be accounted for using calculation method 1 in *4.2.1 Quantitative data*.

Table 4 **Change in mean daily maximum temperature (°C) (UKCP18)**

UK Administrative Region	Climate change scenario	January				February				March				April				May				June			
		Baseline	2030s	2050s	2070s	Baseline	2030s	2050s	2070s	Baseline	2030s	2050s	2070s	Baseline	2030s	2050s	2070s	Baseline	2030s	2050s	2070s	Baseline	2030s	2050s	2070s
North Scotland	Primary	5.0	1.7	2.0	2.7	5.3	1.5	2.2	3.2	6.7	1.3	1.8	2.6	9.0	1.4	1.6	2.4	12.4	1.5	2.0	2.8	14.3	1.4	2.1	3.0
	Higher		1.9	2.7	3.9		1.8	3.0	4.5		1.5	2.4	3.5		1.6	2.2	3.4		1.7	2.6	3.7		1.6	2.7	4.0
West Scotland	Primary	5.7	1.8	2.2	2.9	5.9	1.7	2.4	3.5	7.7	1.4	1.9	2.6	10.1	1.4	1.6	2.4	13.8	1.6	2.1	3.1	15.8	1.5	2.3	3.3
	Higher		2.1	2.9	4.2		2.0	3.2	4.8		1.6	2.5	3.6		1.6	2.1	3.3		1.8	2.7	4.1		1.7	3.0	4.4
East Scotland	Primary	4.8	1.8	2.1	2.9	5.1	1.6	2.3	3.3	7.2	1.4	1.9	2.7	9.5	1.6	1.8	2.6	12.9	1.6	2.3	3.3	15.4	1.6	2.4	3.5
	Higher		2.0	2.9	4.1		1.9	3.1	4.6		1.5	2.5	3.7		1.7	2.4	3.6		1.8	3.0	4.4		1.8	3.2	4.7
North East England	Primary	5.5	1.9	2.2	3.0	5.9	1.7	2.4	3.5	8.1	1.4	2.0	2.7	10.2	1.5	1.7	2.6	13.5	1.6	2.4	3.3	16.1	1.3	2.1	3.1
	Higher		2.1	3.0	4.4		2.0	3.3	4.9		1.6	2.6	3.7		1.6	2.3	3.5		1.8	3.0	4.4		1.5	2.7	4.1
Yorkshire and Humberside	Primary	6.0	1.8	2.2	3.0	6.4	1.9	2.6	3.5	8.9	1.6	2.2	2.8	11.1	1.8	2.2	2.9	14.6	1.6	2.4	3.4	17.2	1.9	2.8	4.0
	Higher		2.1	3.0	4.4		2.1	3.4	4.8		1.8	2.8	3.9		1.9	2.8	3.9		1.8	3.1	4.5		2.2	3.7	5.5
North West England	Primary	6.1	1.8	2.2	2.9	6.3	1.6	2.4	3.4	8.5	1.3	1.9	2.6	11.0	1.4	1.6	2.5	14.7	1.6	2.2	3.3	16.8	1.6	2.4	3.6
	Higher		2.1	3.0	4.2		1.9	3.2	4.8		1.5	2.5	3.6		1.6	2.2	3.4		1.8	2.9	4.4		1.8	3.1	4.8
Wales	Primary	6.6	1.8	2.1	2.9	6.6	1.9	2.6	3.6	8.9	1.3	1.9	2.6	11.2	1.5	1.8	2.6	14.7	1.6	2.2	3.3	17.0	1.7	2.5	3.8
	Higher		2.0	2.9	4.2		2.1	3.4	5.0		1.5	2.5	3.5		1.7	2.3	3.5		1.8	2.9	4.4		2.0	3.3	5.2
West Midlands	Primary	6.7	1.8	2.2	3.0	7.0	1.9	2.6	3.7	9.8	1.3	1.9	2.7	12.2	1.6	1.9	2.7	15.9	1.7	2.4	3.4	18.5	1.8	2.8	4.1
	Higher		2.1	3.0	4.3		2.1	3.5	5.1		1.5	2.5	3.6		1.8	2.5	3.6		1.9	3.1	4.6		2.1	3.6	5.5
East Midlands	Primary	6.5	1.8	2.2	3.0	6.9	1.8	2.6	3.5	9.8	1.6	2.1	2.8	12.1	1.8	2.2	2.9	15.7	1.7	2.5	3.6	18.4	2.1	3.1	4.4
	Higher		2.1	3.0	4.4		2.0	3.3	4.8		1.8	2.7	3.8		2.0	2.8	4.0		1.9	3.2	4.7		2.4	4.0	6.0
East of England	Primary	6.9	1.8	2.2	3.1	7.1	1.8	2.6	3.5	10.2	1.5	2.1	2.8	12.6	1.9	2.3	3.1	16.3	1.7	2.5	3.6	19.1	2.2	3.2	4.6
	Higher		2.1	3.1	4.4		2.0	3.3	4.8		1.7	2.7	3.8		2.0	2.9	4.2		1.9	3.2	4.8		2.5	4.1	6.2
London	Primary	7.7	1.8	2.3	3.1	7.9	1.8	2.6	3.5	11.0	1.5	2.0	2.8	13.4	1.9	2.2	3.1	17.3	1.7	2.4	3.6	20.0	2.3	3.3	5.0
	Higher		2.1	3.1	4.5		2.0	3.3	4.8		1.7	2.6	3.8		2.0	2.9	4.2		1.9	3.1	4.8		2.7	4.4	6.8
South East England	Primary	7.3	1.8	2.3	3.1	7.4	1.8	2.5	3.4	10.3	1.5	2.0	2.7	12.7	1.8	2.2	3.0	16.5	1.7	2.4	3.6	19.2	2.4	3.4	5.0
	Higher		2.1	3.1	4.4		2.0	3.3	4.7		1.7	2.6	3.8		2.0	2.8	4.1		1.9	3.1	4.8		2.7	4.4	6.8
South West England	Primary	7.6	1.8	2.2	2.9	7.7	1.8	2.5	3.6	10.1	1.3	1.8	2.5	12.2	1.6	1.9	2.6	15.7	1.7	2.3	3.5	18.3	1.9	2.9	4.4
	Higher		2.1	2.9	4.2		2.0	3.4	4.9		1.4	2.4	3.5		1.7	2.4	3.6		1.9	3.0	4.7		2.2	3.8	5.9

UK Administrative Region	Climate change scenario	July				August				September				October				November				December			
		Baseline	2030s	2050s	2070s	Baseline	2030s	2050s	2070s	Baseline	2030s	2050s	2070s	Baseline	2030s	2050s	2070s	Baseline	2030s	2050s	2070s	Baseline	2030s	2050s	2070s
North Scotland	Primary	16.3	1.5	2.0	3.1	16.0	2.0	2.7	4.0	13.5	1.7	2.6	3.9	10.4	1.8	2.1	3.1	7.3	1.6	1.9	2.4	5.4	1.9	2.0	2.6
	Higher		1.7	2.7	4.2		2.2	3.5	5.4		1.9	3.3	5.2		2.0	2.8	4.3		1.8	2.5	3.4		2.0	2.6	3.6
West Scotland	Primary	17.6	1.7	2.2	3.5	17.2	2.3	3.4	4.4	14.7	2.1	3.1	4.5	11.4	1.9	2.3	3.5	8.2	1.8	2.0	2.9	6.2	1.9	2.0	2.8
	Higher		1.9	2.9	4.7		2.6	4.4	6.1		2.4	4.0	5.9		2.1	3.1	4.8		2.0	2.7	4.0		2.0	2.6	3.8
East Scotland	Primary	17.7	1.7	2.4	3.7	17.3	2.3	3.1	4.9	14.4	1.9	2.9	4.4	10.8	1.9	2.2	3.3	7.3	1.7	2.0	2.4	5.2	1.9	2.1	2.7
	Higher		2.0	3.1	5.0		2.5	4.2	6.5		2.1	3.7	5.9		2.1	3.0	4.6		1.9	2.5	3.2		2.1	2.7	3.6
North East England	Primary	18.7	1.7	2.4	3.7	18.3	2.4	3.4	4.7	15.5	2.2	3.3	5.1	11.9	2.0	2.4	3.8	8.2	1.8	2.1	3.0	6.0	1.9	2.1	2.9
	Higher		2.0	3.1	5.1		2.6	4.5	6.5		2.5	4.4	6.7		2.3	3.3	5.3		2.1	2.8	4.2		2.1	2.7	3.9
Yorkshire and Humberside	Primary	20.0	2.4	3.2	4.5	19.7	2.5	3.7	5.0	16.7	2.1	3.2	4.5	12.7	2.1	2.7	4.1	8.8	1.9	2.2	3.1	6.6	1.9	2.1	2.9
	Higher		2.7	4.3	6.2		2.8	4.8	6.9		2.3	4.1	6.0		2.4	3.7	5.8		2.1	2.9	4.3		2.0	2.8	3.9
North West England	Primary	19.1	1.7	2.3	3.8	18.7	2.5	3.7	4.9	16.0	2.3	3.4	5.1	12.4	2.0	2.4	3.8	8.8	1.8	2.1	3.0	6.6	1.8	2.1	2.8
	Higher		2.0	3.1	5.2		2.7	4.9	6.8		2.6	4.4	6.7		2.3	3.3	5.3		2.1	2.8	4.2		2.0	2.7	3.9
Wales	Primary	19.4	2.3	3.1	4.6	19.0	2.7	4.1	5.6	16.4	2.3	3.5	5.1	12.8	2.1	2.8	4.2	9.4	1.8	2.1	3.0	7.3	1.7	2.0	2.8
	Higher		2.6	4.1	6.3		3.0	5.3	7.6		2.6	4.5	6.8		2.4	3.7	5.8		2.0	2.8	4.2		1.9	2.6	3.9
West Midlands	Primary	21.3	2.4	3.4	5.0	20.8	2.9	4.3	5.9	17.6	2.5	3.8	5.6	13.4	2.2	2.9	4.4	9.5	1.9	2.2	3.1	7.2	1.8	2.1	2.9
	Higher		2.8	4.5	6.8		3.2	5.6	8.1		2.9	4.9	7.5		2.5	3.9	6.2		2.1	2.9	4.3		2.0	2.7	3.9
East Midlands	Primary	21.3	2.7	3.5	4.9	21.1	2.8	4.1	5.6	17.8	2.3	3.5	5.0	13.6	2.2	2.9	4.4	9.4	1.9	2.2	3.2	7.0	1.8	2.1	2.8
	Higher		3.0	4.7	6.8		3.1	5.3	7.6		2.6	4.5	6.7		2.5	3.9	6.2		2.1	2.9	4.4		2.0	2.8	3.9
East of England	Primary	22.1	2.7	3.7	5.1	22.1	2.8	4.1	5.6	18.7	2.4	3.5	5.1	14.4	2.4	3.0	4.6	10.0	1.9	2.3	3.2	7.5	1.8	2.1	2.9
	Higher		3.1	4.8	7.0		3.2	5.4	7.7		2.7	4.6	6.8		2.7	4.1	6.4		2.1	3.0	4.5		2.0	2.8	4.0
London	Primary	22.9	2.9	3.9	5.5	22.7	3.0	4.5	6.2	19.2	2.5	3.7	5.4	15.0	2.5	3.1	4.7	10.7	1.9	2.3	3.3	8.3	1.7	2.1	2.9
	Higher		3.2	5.1	7.5		3.4	5.9	8.5		2.8	4.8	7.2		2.8	4.2	6.6		2.2	3.0	4.6		1.9	2.8	4.0
South East England	Primary	21.9	2.9	3.9	5.5	21.9	3.1	4.6	6.3	18.6	2.5	3.7	5.3	14.5	2.4	3.1	4.6	10.4	1.9	2.3	3.3	8.0	1.7	2.1	2.9
	Higher		3.3	5.1	7.5		3.5	5.9	8.6		2.8	4.8	7.2		2.7	4.1	6.5		2.2	3.0	4.6		1.9	2.8	4.0
South West England	Primary	20.8	2.5	3.5	5.2	20.6	3.0	4.5	6.2	17.8	2.6	3.8	5.7	14.0	2.2	3.0	4.4	10.5	1.8	2.2	3.1	8.3	1.7	2.0	2.8
	Higher		2.8	4.6	7.1		3.4	5.8	8.5		2.9	4.9	7.6		2.6	4.0	6.2		2.1	2.9	4.3		1.9	2.7	3.9

Baseline = 1981 to 2000   **Baseline units = °C**

5.4 Change in mean daily minimum temperature

The general trend is for the mean daily minimum temperature to increase across all months and regions however, Winter will remain the coldest season. The East of England and London will see the greatest projected increase in Winter minimum temperatures and North and East Scotland the lowest. In Summer, London and South East England will see the largest projected changes, and North and East Scotland the smallest.

Projections for this parameter can be found in *Table 5*. As baseline data are available for this parameter this should be accounted for by following calculation method 1 in *4.2.1 Quantitative data*.

Table 5 **Change in mean daily minimum temperature (°C) (UKCP18)**

UK Administrative Region	Climate change scenario	January				February				March				April				May				June			
		Baseline	2030s	2050s	2070s	Baseline	2030s	2050s	2070s	Baseline	2030s	2050s	2070s	Baseline	2030s	2050s	2070s	Baseline	2030s	2050s	2070s	Baseline	2030s	2050s	2070s
North Scotland	Primary	-0.1	1.9	2.4	3.3	-0.1	1.8	2.4	3.3	0.9	1.7	2.5	3.5	2.0	1.5	1.9	2.6	4.4	1.6	1.9	2.7	7.0	1.6	2.1	2.9
	Higher		2.3	3.3	4.8		2.1	3.2	4.6		1.9	3.4	4.8		1.7	2.5	3.6		1.7	2.5	3.7		1.8	2.8	4.0
West Scotland	Primary	0.6	1.8	2.3	3.3	0.7	1.7	2.6	3.8	1.8	1.6	2.5	3.4	2.8	1.6	1.8	2.5	5.3	1.4	1.7	2.3	7.9	1.2	1.8	2.6
	Higher		2.1	3.2	4.8		2.0	3.5	5.4		1.8	3.3	4.7		1.7	2.4	3.5		1.6	2.2	3.1		1.4	2.4	3.5
East Scotland	Primary	-0.6	2.0	2.5	3.4	-0.4	1.7	2.4	3.2	0.8	1.7	2.6	3.5	1.9	1.6	2.0	2.8	4.4	1.7	2.1	2.9	7.1	1.7	2.4	3.2
	Higher		2.3	3.3	4.9		2.0	3.2	4.6		1.9	3.4	4.9		1.8	2.6	3.8		1.9	2.7	4.0		2.0	3.1	4.5
North East England	Primary	0.2	2.0	2.6	3.7	0.2	1.7	2.6	3.7	1.5	1.6	2.5	3.3	2.6	1.6	1.8	2.6	5.0	1.4	1.9	2.4	7.8	1.2	1.9	2.7
	Higher		2.3	3.5	5.2		2.0	3.5	5.3		1.8	3.3	4.6		1.8	2.4	3.6		1.5	2.4	3.2		1.4	2.5	3.7
Yorkshire and Humberside	Primary	0.5	2.0	2.6	3.7	0.6	1.6	2.5	3.3	2.1	1.5	2.1	2.9	3.3	1.6	1.8	2.6	5.9	1.7	2.1	3.0	8.6	1.4	2.1	3.1
	Higher		2.3	3.5	5.3		1.8	3.2	4.5		1.7	2.9	4.2		1.8	2.4	3.6		1.9	2.8	4.2		1.6	2.8	4.3
North West England	Primary	0.8	1.8	2.3	3.3	0.9	1.7	2.6	3.7	2.4	1.5	2.4	3.3	3.4	1.6	1.8	2.6	6.1	1.4	1.8	2.4	8.9	1.2	1.9	2.7
	Higher		2.1	3.2	4.7		2.0	3.5	5.2		1.7	3.2	4.5		1.8	2.4	3.6		1.5	2.2	3.2		1.4	2.5	3.7
Wales	Primary	1.3	1.8	2.4	3.4	1.1	1.7	2.6	3.8	2.8	1.4	2.3	3.2	3.5	1.6	1.8	2.6	6.2	1.5	1.8	2.7	8.8	1.4	2.1	3.2
	Higher		2.1	3.3	4.8		2.0	3.5	5.4		1.7	3.1	4.5		1.8	2.4	3.7		1.7	2.4	3.7		1.6	2.8	4.5
West Midlands	Primary	1.0	1.9	2.7	3.7	0.8	1.7	2.6	3.8	2.7	1.4	2.4	3.2	3.6	1.6	1.9	2.7	6.3	1.5	1.9	2.7	9.2	1.4	2.2	3.3
	Higher		2.3	3.6	5.3		2.0	3.5	5.4		1.7	3.2	4.6		1.8	2.4	3.7		1.7	2.5	3.8		1.7	2.9	4.6
East Midlands	Primary	0.7	2.0	2.7	3.8	0.6	1.5	2.5	3.3	2.5	1.5	2.1	2.9	3.4	1.6	1.8	2.6	6.2	1.7	2.1	3.0	9.1	1.4	2.1	3.2
	Higher		2.3	3.6	5.4		1.7	3.2	4.6		1.7	2.9	4.2		1.8	2.4	3.7		1.9	2.8	4.2		1.6	2.9	4.4
East of England	Primary	1.2	2.1	2.8	3.9	0.8	1.6	2.5	3.5	2.8	1.4	2.1	3.0	3.9	1.6	1.8	2.7	6.8	1.7	2.1	3.0	9.7	1.4	2.2	3.3
	Higher		2.4	3.8	5.7		1.8	3.2	4.7		1.6	2.9	4.2		1.7	2.4	3.7		1.9	2.8	4.2		1.6	2.9	4.5
London	Primary	2.2	2.1	2.8	4.0	1.7	1.6	2.5	3.5	3.9	1.4	2.1	3.0	4.9	1.6	1.8	2.7	7.9	1.7	2.1	3.1	10.9	1.5	2.3	3.5
	Higher		2.4	3.9	5.7		1.8	3.3	4.8		1.6	2.8	4.2		1.7	2.4	3.7		2.0	2.9	4.4		1.7	3.1	4.8
South East England	Primary	1.5	2.1	2.8	4.0	1.0	1.6	2.5	3.5	3.0	1.4	2.1	3.0	3.9	1.6	1.8	2.7	7.0	1.8	2.1	3.1	9.7	1.9	2.7	4.1
	Higher		2.5	3.9	5.7		1.8	3.3	4.8		1.6	2.8	4.3		1.7	2.4	3.7		2.0	2.8	4.4		2.3	3.6	5.7
South West England	Primary	2.0	2.0	2.7	3.8	1.6	1.8	2.7	3.8	3.3	1.3	2.3	3.2	4.0	1.5	1.8	2.7	7.0	1.5	1.9	2.8	9.6	1.5	2.3	3.5
	Higher		2.3	3.7	5.5		2.1	3.5	5.3		1.6	3.1	4.6		1.7	2.4	3.7		1.7	2.4	3.8		1.8	3.1	4.9

UK Administrative Region	Climate change scenario	July				August				September				October				November				December			
		Baseline	2030s	2050s	2070s	Baseline	2030s	2050s	2070s	Baseline	2030s	2050s	2070s	Baseline	2030s	2050s	2070s	Baseline	2030s	2050s	2070s	Baseline	2030s	2050s	2070s
North Scotland	Primary	9.3	1.5	1.9	2.7	9.1	1.7	2.3	3.2	7.1	1.6	2.3	3.4	4.6	1.8	2.1	3.2	2.1	1.9	2.3	2.8	0.1	2.2	2.5	3.0
	Higher		1.7	2.5	3.8		2.0	3.1	4.5		1.9	3.1	4.8		2.1	2.9	4.5		2.1	2.9	3.9		2.5	3.2	4.1
West Scotland	Primary	10.0	1.6	2.1	3.0	9.9	1.8	2.7	3.8	7.9	1.8	2.5	3.8	5.5	1.8	2.2	3.3	2.8	2.1	2.5	3.1	1.0	1.9	2.3	3.0
	Higher		1.8	2.8	4.3		2.1	3.6	5.3		2.1	3.4	5.3		2.1	3.1	4.7		2.3	3.2	4.3		2.1	3.0	4.2
East Scotland	Primary	9.3	1.6	2.0	3.0	9.1	1.8	2.6	3.6	7.0	1.7	2.3	3.6	4.3	1.8	2.1	3.3	1.7	2.1	2.5	3.0	-0.3	2.2	2.5	3.0
	Higher		1.8	2.7	4.2		2.1	3.4	5.1		2.0	3.2	5.0		2.1	3.0	4.7		2.3	3.1	4.2		2.4	3.3	4.1
North East England	Primary	10.1	1.6	2.2	3.2	10.0	1.8	2.7	3.9	7.9	1.9	2.6	3.9	5.2	1.8	2.2	3.4	2.6	2.2	2.6	3.2	0.6	1.9	2.3	3.0
	Higher		1.9	2.9	4.5		2.1	3.6	5.4		2.2	3.5	5.4		2.1	3.1	4.9		2.4	3.3	4.4		2.1	3.0	4.1
Yorkshire and Humberside	Primary	11.0	1.7	2.4	3.4	10.8	1.8	2.6	3.8	8.8	1.9	2.6	3.9	6.0	1.8	2.4	3.8	3.1	1.7	2.2	3.2	1.2	1.8	2.3	3.0
	Higher		1.9	3.2	4.8		2.1	3.6	5.3		2.2	3.5	5.4		2.2	3.3	5.3		2.0	3.0	4.5		2.1	3.0	4.1
North West England	Primary	11.2	1.6	2.2	3.2	10.9	1.8	2.7	3.9	8.8	1.9	2.5	3.9	6.1	1.8	2.3	3.5	3.3	2.3	2.7	3.4	1.3	1.9	2.3	3.0
	Higher		1.9	2.9	4.5		2.1	3.7	5.5		2.2	3.4	5.5		2.1	3.1	5.0		2.5	3.4	4.6		2.1	3.0	4.2
Wales	Primary	11.0	1.6	2.3	3.5	10.8	1.8	2.6	4.0	9.0	2.0	2.8	4.3	6.5	1.8	2.3	3.5	3.8	1.9	2.3	3.4	2.0	1.8	2.2	3.0
	Higher		1.9	3.1	4.8		2.1	3.6	5.6		2.3	3.7	5.9		2.1	3.2	5.0		2.2	3.1	4.7		2.0	2.9	4.2
West Midlands	Primary	11.4	1.6	2.5	3.6	11.1	1.8	2.8	4.2	9.1	2.0	2.9	4.5	6.3	1.8	2.3	3.6	3.5	2.0	2.4	3.5	1.6	1.8	2.3	3.0
	Higher		1.9	3.2	5.0		2.1	3.7	5.9		2.4	3.8	6.1		2.2	3.2	5.1		2.2	3.2	4.9		2.0	3.0	4.2
East Midlands	Primary	11.3	1.8	2.5	3.6	11.1	1.9	2.8	4.0	9.2	1.9	2.7	4.0	6.3	1.9	2.5	3.9	3.4	1.7	2.3	3.4	1.4	1.8	2.3	3.0
	Higher		2.0	3.3	5.0		2.1	3.7	5.6		2.2	3.6	5.6		2.2	3.4	5.4		2.0	3.0	4.6		2.0	3.0	4.2
East of England	Primary	11.9	1.8	2.6	3.7	11.8	1.9	2.9	4.1	10.0	1.9	2.7	4.1	7.1	1.9	2.5	4.0	3.8	1.7	2.4	3.5	2.0	1.9	2.5	3.3
	Higher		2.1	3.4	5.2		2.2	3.8	5.7		2.2	3.6	5.7		2.2	3.5	5.6		2.0	3.2	4.8		2.2	3.2	4.6
London	Primary	13.2	1.9	2.7	4.0	13.0	2.0	3.1	4.5	10.8	1.9	2.8	4.3	7.9	1.9	2.6	4.0	4.6	1.8	2.4	3.6	2.9	1.8	2.4	3.1
	Higher		2.2	3.6	5.5		2.3	4.1	6.2		2.2	3.8	6.0		2.3	3.5	5.7		2.1	3.2	5.0		2.0	3.1	4.3
South East England	Primary	12.0	1.9	2.8	4.0	11.9	2.0	3.1	4.6	9.8	1.9	2.8	4.4	7.1	1.9	2.6	4.0	3.9	1.8	2.4	3.6	2.3	1.8	2.4	3.1
	Higher		2.2	3.6	5.6		2.4	4.2	6.4		2.3	3.8	6.1		2.3	3.5	5.7		2.1	3.2	5.0		2.1	3.1	4.3
South West England	Primary	11.8	1.7	2.6	3.8	11.7	1.9	2.9	4.5	9.8	2.0	2.9	4.6	7.2	1.9	2.4	3.7	4.4	2.0	2.4	3.6	2.7	1.8	2.3	3.1
	Higher		2.0	3.4	5.3		2.2	4.0	6.3		2.3	3.9	6.2		2.2	3.3	5.2		2.3	3.2	5.0		2.0	3.1	4.3

Baseline = 1981 to 2000 **Baseline units = °C**

6 Precipitation

Total precipitation (rainfall, sleet, hail and snow) is projected to increase in the late Autumn to early Spring months as a combination of increased average precipitation and increased severity and frequency of storms. In late Spring to early Autumn the frequency of extreme storms is projected to increase, but the total and average precipitation is projected to decline. The combined effects of these seasonal changes tend to cancel each other out with the actual level of annual average precipitation expected to stay roughly the same.

The increased winter precipitation and summer storms could lead to more frequent and severe flooding and snowfalls (Section 7 Flooding) and Section *6.3 Snow*). The reduced summer precipitation combined with warmer temperatures, will increase the frequency and severity of droughts.

The warmer temperatures (*5 Temperature*) mean that the frequency of snowfall events will reduce, but it should be noted that current extremes of winter weather will still be possible.

This section contains tables of quantitative projections from UKCP09 data for the following precipitation parameters:

UKCP18
6.1 Change in average daily precipitation rate (%)

UKCP09
6.2 Change in precipitation on the wettest day (%)

These projections are averages for their respective geographic regions, so local effects may need to be considered depending on the sensitivity of the asset and the accuracy of the assessment that is required. For example, an upland area may receive greater rainfall than the valley to the east of it. Examples of factors to consider include; microclimate (prevailing wind etc.), topology and asset characteristics (orientation, material, susceptibility to water impacts, frequency/nature of use etc).

6.1 Change in average daily precipitation rate (%)

Daily precipitation rates are projected to increase in Winter and decrease in Summer. This will exaggerate the current pattern of higher daily precipitation totals in Winter and lower ones in Summer. The driest month across all UK regions is projected to be July, while January is projected to be the wettest.

As the challenges to our assets come from periods of continuous wet or dry weather this section illustrates the upper ranges of potential Winter precipitation increases, and the highest potential Summer reductions. Projections for the upper range of Winter precipitation increases are provided in *Table 6* and projections for the greatest potential Summer precipitation reductions are in *Table 7*.

Although not classed as a Winter month, November is included in *Table 6* because its current high daily precipitation coupled with its projected percentage changes in the UKCP18 data means that its future projected daily precipitation can exceed that of the Winter months (December, January, February).

With the exception of November, data is not provided for the Spring and Autumn months as the values for these would fall within the ranges illustrated by those for Winter and Summer. It is recommended that both tables be used when assessing the impacts of future daily precipitation.

Climate Change Projections

NetworkRail

[Guidance Note | Weather Resilience and Climate Change Adaptation]

Each monthly value is the average percentage change in daily precipitation from 20 years of modelled data. The baseline is the modelled average daily precipitation (mm) for each month from 1981 to 2000.

As baseline data is available it should be accounted for by following calculation method 1 in 4.2.1 Quantitative data.

Table 6 **Change in Winter average daily precipitation rate (%) 90th percentile (UKCP18)**

UK Administrative Region	Climate change scenario	January				February				November				December			
		Baseline	2030s	2050s	2070s	Baseline	2030s	2050s	2070s	Baseline	2030s	2050s	2070s	Baseline	2030s	2050s	2070s
North Scotland	Primary	6.8	20.6	27.5	41.1	5.5	22.8	24.5	35.6	5.9	22.0	29.7	31.9	6.4	31.4	30.9	37.7
	Higher		24.5	36.7	57.5		25.5	31.8	48.5		24.4	36.3	44.9		34.1	39.9	52.7
West Scotland	Primary	6.4	25.8	38.1	47.9	5.0	26.1	31.6	40.8	5.7	27.7	38.4	47.8	6.6	31.4	28.3	41.9
	Higher		30.5	49.2	67.6		28.3	39.1	55.2		30.9	46.4	61.8		34.9	38.5	57.8
East Scotland	Primary	4.3	34.7	39.2	44.3	3.2	23.5	28.9	29.6	4.0	21.4	31.1	35.1	4.2	27.3	26.0	32.1
	Higher		36.6	47.1	58.0		24.1	32.9	37.1		23.4	37.6	47.3		29.8	33.0	42.8
North East England	Primary	2.7	35.6	42.1	45.1	2.0	23.7	33.0	33.6	3.0	25.8	25.7	36.5	2.9	23.5	20.7	31.2
	Higher		38.1	50.8	60.3		26.0	38.7	44.9		27.7	31.7	47.3		26.1	26.4	40.2
Yorkshire and Humberside	Primary	2.7	22.9	27.3	29.4	1.9	16.5	24.7	27.6	2.8	29.5	28.0	40.0	3.0	21.0	19.5	34.7
	Higher		25.2	33.8	40.9		17.9	30.7	37.7		31.2	34.6	50.7		23.0	25.3	45.0
North West England	Primary	4.2	25.1	36.3	44.5	3.1	19.7	29.3	33.3	4.1	25.9	29.1	39.6	4.7	24.5	23.1	35.7
	Higher		29.2	46.9	63.9		21.8	35.6	45.4		27.6	36.2	49.8		27.1	32.1	48.9
Wales	Primary	5.3	22.2	31.8	42.1	3.7	21.2	28.4	36.4	5.2	33.4	37.7	48.2	5.9	22.3	22.4	37.6
	Higher		25.9	40.1	57.8		23.3	35.8	49.5		36.0	44.9	61.4		24.9	30.5	50.3
West Midlands	Primary	2.4	27.7	33.7	45.8	1.6	23.7	31.0	37.1	2.4	32.6	34.7	49.6	2.6	18.3	21.5	35.7
	Higher		31.5	42.9	62.4		26.0	39.3	52.0		34.6	42.4	63.7		20.8	27.8	46.3
East Midlands	Primary	2.1	26.3	31.3	42.1	1.4	22.1	31.0	34.5	2.1	31.1	27.2	42.9	2.2	20.9	21.0	35.6
	Higher		29.7	39.9	56.5		23.8	38.0	46.2		32.6	34.2	52.9		23.1	27.3	47.2
East of England	Primary	1.8	27.7	31.1	41.9	1.2	24.0	32.7	37.3	1.9	34.1	32.1	39.1	1.9	20.2	26.1	38.6
	Higher		30.7	39.4	55.9		26.2	39.4	48.8		35.7	37.8	48.5		22.6	33.3	51.0
London	Primary	2.0	30.7	33.9	45.4	1.2	30.3	37.0	42.9	1.9	32.2	33.8	35.7	2.1	23.6	31.1	44.4
	Higher		34.2	43.0	59.6		32.3	44.1	55.4		33.5	39.7	44.2		25.9	39.7	58.2
South East England	Primary	2.6	32.7	37.1	51.7	1.6	29.9	37.7	43.1	2.6	33.5	40.3	45.4	2.8	28.4	34.8	50.3
	Higher		37.1	47.0	67.6		31.8	45.3	57.2		34.7	45.2	54.3		30.8	44.5	66.6
South West England	Primary	3.7	33.2	39.8	56.3	2.6	29.5	36.1	43.2	3.7	33.0	39.4	46.9	4.2	21.1	27.2	38.4
	Higher		37.5	50.8	74.0		32.8	45.5	60.2		35.4	45.7	59.7		23.7	35.1	51.3

Baseline = 1981 to 2000 **Baseline units = mm**

Table 7 **Change in Summer average daily precipitation rate (%) 10th percentile (UKCP18)**

UK Administrative Region	Climate change scenario	June				July				August			
		Baseline	2030s	2050s	2070s	Baseline	2030s	2050s	2070s	Baseline	2030s	2050s	2070s
North Scotland	Primary	2.9	-8.7	-18.1	-17.1	3.2	-23.5	-29.2	-34.0	4.0	-13.0	-22.3	-25.1
	Higher		-10.0	-21.0	-24.2		-23.6	-34.2	-43.6		-14.6	-26.5	-32.6
West Scotland	Primary	2.9	-15.0	-22.3	-26.6	3.6	-29.9	-32.3	-37.7	4.3	-22.9	-28.4	-32.8
	Higher		-16.6	-25.8	-35.0		-31.9	-38.5	-48.4		-25.0	-33.2	-40.8
East Scotland	Primary	2.5	-10.8	-26.9	-33.2	2.4	-24.2	-33.5	-41.5	2.8	-23.5	-29.7	-37.5
	Higher		-13.6	-31.2	-42.6		-25.2	-39.7	-51.5		-26.1	-36.3	-47.8
North East England	Primary	2.1	-10.6	-19.9	-30.7	1.9	-24.2	-35.7	-43.7	2.3	-26.9	-30.5	-33.5
	Higher		-11.8	-23.7	-38.1		-25.7	-42.9	-54.4		-28.7	-35.7	-42.0
Yorkshire and Humberside	Primary	2.2	-18.2	-31.9	-38.1	1.8	-33.8	-40.7	-44.5	2.2	-27.3	-33.2	-43.1
	Higher		-18.9	-36.2	-46.3		-35.9	-48.1	-58.1		-28.4	-39.4	-52.6
North West England	Primary	2.7	-18.6	-25.0	-31.7	2.6	-26.7	-36.0	-47.6	3.2	-27.3	-35.3	-41.4
	Higher		-19.7	-29.2	-39.2		-28.3	-43.9	-60.4		-29.4	-42.1	-52.0
Wales	Primary	3.0	-28.1	-33.0	-42.1	2.5	-36.2	-41.6	-49.0	3.6	-30.6	-38.1	-51.1
	Higher		-30.2	-38.3	-51.7		-39.0	-50.5	-63.4		-32.6	-45.7	-63.2
West Midlands	Primary	2.0	-30.1	-42.1	-48.9	1.6	-32.7	-40.2	-46.2	2.1	-33.4	-37.1	-54.5
	Higher		-32.2	-47.8	-59.8		-35.8	-48.3	-60.1		-35.7	-44.6	-64.9
East Midlands	Primary	2.0	-22.4	-36.1	-42.4	1.6	-36.1	-42.6	-46.4	1.9	-30.4	-38.3	-51.3
	Higher		-23.8	-40.6	-51.3		-38.4	-50.6	-61.0		-31.8	-45.7	-62.1
East of England	Primary	1.9	-23.1	-33.2	-45.3	1.6	-37.2	-44.4	-47.7	1.7	-35.1	-42.3	-52.3
	Higher		-25.0	-39.0	-55.5		-39.7	-53.1	-62.8		-36.9	-50.2	-63.6
London	Primary	1.8	-21.6	-34.8	-44.9	1.5	-39.2	-48.2	-51.5	1.6	-42.4	-48.9	-53.7
	Higher		-23.2	-39.7	-55.2		-41.1	-57.4	-66.5		-44.3	-57.3	-65.8
South East England	Primary	1.8	-22.7	-35.2	-47.7	1.5	-40.3	-48.6	-51.3	1.8	-41.0	-49.3	-54.6
	Higher		-24.7	-41.2	-58.5		-42.9	-58.0	-67.6		-43.1	-57.7	-66.8
South West England	Primary	2.2	-31.6	-43.4	-54.2	1.8	-39.0	-45.1	-54.5	2.4	-40.3	-43.9	-58.4
	Higher		-34.2	-50.1	-65.5		-41.8	-54.7	-69.3		-42.3	-52.3	-70.5

Baseline = 1981 to 2000 **Baseline units = mm**

6.2 Change in precipitation on the wettest day (%)

An increase in the severity and frequency of storms is projected across the year. As *Table 8* shows, the trend is for increases in precipitation on the wettest day across all months. This could lead to more frequent and severe flooding and snowfall (Section *7 Flooding* and Section *6.3 Snow*).

No baseline data is available for this parameter and this should be accounted for by following the second calculation methodology in *4.2.1 Quantitative data*.

When using this data, the following points should be considered:

- Projected increases in minimum, average and maximum temperatures (Section *5 Temperature*) increase the likelihood of winter precipitation being rain (rather than snow, sleet or hail). However, as current extremes of cold will still be possible, greater snowfalls as a result of more intense storms cannot be ruled out, and
- Summer convective storms usually have small, but intense footprints and the UKCP09 25km grid does not model them well. It spreads their intensity and any increases across the 25km giving modelled increases that are known to be lower than expected. The values in *Table 8* are therefore likely to be conservative.

Each monthly value is the average percentage change in the average highest daily precipitation from 30 years of modelled data. No baseline data is available for this parameter, so this should be accounted for by following calculation method 2 in *4.2.1 Quantitative data*.

Table 8 **Change in precipitation on the wettest day (%) (UKCP09)**

UK administrative region	Climate change scenario	Winter				Spring				Summer				Autumn			
		Baseline	2020s	2050s	2080s	Baseline	2020s	2050s	2080s	Baseline	2020s	2050s	2080s	Baseline	2020s	2050s	2080s
North Scotland	Primary		12.4	17.3	22.1		14.6	27.2	35.0		9.1	14.3	19.2		16.3	26.9	37.2
	Higher		11.2	18.9	28.0		15.3	30.0	49.2		10.2	16.1	23.8		16.7	31.2	46.0
West Scotland	Primary		13.2	21.0	28.6		15.9	23.4	30.9		10.4	11.5	13.6		17.9	28.9	40.0
	Higher		12.2	23.9	38.3		14.5	24.8	42.3		12.3	12.9	18.3		18.4	33.4	48.4
East Scotland	Primary		11.8	20.8	27.8		12.0	17.8	23.4		13.1	11.8	14.2		15.9	24.4	34.0
	Higher		14.0	22.8	35.2		11.7	19.7	31.9		15.0	18.0	25.4		16.5	28.6	40.4
North East England	Primary		15.4	25.9	34.2		15.8	21.3	26.4		16.4	15.1	17.5		18.7	22.5	30.2
	Higher		17.7	27.8	42.9		16.3	21.4	31.0		18.4	20.2	26.8		15.6	25.7	35.9
Yorkshire and Humberside	Primary		13.9	24.6	33.1		13.9	19.1	24.1		17.1	15.3	18.6		15.8	22.6	31.2
	Higher		16.4	26.9	42.2		14.4	19.0	28.4		19.4	22.5	30.7		16.1	22.7	35.3
North West England	Primary		15.8	25.9	33.2		13.5	25.7	33.4		17.1	18.5	21.4		14.6	22.6	31.7
	Higher		16.0	24.7	42.7		14.0	28.3	47.2		16.7	19.8	26.1		14.9	22.5	36.6
Wales	Primary		16.3	27.1	35.2		12.3	22.5	29.1		20.0	22.9	27.2		12.5	19.2	25.7
	Higher		16.5	26.0	44.4		12.7	24.4	39.8		19.9	24.8	34.3		14.8	20.5	33.3
West Midlands	Primary		16.2	24.3	32.5		15.9	23.9	31.6		23.6	25.2	29.0		13.6	21.7	29.2
	Higher		14.7	27.5	42.7		17.6	23.8	37.7		23.3	26.4	34.9		16.1	22.9	37.9
East Midlands	Primary		16.6	25.0	33.3		15.6	24.0	31.9		22.1	22.1	24.8		13.9	20.7	27.2
	Higher		15.1	27.6	43.9		16.8	23.8	38.4		21.8	23.4	28.0		15.8	21.4	34.2
East of England (Anglia)	Primary		17.7	31.8	43.5		12.1	15.5	18.5		20.1	17.8	18.8		13.1	18.6	23.9
	Higher		21.1	34.6	55.8		12.3	17.2	24.1		19.9	18.6	18.8		14.6	19.6	29.7
London	Primary		19.1	33.0	44.9		10.3	12.6	14.7		25.4	21.7	22.5		15.6	21.4	28.8
	Higher		20.5	27.3	64.3		9.9	13.0	17.5		24.6	22.4	22.3		15.8	21.7	33.0
South East England	Primary		18.8	34.6	48.3		8.6	10.9	12.8		20.6	17.2	19.0		14.6	21.2	28.7
	Higher		22.5	38.4	62.5		8.9	12.3	17.3		20.2	19.3	19.4		14.7	21.3	32.7
South West England	Primary		14.6	27.1	37.2		11.6	16.7	21.4		15.5	12.8	13.9		15.0	22.8	32.2
	Higher		17.5	29.3	47.2		12.6	17.1	26.3		14.6	13.7	14.8		15.2	22.9	37.5

Baseline 1961 to 1990 **Baseline units mm**

6.3 Snow

Modelling the frequency of future snow robustly is challenging for a variety of reasons. As the UKCP09 model ensembles showed large variations in their outputs and there are significant uncertainties in the data, probabilistic projections were not included in the published suite of data.

For UKCP18, the best information available on snow in the UKCP suite of products is from the 12km and 2.2km projections for the RCP8.5 Scenario. This is summarised in the UKCP18 Factsheet found at https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/research/ukcp/ukcp18-factsheet-snow.pdf

It should be note that the factsheet advises that both datasets should be used in any analysis and that caution should be taken when doing this.

Widespread and substantial snow events have occurred in 2009, 2010, 2013 and 2018, but their number and severity has generally declined since the 1960s. Analysis of UKCP18 local CPM projections for the RCP8.5 high-emissions scenario show consistent decreases in mean daily snowfall and daily lying snow across Great Britain between 1981-2000 and 2061-2080. The results are summarised in the bullets below and *Figure 3*:

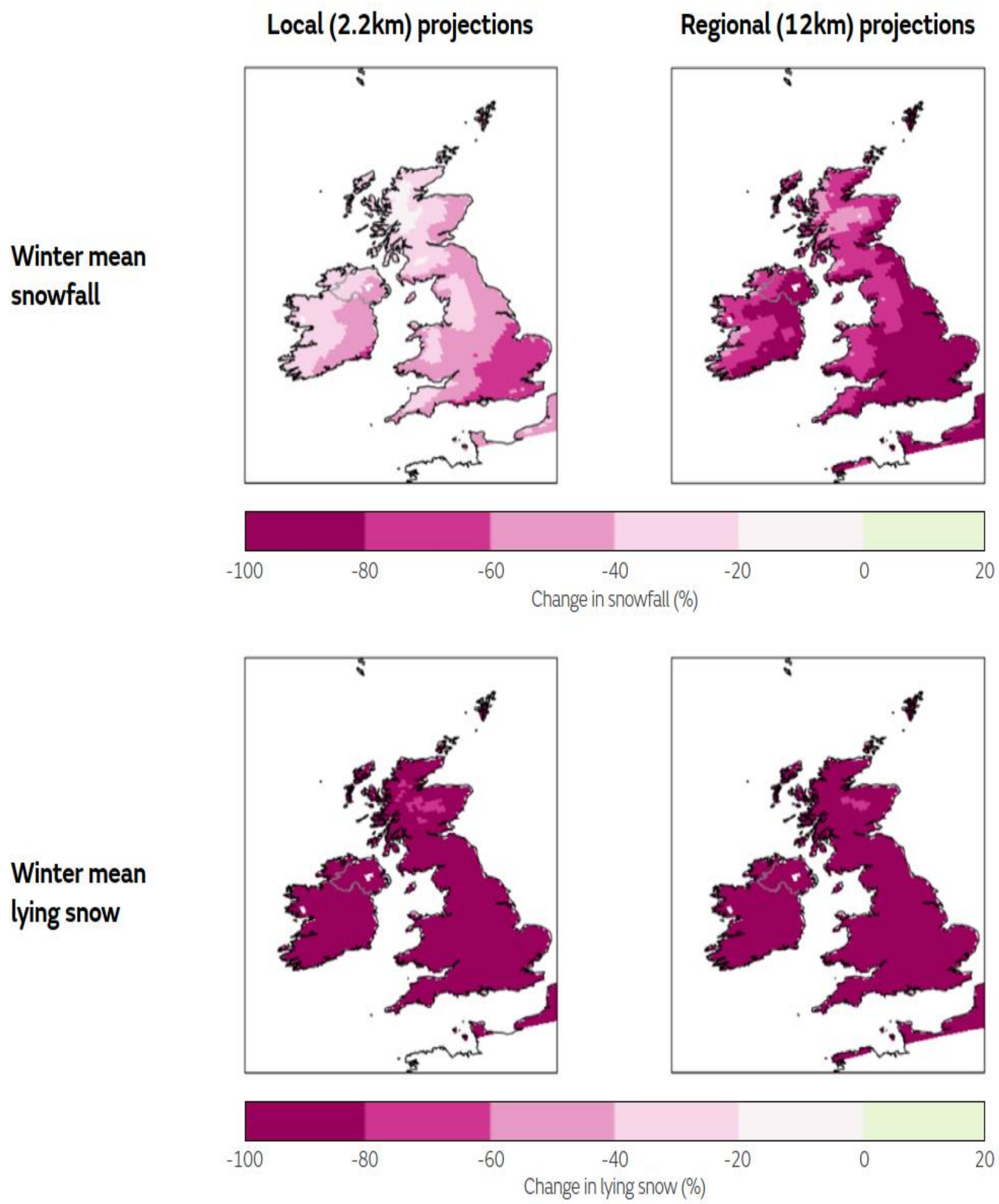
- By the end of the 21st century, lying snow is projected to decrease significantly over the whole of the UK, with smaller decreases are seen over mountainous regions in the north and west. Falling snow follows the same pattern,
- Seasonally, the smallest changes in daily snowfall occur in Winter and the largest in Summer and Autumn. However, this is likely due to much smaller absolute values in the baselines for summer and autumn resulting in a larger relative change,
- For extreme daily snowfall the Scottish mountains and some parts of Northern England show a small increase in winter and spring,
- Mean lying snow in Winter shows a large decrease across Great Britain except for the Scottish Highlands which show a smaller decrease,
- For extremes of daily lying snowfall the South-East of England continues to show large decreases, however, mountainous regions and eastern parts of Great Britain show a smaller decrease, particularly for the 90th percentile of the CPM ensemble, and
- There are differences in estimates of future snow between the 12km and 2.2km projections but both are plausible. Decreases in both falling and lying snow (over Scottish mountains) are larger in the regional projections compared to the local projections.

Additional analysis of UKCP18 Snow Factsheet and the UKCP18 datasets by WSP have provided some quantitative data that can be used to enhance the qualitative narrative as follows:

- Mean winter snowfall will decrease by between -10% for parts of Scotland and -70% for Southern England,
- 90th percentile extreme snowfall shows a decrease of -55% for southern England and an increase of +35% for south west Scotland in winter, and
- Winter lying snowfall ranges from an increase of +20% for parts of Scotland to a decrease of -100% in southern England.

When using any of the information above, it should be noted that, whilst there is a general trend for reductions in the severity and frequency of snowfall under climate change the winter weather extremes that we currently experience will still remain possible.

Figure 3 **Future change (%) in snow variables in winter for 2061-2080 compared to 1981-2000.** Higher scenario (RCP 8.5) averaged across full model results for the UKCP18 2.2km and 12km projections



7 Flooding

When we use the term flooding it is referring to: surface water flooding (also known as pluvial, rainfall or flash flooding), groundwater flooding, river flooding (also known as fluvial flooding), and coastal flooding. Coastal flooding is dealt with in Section *8 Sea Level Rise*. Definitions of the flood types can be found in Section *14 Glossary.*

Extreme and/or prolonged precipitation events or snowmelt can result in surface water, groundwater and river flooding. The degree of flooding, its severity, speed of onset and duration is determined by the intensity and frequency of the events. For example, rapid surface water flooding can be caused by one extreme rainfall or snow melt event whereas groundwater flooding can be caused by days, weeks or months of lower intensity rainfall.

Maps showing current areas of flood risk can be found at:

- England, EA flood maps https://flood-warning-information.service.gov.uk/long-term-flood-risk/map,
- Scotland, SEPA flood maps http://map.sepa.org.uk/floodmap/map.htm, and
- Wales, NRW flood maps https://naturalresources.wales/evidence-and-data/maps/long-term-flood-risk/?lang=en.

Climate change will significantly increase future flood risk and to help understand this the EA, SEPA and NRW have used precipitation projections from UKCP09 to model changes in event intensity and river flows. These should be used when carrying out Flood Risk Assessments (FRAs) and their guidance is provided in the sections below:

7.1 Peak rainfall intensity allowance in small and urban catchments
7.2 Peak river flow allowances by river basin district

7.1 Peak rainfall intensity allowance in small and urban catchments

The tables below are drawn from current EA, SEPA and NRW guidance for peak rainfall intensity allowances in small and urban catchments. These are based on UKCP09 projections and are under review, but should continue to be used as they remain the current regulatory guidance. This section will be updated when the regulators produce new guidance based on UKCP18 projections.

7.1.1 England

The EA have produced national guidance for England on uplifts for peak rainfall intensity in small and urban catchments based on UKCP09 climate projections (allowances are not currently produced for large and/or rural catchments for which the EA advise use of the peak river flow allowances in *Table 12*). These are percentage changes to be added to storm intensities from the baseline period of 1961 – 1990. *Table 9* shows the EA scenarios best aligned with our Higher and Primary climate change planning scenarios. Full EA guidance can be found on the Defra website (https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances#table-2).

Table 9 **Change in peak rainfall intensity allowance in small and urban catchments (%) (UKCP09)**

Applies across all of England	2020s (2015 to 2039)	2050s (2040 to 2069)	2080s (2070 to 2115)
Central	5	10	20
Upper end	10	20	40

Upper end = High emissions scenario 90% - equivalent to our Higher scenario
Central = Medium emissions scenario 70% - use as our Primary scenario
Baseline 1961 to 1990

For FRAs and Strategic FRAs the EA recommends that both the Central and Upper end allowances be used to understand the potential range of the impacts. For all projects or activities, it is recommended that more precise local data be used to carry out a full site-specific FRA in line with the full EA guidance.

When using these allowances, it should be borne in mind that:

- The EA Upper end scenario is equal to our Higher scenario, but the EA Central scenario is lower than our Primary one. This should be accounted for when using it in FRAs and subsequent conclusions and designs, and

- Summer convective storms usually have small, but intense footprints and the UKCP09 25km grid does not model them well. It spreads their intensity and any increases across the 25km giving modelled increases that are known to be lower than expected. The values in *Table 9* are therefore likely to be conservative.

7.1.2 Scotland

SEPA have produced national guidance on uplifts for peak rainfall intensity in smaller catchments based on UKCP09 climate projections (*Table 10*). In their guidance smaller catchments are defined as those smaller than 30km^2 and river catchments between 30km^2 and 50km^2 where peak rainfall intensity uplift is greater than the peak river flow uplift. SEPA peak river flow uplifts can be seen in *Table 13*.

Table 10 **Change in peak rainfall intensity allowance in smaller catchments (%) (UKCP09)**

Region	Total potential change for 2100
East	35%
West	55%

50th percentile for the High scenario - use as our Primary scenario
Baseline = 1961 to 1990

When adjusting the design rainfall for a scheme the relevant allowance should be selected from *Table 10* and applied within a rainfall-runoff method. Further information and guidance from SEPA can be found here:

https://www.sepa.org.uk/media/162602/ss-nfr-p-002-technical-flood-risk-guidance-for-stakeholders.pdf

For all projects or activities, it is recommended that more precise local data be used to carry out a full site-specific FRA in line with the full SEPA guidance here:

https://www.sepa.org.uk/media/162602/ss-nfr-p-002-technical-flood-risk-guidance-for-stakeholders.pdf

7.1.3 Wales

NRW have produced guidance on national peak rainfall uplifts for rainfall intensity in small and urban catchments (allowances are not currently produced for large and/or rural catchments). These are percentage changes to be added to storm intensities from the baseline period of 1961 – 1990. *Table 11* shows the NRW scenarios that best align with our Higher and Primary climate change planning scenarios. The full NRW guidance can be found at: https://gov.wales/sites/default/files/publications/2019-06/adapting-to-climate-change-guidance-for-flood-and-coastal-erosion-risk-management-authorities-in-wales.pdf.

Table 11 **Change in peak rainfall intensity allowance in small and urban catchments (%) (UKCP09)**

Applies across all of Wales	2020s (2015 to 2039)	2050s (2040 to 2069)	2080s (2070 to 2115)
Central	5	10	20
Upper end	10	20	40

Upper end = High emissions scenario 90% - equivalent to our Higher scenario
Central = Medium emissions scenario 70% - use as our Primary scenario
Baseline 1961 to 1990

For FRAs and Strategic FRAs NRW recommends that both the Central and Upper end allowances be used to understand the potential range of the impacts. For all projects or activities, it is recommended that more precise local data be used to carry out a full site-specific FRA in line with the full NRW guidance.

When using these allowances, it should be borne in mind that:

- The NRW Upper end scenario is equal to our Higher scenario, but their Central scenario is lower than our Primary one. This should be accounted for when using it in FRAs and subsequent conclusions and designs, and
- Summer convective storms usually have small, but intense footprints and the UKCP09 25km grid does not model them well. It spreads their intensity and any increases across the 25km giving modelled increases that are known to be lower than expected. The values in *Table 11* are therefore likely to be conservative.

7.2 Peak river flow allowances by river basin district

The EA, SEPA and NRW have used UKCP09 precipitation data to model future peak river flow uplifts for each river basin district in their respective regulatory boundaries. Their guidance is summarised in, *Table 12*, *Table 13* and *Table 14* which contain % uplifts to be added to current river flows. All three regulators are currently using UKCP18 data to review and update their guidance however the data below is still the most current regulatory guidance and should be used. This section will be updated to reflect any new guidance issued by the regulators.

7.2.1 England

Table 12 shows the current EA Higher Central and Upper end guidance on climate change uplifts for use in calculating future peak river flows in FRAs. These are expressed as a % change to be added to the relevant river(s) peak flow(s) from the 1961 - 1990 baseline period. Maps of the English river basins can be found at *https://www.gov.uk/government/publications/river-basin-district-map* and further guidance on the use of the allowances in FRAs is accessed at *https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances*.

When using the allowances in *Table 12* it should be borne in mind that:

- The EA Upper end scenario is equal to our Higher Scenario, but the EA Central scenario is lower than our Primary one. This should be accounted for when using it in FRAs and subsequent conclusions and designs, and
- River flows respond to rainfall, so the fact that Summer convective storms are not modelled well by the UKCP09 25km grid means that the allowances in the table may be conservative.

Four of the river basin districts modelled by the EA are shared with other devolved administrations as follows:

- Solway and Tweed river basin districts also fall within Scotland and peak river flow allowances have also been modelled by SEPA (Section *7.2.2 Scotland*), and
- Severn and Dee river basin districts also fall within Wales and peak river flow allowances have also been modelled by NRW (Section *7.2.3 Wales*).

When undertaking FRAs in these river basin districts use the allowance appropriate to the devolved administration within which the project or activity is occurring. If it falls within more than one devolved administration, then either:

- For schemes obligated to carry out a FRA agree the most appropriate value to use with the regulators, or
- Use the higher of the values where a FRA is not a regulatory requirement.

Table 12 **EA climate change allowances for peak river flow by river basin district (%) (UKCP09)**

River Basin District	Climate Change Estimate	2020s (2015 to 2039)	2050s (2040 to 2069)	2080s (2070 to 2115)
Northumbria	Higher Central	15	20	25
	Upper end	20	30	50
Humber	Higher Central	15	20	30
	Upper end	20	30	50
Anglian	Higher Central	15	20	35
	Upper end	25	35	65
SE England	Higher Central	15	30	45
	Upper end	25	50	105
Thames	Higher Central	15	25	35
	Upper end	25	35	70
SW England	Higher Central	20	30	40
	Upper end	25	40	85
Severn	Higher Central	15	25	35
	Upper end	25	40	70
Dee	Higher Central	15	20	25
	Upper end	20	30	45
NW England	Higher Central	20	30	35
	Upper end	20	35	70
Solway	Higher Central	15	25	30
	Upper end	20	30	60
Tweed	Higher Central	15	20	32
	Upper end	20	25	25

Higher central = Medium emissions scenario 70% - use as our Primary scenario
Upper end = High emissions scenario 90% - equivalent to our Higher scenario
Baseline 1961 to 1990

7.2.2 Scotland

Table 13 shows the current SEPA guidance scenario for calculating future peak river flows that is compatible with our Higher planning scenario These are expressed as a % change to be added to the relevant river(s) peak flow(s) from the baseline period of 1961 - 1990. Maps of the Scottish River Basins and more scenarios are available at *https://www.sepa.org.uk/media/219494/ceh-cc-report-wp1-overview-final.pdf*. Guidance on how to use them is at https://www.sepa.org.uk/media/426913/lups_cc1.pdf.

In contrast to the EA and NRW, SEPA only provide allowances for the 2080s for one High scenario. However, as the Solway and Tweed river basin districts fall within both Scotland and England, future peak river flow allowances for the 2020s, 2050s and 2080s are also available from the EA (*Table 12*). These could be used in addition to the SEPA allowances to further understand the future flood risk between now and 2080. If your project or activity falls within both devolved administrations, then seek agreement with the regulators over which to use.

When using the allowances in *Table 13*, it should be borne in mind that:

- River flows respond to rainfall, so the fact that Summer convective storms are not modelled well by the UKCP09 25km grid means that the allowances in the table may be conservative, and
- EA and SEPA allowances are derived from different climate scenarios and models. If EA allowances are used in the Tweed or Solway river basin districts, you are advised to seek agreement for the approach with SEPA.

Table 13 **SEPA climate change allowances for peak river flow by river basin region (%) (UKCP09)**

River Basin Region	Total change to the year 2100
Argyll	56%
Clyde	44%
Forth	40%
North East	24%
North Highland	37%
Solway	44%
Tay	35%
Tweed	33%
West Highland	56%

67th percentile for the High scenario - use as our High scenario
Baseline = 1961 to 1990

7.2.3 Wales

Table 14 shows the NRW Central and Upper end guidance for climate change allowances to calculate future peak river flows in FRAs. These are expressed as a % change to be added to the relevant river(s) peak flow(s) from the baseline period of 1961 - 1990. Boundary maps of the Welsh River basins can be found at *https://naturalresources.wales/flooding/managing-flood-risk/flood-risk-maps-for-river-basin-districts/?lang=en*. Guidance on their use in FRAs can be found at https://gov.wales/sites/default/files/publications/2019-06/adapting-to-climate-change-guidance-for-flood-and-coastal-erosion-risk-management-authorities-in-wales.pdf.

As the Severn and Dee river basin districts fall within both Wales and England future peak river flow allowances have also been modelled by the EA (Section *7.2.1 England*). When undertaking FRAs in these river basin districts use the allowance appropriate to the devolved administration within which the project or activity is occurring. If it falls within more than one devolved administration, then either:

- Agree with the regulator(s) the appropriate value to use for schemes that are obligated to carry out a FRA, or
- Use the higher of the values where a FRA is not a regulatory requirement.

When using the allowances in *Table 14*, it should be borne in mind that:

- The NRW Upper end scenario is equivalent to our Higher scenario, but the NRW Central scenario is lower than our Primary scenario. This should be accounted for when using these allowances in FRAs and any subsequent conclusions and designs, and
- River flows respond to rainfall, so the fact that Summer convective storms are not modelled well by the UKCP09 25km grid means that the figures in the table may be conservative.

Table 14 **NRW climate change allowances for peak river flow by river basin district (%) (UKCP09)**

River Basin District	Climate Change Estimate	2020s (2015 to 2039)	2050s (2040 to 2069)	2080s (2070 to 2115)
Severn	Central estimate	10	20	25
	Upper end	25	40	70
West Wales	Central estimate	15	25	30
	Upper end	25	40	75
Dee	Central estimate	10	15	20
	Upper end	20	30	45

Central estimate = Medium emissions scenario 50% - use as our Primary scenario
Upper end = High emissions scenario 90% - equivalent to our Higher scenario
Baseline 1961 to 1990

8 Sea Level Rise

Coastal assets are subject to the dual threats of flooding and erosion as a result of high tides and storm surges. Since the start of the 20th century mean sea level has risen around the whole of the UK coast by an average of 16 cm. However, the actual level of increase varies from location to location. The main factors causing these differences are:

- Land level changes since the last ice age; the North of the UK is rising, and the South sinking, and
- Local differences in, and changes to, coastal morphology (natural shoreline features and erosion, manmade defences, seabed deposition and erosion).

Climate change will significantly increase sea levels, and this combined with projected increases in the frequency and severity of winter and summer storms will increase the risk and severity of coastal flooding and erosion events.

This section contains tables showing:

8.1 Regulator guidance for sea level rise allowances
8.2 UKCP18 sea level projections
8.3 Regulator guidance for storm surge allowances

All activities and projects should use the allowances from the appropriate regulator in conjunction with their formal guidance (links are included in Section *8.1 Regulator guidance for sea level rise allowances*).

Section *8.2 UKCP18 sea level projections* provides sea level rise projections for 3 locations within each of the UK administrative regions. This provides more localised data to enhance the use of the regional averages provided by the EA, SEPA and NRW.

NOTE: - UKCP18 has not generated sea level rise projections for the RCP6.0 scenario. This means that neither the Regulator's guidance nor the UKP18 data in *Table 18* provide data that exactly matches our chosen primary scenario of RCP6.0 90%. In all cases the nearest matches from the most current data available have been chosen, and this has been indicated in the text of the relevant section.

8.1 Regulator guidance for sea level rise allowances

8.1.1 England

The EA has generated guidance on sea level rise for English coastal regions using UKCP18 data for the RCP8.5 scenario. *Table 15* provides the guidance on annual height changes for defined time periods most compatible with our Primary and Higher scenarios. These should be added in sequence to the current sea level to give a total height change for the asset or activity lifespan being assessed. For example, a sea defence being built in the East of England (Anglian river basin district) with an end of design life in 2060 will experience sea level rises under the Higher central allowance of; 0.58cm/year between 2020 and 2035 (15 years) and 0.87cm/year between 2036 and 2060 (25 years). This will give a total sea level rise (compared to a 2018 baseline) over the asset life of:

(0.58 x 15) + (0.87 x 25) = 31.45cm for the Higher central allowance

For the Upper end allowance, the total sea level rise over the asset life would be:

(0.7 x 15) + (1.13 x 25) = 38.75cm for the Upper end allowance.

Further guidance on baseline sea level and guidance on the climate change allowance use in FRAs can be found at *https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances*.

As the projections in *Table 15* are averages for their respective geographic regions, local effects may need to be considered depending on the sensitivity of the asset and the accuracy of the assessment that is required. For example, shoreline features, defences, seabed changes, assets characteristics, location within the region etc.

Table 15 **EA guidance on sea level rise allowance (cm/year) by river basin (UKCP18)**

Area of England	Allowance	2000 to 2035 (cm/year)	2036 to 2065 (cm/year)	2066 to 2095 (cm/year)	2096 to 2125 (cm/year)	Cumulative rise 2000 to 2125 (cm)
Anglian	Higher central	0.58	0.87	1.16	1.30	120
	Upper end	0.70	1.13	1.58	1.81	160
South East	Higher central	0.57	0.87	1.16	1.31	120.0
	Upper end	0.69	1.13	1.58	1.82	160.0
South West	Higher central	0.58	0.88	1.17	1.31	121
	Upper end	0.70	1.14	1.60	1.84	162
Northumbria	Higher central	0.46	0.75	1.01	1.12	103.00
	Upper end	0.58	1.00	1.43	1.65	143.00
Humber	Higher central	0.55	0.84	1.11	1.24	115
	Upper end	0.67	1.10	1.53	1.76	155
North west	Higher central	0.45	0.73	1.00	1.12	101.00
	Upper end	0.57	0.99	1.42	1.63	141.00

Baseline = 1981 to 2000
Higher central - 70th percentile of RCP 8.5 - use as our Primary scenario
Upper end - 95th percentile of RCP 8.5 - use as our Higher scenario

In creating this data some river basin districts have been amalgamated and users should apply the following rules if their river basin does not appear in the table above:

- Thames river basin district use South East,
- Severn river basin district use South West,
- Solway Tweed river basin district on the English west coast use North West,
- Solway Tweed river basin district on the English east coast Northumbria, and
- Dee river basin district use North West.

8.1.2 Scotland

SEPA provides sea level rise allowances for river basin regions in Scotland and gives the cumulative sea level rise from 2017 to 2100 based on the outputs from the 95th percentile of the RCP8.5 scenario for UKCP18. *Table 16* provides the guidance on cumulative rises most compatible with our Higher scenario. This should be added to the 2017 sea level to give a total height change for the asset or activity being assessed. For example, a sea defence being built in Stirlingshire (Forth River Basin) with an end of design life in 2100 will experience a total sea level rise of; 86 cm (compared to a 2018 baseline) over the asset life.

Further guidance on baseline sea level and guidance on the climate change allowance use in FRAs can be found at https://www.sepa.org.uk/media/426913/lups_cc1.pdf.

SEPA also recommend that an additional allowance of 0.15m per decade after the year 2100 be applied where the design life of a development is known to extend beyond that date.

As the projections in *Table 16* are averages for their respective geographic regions, local effects may need to be considered depending on the sensitivity of the asset and the accuracy of the assessment that is required. For example, shoreline features, defences, seabed changes, assets characteristics, location within the region etc.

Table 16 **SEPA guidance on sea level rise, cumulative (cm) (UKCP18)**

River Basin Region	Cumulative rise (cm) from 2017 to 2100
Argyll	86
Clyde	85
Forth	86
North East	87
North Highland	89
Solway	88
Tay	85
Tweed	89
West Highland	89

95th percentile of RCP 8.5 - use as our Higher scenario
Baseline = 1981 to 2000

8.1.3 Wales

NRW provides sea level rise guidance for all Welsh coastal regions using UKCP09 data (*Table 17*). This gives annual height changes for defined time periods under two climate scenarios. The annual change allowance is equivalent to our Higher scenario and, in the absence of a Primary scenario equivalent, should be used as the default allowance for all projects or activities. The High++ scenario represents an extreme but possible future and it is recommended that it be used as a sensitivity test where the consequences of asset failure would be catastrophic.

The allowances should be added in sequence to the 1990 sea level to give a total height change over the lifespan of the asset or activity being assessed. For example, a sea defence being built in Wales with an end of design life in 2060 will experience sea level rises of; 0.35mm/year between 1990 and 2025 (35 years), 0.8mm/year between 2025 and 2050 (25 years) and 1.15mm/year between 2055 and 2060 (5 years). This will give a total sea level rise over the asset life of:

(0.35 x 35) + (0.8 x 25) + (1.15 x 5) = 38cm

Further guidance on their use in FRAs can be found at: https://gov.wales/sites/default/files/publications/2019-06/adapting-to-climate-change-guidance-for-flood-and-coastal-erosion-risk-management-authorities-in-wales.pdf.

As the projections in *Table 17* are averages for their respective geographic regions local effects may need to be considered depending on the sensitivity of the asset and the accuracy of the assessment that is required. For example, shoreline features, defences, seabed changes, assets characteristics, location within the region etc.

NOTE: - As *Table 17* uses data that is derived from UKCP09 it does not reflect the significantly greater changes projected by UKCP18. The data should therefore only be used as part of an initial risk assessment and activities and projects should contact NRW to obtain bespoke advice on how to use the UKCP18 data. This section will be updated once NRW releases new guidance.

Table 17 **NRW guidance on sea level rise (cm/year) (UKCP09)**

Scenario	1990-2025	2025-2055	2055-2085	2085-2115
Annual change allowance	0.35	0.8	1.15	1.45
High++	0.6	1.25	2.4	3.3

8.2 UKCP18 sea level projections

This section provides sea level rise figures from the UKCP18 projections to compliment the information available from the regulators. It gives more localised projections for all of the UK regions to enhance the use of the regional averages provided in the sections above as well as providing a source for UKCP18 data for Wales in the absence of NRW UKCP18 allowances. *Table 18* contains cumulative sea level rise projections for our Primary and Higher scenarios at three locations within each of the coastal UK administrative regions. The data is expressed in centimetres and each figure represents the cumulative sea level rise for up to the chosen year (2030, 2050 and 2070), they are not annual increase figures, so they should not be added on an annual basis.

Although the figures in *Table 18* provide more location specific guidance than the averages provided by the regulators, they are only accurate for the locations chosen. They can be used to inform impact assessments for other nearby locations within their region, but other local effects may need to be considered depending on the sensitivity of the asset and the accuracy of the assessment that is required. For example, shoreline features, defences, seabed changes, assets characteristics, location within the region etc.

No baseline data is available for this parameter and this should be accounted for by following the second calculation methodology in *4.2.1 Quantitative data*.

If projects or activities are using this version of the document to update previous assessments or other work, it should be noted that the most distant projections provided are now for the 2070s rather than the 2080s. Users should take this into account when explaining any reductions seen in the most distant sea level rise projections.

Table 18 **UKCP18 sea level rise projections (cm)**

UK Administrative Region	Location	Climate change scenario	Baseline	2030	2050	2070
North Scotland	Inverness	Primary		13.1	25.2	39.9
		Higher		14.1	29.7	51.3
	Ullapool	Primary		14.8	27.7	43.2
		Higher		15.7	32.2	54.5
	Fort William	Primary		12.4	24.1	38.5
		Higher		13.3	28.7	50.1
West Scotland	Oban	Primary		12.4	24.1	38.6
		Higher		13.3	28.7	50.1
	Ayr	Primary		11.9	23.4	37.6
		Higher		12.8	28.0	49.3
	Portpatrick	Primary		12.6	24.6	39.4
		Higher		13.6	29.3	51.1
East Scotland	Fraserburgh	Primary		14.1	26.6	41.8
		Higher		15.0	31.2	53.3
	Aberdeen	Primary		13.2	25.4	40.2
		Higher		14.2	29.9	51.7
	Dundee	Primary		12.3	24.0	38.3
		Higher		13.2	28.6	49.9
North East England	Berwick-upon-Tweed	Primary		13.5	25.9	41.0
		Higher		14.5	30.5	52.7
	Newcastle-upon-Tyne	Primary		15.3	28.7	44.8
		Higher		16.3	33.4	56.6
	Hartlepool	Primary		16.3	30.2	46.9
		Higher		17.3	34.9	58.7
Yorkshire & Humberside	Whitby	Primary		17.4	31.8	49.0
		Higher		18.3	36.5	60.9
	Scarborough	Primary		18.1	32.9	50.5
		Higher		19.1	37.7	62.5
	Hull	Primary		18.9	34.2	52.2
		Higher		19.9	38.9	64.2
East Midlands	Cleethorpes	Primary		18.8	34.0	51.9
		Higher		19.7	38.7	64.0
	Skegness	Primary		19.3	34.9	53.2
		Higher		20.3	39.6	65.2
	Freiston Shore	Primary		19.1	34.5	52.7
		Higher		20.1	39.2	64.7
North West England	Whitehaven	Primary		13.6	26.1	41.3
		Higher		14.5	30.8	53.1
	Blackpool	Primary		15.3	28.8	45.0
		Higher		16.3	33.5	56.9
	Liverpool	Primary		15.9	29.7	46.2
		Higher		16.9	34.4	58.1
Wales	Holyhead	Primary		15.3	28.8	45.1
		Higher		16.3	33.5	57.1
	Aberystwyth	Primary		17.2	31.6	48.9
		Higher		18.1	36.4	60.9
	Swansea	Primary		18.4	33.6	51.6
		Higher		19.4	38.4	63.7
East of England (Anglia)	Kings Lynn	Primary		19.3	34.8	53.1
		Higher		20.3	39.6	65.2
	Great Yarmouth	Primary		19.9	35.7	54.4
		Higher		20.9	40.5	66.6
	Southend-on-Sea	Primary		19.2	34.7	53.1
		Higher		20.2	39.5	65.3
South East England	Margate	Primary		19.2	34.8	53.1
		Higher		20.2	39.6	65.3
	Brighton	Primary		19.1	34.6	52.9
		Higher		20.1	39.4	65.2
	Portsmouth	Primary		19.1	34.7	53.0
		Higher		20.2	39.5	65.3
South West England	Weston-Super-Mare	Primary		18.8	34.1	52.2
		Higher		19.8	38.9	64.5
	Penzance	Primary		20.3	36.5	55.6
		Higher		21.3	41.4	68.0
	Torquay	Primary		19.5	35.3	54.0
		Higher		20.6	40.2	66.3

Baseline = 1981 to 2000

8.3 Regulator guidance for storm surge allowances

Climate change will lead to greater coastal erosion and flooding due to increases in the frequency and intensity of storm events and greater coastal water depths from sea level rise. There is no UKCP09, UKCP18 or regulatory guidance for changes in storm frequency, but there is guidance on offshore wind speeds and extreme wave heights.

8.3.1 England

Table 19 contains the EA guidance on offshore wind speeds and extreme wave height allowances for the English coastal regions. The data is in the form of a percentage change that should be applied to the wind speeds and the wave height relevant to the location of the project or activity. This should be added to the 1961 to 1990 baseline and the EA expect both the Allowance and the Sensitivity tests to be used for all epochs that apply so that the full range of impact and be understood. Further guidance on their use in FRAs can be found at *https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances*.

Table 19 **EA Offshore windspeed and extreme wave height (%) (UKCP09)**

Applies around all the English coast	Scenario	1990 to 2055	2056 to 2115
Offshore wind speed	Allowance	5	10
	Sensitivity test	10	20
Extreme wave height	Allowance	5	10
	Sensitivity test	10	20

Baseline 1961 to 1990

As the allowances in *Table 19* are averages for the whole of the English coast the project or activity should use baseline wind speeds and wave heights specific to its location. Depending on the sensitivity of the asset, and the accuracy of the assessment that is required, it should also consider taking into account local effects that may influence these parameters, for example, shoreline features, exposure buildings or defences etc.

8.3.2 Scotland

The SEPA guidance on climate change allowances for flood risk assessment in land use planning does not currently produce specific offshore wind speed or extreme wave height projections for future timescales. Based on the range of changes in offshore wave climate reported in the UKCP18 Marine Report it recommends that; sites where wave overtopping is expected to be sensitive to changes in the offshore wave climate should be subject to a 10 – 20% increase in extreme offshore wave heights.

Further detail can be found at *https://www.sepa.org.uk/media/426913/lups_cc1.pdf*) and it is recommended that projects and activities contact SEPA to discuss site specific guidance.

8.3.3 Wales

Table 20 contains the NRW guidance on offshore wind speeds and wave height allowances for the Welsh coast. The data is in the form of a percentage change that should be applied to the wind speeds and the wave height relevant to the location of the project or activity. This should be added to the 1961 to 1990 baseline. Further guidance on their use in FRAs can be found at:

https://gov.wales/sites/default/files/publications/2019-06/adapting-to-climate-change-guidance-for-flood-and-coastal-erosion-risk-management-authorities-in-wales.pdf.

Table 20 **NRW Offshore wind speed and extreme wave height (%) (UKCP09)**

Applies around all the Welsh coast	1990 to 2025	2025 to 2055	2055 to 2085	2085 to 2115
Offshore wind speed	5		10	
Extreme wave height	5		10	

Baseline 1961 to 1990

As the allowances in *Table 20* are averages for the whole of the Welsh coast the project or activity should use baseline wind speeds and wave heights specific to its location. Depending on the sensitivity of the asset and the accuracy of the assessment that is required It should also consider taking into account local effects that may influence these parameters, for example, shoreline features, exposure buildings or defences etc.

9 Humidity

Humidity can affect some assets directly and others through its influence on a number of weather parameters. For example: humidity in location cabinets, the likelihood of fog and evapotranspiration rates. In combination with high temperatures, it can also affect workforce welfare.

Climate change will lead to increases in humidity for all regions of the UK across all three epochs covered by the guidance. Increase will be higher in the north and west of the UK and lower in the south and east.

UKCP18 has produced data on specific humidity (the weight of water vapour in a given volume of air expressed as per unit weight of dry air) at 1.5m above ground level in the summer months (*Table 21*).

No baseline data is available for this parameter and this should be accounted for by following the second calculation methodology in *4.2.1 Quantitative data*.

Table 21 **Change in specific humidity in summer (%) (UKCP18)**

UK Administrative Region	Climate change scenario	June				July				August			
		Baseline	2030s	2050s	2070s	Baseline	2030s	2050s	2070s	Baseline	2030s	2050s	2070s
North Scotland	Primary		12.0	15.5	20.8		11.9	15.2	20.1		12.0	16.0	22.5
	Higher		13.4	20.3	29.2		13.5	20.6	29.6		14.1	22.0	32.5
West Scotland	Primary		12.5	15.2	21.0		12.5	16.1	20.5		12.6	16.7	23.6
	Higher		13.9	20.0	29.3		14.3	21.9	30.1		14.9	22.8	33.6
East Scotland	Primary		12.0	15.2	21.1		11.6	14.3	20.4		12.1	16.2	23.2
	Higher		13.4	20.1	29.5		13.2	19.9	30.0		14.2	22.4	33.4
North East England	Primary		11.8	14.6	20.7		12.6	15.9	20.5		12.7	17.1	23.6
	Higher		13.2	19.3	28.7		14.3	21.6	30.1		14.9	23.3	33.5
Yorkshire and Humberside	Primary		11.0	14.8	20.3		15.2	21.1	27.5		12.4	16.2	22.2
	Higher		12.2	19.3	27.9		17.4	27.9	39.0		14.5	22.0	31.6
North West England	Primary		12.2	14.9	20.9		11.8	15.2	19.7		12.4	15.9	22.3
	Higher		13.5	19.6	29.0		13.5	20.7	28.8		14.5	21.9	31.9
Wales	Primary		10.8	15.5	19.9		11.3	14.9	19.5		11.7	14.9	20.9
	Higher		11.9	19.1	26.2		12.9	20.4	28.4		13.8	20.5	29.9
West Midlands	Primary		10.0	13.9	18.7		10.5	13.8	17.9		11.6	14.7	20.1
	Higher		11.0	17.2	24.5		12.0	18.9	26.3		13.5	20.1	28.8
East Midlands	Primary		10.4	14.1	19.5		14.0	19.3	25.2		15.8	19.4	28.8
	Higher		11.7	18.4	26.7		15.9	25.7	35.8		18.4	27.3	41.1
East of England	Primary		10.1	14.1	18.9		13.7	18.7	24.2		14.9	18.2	27.4
	Higher		11.3	18.2	25.9		15.6	24.9	34.3		17.5	25.8	39.1
London	Primary		10.0	13.5	18.3		13.0	17.5	22.6		14.1	17.1	25.4
	Higher		11.1	17.5	25.0		14.8	23.3	32.1		16.6	24.1	36.5
South East England	Primary		10.1	13.6	18.7		12.8	17.5	22.8		13.8	16.8	24.9
	Higher		11.2	17.7	25.6		14.6	23.3	32.3		16.2	23.8	36.0
South West England	Primary		11.1	15.0	20.7		10.5	13.8	18.0		10.7	13.8	18.8
	Higher		12.5	19.5	28.3		12.0	18.9	26.4		12.5	18.9	27.0

Baseline = 1981 to 2000

10 Fog

Modelling the frequency of future fog days to achieve robust outputs is challenging for a variety of reasons. As the UKCP09 and UKCP18 model ensembles showed large variations in their outputs with significant uncertainties in the data, probabilistic projections were not included in the published suite of data.

In 2010, the UK Climate Impacts Programme produced a supplementary technical note on changes in the frequency of fog days – *Future changes in fog frequency from the UKCP09 ensemble of regional climate model projections:* https://webarchive.nationalarchives.gov.uk/20181204111026/http:/ukclimateprojections-ukcp09.metoffice.gov.uk/22530.

Eleven climate models were run from 1950 to 2099 using the UKCP09 medium emissions scenario and a 1961 to 1990 baseline to generate projections for percentage changes in the number of fog days by 2080s (*Table 22)*.

As this study used one emissions scenario, it has produced just one set of projections and these should be used as our Primary scenario. Data for the 1961 to 1990 baseline is not currently available so risk assessments using these projections should apply them to existing fog day frequency data, for example from the Network Rail Weather (www.nrws.co.uk) Service or the Met Office (https://www.metoffice.gov.uk/services/data).

Table 22 **Changes in fog day numbers for the UK (%) (UKCP09)**

UK administrative region	Winter		Spring		Summer		Autumn	
	Baseline	2080s	Baseline	2080s	Baseline	2080s	Baseline	2080s
North Scotland		-31		-45		-35		-29
East Scotland		-55		-56		-42		-41
West Scotland		-45		-57		-43		-28
North East England		-34		-47		-56		-27
North West England		-25		-47		-56		-25
Yorkshire & Humberside		-24		-40		-61		-22
East Midlands		2		-34		-66		-20
West Midlands		2		-37		-69		-19
Wales		-27		-52		-57		-27
East of England		7		-33		-61		-27
London		20		-38		-67		-28
South East England		7		-42		-70		-31
South West England		4		-40		-69		-28

Baseline 1961 to 1990

11 Wind

Modelling future wind speed and storminess to achieve robust outputs is challenging for a variety of reasons. In November 2010, to address the absence of quantitative data, the Met Office produced a fact sheet on wind speed that has been updated for UKCP18
https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/research/ukcp/ukcp18-fact-sheet-wind.pdf
This concludes that:

- There are no compelling trends in maximum gust speeds from the UK wind network over the last four decades,
- Global projections over the UK show increases in near surface wind speeds in the 2nd half of the 21st century,
- For the winter season, when more significant impacts of wind are experienced this is accompanied by an increase in frequency of winter storms over the UK, but;
- That the increase in wind speeds is modest compared to interannual variability.

Wind speed projections are not available for the probabilistic projections due to low levels of confidence. Although some derived data sets were produced for the 2.2km projections they are not provided here due to their low levels of confidence and the caution urged in using them. If wind impacts may be an issue for your asset or project, please refer to the factsheet link above for more detail on the data's caveats and limitations.

12 Lightning

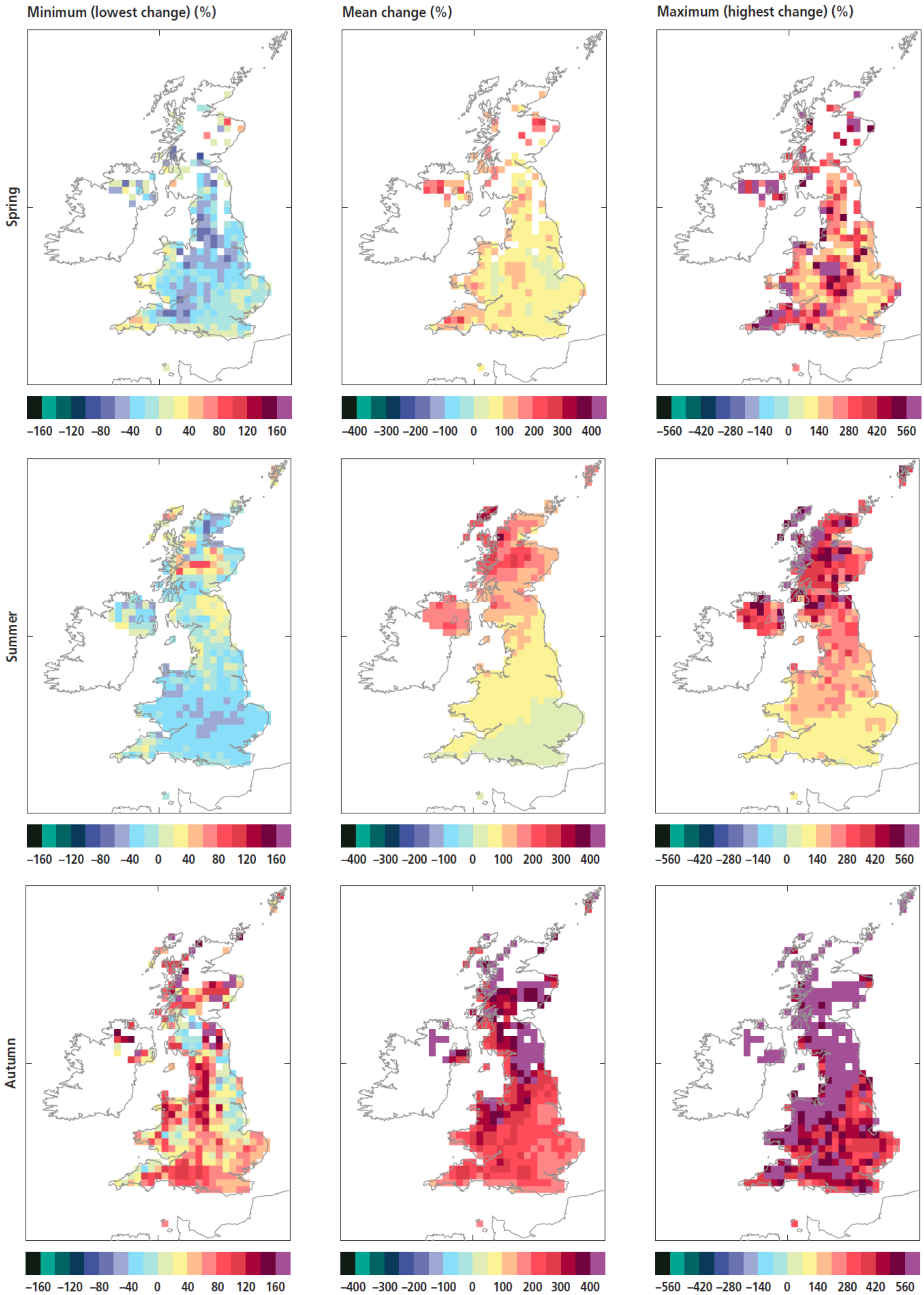
Modelling the frequency of future lightning strikes to achieve robust outputs is challenging for a variety of reasons. In November 2010, the Met Office produced a supplementary technical note on lightning - *Future changes in lightning from the UKCP09 ensemble of regional climate model projections:* https://webarchive.nationalarchives.gov.uk/20181204111026/http:/ukclimateprojections-ukcp09.metoffice.gov.uk/22530

Eleven climate models were run from 1950 to 2099 using the UKCP09 medium emissions scenario and a 1961 to 1990 baseline to generate projections for percentage changes in the number of lightning days the 2080s.

The outputs are a series of maps showing the possible range of changes in lightning days from across the models. These are shown in *Figure 4* and depict the lowest, mean and maximum changes for the Spring, Summer and Autumn seasons (as defined in Section *4.2.1 Quantitative data*). Outputs for Winter are not included in the maps as the small number of baseline lightning days, mean that the small projected increases are not statistically robust.

When using these projections, it should be noted that the technical note states that the uncertainty in the estimated changes given above is substantial.

Figure 4 **Seasonal changes in lightning projections (UKCP09 medium emissions)**



13 Event frequencies

13.1 Weather threshold frequencies

For CP5 the RSSB analysed our asset failure data and weather records and identified national thresholds at which asset groups showed a doubling or trebling of failure rates for daily maximum and minimum temperatures and Summer and Winter daily rainfall. This was published in the RSSB report 'WP1B: Operational weather thresholds analysis' as a table showing the thresholds using the terms 'Significant' (doubling) and 'Very significant' (trebling).

In 2019 this analysis was updated with a further 5 years of data to review the national data and produce new Route level data sets. These were analysed using real world weather data from 1981 to 2000 to calculate the frequency with which the thresholds were exceeded in that time period. This has produced a baseline frequency of occurrence which has then enabled us to use the UKCP18 data for our Primary and Higher projections to calculate future exceedance levels. These have then been converted to multipliers that can be applied to the baseline frequency value to project future frequencies of threshold exceedances or to current failure rates to project future rates.

As the UKCP18 data sets used to calculate the future threshold frequencies are based on the UK Administrative regions the data in the following threshold frequency tables covers different geographical areas to those represented by our Routes. To allow users to identify the appropriate frequency multiplier to use the UK Administrative regions have been mapped to our routes in *Table 23*. For example, the South West England region is mapped to two routes, Western Thames and Western West. The asset thresholds for these two routes were combined, and the exceedances of the combined thresholds calculated. The baseline and future exceedance data calculated can be found in tables 25 to 38 in this section with the future exceedances of the thresholds expressed as multipliers of the baseline.

Table 23 **Network Rail Routes and mapping to UKCP18 administrative regions**

Network Rail Route	Matching UK Administration region(s)
Anglia	East of England and London
East Midlands	East Midlands and London
Kent	South East England and London
London North East	Yorkshire & Humberside, North East England and London
North West and Central North	North West England
North West and Central South	West Midlands, South East England and London
Scotland	North Scotland, East Scotland and West Scotland
Sussex	South East England and London
Wales	Wales
Western Thames	South West England and London
Western West	South West England

While the baseline frequencies are based on actual weather data, this type of modelling can contain uncertainties due to the rarity of extreme weather events and the modelling of future weather event probabilities. The threshold exceedance frequency multipliers displayed in this section therefore have confidence ratings that should be taken into account when using them. These are summarised in *Table 24* below and the asset frequency multipliers are coloured accordingly in the tables for each region.

Table 24 **Threshold multiplier confidence ratings**

High	Baseline frequency is ≥ 1 day/year	Data are robust
Medium	Baseline frequency is between 0.2 and 1 days/year	Use to understand the projected scale of changes only
Low	Baseline frequency is < 0.2 days/year	Only use to understand the direction of projected changes

To avoid the introduction of errors into the data the user:

Should, if rounding the data, do so as follows; projected frequencies greater than 1 be rounded to one decimal place and those smaller than 1 should be rounded to one significant figure.

Should not use current weather event frequencies or observations as the baseline. Doing so will lead to double counting of the climate change effects as they already include much of the projected change up to 2020.

The text boxes below provide worked examples of how to use the data.

Worked example 4: Calculating the projected frequency of a threshold occurrence

How often will winter rainfall of 24 mm/day occur in North Scotland in the 2050s under our Primary scenario?

Weather Parameter	Weather Sub Parameter	Threshold	Baseline Frequency/days	Climate Change Scenario	Frequency multiplier		
					2030s	2050s	2070s
Rainfall	Daily rainfall winter/mm	5	33.92	Primary	1.02	0.99	0.99
				Higher	1.00	0.99	1.03
		11	17.43	Primary	1.05	1.02	1.03
				Higher	1.02	1.04	1.12
		14	12.70	Primary	1.07	1.03	1.05
				Higher	1.04	1.06	1.16
		18	8.47	Primary	1.09	1.05	1.08
				Higher	1.06	1.10	1.21
		21	6.33	Primary	1.10	1.06	1.10
				Higher	1.07	1.12	1.26
		24	4.78	Primary	1.12	1.07	1.11
				Higher	1.08	1.14	1.29
		33	2.11	Primary	1.16	1.11	1.18
				Higher	1.12	1.19	1.41
		34	1.94	Primary	1.16	1.10	1.18
				Higher	1.12	1.19	1.42

1) Obtain the baseline number of days per year for the threshold of interest – 4.78,
2) Obtain the frequency multiplier for the threshold and time period of interest – 1.07, and
3) Multiply the two numbers to obtain the threshold occurrence frequency in the desired time period $4.78 \times 1.07 = 5.1$ (rounded to one decimal place)

As the confidence rating is green, this result can be used in any project calculations.

Worked example 5: Extrapolating the failure rate of an existing asset type

An asset in the South East England fails 9 times/year on average at 31°C. How many failures could it see in the 2070s under our Higher scenario?

Weather Parameter	Weather Sub Parameter	Threshold	Baseline Frequency/days	Climate Change Scenario	Frequency multiplier		
					2030s	2050s	2070s
Temperature	Daily Max Temperature/°C	23	29.65	Primary	1.78	2.27	2.88
				Higher	2.18	2.96	3.82
		24	21.36	Primary	1.94	2.56	3.39
				Higher	2.45	3.52	4.78
		25	14.55	Primary	2.27	3.03	4.19
				Higher	2.90	4.34	6.37
		26	9.39	Primary	2.74	3.86	5.42
				Higher	3.70	5.68	9.01
		27	5.81	Primary	3.15	4.81	7.11
				Higher	4.49	7.39	12.66
		28	3.48	Primary	3.39	5.55	9.01
				Higher	5.13	9.50	17.40
		29	2.00	Primary	3.39	5.96	10.60
				Higher	5.46	11.25	22.59
		30	1.03	Primary	4.14	7.03	13.50
				Higher	6.52	14.26	32.94
		31	0.46	Primary	4.92	7.79	15.74
				Higher	7.58	16.88	43.68
		33	0.09	Primary	6.25	8.52	20.47
				Higher	8.61	20.78	65.11
		35	0.02	Primary	7.22	9.01	14.40
				Higher	9.55	15.01	41.29

1) Frequency multiplier for the 31°C, 2070s Higher scenario = 43.68
2) Multiply by the current failure rate to obtain a future failure rate 9 × 43.68 = 393.12

As the current failure rate is responding to current weather it already accounts for climate change up to this point, so steps 3 and 4 need to be undertaken to avoid double counting of this:

3) Calculate the projected frequency of failures for the 2030s (see steps 1 and 2) 9 × 7.58 = 68.22
4) Subtract the result from the first calculation 393.12 – 68.22 = 324.9

As the threshold multipliers have a yellow rating the number derived should not be used in calculations. The direction and scale of the change can however be used to guide design and strategy decisions.

NOTE – As many of the thresholds represent extreme events not all of the thresholds are seen in all of the regions in either the current or future weather data, and/or there are not enough instances of asset failure to allow modelling. In these cases, the region threshold exceedance tables will not show data for those parameters and where necessary data from the UK table should be used as a surrogate.

The regional and national data tables can be accessed through the following links:

Table 25 **North Scotland (UKCP18)**

Weather Parameter	Weather Sub Parameter	Threshold	Baseline Frequency/days	Climate Change Scenario	Frequency multiplier		
					2030s	2050s	2070s
Rainfall	Daily rainfall winter/mm	5	33.92	Primary	1.02	0.99	0.99
				Higher	1.00	0.99	1.03
		11	17.43	Primary	1.05	1.02	1.03
				Higher	1.02	1.04	1.12
		14	12.70	Primary	1.07	1.03	1.05
				Higher	1.04	1.06	1.16
		18	8.47	Primary	1.09	1.05	1.08
				Higher	1.06	1.10	1.21
		21	6.33	Primary	1.10	1.06	1.10
				Higher	1.07	1.12	1.26
		24	4.78	Primary	1.12	1.07	1.11
				Higher	1.08	1.14	1.29
		33	2.11	Primary	1.16	1.11	1.18
				Higher	1.12	1.19	1.41
		34	1.94	Primary	1.16	1.10	1.18
				Higher	1.12	1.19	1.42
Rainfall	Daily rainfall summer/mm	5	19.22	Primary	0.99	0.97	0.93
				Higher	0.97	0.93	0.86
		11	7.40	Primary	1.01	0.99	0.94
				Higher	0.99	0.94	0.87
		14	4.83	Primary	1.01	0.98	0.94
				Higher	0.99	0.95	0.88
		18	2.76	Primary	1.03	1.00	0.97
				Higher	1.00	0.98	0.90
		21	1.84	Primary	1.06	1.02	1.00
				Higher	1.02	1.01	0.94
		24	1.26	Primary	1.09	1.05	1.04
				Higher	1.05	1.05	1.00
		33	0.43	Primary	1.27	1.17	1.22
				Higher	1.17	1.25	1.25
		34	0.38	Primary	1.30	1.20	1.25
				Higher	1.20	1.28	1.28
Temperature	Daily Max Temperature/°C	18	24.31	Primary	1.54	1.89	2.37
				Higher	1.81	2.42	3.38
		20	12.48	Primary	1.64	2.06	2.65
				Higher	1.94	2.73	4.06
		21	8.74	Primary	1.70	2.20	2.83
				Higher	2.08	2.93	4.47
		22	5.89	Primary	1.88	2.46	3.18
				Higher	2.31	3.31	5.24
		23	3.68	Primary	2.11	2.89	3.86
				Higher	2.70	3.98	6.60
		24	2.05	Primary	2.51	3.70	5.19
				Higher	3.48	5.38	9.53
		25	0.97	Primary	3.40	5.25	7.90
				Higher	4.90	8.19	16.24
		26	0.36	Primary	4.62	8.23	13.27
				Higher	7.71	13.91	32.75
		27	0.09	Primary	5.69	12.25	23.19
				Higher	11.08	25.57	75.66
		28	0.01	Primary	7.26	16.50	39.64
				Higher	15.84	43.16	176.25
Temperature	Daily Min Temperature/°C	0	79.43	Primary	0.68	0.52	0.32
				Higher	0.54	0.30	0.12
		-1	56.27	Primary	0.59	0.41	0.21
				Higher	0.43	0.19	0.07
		-2	38.12	Primary	0.51	0.33	0.15
				Higher	0.35	0.14	0.05
		-4	16.83	Primary	0.42	0.26	0.12
				Higher	0.28	0.11	0.04
		-7	4.96	Primary	0.41	0.23	0.10
				Higher	0.26	0.09	0.03
		-8	3.29	Primary	0.40	0.22	0.09
				Higher	0.24	0.08	0.02
		-12	0.61	Primary	0.34	0.21	0.10
				Higher	0.23	0.09	0.04
		-15	0.15	Primary	0.38	0.29	0.19
				Higher	0.27	0.14	0.08

Baseline = 1981 to 2000

Table 26 **West Scotland (UKCP18)**

Weather Parameter	Weather Sub Parameter	Threshold	Baseline Frequency/days	Climate Change Scenario	Frequency multiplier 2030s	2050s	2070s
Rainfall	Daily rainfall winter/mm	5	33.55	Primary	1.04	1.01	1.02
				Higher	1.02	1.03	1.08
		11	17.89	Primary	1.07	1.05	1.09
				Higher	1.06	1.10	1.18
		14	13.00	Primary	1.09	1.08	1.12
				Higher	1.08	1.14	1.24
		18	8.47	Primary	1.10	1.10	1.17
				Higher	1.11	1.18	1.32
		21	6.09	Primary	1.12	1.12	1.20
				Higher	1.13	1.22	1.39
		24	4.42	Primary	1.14	1.14	1.24
				Higher	1.16	1.26	1.45
		33	1.78	Primary	1.20	1.23	1.34
				Higher	1.24	1.36	1.64
		34	1.60	Primary	1.21	1.24	1.36
				Higher	1.25	1.38	1.67
Rainfall	Daily rainfall summer/mm	5	20.52	Primary	0.93	0.89	0.82
				Higher	0.90	0.82	0.71
		11	8.95	Primary	0.95	0.90	0.82
				Higher	0.91	0.81	0.69
		14	6.07	Primary	0.94	0.90	0.82
				Higher	0.91	0.81	0.69
		18	3.56	Primary	0.95	0.91	0.84
				Higher	0.93	0.83	0.72
		21	2.48	Primary	0.95	0.91	0.85
				Higher	0.93	0.83	0.73
		24	1.69	Primary	0.97	0.94	0.88
				Higher	0.96	0.86	0.77
		33	0.54	Primary	1.13	1.11	1.06
				Higher	1.11	1.05	1.00
		34	0.47	Primary	1.17	1.12	1.11
				Higher	1.12	1.09	1.05
Temperature	Daily Max Temperature/°C	18	34.66	Primary	1.60	1.97	2.39
				Higher	1.88	2.45	3.23
		20	17.68	Primary	1.70	2.21	2.83
				Higher	2.10	2.93	4.35
		21	12.51	Primary	1.78	2.31	3.05
				Higher	2.21	3.15	4.85
		22	8.60	Primary	1.92	2.52	3.41
				Higher	2.39	3.49	5.62
		23	5.61	Primary	2.18	2.90	4.02
				Higher	2.70	4.13	6.74
		24	3.41	Primary	2.57	3.50	5.07
				Higher	3.26	5.21	8.97
		25	1.88	Primary	2.98	4.20	6.64
				Higher	4.03	6.87	12.67
		26	0.89	Primary	3.36	5.06	8.93
				Higher	4.85	9.40	18.82
		27	0.36	Primary	4.11	7.34	14.28
				Higher	6.80	15.45	38.42
		28	0.10	Primary	5.43	12.14	24.14
				Higher	11.56	27.05	90.53
Temperature	Daily Min Temperature/°C	0	63.22	Primary	0.69	0.56	0.38
				Higher	0.58	0.36	0.18
		-1	43.66	Primary	0.61	0.47	0.28
				Higher	0.49	0.26	0.11
		-2	28.96	Primary	0.51	0.37	0.20
				Higher	0.39	0.18	0.07
		-4	11.57	Primary	0.33	0.21	0.10
				Higher	0.22	0.09	0.03
		-7	2.80	Primary	0.34	0.15	0.07
				Higher	0.17	0.07	0.03
		-8	1.79	Primary	0.37	0.18	0.09
				Higher	0.18	0.08	0.04
		-12	0.35	Primary	0.50	0.27	0.16
				Higher	0.27	0.17	0.16
		-15	0.06	Primary	0.82	0.50	0.34
				Higher	0.50	0.39	0.17

Baseline = 1981 to 2000

Table 27 **East Scotland (UKCP18)**

Weather Parameter	Weather Sub Parameter	Threshold	Baseline Frequency/days	Climate Change Scenario	Frequency multiplier 2030s	2050s	2070s
Rainfall	Daily rainfall winter/mm	5	21.58	Primary	1.03	1.02	1.03
				Higher	1.02	1.03	1.07
		11	10.22	Primary	1.06	1.06	1.10
				Higher	1.06	1.11	1.18
		14	7.33	Primary	1.07	1.08	1.13
				Higher	1.08	1.15	1.22
		18	4.78	Primary	1.08	1.10	1.17
				Higher	1.10	1.19	1.30
		21	3.46	Primary	1.09	1.12	1.20
				Higher	1.12	1.22	1.34
		24	2.49	Primary	1.11	1.13	1.24
				Higher	1.13	1.26	1.42
		33	0.97	Primary	1.20	1.22	1.34
				Higher	1.24	1.37	1.57
		34	0.87	Primary	1.20	1.24	1.36
				Higher	1.25	1.38	1.58
Rainfall	Daily rainfall summer/mm	5	15.01	Primary	0.96	0.91	0.85
				Higher	0.92	0.84	0.72
		11	5.42	Primary	0.99	0.92	0.87
				Higher	0.94	0.85	0.73
		14	3.47	Primary	0.99	0.93	0.87
				Higher	0.95	0.85	0.74
		18	1.95	Primary	0.99	0.95	0.91
				Higher	0.96	0.89	0.79
		21	1.31	Primary	1.01	0.96	0.93
				Higher	0.97	0.92	0.83
		24	0.89	Primary	1.05	0.98	0.96
				Higher	1.00	0.95	0.90
		33	0.26	Primary	1.33	1.23	1.27
				Higher	1.24	1.28	1.33
		34	0.23	Primary	1.36	1.24	1.3
				Higher	1.24	1.32	1.34
Temperature	Daily Max Temperature/°C	18	37.02	Primary	1.56	1.89	2.29
				Higher	1.83	2.34	2.96
		20	18.54	Primary	1.73	2.24	2.95
				Higher	2.14	3.03	4.32
		21	12.56	Primary	1.86	2.47	3.35
				Higher	2.35	3.46	5.29
		22	8.11	Primary	2.04	2.84	3.99
				Higher	2.66	4.14	6.74
		23	4.90	Primary	2.36	3.42	4.99
				Higher	3.19	5.16	9.02
		24	2.70	Primary	2.86	4.36	6.67
				Higher	4.09	6.88	13.18
		25	1.32	Primary	3.56	5.77	9.96
				Higher	5.40	10.44	20.93
		26	0.56	Primary	4.64	7.43	14.66
				Higher	6.71	15.61	36.68
		27	0.20	Primary	6.13	10.49	24.75
				Higher	9.84	27.39	79.20
		28	0.07	Primary	6.96	14.17	33.98
				Higher	12.59	37.46	141.54
Temperature	Daily Min Temperature/°C	0	85.86	Primary	0.71	0.57	0.37
				Higher	0.59	0.35	0.17
		-1	61.53	Primary	0.62	0.45	0.26
				Higher	0.48	0.23	0.10
		-2	42.04	Primary	0.52	0.35	0.18
				Higher	0.38	0.16	0.07
		-4	18.24	Primary	0.40	0.27	0.12
				Higher	0.28	0.11	0.05
		-7	5.41	Primary	0.39	0.23	0.11
				Higher	0.26	0.10	0.03
		-8	3.61	Primary	0.38	0.22	0.10
				Higher	0.24	0.09	0.03
		-12	0.79	Primary	0.30	0.20	0.09
				Higher	0.21	0.08	0.03
		-15	0.21	Primary	0.33	0.20	0.11
				Higher	0.20	0.10	0.08

Baseline = 1981 to 2000

Table 28 **North East England (UKCP18)**

Weather Parameter	Weather Sub Parameter	Threshold	Baseline Frequency/days	Climate Change Scenario	Frequency multiplier 2030s	2050s	2070s
Rainfall	Daily rainfall winter/mm	16	2.72	Primary	1.05	1.03	1.18
				Higher	1.05	1.20	1.32
		19	1.80	Primary	1.03	1.05	1.21
				Higher	1.06	1.24	1.41
		22	1.16	Primary	1.06	1.09	1.25
				Higher	1.10	1.29	1.52
		29	0.42	Primary	1.11	1.15	1.34
				Higher	1.16	1.37	1.80
		30	0.37	Primary	1.10	1.13	1.34
				Higher	1.15	1.37	1.80
		31	0.33	Primary	1.08	1.11	1.31
				Higher	1.14	1.36	1.78
Rainfall	Daily rainfall summer/mm	16	1.98	Primary	1.05	0.95	0.96
				Higher	0.96	0.93	0.81
		19	1.33	Primary	1.06	0.97	1.00
				Higher	0.98	0.96	0.82
		22	0.91	Primary	1.12	1.00	1.05
				Higher	1.02	1.02	0.88
		29	0.39	Primary	1.30	1.19	1.26
				Higher	1.20	1.25	1.00
		30	0.34	Primary	1.37	1.22	1.34
				Higher	1.25	1.34	1.08
		31	0.30	Primary	1.43	1.24	1.40
				Higher	1.28	1.40	1.15
Temperature	Daily Max Temperature/°C	20	24.87	Primary	1.70	2.15	2.76
				Higher	2.07	2.81	3.82
		21	17.00	Primary	1.84	2.41	3.20
				Higher	2.31	3.31	4.78
		22	11.18	Primary	2.01	2.73	3.77
				Higher	2.62	3.92	6.09
		24	4.07	Primary	2.73	3.99	6.22
				Higher	3.79	6.43	11.56
		25	2.22	Primary	3.02	4.76	8.04
				Higher	4.48	8.46	16.6
		27	0.48	Primary	3.97	5.88	12.06
				Higher	5.64	13.31	32.14
		28	0.20	Primary	3.76	6.14	13.00
				Higher	6.02	14.27	43.78
		29	0.09	Primary	3.48	5.49	10.36
				Higher	5.46	11.02	40.78
		30	0.04	Primary	3.08	3.97	7.01
				Higher	4.01	8.02	28.87
		31	0.03	Primary	2.94	2.79	4.96
				Higher	2.98	5.40	17.99
		33	< 0.01	Primary	N/A	N/A	N/A
				Higher	N/A	N/A	N/A
		34	< 0.01	Primary	N/A	N/A	N/A
				Higher	N/A	N/A	N/A
Temperature	Daily Min Temperature/°C	0	67.81	Primary	0.68	0.54	0.34
				Higher	0.56	0.31	0.14
		-2	30.66	Primary	0.48	0.32	0.14
				Higher	0.35	0.13	0.04
		-4	12.11	Primary	0.33	0.20	0.07
				Higher	0.22	0.07	0.03
		-5	7.52	Primary	0.33	0.17	0.06
				Higher	0.20	0.06	0.02
		-7	3.03	Primary	0.33	0.18	0.09
				Higher	0.20	0.08	0.04
		-8	1.96	Primary	0.33	0.20	0.12
				Higher	0.21	0.11	0.04
		-11	0.53	Primary	0.38	0.22	0.16
				Higher	0.24	0.16	0.11
		-12	0.32	Primary	0.46	0.32	0.14
				Higher	0.33	0.14	0.24
		-13	0.18	Primary	0.60	0.43	0.24
				Higher	0.48	0.24	0.14
		-15	0.04	Primary	0.67	0.36	0.00
				Higher	0.42	0.00	0.00

Baseline = 1981 to 2000

Table 29 **Yorkshire and Humberside (UKCP18)**

Weather Parameter	Weather Sub Parameter	Threshold	Baseline Frequency/days	Climate Change Scenario	Frequency multiplier		
					2030s	2050s	2070s
Rainfall	Daily rainfall winter/mm	16	2.58	Primary	1.12	1.12	1.23
				Higher	1.13	1.27	1.43
		19	1.73	Primary	1.15	1.15	1.25
				Higher	1.16	1.30	1.51
		22	1.20	Primary	1.17	1.15	1.26
				Higher	1.17	1.31	1.58
		29	0.53	Primary	1.23	1.20	1.37
				Higher	1.22	1.42	1.75
		30	0.47	Primary	1.25	1.22	1.40
				Higher	1.25	1.43	1.79
		31	0.42	Primary	1.25	1.23	1.40
				Higher	1.26	1.44	1.82
Rainfall	Daily rainfall summer/mm	16	1.97	Primary	0.98	0.87	0.80
				Higher	0.89	0.78	0.72
		19	1.32	Primary	1.00	0.88	0.81
				Higher	0.89	0.80	0.75
		22	0.90	Primary	1.01	0.90	0.86
				Higher	0.91	0.85	0.77
		29	0.38	Primary	1.20	1.04	1.03
				Higher	1.03	1.04	0.96
		30	0.34	Primary	1.22	1.06	1.05
				Higher	1.06	1.06	1.00
		31	0.31	Primary	1.23	1.07	1.08
				Higher	1.06	1.08	1.00
Temperature	Daily Max Temperature/°C	20	39.95	Primary	1.59	1.91	2.29
				Higher	1.84	2.34	2.91
		21	29.71	Primary	1.68	2.08	2.61
				Higher	2.00	2.66	3.48
		22	21.59	Primary	1.79	2.26	2.96
				Higher	2.19	3.03	4.17
		24	10.00	Primary	2.25	3.02	4.18
				Higher	2.89	4.32	6.64
		25	6.24	Primary	2.62	3.68	5.36
				Higher	3.52	5.59	9.11
		27	2.08	Primary	3.67	5.52	9.53
				Higher	5.16	9.98	18.86
		28	1.08	Primary	3.58	5.76	10.30
				Higher	5.49	11.09	24.08
		29	0.53	Primary	3.68	5.65	11.37
				Higher	5.36	12.06	28.18
		30	0.23	Primary	4.71	6.33	14.38
				Higher	6.33	15.61	41.48
		31	0.09	Primary	5.28	7.68	14.90
				Higher	7.69	16.78	55.92
		33	0.03	Primary	2.34	2.21	4.68
				Higher	2.42	4.82	15.62
		34	0.02	Primary	2.99	3.00	3.89
				Higher	3.04	4.44	19.58
Temperature	Daily Min Temperature/°C	0	54.93	Primary	0.65	0.52	0.32
				Higher	0.54	0.30	0.12
		-2	23.70	Primary	0.44	0.31	0.14
				Higher	0.33	0.13	0.04
		-4	8.68	Primary	0.28	0.17	0.07
				Higher	0.19	0.06	0.02
		-5	5.08	Primary	0.27	0.15	0.06
				Higher	0.16	0.06	0.02
		-7	1.87	Primary	0.28	0.15	0.07
				Higher	0.16	0.07	0.04
		-8	1.14	Primary	0.27	0.16	0.08
				Higher	0.17	0.08	0.04
		-11	0.18	Primary	0.83	0.40	0.19
				Higher	0.46	0.17	0.14
		-12	0.07	Primary	1.00	0.54	0.47
				Higher	0.56	0.58	0.26
		-13	0.02	Primary	1.00	0.92	0.83
				Higher	0.54	0.04	0.00
		-15	< 0.01	Primary	N/A	N/A	N/A
				Higher	N/A	N/A	N/A

Baseline = 1981 to 2000

Table 30 **North West England (UKCP18)**

Weather Parameter	Weather Sub Parameter	Threshold	Baseline Frequency/days	Climate Change Scenario	Frequency multiplier		
					2030s	2050s	2070s
Rainfall	Daily rainfall winter/mm	22	2.62	Primary	1.18	1.18	1.30
				Higher	1.20	1.33	1.55
		32	0.96	Primary	1.26	1.27	1.48
				Higher	1.30	1.50	1.84
		35	0.73	Primary	1.28	1.31	1.51
				Higher	1.34	1.53	1.91
Rainfall	Daily rainfall summer/mm	22	1.34	Primary	0.96	0.89	0.80
				Higher	0.89	0.79	0.67
		32	0.40	Primary	1.10	1.02	0.90
				Higher	1.02	0.90	0.82
		35	0.29	Primary	1.13	1.06	0.94
				Higher	1.08	0.94	0.90
Temperature	Daily Max Temperature/°C	21	23.36	Primary	1.66	2.08	2.66
				Higher	1.99	2.73	3.81
		22	16.82	Primary	1.76	2.24	2.93
				Higher	2.15	3.03	4.36
		23	11.64	Primary	1.95	2.51	3.36
				Higher	2.40	3.46	5.20
		24	7.71	Primary	2.19	2.93	4.00
				Higher	2.79	4.13	6.48
		25	4.89	Primary	2.50	3.42	4.98
				Higher	3.31	5.12	8.44
		26	2.99	Primary	2.73	3.89	6.15
				Higher	3.74	6.42	11.35
		27	1.71	Primary	2.93	4.22	7.26
				Higher	3.99	7.61	15.30
		28	0.85	Primary	3.23	4.53	8.70
				Higher	4.32	9.30	20.63
		29	0.36	Primary	4.13	5.46	10.35
				Higher	5.21	11.4	29.70
		30	0.15	Primary	4.21	5.51	10.02
				Higher	5.47	10.79	31.57
Temperature	Daily Min Temperature/°C	0	54.23	Primary	0.68	0.55	0.36
				Higher	0.57	0.34	0.16
		-1	38.03	Primary	0.60	0.46	0.26
				Higher	0.47	0.25	0.09
		-3	16.18	Primary	0.39	0.25	0.12
				Higher	0.27	0.11	0.03
		-6	3.53	Primary	0.28	0.14	0.06
				Higher	0.16	0.06	0.03
		-7	2.13	Primary	0.29	0.15	0.07
				Higher	0.16	0.07	0.04

Baseline = 1981 to 2000

Table 31 **Wales (UKCP18)**

Weather Parameter	Weather Sub Parameter	Threshold	Baseline Frequency/days	Climate Change Scenario	Frequency multiplier 2030s	2050s	2070s
Rainfall	Daily rainfall winter/mm	15	8.30	Primary	1.11	1.10	1.20
				Higher	1.10	1.22	1.34
		17	6.59	Primary	1.12	1.13	1.23
				Higher	1.13	1.25	1.40
		22	3.82	Primary	1.16	1.16	1.29
				Higher	1.17	1.32	1.54
		23	3.42	Primary	1.16	1.17	1.31
				Higher	1.18	1.34	1.58
Rainfall	Daily rainfall summer/mm	15	4.23	Primary	0.85	0.76	0.64
				Higher	0.78	0.62	0.48
		17	3.31	Primary	0.83	0.76	0.63
				Higher	0.77	0.61	0.47
		22	1.79	Primary	0.81	0.75	0.63
				Higher	0.76	0.61	0.48
		23	1.58	Primary	0.82	0.76	0.64
				Higher	0.77	0.62	0.48
Temperature	Daily Max Temperature/°C	24	8.27	Primary	2.33	3.12	4.39
				Higher	2.96	4.58	7.33
		26	3.05	Primary	3.22	4.76	7.70
				Higher	4.52	8.06	15.08
		28	0.90	Primary	4.17	6.77	13.42
				Higher	6.42	14.62	33.42
		30	0.19	Primary	5.65	8.08	16.53
				Higher	8.18	18.21	61.29
		32	0.03	Primary	4.43	4.84	11.65
				Higher	5.37	12.73	52.66
Temperature	Daily Min Temperature/°C	0	47.57	Primary	0.68	0.56	0.38
				Higher	0.58	0.37	0.17
		-2	21.49	Primary	0.52	0.42	0.23
				Higher	0.44	0.21	0.06
		-3	13.81	Primary	0.43	0.32	0.15
				Higher	0.34	0.14	0.03
		-5	5.17	Primary	0.28	0.15	0.06
				Higher	0.18	0.06	0.02
		-6	3.07	Primary	0.26	0.14	0.06
				Higher	0.16	0.06	0.03
		-7	1.81	Primary	0.30	0.15	0.05
				Higher	0.18	0.06	0.03
		-10	0.34	Primary	0.56	0.35	0.16
				Higher	0.39	0.18	0.13

Baseline 1981 to 2000

Table 32 **West Midlands (UKCP18)**

Weather Parameter	Weather Sub Parameter	Threshold	Baseline Frequency/days	Climate Change Scenario	Frequency multiplier 2030s	2050s	2070s
Rainfall	Daily rainfall winter/mm	24	0.31	Primary	1.44	1.62	1.86
				Higher	1.61	1.91	2.50
		25	0.26	Primary	1.50	1.66	1.93
				Higher	1.62	1.98	2.59
		34	0.07	Primary	1.80	1.63	1.90
				Higher	1.66	1.99	2.60
Rainfall	Daily rainfall summer/mm	24	0.52	Primary	1.00	0.92	0.78
				Higher	0.91	0.77	0.82
		25	0.46	Primary	1.04	0.94	0.80
				Higher	0.92	0.8	0.85
		34	0.15	Primary	1.30	1.19	1.00
				Higher	1.15	1.00	1.11
Temperature	Daily Max Temperature/°C	24	16.19	Primary	2.05	2.64	3.56
				Higher	2.54	3.66	5.29
		26	7.05	Primary	2.77	3.83	5.63
				Higher	3.66	5.82	9.57
		27	4.45	Primary	3.01	4.32	6.87
				Higher	4.10	7.13	12.44
		28	2.70	Primary	3.07	4.62	7.77
				Higher	4.39	8.16	15.9
		29	1.48	Primary	3.70	5.34	9.52
				Higher	5.10	10.15	21.32
		31	0.30	Primary	5.37	7.03	13.26
				Higher	7.22	13.8	39.36
		33	0.07	Primary	4.62	5.05	9.44
				Higher	4.99	9.66	27.86
		35	0.01	Primary	7.18	4.86	8.15
				Higher	5.81	8.70	28.28
Temperature	Daily Min Temperature/°C	0	51.38	Primary	0.69	0.58	0.41
				Higher	0.60	0.39	0.19
		-2	23.55	Primary	0.56	0.45	0.27
				Higher	0.47	0.25	0.09
		-4	9.90	Primary	0.38	0.24	0.12
				Higher	0.27	0.11	0.04
		-5	5.94	Primary	0.32	0.18	0.09
				Higher	0.20	0.09	0.04
		-8	1.35	Primary	0.37	0.25	0.12
				Higher	0.28	0.13	0.10
		-9	0.82	Primary	0.46	0.33	0.15
				Higher	0.36	0.16	0.14

Baseline = 1981 to 2000

Table 33 **East Midlands (UKCP18)**

Weather Parameter	Weather Sub Parameter	Threshold	Baseline Frequency/days	Climate Change Scenario	Frequency multiplier 2030s	2050s	2070s
Rainfall	Daily rainfall winter/mm	13	2.04	Primary	1.13	1.16	1.32
				Higher	1.16	1.34	1.56
Rainfall	Daily rainfall summer/mm	13	2.49	Primary	0.97	0.90	0.74
				Higher	0.91	0.72	0.66
Temperature	Daily Max Temperature/°C	22	33.23	Primary	1.69	2.09	2.61
				Higher	2.02	2.67	3.40
		23	24.72	Primary	1.80	2.30	2.95
				Higher	2.20	3.04	4.09
		24	17.48	Primary	2.02	2.61	3.48
				Higher	2.51	3.59	5.11
		25	11.89	Primary	2.36	3.08	4.29
				Higher	2.98	4.43	6.74
		26	7.84	Primary	2.71	3.78	5.50
				Higher	3.65	5.71	9.05
		27	4.86	Primary	3.17	4.68	7.17
				Higher	4.44	7.47	12.53
		28	2.83	Primary	3.36	5.20	8.68
				Higher	4.88	9.17	16.87
		29	1.55	Primary	3.61	5.76	10.44
				Higher	5.39	11.26	22.68
		30	0.79	Primary	4.07	6.37	11.74
				Higher	6.09	12.78	29.91
		31	0.32	Primary	6.14	9.55	19.53
				Higher	9.36	20.68	56.91
		32	0.12	Primary	9.50	12.06	24.35
				Higher	11.75	26.45	81.20
Temperature	Daily Min Temperature/°C	-2	23.13	Primary	0.53	0.40	0.23
				Higher	0.42	0.22	0.08
		-3	14.94	Primary	0.44	0.31	0.16
				Higher	0.33	0.15	0.06
		-6	3.35	Primary	0.30	0.18	0.07
				Higher	0.20	0.07	0.04
		-7	2.11	Primary	0.30	0.18	0.06
				Higher	0.20	0.07	0.05

Baseline = 1981 to 2000

Table 34 **East of England (UKCP18)**

The East of England generally experiences low levels of rainfall and consequently there are too few faults resulting from heavy rain to allow an asset threshold to be estimated. For this reason, no rainfall thresholds are specified for this region and where they are needed figures from the national table (*Table 38)* should be used as a surrogate.

Weather Parameter	Weather Sub Parameter	Threshold	Baseline Frequency/days	Climate Change Scenario	Frequency multiplier		
					2030s	2050s	2070s
Temperature	Daily Max Temperature/°C	20	69.23	Primary	1.41	1.60	1.81
				Higher	1.57	1.84	2.12
		24	22.87	Primary	1.88	2.41	3.14
				Higher	2.33	3.28	4.46
		25	15.86	Primary	2.13	2.84	3.81
				Higher	2.72	3.97	5.76
		26	10.50	Primary	2.52	3.46	4.85
				Higher	3.35	5.06	7.74
		27	6.61	Primary	2.98	4.41	6.41
				Higher	4.18	6.69	10.90
		28	3.91	Primary	3.28	5.11	8.20
				Higher	4.75	8.53	14.65
		29	2.19	Primary	3.50	5.73	9.85
				Higher	5.32	10.44	19.50
		30	1.12	Primary	4.04	6.35	11.70
				Higher	5.90	12.72	26.62
		31	0.50	Primary	4.80	7.41	15.24
				Higher	6.80	16.12	36.95
		32	0.19	Primary	8.41	11.69	23.05
				Higher	11.57	25.11	70.48
		33	0.08	Primary	9.78	12.46	22.90
				Higher	12.46	25.43	91.55
		34	0.04	Primary	4.62	6.11	11.60
				Higher	6.09	12.6	43.53
		36	< 0.01	Primary	N/A	N/A	N/A
				Higher	N/A	N/A	N/A
Temperature	Daily Min Temperature/°C	1	65.07	Primary	0.71	0.60	0.44
				Higher	0.62	0.42	0.22
		0	45.97	Primary	0.66	0.54	0.36
				Higher	0.55	0.35	0.16
		-1	31.29	Primary	0.58	0.46	0.29
				Higher	0.48	0.28	0.11
		-2	20.43	Primary	0.50	0.38	0.23
				Higher	0.40	0.21	0.07
		-3	13.21	Primary	0.43	0.29	0.15
				Higher	0.32	0.14	0.05
		-5	5.02	Primary	0.28	0.16	0.06
				Higher	0.18	0.05	0.03
		-7	1.69	Primary	0.24	0.18	0.07
				Higher	0.18	0.07	0.04
		-9	0.52	Primary	0.32	0.25	0.12
				Higher	0.23	0.12	0.10

Baseline = 1981 to 2000

Table 35 **London (UKCP18)**

Weather Parameter	Weather Sub Parameter	Threshold	Baseline Frequency/days	Climate Change Scenario	Frequency multiplier		
					2030s	2050s	2070s
Rainfall	Daily rainfall winter/mm	5	10.81	Primary	1.06	1.08	1.15
				Higher	1.08	1.15	1.25
		10	3.18	Primary	1.08	1.19	1.31
				Higher	1.18	1.32	1.56
		13	1.64	Primary	1.12	1.21	1.36
				Higher	1.19	1.36	1.71
		16	0.80	Primary	1.24	1.26	1.53
				Higher	1.25	1.50	1.92
		19	0.42	Primary	1.38	1.18	1.50
				Higher	1.20	1.50	1.89
		20	0.36	Primary	1.34	1.14	1.32
				Higher	1.20	1.29	1.67
		22	0.26	Primary	1.17	1.00	1.16
				Higher	1.00	1.13	1.60
		24	0.20	Primary	1.00	1.00	1.25
				Higher	1.00	1.08	1.66
		25	0.16	Primary	1.10	1.07	1.34
				Higher	1.00	1.25	1.57
		27	0.11	Primary	1.17	1.25	1.50
				Higher	1.22	1.42	1.98
		29	0.05	Primary	2.33	1.96	2.24
				Higher	1.91	2.32	2.19
		30	0.03	Primary	1.92	2.03	1.92
				Higher	1.98	2.00	2.15
		31	0.02	Primary	1.82	1.69	2.04
				Higher	1.59	2.12	2.08
		34	< 0.01	Primary	N/A	N/A	N/A
				Higher	N/A	N/A	N/A
Rainfall	Daily rainfall summer/mm	5	9.36	Primary	0.91	0.84	0.72
				Higher	0.85	0.69	0.53
		10	3.52	Primary	0.90	0.84	0.72
				Higher	0.85	0.70	0.58
		13	2.19	Primary	0.89	0.83	0.71
				Higher	0.83	0.71	0.62
		16	1.28	Primary	1.00	0.92	0.84
				Higher	0.91	0.84	0.72
		19	0.86	Primary	1.03	0.97	0.82
				Higher	0.95	0.88	0.75
		20	0.75	Primary	1.05	0.99	0.82
				Higher	1.00	0.96	0.81
		22	0.57	Primary	0.95	0.95	0.78
				Higher	0.93	0.77	0.60
		24	0.41	Primary	1.25	1.13	1.19
				Higher	1.09	1.08	1.00
		25	0.34	Primary	1.44	1.18	1.20
				Higher	1.20	1.07	1.00
		27	0.26	Primary	1.34	1.28	1.17
				Higher	1.25	1.00	1.00
		29	0.19	Primary	1.44	1.00	1.34
				Higher	1.00	1.25	1.00
		30	0.16	Primary	1.50	1.22	1.40
				Higher	1.20	1.38	1.00
		31	0.14	Primary	1.67	1.25	1.33
				Higher	1.25	1.25	1.00
		34	0.09	Primary	1.98	1.25	1.98
				Higher	1.13	1.98	1.34
Temperature	Daily Max Temperature/°C	20	78.81	Primary	1.37	1.52	1.72
				Higher	1.50	1.74	1.98
		21	63.07	Primary	1.45	1.67	1.93
				Higher	1.63	1.96	2.27
		22	48.76	Primary	1.58	1.88	2.23
				Higher	1.82	2.28	2.71
		23	37.80	Primary	1.65	2.04	2.53
				Higher	1.97	2.59	3.21
		24	28.44	Primary	1.76	2.24	2.86
				Higher	2.15	2.95	3.86
		25	20.34	Primary	1.95	2.53	3.33
				Higher	2.42	3.50	4.85
		26	13.70	Primary	2.25	3.03	4.12
				Higher	2.90	4.29	6.44
		27	8.76	Primary	2.68	3.72	5.26
				Higher	3.55	5.46	8.73
		28	5.44	Primary	2.82	4.26	6.50
				Higher	4.05	6.81	11.64

Weather Parameter	Weather Sub Parameter	Threshold	Baseline Frequency/days	Climate Change Scenario	Frequency multiplier 2030s	2050s	2070s
		29	3.35	Primary	2.68	4.37	7.10
				Higher	4.02	7.50	13.90
		30	1.74	Primary	2.97	4.71	8.53
				Higher	4.38	9.03	18.94
		31	0.79	Primary	3.37	4.67	8.52
				Higher	4.49	9.25	22.30
		32	0.34	Primary	3.24	4.48	8.01
				Higher	4.51	8.82	22.42
		33	0.15	Primary	3.83	4.97	8.66
				Higher	4.80	9.02	23.34
		34	0.08	Primary	2.98	3.34	6.08
				Higher	3.37	6.21	15.67
		35	0.03	Primary	4.37	5.04	6.79
				Higher	4.80	6.82	18.29
		36	< 0.01	Primary	N/A	N/A	N/A
				Higher	N/A	N/A	N/A
Temperature	Daily Min Temperature/°C	2	71.41	Primary	0.75	0.63	0.48
				Higher	0.65	0.46	0.25
		1	52.92	Primary	0.68	0.56	0.39
				Higher	0.58	0.37	0.16
		0	37.47	Primary	0.60	0.48	0.30
				Higher	0.50	0.28	0.11
		-1	25.13	Primary	0.52	0.39	0.22
				Higher	0.41	0.20	0.07
		-2	16.31	Primary	0.41	0.28	0.15
				Higher	0.30	0.14	0.05
		-3	10.06	Primary	0.33	0.21	0.10
				Higher	0.23	0.10	0.03
		-4	5.86	Primary	0.28	0.19	0.11
				Higher	0.20	0.10	0.04
		-5	3.22	Primary	0.32	0.21	0.10
				Higher	0.22	0.10	0.05
		-6	1.81	Primary	0.29	0.26	0.12
				Higher	0.26	0.11	0.07
		-7	0.99	Primary	0.45	0.38	0.20
				Higher	0.34	0.17	0.13
		-8	0.53	Primary	0.66	0.50	0.28
				Higher	0.50	0.25	0.20
		-9	0.31	Primary	1.03	0.84	0.22
				Higher	0.87	0.21	0.08
		-10	0.17	Primary	0.81	0.65	0.16
				Higher	0.69	0.15	0.08
		-11	0.06	Primary	0.77	0.80	0.18
				Higher	0.81	0.17	0.07
		-12	0.02	Primary	0.50	0.52	0.14
				Higher	0.52	0.12	0.07
		-13	0.01	Primary	0.41	0.32	0.15
				Higher	0.34	0.14	0.05
		-15	0.01	Primary	0.21	0.09	0.05
				Higher	0.08	0.05	0.02

Baseline = 1981 to 2000

Table 36 **South East England (UKCP18)**

Weather Parameter	Weather Sub Parameter	Threshold	Baseline Frequency/days	Climate Change Scenario	Frequency multiplier		
					2030s	2050s	2070s
Rainfall	Daily rainfall winter/mm	5	14.04	Primary	1.05	1.07	1.13
				Higher	1.06	1.13	1.21
		10	5.55	Primary	1.07	1.13	1.25
				Higher	1.12	1.25	1.42
		24	0.34	Primary	1.57	1.60	2.02
				Higher	1.55	2.07	3.46
		25	0.27	Primary	1.64	1.64	2.10
				Higher	1.58	2.12	3.66
		27	0.17	Primary	1.72	1.73	2.15
				Higher	1.65	2.20	4.14
		30	0.09	Primary	1.76	1.67	2.14
				Higher	1.72	2.16	4.13
		34	0.03	Primary	2.30	2.28	2.64
				Higher	2.28	2.54	4.40
Rainfall	Daily rainfall summer/mm	5	9.61	Primary	0.89	0.78	0.67
				Higher	0.81	0.64	0.49
		10	3.77	Primary	0.86	0.77	0.62
				Higher	0.79	0.60	0.48
		24	0.42	Primary	1.14	0.96	0.80
				Higher	0.98	0.76	0.70
		25	0.38	Primary	1.13	0.96	0.82
				Higher	0.97	0.78	0.72
		27	0.29	Primary	1.21	1.03	0.90
				Higher	1.03	0.85	0.84
		30	0.20	Primary	1.31	1.12	1.00
				Higher	1.14	0.96	0.96
		34	0.12	Primary	1.59	1.47	1.19
				Higher	1.43	1.11	1.11
Temperature	Daily Max Temperature/°C	23	29.65	Primary	1.78	2.27	2.88
				Higher	2.18	2.96	3.82
		24	21.36	Primary	1.94	2.56	3.39
				Higher	2.45	3.52	4.78
		25	14.55	Primary	2.27	3.03	4.19
				Higher	2.90	4.34	6.37
		26	9.39	Primary	2.74	3.86	5.42
				Higher	3.70	5.68	9.01
		27	5.81	Primary	3.15	4.81	7.11
				Higher	4.49	7.39	12.66
		28	3.48	Primary	3.39	5.55	9.01
				Higher	5.13	9.50	17.40
		29	2.00	Primary	3.39	5.96	10.60
				Higher	5.46	11.25	22.59
		30	1.03	Primary	4.14	7.03	13.50
				Higher	6.52	14.26	32.94
		31	0.46	Primary	4.92	7.79	15.74
				Higher	7.58	16.88	43.68
		33	0.09	Primary	6.25	8.52	20.47
				Higher	8.61	20.78	65.11
		35	0.02	Primary	7.22	9.01	14.40
				Higher	9.55	15.01	41.29
Temperature	Daily Min Temperature/°C	2	84.27	Primary	0.79	0.7	0.55
				Higher	0.71	0.53	0.34
		1	64.44	Primary	0.74	0.63	0.48
				Higher	0.65	0.46	0.25
		0	47.00	Primary	0.68	0.57	0.40
				Higher	0.58	0.38	0.18
		-1	32.53	Primary	0.62	0.51	0.34
				Higher	0.52	0.32	0.13
		-2	21.52	Primary	0.55	0.44	0.27
				Higher	0.46	0.25	0.09
		-3	13.98	Primary	0.46	0.34	0.19
				Higher	0.36	0.18	0.06
		-4	8.77	Primary	0.35	0.22	0.12
				Higher	0.25	0.11	0.03
		-5	5.15	Primary	0.28	0.17	0.09
				Higher	0.19	0.09	0.03
		-6	2.94	Primary	0.27	0.17	0.08
				Higher	0.19	0.08	0.04
		-8	1.09	Primary	0.26	0.18	0.10
				Higher	0.20	0.10	0.06
		-9	0.66	Primary	0.33	0.22	0.11
				Higher	0.24	0.11	0.11

Baseline = 1981 to 2000

Table 37 **South West England (UKCP18)**

Weather Parameter	Weather Sub Parameter	Threshold	Baseline Frequency/days	Climate Change Scenario	Frequency multiplier 2030s	2050s	2070s
Rainfall	Daily rainfall winter/mm	5	20.97	Primary	1.05	1.04	1.08
				Higher	1.04	1.08	1.13
		15	4.75	Primary	1.13	1.17	1.31
				Higher	1.16	1.31	1.54
		16	4.03	Primary	1.14	1.19	1.33
				Higher	1.17	1.34	1.60
		20	2.14	Primary	1.18	1.21	1.42
				Higher	1.20	1.44	1.82
		21	1.84	Primary	1.18	1.21	1.43
				Higher	1.20	1.45	1.86
		24	1.16	Primary	1.19	1.19	1.50
				Higher	1.19	1.54	2.03
		25	0.99	Primary	1.19	1.20	1.52
				Higher	1.19	1.56	2.08
		31	0.39	Primary	1.33	1.35	1.78
				Higher	1.35	1.86	2.58
Rainfall	Daily rainfall summer/mm	5	12.03	Primary	0.87	0.79	0.65
				Higher	0.80	0.62	0.49
		15	2.66	Primary	0.80	0.70	0.58
				Higher	0.71	0.56	0.42
		16	2.28	Primary	0.8	0.70	0.58
				Higher	0.71	0.57	0.43
		20	1.23	Primary	0.83	0.72	0.63
				Higher	0.72	0.62	0.48
		21	1.06	Primary	0.82	0.73	0.63
				Higher	0.72	0.63	0.50
		24	0.67	Primary	0.88	0.78	0.68
				Higher	0.77	0.67	0.56
		25	0.58	Primary	0.90	0.79	0.70
				Higher	0.78	0.70	0.60
		31	0.26	Primary	1.10	0.94	0.89
				Higher	0.92	0.90	0.81
Temperature	Daily Max Temperature/°C	23	29.65	Primary	1.78	2.27	2.88
				Higher	2.18	2.96	3.82
		24	21.36	Primary	1.94	2.56	3.39
				Higher	2.45	3.52	4.78
		25	14.55	Primary	2.27	3.03	4.19
				Higher	2.90	4.34	6.37
		26	9.39	Primary	2.74	3.86	5.42
				Higher	3.70	5.68	9.01
		27	5.81	Primary	3.15	4.81	7.11
				Higher	4.49	7.39	12.66
		28	3.48	Primary	3.39	5.55	9.01
				Higher	5.13	9.50	17.40
		29	2.00	Primary	3.39	5.96	10.60
				Higher	5.46	11.25	22.59
		30	1.03	Primary	4.14	7.03	13.50
				Higher	6.52	14.26	32.94
		31	0.46	Primary	4.92	7.79	15.74
				Higher	7.58	16.88	43.68
		33	0.09	Primary	6.25	8.52	20.47
				Higher	8.61	20.78	65.11
		35	0.02	Primary	7.22	9.01	14.40
				Higher	9.55	15.01	41.29
Temperature	Daily Min Temperature/°C	3	94.75	Primary	0.82	0.73	0.60
				Higher	0.74	0.59	0.40
		0	38.33	Primary	0.66	0.55	0.39
				Higher	0.57	0.37	0.17
		-1	25.84	Primary	0.61	0.50	0.33
				Higher	0.52	0.31	0.13
		-2	16.67	Primary	0.55	0.44	0.27
				Higher	0.46	0.25	0.09
		-3	10.41	Primary	0.47	0.36	0.21
				Higher	0.38	0.19	0.06
		-4	6.31	Primary	0.36	0.25	0.13
				Higher	0.28	0.13	0.04
		-7	1.19	Primary	0.29	0.16	0.08
				Higher	0.18	0.08	0.07
		-10	0.18	Primary	0.61	0.50	0.33
				Higher	0.50	0.27	0.20

Baseline = 1981 to 2000*Table 38* ***UK (UKCP18)***

Weather Parameter	Weather Sub Parameter	Threshold	Baseline Frequency/days	Climate Change Scenario	Frequency multiplier 2030s	2050s	2070s
Rainfall	Daily rainfall winter/mm	7	15.86	Primary	1.05	1.04	1.07
				Higher	1.04	1.08	1.14
		11	9.36	Primary	1.06	1.06	1.11
				Higher	1.06	1.12	1.23
		14	6.46	Primary	1.08	1.08	1.15
				Higher	1.08	1.16	1.28
		17	4.49	Primary	1.10	1.10	1.18
				Higher	1.10	1.20	1.34
		25	1.81	Primary	1.15	1.15	1.25
				Higher	1.15	1.28	1.51
		38	0.48	Primary	1.26	1.27	1.42
				Higher	1.29	1.44	1.84
Rainfall	Daily rainfall summer/mm	7	10.02	Primary	0.94	0.87	0.79
				Higher	0.88	0.78	0.65
		11	5.34	Primary	0.94	0.88	0.79
				Higher	0.89	0.78	0.66
		14	3.45	Primary	0.94	0.88	0.79
				Higher	0.89	0.79	0.67
		17	2.26	Primary	0.95	0.89	0.81
				Higher	0.90	0.80	0.69
		25	0.78	Primary	1.04	0.97	0.90
				Higher	0.98	0.89	0.82
		38	0.16	Primary	1.45	1.36	1.33
				Higher	1.36	1.33	1.31
Temperature	Daily Max Temperature/°C	20	37.98	Primary	1.53	1.82	2.18
				Higher	1.76	2.21	2.81
		21	28.52	Primary	1.63	1.98	2.46
				Higher	1.90	2.51	3.27
		22	20.99	Primary	1.74	2.18	2.76
				Higher	2.09	2.84	3.89
		23	15.00	Primary	1.87	2.41	3.15
				Higher	2.30	3.26	4.65
		24	10.25	Primary	2.09	2.76	3.78
				Higher	2.66	3.91	5.83
		25	6.67	Primary	2.43	3.32	4.72
				Higher	3.20	4.92	7.78
		26	4.15	Primary	2.89	4.12	6.23
				Higher	3.97	6.53	10.97
		27	2.47	Primary	3.53	5.30	8.46
				Higher	5.03	8.90	16.27
		28	1.41	Primary	3.96	6.36	11.05
				Higher	5.98	11.73	23.39
		29	0.76	Primary	4.62	7.77	14.87
				Higher	7.23	16.06	36.44
		30	0.38	Primary	5.49	9.73	19.31
				Higher	9.21	21.12	54.16
		31	0.16	Primary	6.94	11.73	24.14
				Higher	11.01	25.95	80.59
		32	0.07	Primary	9.99	16.59	37.39
				Higher	16.83	41.02	146.84
		35	0.01	Primary	6.10	10.29	23.76
				Higher	10.44	27.09	95.42
Temperature	Daily Min Temperature/°C	0	58.10	Primary	0.68	0.55	0.36
				Higher	0.57	0.34	0.16
		-1	40.24	Primary	0.60	0.46	0.27
				Higher	0.48	0.25	0.10
		-3	17.29	Primary	0.44	0.30	0.15
				Higher	0.32	0.14	0.04
		-7	2.71	Primary	0.33	0.18	0.07
				Higher	0.21	0.07	0.02
		-9	1.09	Primary	0.32	0.16	0.06
				Higher	0.18	0.06	0.02
		-11	0.44	Primary	0.32	0.15	0.06
				Higher	0.17	0.05	0.01
		-15	0.06	Primary	0.29	0.17	0.08
				Higher	0.17	0.07	0.05
		-16	0.03	Primary	0.32	0.22	0.11
				Higher	0.23	0.09	0.06

Baseline = 1981 to 2000

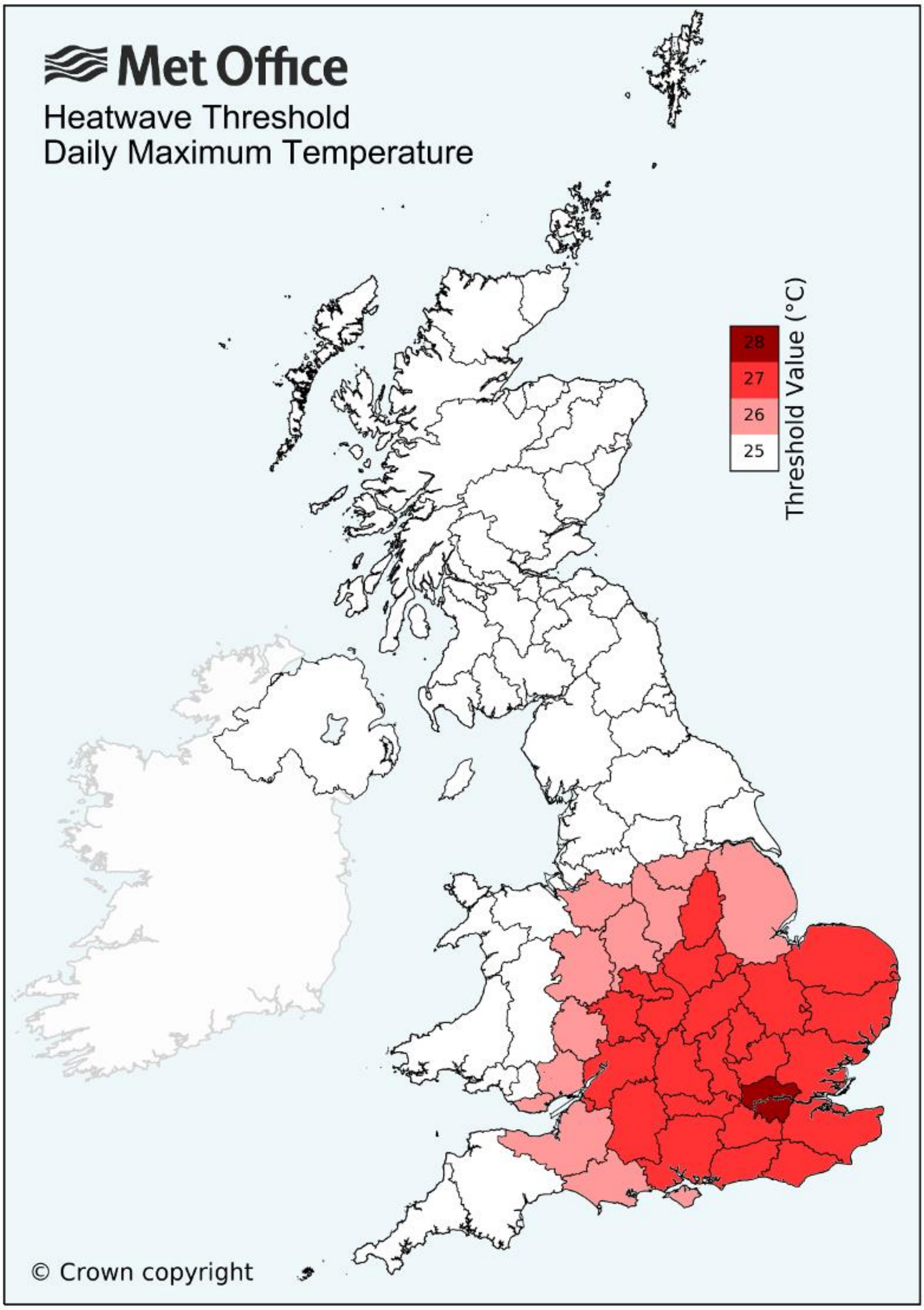
N.B. 'UK' excludes Northern Ireland

14 Glossary

Adaptation	Climate change adaptation is action taken to improve the resilience of assets, networks and systems to future weather conditions, avoiding, minimising or mitigating the impact of more severe or frequent adverse and extreme weather events and gradual or erratic changes in weather patterns due to climate change.
Autumn	September, October, November.
Baseline	A 20-year period from 1981 to 2000 from which to calculate the projected changes in the UK climate. This period was chosen, as it was a particularly stable period in the recent climate with very little in the way of climate perturbing events such as volcanic eruptions.
Climate	Defined as average weather over a longer time period (ranging from months to many years). The classic period for averaging these variables is 30 years, as defined by the World Meteorological Organisation. For the definition of weather see below.
Climate Change	A change in global or regional climate patterns, attributed to changes in levels of atmospheric greenhouse gases.
Climate Projection	Modelled response of the climate system to a scenario of future greenhouse gas emissions (or of greenhouse gas concentration levels). For example, the UKCP18 RCP2.5 scenario assumes rapid decarbonisation of the world economy and a rapid shift to renewable energy.
Climate Scenario	A projection of future greenhouse gas emissions used by analysts to assess future vulnerability to climate change using future population levels, economic activity, the structure of governance, social values, and patterns of technological change. Economic and energy modelling can be used to analyse and quantify the effects of such drivers.
Coastal Flooding	Is where high tides and/or storm surges raise the sea level and/or wave height above that of the natural coastline or defences causing over topping.
EA	Environment Agency- English environmental regulator.
FRA	Flood Risk Assessment as defined by the EA, SEPA or NRW.
Greenhouse Gases	The main greenhouse gases are; water vapour, carbon dioxide, methane, ozone, nitrous oxide are chlorofluorocarbons.
Groundwater Flooding	When snow melt or rainfall soaking into the ground raises the level of the water table until it is above ground level.
Heat wave	A heat wave occurs when a location records a period three or more consecutive days with daily maximum temperatures meeting or exceeding a heatwave temperature threshold. The threshold varies by UK county, see the UK temperature threshold map in *APPENDIX 1 – UK heatwave threshold map*
NRW	Natural Resources Wales – Welsh environmental regulator.

RCP	Representative Concentration Pathways are the current IPCC climate projection scenarios There are four: RCP2.6, RCP4.5, RCP6.0 and RCP8.5. These scenarios have been used in the UKCP18 climate projections.
RCP6.0	Representative Concentration Pathway 6.0 - emissions peak around 2080, then decline.
RCP8.5	Representative Concentration Pathway 8.5 - emissions rise throughout the 21st century.
Resilience	The ability of assets, networks and systems to anticipate, absorb, adapt to and rapidly recover from disruptive events. This includes the adaptive capacity gained from understanding current and future risks to our assets.
River Basin	A river basin is an area of land drained by a river and its tributaries. One river basin is separated from the next by a watershed, which is an area or ridge of land that separates waters flowing to the different rivers.
River Flooding	Also known as fluvial flooding. Caused by the migration of snowmelt or rainfall into watercourses raising their flows to the point where they exceed the channel capacity and overtop the banks and/or flood defences into the flood plain.
SEPA	Scottish Environmental Protection Agency - Scottish Environmental Regulator.
Spring	March, April, May.
Summer	June, July, August.
Storm Surge	An increase in sea level under storm conditions, beyond the normal tidal maximum, due to low atmospheric pressure and gale force winds forcing water towards the coastline.
Surface Water Flooding	Also known as pluvial, rainfall or flash flooding. The result of rapid snowmelt or intense or prolonged rain falling onto land and accumulating at low points in the topography.
Threshold	Weather variable value, which when exceeded, causes significant or very significant increases in asset failures/disruption incidents. These are based on the TraCCA (Tomorrow's railway and climate change adaptation) WP1B Operations weather thresholds analysis report updated to account for additional Network Rail weather related asset failure data. The thresholds of interest may also change in future if asset design or operation changes.
UKCP09	National climate projections for the UK produced in 2009.
UKCP18	National climate projections for the UK produced in 2018.
Vulnerability	In this context, the predisposition to being adversely affected by weather events or impacts.
Weather	The occurrence of weather variables such as temperature, precipitation and humidity, in the short term, as opposed to the long-term definition of climate. See above.
Winter	December, January, February.
Weather resilience	Weather resilience is the ability of assets, networks and systems to anticipate, absorb, adapt to and/or recover from disruptive weather events.

APPENDIX 1 – UK heatwave threshold map



The construction of this map is described in: McCarthy M. et al. (2019). A new heatwave definition for the UK. *Weather*, https://rmets.onlinelibrary.wiley.com/doi/10.1002/wea.3629

APPENDIX 2 – Version Control

Date	Change description	Change owner	New document version
14/08/19	Issue 1	David Quincey, Climate Change Adaptation Manager	Issue 1
06/11/20	Updated to UKCP18	David Quincey, Climate Change Adaptation Manager	Issue 2
26/02/21	Removal of Thresholds Guidance note text and replacement of broken links	David Quincey, Climate Change Adaptation Manager	Issue 3