Bristol One City Climate Strategy

Preliminary Climate Resilience Assessment

FINAL ISSUE

24th February 2020

ARUP BRISTOL ONE CITY

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Executive summary

Introduction

Arup was commissioned by Bristol City Council, on behalf of the Environmental Sustainability Board, to conduct a preliminary climate resilience assessment for Bristol.

This focused on gathering existing data and information on climate vulnerability, which comprises:

- Climate hazards, and how these are projected to change in the coming decades on the basis of the best climate science.
- The sensitivity of the physical, social, environmental and economic systems in Bristol to these hazards; and
- Adaptive capacity, which is the ability of systems, organisations or people to adjust to events, respond to consequences or take advantage of opportunities.

This assessment is focused on the exposure of Bristol's assets to climate hazards.

Climate hazards

The future climate is not certain, and we should be planning for a range of scenarios; this report recommends considering RCP4.5 and RCP8.5 emissions scenarios (see introduction and methodology for further detail on these terms). Under an RCP8.5 scenario, by the time today's school children retire in 2080, Bristol could see:

Sea level on Bristol's coastline is projected to increase by up to

+72cm

Winter precipitation rate is projected to increase by up to

48%

Summer maximum temperature is projected to increase by over

+9°C

By 2080, summer precipitation rate in Bristol is projected to decrease by up to

68%

The likelihood of other hazards, such as extreme cold, are projected to reduce but it is still essential that we are prepared for them.

Physical, social and economic impacts of extreme weather

Climate change is a global stress that results in increased frequency and intensity of climate shocks or hazards. The climate hazards identified could have very serious impacts for the people of Bristol.

Of each of the climate hazards, we understand the spatial distribution of flooding best and therefore the potential physical impacts are clearer. We know there are risks to homes, businesses, schools, community assets, and critical infrastructure (including, for example, Temple Meads station). These impacts will get progressively worse to 2080.

Whilst we know less about the spatial distribution of extreme heat and drought, we know the physical impacts can be serious.

The potential impacts to our people and public services are wide ranging. We can learn and adapt from events such as the 2003 heatwave in Europe, where 2,000 people died in the UK *(Met Office, 2019d)*.

Our food system is at risk of shortages of supply and increased costs, particularly given the global nature of the supply chain.

Our wider economic supply chain is also at risk, with clothes and electronic equipment, being the other areas particularly at risk.

Adapting and preparing for a changing climate

Bristol is not starting from scratch; planning, securing funding and developing detailed designs have already been achieved to support preparation and adaptation for a changing climate in key areas. Activities include the identification of a flood defence scheme in Avonmouth and Severnside, individual organisation's plans such as Bristol Water's Drought Plan, or the local NHS trusts' adaptation plan and preparedness to respond and recover through things like the Local Resilience Forum, or community places of safety.

There is still much more to be done.

Complexity and uncertainty

Climate change is a complex challenge. We know that risks are interconnected, as well as having the potential to cause cascading impacts.

We recognise the interconnected and global nature of the world, which exposes Bristol to physical climate risks well beyond the city's boundary. Impacts may be non-linear, and compounding impacts could cause system breakdown.

Recommendations

There is a need to take greater adaptation action now, based on our current knowledge of the risks we face. This includes:

- Progressing adaptation plans for flood risk management in Avonmouth and Severnside and the City Centre
- Improving our ability to respond to and recover from extreme weather events
- Restoring, protecting, enhancing and expanding green infrastructure networks
- Preparing buildings for extreme heat
- Improving co-ordination and governance of climate resilience in Bristol
- A more detailed evidence base for heat, drought, storms and high winds.

There are a number of areas where we have identified the need for more evidence and knowledge. In particular, this includes a better understanding of interacting and cascading risks, including across the supply chain. There is also a need for a better local understanding of complex climate hazards, such as storms and other types of drought.

In many areas, knowledge is also lacking at a national and international level, and opportunities to collaborate should be sought.

Contents

1. Introduction

Overview

Arup has been commissioned to undertake a high-level climate resilience assessment for the citywide assets within the City of Bristol. This assessment is focused on the exposure of these assets to climate hazards.

This study was commissioned by Bristol City Council (BCC) to provide evidence to feed into the One City Climate Strategy. This study is focused on risk assessment, or understanding and analysing physical climate risk.

This climate adaptation evidence base sits alongside climate mitigation studies which have also been produced to feed into the One City Climate Strategy.

Bristol context

This study builds on the work undertaken for Bristol Resilience Strategy (100 Resilient Cities, *2016*) and the factsheets produced by the Met Office for Bristol City Council (*Met Office, 2019b*). This report can provide evidence to support wider climate action in the city.

BCC was the first UK local authority to declare a climate emergency for the city on 13th November 2018. BCC has also set an ambitious goal of making Bristol carbon neutral and climate resilient by 2030 (*CEUK, 2019*).

A number of institutions in the city have declared a climate emergency including the University of Bristol, University of the West of England, North Bristol NHS Trust and University Hospitals Bristol NHS Foundation, We the Curious, the Watershed, The Bristol Old Vic and the Colston Hall.

Bristol recognises the need to play a part in minimising the impact of climate change on the most vulnerable communities through emissions reductions and supporting and providing security to climate migrants.

Introduction to climate hazards in Bristol

Our climate is warming and the impact this is having on people and ecosystems is already severe. The past four years (2015 to 2018) were the four warmest years globally on record (*WMO, 2019*).

The Intergovernmental Panel on Climate Change (IPCC) has produced assessment reports since 1990 that synthesise published literature and research on climate change. This has shown that global average temperatures have increased by 0.87°C since 1850-1900 (compared to the decade 2006-2015) (*IPCC 2018*).

This report explores the potential impact of specific climate hazards in Bristol. This is focused on trends in climate rather than weather. Weather describes atmospheric changes over a short time period (days) whereas climate is the long-term pattern of weather.

The impact associated with climate hazards can be considered as 'risks', or a 'threat' with potentially negative impacts. These could be felt as:

- a short-term shock or incident that threatens the city's ability to function, such as an extreme weather event like a flood or a heatwave;
- a stress which is a longer-term cumulative issue such as climate change which affects weather systems and rising temperatures (*100 Resilient Cities, 2015*); or
- an opportunity to develop / an uncertainty that could have a positive impact.

We have focused on three key primary climate hazards for this assessment:

- Flooding
- Extreme Heat
- Drought

These hazards reflect the key climate risks for the city and reflect the climate risks identified by the National Risk Register (*Cabinet Office, 2017*) and the UK Climate Change Risk Assessment (*CCC, 2017*). The physical hazards included in this report have been determined based on the latest climate projections (*Met Office, 2019b*).

Though storms, storm surges and high winds pose a threat to infrastructure *(CCC, 2017)*, the difficulty in predicting future patterns of these hazards has meant that they are not fully addressed in this assessment. Please see page 15 for further information.

Bristol's city assets

At a high level we have identified the groups of assets that are key to the continued function of Bristol, and to Bristol's ability to grow and flourish. By assets, we mean both physical and non-physical components of a city's systems.

Our study comprises three key asset themes:

- **Physical assets**: This includes the grey, green and blue infrastructure and buildings across the city. This comprises both the critical nodes and main linear infrastructure.
- **Social assets**: This includes health, education and community assets both physical and intangible (including human and social capital).
- **Business and the economy**: The city's network of producers, distributors and consumers of goods and services.

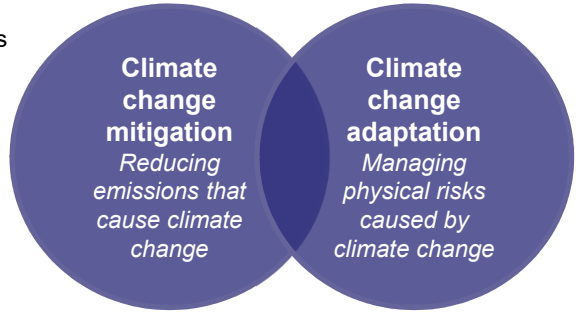


***Figure 1**. Climate change mitigation and climate change adaptation*

2. Methodology

Overall approach

The overall approach to this preliminary climate resilience assessment of Bristol is founded in ISO 14091, an international standard for adaptation to climate change that provides guidelines on vulnerability, impacts and risk assessments *(ISO, 2016)*.

For this assessment our definition of risk is the risk of climate vulnerability which is made up of:

- **Hazard exposure**: exposure of assets to the identified climate hazards, including area impacted, the severity and frequency of these hazards.
- **Sensitivity**: the vulnerability of assets to be impacted by these hazards based on their condition and capacity and the potential consequences of these hazards on people.
- **Adaptive capacity**: the ability of systems, organisations or people to adjust to events, respond to consequences or take advantage of opportunities.

This is aligned with the draft ISO14091:2020 standard for climate vulnerability assessments (Figure 2).

As this is a preliminary climate resilience assessment, the focus of this study has been on understanding the hazard exposure in Bristol. The approach that we have taken to the hazard exposure is therefore the focus for this methodology.

We have undertaken a qualitative sensitivity analysis, based on a literature review. This has predominantly been through the application of national level assessments to the Bristol context.

A full adaptive capacity assessment for the city was beyond the scope of this study. However, we have considered key planning and implementation activity underway in the city to adapt and respond to climate change impacts in Bristol.

More detail on our approach to assessing hazard exposure and sensitivity is set out in the remainder of this section.

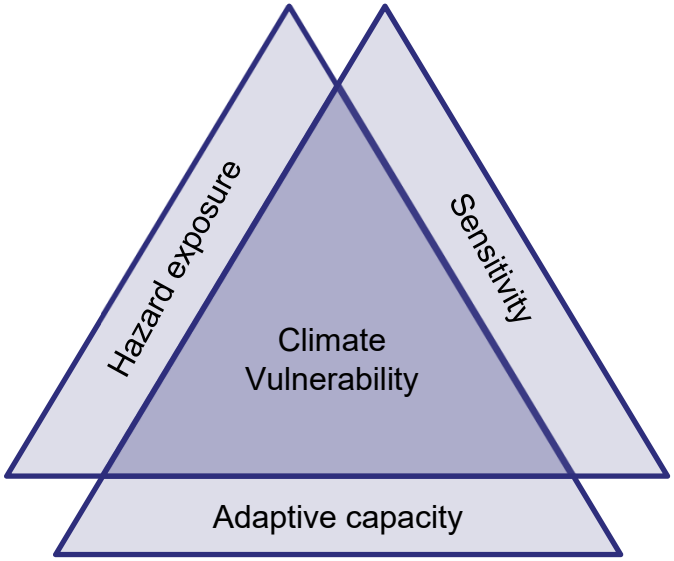
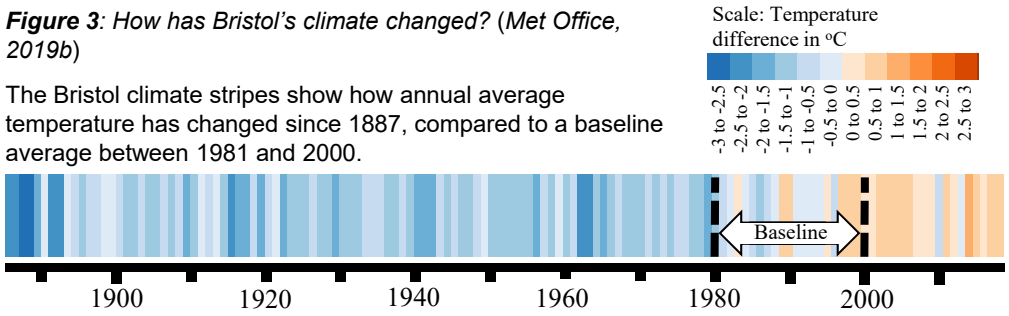


***Figure 2**. Our key considerations of climate risk.*
This summarises input from draft ISO 14091. (ISO 2016)

***Figure 3**: How has Bristol's climate changed?* (*Met Office, 2019b*)

The Bristol climate stripes show how annual average temperature has changed since 1887, compared to a baseline average between 1981 and 2000.



2. Methodology

Hazard exposure

Climate science and climate projections

Climate projections are based on models of the increasing greenhouse gas concentrations in the atmosphere which in turn cause changes to the climate. However, since the climate is so complex, there are multiple scenarios for plausible futures. These models are based on both likelihood of climatic changes (reflected by the percentile) and on a range of climate scenarios (Representative Concentration Pathway (RCP) scenarios).

RCPs are plausible future scenarios used for the IPCC's most recent reports, describing total radiative forcing (the cumulative measure of human greenhouse gas emissions from all sources expressed in Watts per square metre).

These scenarios are dependent on the atmospheric greenhouse gas concentration over the coming years (directly impacted by human activity and our ability, globally, to mitigate) and are based on a range of assumptions for different demographic, policy, economic, technological, and institutional futures *(IPCC, 2014)*.

To support risk planning, we need to understand the worst potential impact of climate change in Bristol; the most extreme case of climate projections. Equally, understanding more likely future climate conditions allows for an understanding of climate change impacts that reflect global trends in climate change mitigation.

As such, this assessment considers to the climate change impacts under an RCP4.5 (more likely) and RCP8.5 (extreme) emissions scenario. For more information on scenario selection, please see below.

It is worth noting that the UK Climate Change Risk Assessment 2017 refers to a study by the Adaptation Sub-Committee (Warren et al., 2016) which found that:

"*Even if global temperature increases are limited to 2°C or less, there are projected to be high magnitude impacts for the UK. At global average temperature rises approaching 4°C, impacts become increasingly severe and may not be avoidable through adaptation*".

The conclusions drawn in this assessment are supported by a wealth of climate science. Much of the context for this report is drawn from national and international evaluations of the causes and impacts of climate change. In particular, this assessment draws on the evidence bases provided in the IPCC's Fifth Assessment Report *(IPCC, 2014)* and the Committee on Climate Change's UK Climate Change Risk Assessment *(CCC, 2017)*.

Projections for future climate conditions are extracted from the Met Office UKCP18 database which uses cutting-edge climate modelling methods to project future patterns in variables such as temperature and rainfall in the UK *(UKCP18, 2018)*.

Climate science is not exact. All of the sources used in this assessment help to provide an understanding of conditions and events that might be experienced in the future. However, all climate science and modelling is subject to assumptions, caveats and limitations that mean that no assessment can be considered as an absolute reflection or prediction of future conditions *(UKCP18, 2018)*. Furthermore, it should be noted that the UK climate projections (UKCPs) used in this assessment are extracted from a Met Office dataset of 25km grid square probabilistic projections. New data at a higher resolution will be available in the future.

As such, future conditions described in this assessment may be subject to change or refinement as new data becomes available.

Hazard scenario selection

As described above, in this assessment, we used climate projections under high and more likely emissions scenarios as the basis for the hazard and sensitivity analysis.

The UKCP18 climate projections used in this study are based on emissions scenarios according to Representative Concentration Pathway (RCPs). Typically, climate models are based on all four RCPs (2.6, 4.5, 6.0 and 8.5). However, for this study, we have used climate projections under RCP4.5 and

An RCP4.5 Bristol

An RCP4.5 Bristol reflects future conditions under an intermediate emissions scenario which assumes an increase in global temperatures of 2.4°C above pre-industrial levels by 2100. Under this emissions scenario, mitigation interventions are implemented to some extent but not with the rapidity or stringency of the RCP2.6 scenario *(IPCC, 2014)*. The 50th percentile data is where there is an equal chance that climate conditions will be either more or less extreme than those stated in the UKCPs (*Met Office, 2019a*).

An RCP8.5 Bristol

An RCP 8.5 Bristol reflects future conditions under a scenario which assumes that there are comparatively high greenhouse gas emissions brought about by rapid population growth and a high energy demand from fossil fuel dominance. This scenario is the highest of the RCPs, assuming an increase in global temperature of 4.3°C above pre-industrial levels by 2100.This is characterised by 90th percentile UKCP18 data where there is only a 10% chance that climate conditions will be more extreme than those used in the UKCPs (*Met Office, 2019a*).

2. Methodology

Hazard exposure

RCP8.5 to frame extreme and more likely future climate risks and impacts in Bristol. The choice of two distinct scenarios enables us to test resilience in a range of plausible futures, whilst retaining a simple framework commensurate with a preliminary assessment.

Globally, the most extreme impacts of climate change will be felt under an RCP8.5 emissions scenario, where little to no effort is made to abate emissions between now and 2100 *(IPCC, 2014)*. As such, 90th percentile climate projections (to demonstrate the upper limit of future conditions) under this emissions scenario have been used to assess the extreme potential impacts of climate change in Bristol.

The RCP4.5 intermediate emissions scenario represents an emissions pathway where mitigation interventions are implemented globally, though not as rapidly or stringently as demonstrated in the RCP2.6 scenario. This is reflective of current global trends in legislation, economic activity, energy use and lifestyle. As such, RCP4.5 50th percentile (to represent average conditions under this scenario) climate projections have been used to evaluate the more likely impacts of climate change in Bristol.

Flood mapping

In addition to climate change projections describing changes in ambient temperature, rainfall and sea level, we have used Bristol City Council's flood modelling and flood maps to consider future flood risk in the city.

For the flood mapping, provided by Bristol City Council, the previous climate projections (UKCP09) is used. This information has not been formally audited or verified.

Interacting risks

Bristol has already considered its key long-term challenges. The Bristol Preliminary Resilience Assessment, the baseline assessment for the city resilience strategy, identified 27 shocks and stresses for the city. (Figure 5, 100 Resilient Cities, 2015).

These are wider than just climate risk but highlight that both climate change and severe weather are key challenges for the city. These shocks and stresses can also hit the city at the same time or one can cause cascading impacts to others, demonstrated by Figure 4. This would cause cumulative impacts outside of the scope of this assessment.

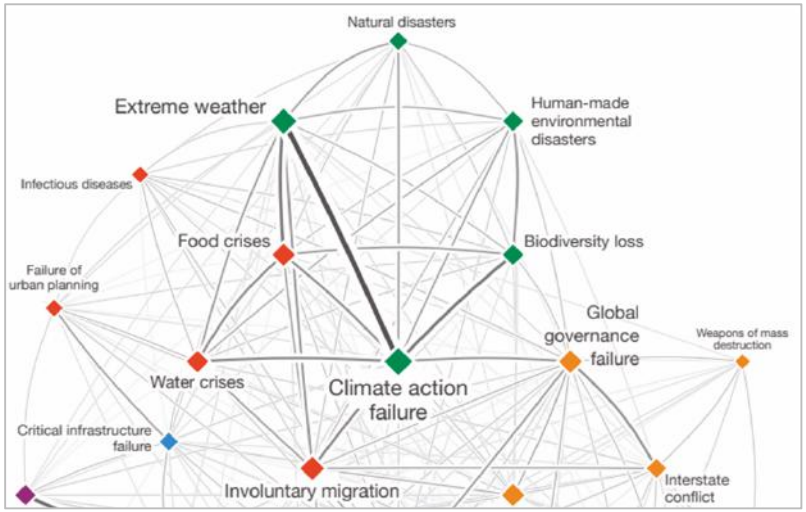


***Figure 4**. The interconnections between global risks, 2020. The thickness of the line relates to the strength of the interconnection (WEF, 2020)*

Shocks Relevant to Bristol

- Severe Weather (esp. flooding)
- Major Infrastructure Failure
- International Event
- Disease Outbreak
- Public Protest/Disorder
- Terrorist & Malicious Attacks
- Industrial Action
- Industrial Accidents, Environmental Pollution & Ordnance
- Transport Accidents
- Structural Hazard

Stresses Relevant to Bristol

- Climate Change
- Environmental Degradation
- Food Supply
- Water Shortages
- Health Inequality
- Transport Congestion
- Ageing Infrastructure
- Fuel Supply
- Change in Political Leadership
- Ageing Population
- Growing Unemployment
- Economic Downturn
- Population Growth
- Civil & Political Unrest
- Anti-microbial Resistance
- Devolution

***Figure 5**. Bristol's key shocks and stresses (100 Resilient Cities, 2015)*

2. Methodology

Hazard exposure

This section outlines our approach to hazard exposure evaluation. Bristol is projected to experience a number of different climate hazards in the future. We have chosen to focus on three of these hazards in this assessment. These are:

- Flooding and sea level rise
- Extreme heat, which includes heatwaves and impacts of an increased Urban Heat Island
- Drought, which is focused on meteorological drought but also considers the impact of water scarcity.

Extreme cold has also been considered as a hazard which will affect the city. However it is a climate hazard which is projected to decrease in occurrence. While the impacts have been assessed, it has not been of focus for our recommendations and conclusions.

There are other extreme weather events that may impact the city and variable weather patterns are still projected to occur. For example the climate projection models for storms in the UK still have very large associated uncertainties. We have therefore focused on severe weather where projections have a reasonable certainty around them (*CCC, 2017*).

Similarly, high wind events have not been considered as there are no compelling trends (based on maximum gust speeds) over the last four decades to project future trends (*Met Office, 2019e*). Wind tends to be impacted by small scale weather features and is as such difficult to project in large scale models.

For future climate exposure we have considered three future time periods, 2030, 2050 and 2080 (when today's current school children retire).

For 2050, we have also set qualitative ratings for the hazard exposure for the city of Bristol. This reflects the likelihood and certainty of each hazard occurring in the city and is based on the following assumptions:

Likelihood rating

The likelihood rating is focused on the impact to the people of Bristol.

- Low: This hazard is unlikely to occur and impact the city of Bristol.
- Medium: This hazard is projected to occur in Bristol.
- High: This hazard is very likely to occur in the city of Bristol.

Confidence rating

The confidence rating expresses the certainty of our understanding of this hazard occurring in Bristol in the future, and is defined as:

- Very certain: There is significant evidence and projection certainty for this hazard occurring in the city.
- More certain than not: There is some certainty in the hazard projections occurring in Bristol.
- More evidence required: More evidence is needed to provide some certainty to these hazard projections. Projections may be inconclusive or contradictory.

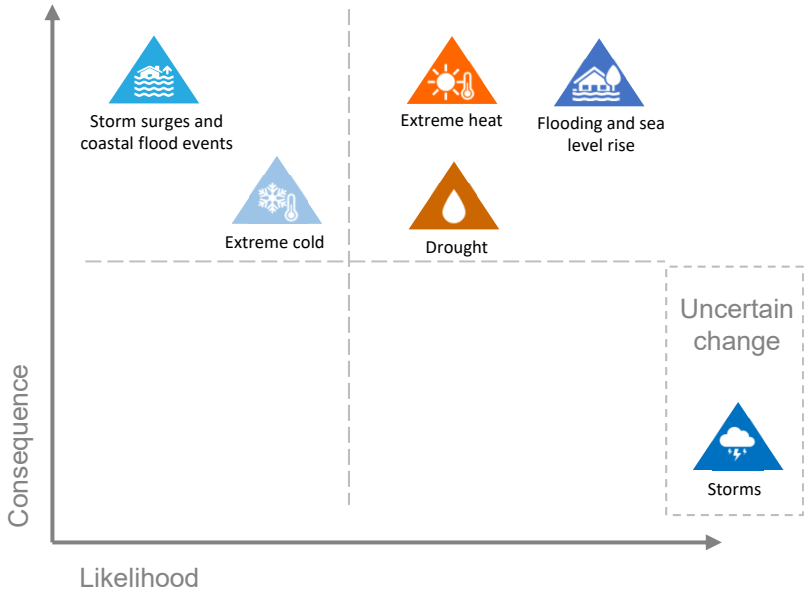


***Figure 6**. The project consequence and likelihood of future hazards in 2050 in an RCP8.5 Bristol (Met Office, 2019b)*

Hazard	Likelihood in 2050	Confidence
Extreme heat	H / M	More certain than not

***Figure 7**. An example of hazard exposure and confidence rating given to each climate hazard*

2. Methodology
Sensitivity of assets

As per the outlined approach to this assessment and in alignment with ISO14091, asset sensitivity is one of the three elements required to assess climate vulnerability.

This section sets out some of the key challenges to assessing sensitivity, and our approach developing a qualitative assessment, in line with the preliminary nature of this climate resilience assessment.

Asset sensitivity

Flood maps show areas of risk and asset exposure. These have been used to undertake a visual analysis of the likely sensitivity of assets in the city to flooding. It was outside the scope of this preliminary assessment to undertake detailed spatial analysis.

We recognise that the same spatial hazard representation has not been available for other hazards. Therefore, we have not conducted any spatial interpretation for other hazards.

Our approach regarding the sensitivity of assets have been made based on qualitative analysis of Bristol's assets, supported by research of national and international risk assessments, rather than through an evaluation of the direct sensitivity of individual assets in the city. This could be undertaken as a more detailed assessment in due course.

Assets and their physical manifestation

The physical nature of assets within groups such as transport, water, energy and buildings means that climate change induced impacts are much easier to assess. This is reflected in the greater level of detail presented in the physical asset sensitivity sections. Whilst we have evaluated and discussed impacts to socio-economic assets, we have, in some cases, used the physical manifestation of these systems as a proxy.

We recognise that further work would be needed to fully understand the extent and severity of climate change impacts on the less tangible social and economic systems in Bristol.

Interdependent systems

As the city is made up of complex interdependent systems, climate risks can have direct or indirect relationships between wider city assets and cause cascading shocks and stresses. Therefore, failure of an asset can cause impacts far beyond the directly impacted area, and the failure of assets geographically remote from Bristol can have knock on consequences for the city. For example, food supply networks and water availability outside the city boundaries could be affected by a climate event which would in turn impact availability of food and water in the city. Climate change impacts could also increase the likelihood of disease outbreaks elsewhere which could also affect the city's ability to function effectively.

The key shocks and stresses, from this preliminary resilience assessment for Bristol that relate to climate change are severe weather and climate change. These in turn can lead to other shocks and stresses.

For example, flooding of an electricity substation, causing its failure, could cause the failure of water treatment works and associated pumping stations. This failure would lead to water shortages in communities, which could have potential health implications.

If a severe weather event causes a transport hub to be inaccessible, either during the period of the event or subsequently due to damage, it would have an effect across the city. This can affect citizens' ability to travel through the city, impacting access to healthcare, education and businesses. This in turn can have an impact on the economic prosperity of the city, impact a community's quality of life and may disproportionately impact vulnerable people.

Any such interdependency analysis or assessment was outside the scope of this study.

It is recognised as a gap in the UK's national climate change risk assessment, and is an area where our collective understanding is growing all the time. In a future iteration of this assessment, it may be possible to carry out a more comprehensive assessment of this nature.

2. Methodology

Sensitivity of assets

We have applied a qualitative assessment for the three hazards that are projected to get significantly worse in the future - flooding, extreme heat and drought and included the potential impacts on both assets and the people of Bristol.

Extreme cold is projected to be less prevalent in the future, but may still occur. We have therefore included the potential impact on the assets and citizens of Bristol in this section but have not included a sensitivity score.

The overall sensitivity score (low, medium or high) of an asset is a combination of the likelihood of an event of condition occurring with the severity of consequence or impact it will have on the related asset. The likelihood of a hazard occurring has been established through the hazard assessment described previously. The description that follows explains the approach to rating the consequence of hazards on different assets groups.

Consequence rating

The consequence rating is focused on the impact to the people of Bristol in the future, focusing on the year 2050.

- Low: There is projected to be limited impact to the people of Bristol. There may be some disruption to current functioning of the city, but these will be minor or very localised. For example, this might be failure in short-term waste collection leading to unpleasant smells or short-term lack of access to cultural facilities.
- Medium: There is projected to be some impact to the people of Bristol. This may be experienced as localised disruption or some danger to human health and wellbeing. For example, this could be failure of a community's water supply or short-term inaccessibility of education establishments.
- High: There is projected to be significant impact to the people of Bristol. This may be experienced as severe and widespread disruption or significant dangers posed to citizens. For example, this could be city wide gridlock of the transportation system or the potential for severe injury or death.

Confidence rating

The confidence rating is defined as the certainty of this consequence occurring to the city of Bristol in the future, 2050. It is the same as the certainty for hazard exposure and is defined as:

- Very certain: There is significant amounts of evidence for the impact occurring in Bristol. This will be based on Bristol specific evidence or high certainty data for the UK.
- More certain than not: There is some certainty that the impact may occur in Bristol. There is evidence for this impact but it may be based on UK or international data, but is not Bristol specific or high certainty.
- More evidence required: More evidence is needed to provide some certainty to these impacts. There is limited or conflicting evidence for this impact.

Hazard	Consequence in 2050	Confidence
Flood	M	More certain than not
Extreme Heat	M	More certain than not
Drought	H	Very certain

Figure 8: *An example of asset consequence and confidence rating against each of the three physical hazards considered in this assessment*

Hazard/sensitivity rating

In the previous section, a rating was determined for hazard exposure, which reflects the likelihood of a hazard occurring. If we combine the consequence rating and hazard likelihood rating we can create an overall hazard/sensitivity rating for each asset group. This rating describes the overall hazard/sensitivity score based on the matrix in Figure 9.

This hazard/sensitivity matrix highlights the additional focus on high consequence events. This supports increased resilience through the prioritisation of high consequence events, in spite of low likelihood due to the severe impact it could potentially cause.

A summary of asset hazard/sensitivity scores for physical, social and business/economy assets can be found in Tables 1, 2 and 3 respectively while individual asset consequence ratings are given in each respective asset group assessment.

It should be noted that these overall assessments to note account for the confidence ratings for either the hazards or for the consequences. This helps to provide a simple framework for assessment, but has clear limitations.

		Consequence		
		L	M	H
Hazard Likelihood	L	L	M	M
	M	L	M	H
	H	L	H	H

Figure 9: *The hazard/sensitivity matrix*

3. Bristol's climate hazard exposure

Flooding and sea level rise

Bristol is exposed to the tides of the Bristol Channel and the Severn Estuary. Flooding is one of the key risks to the city in the future, that could have extreme consequences.

In an RCP8.5 scenario, the sea level around Bristol is projected to rise by over 70cm in the next 60 years (*Met Office, 2019b*). Sea level rise in the south of the UK is projected to be more severe than the rest of the UK due to land movement. In a more moderate RCP4.5 scenario, sea level is still projected to rise by over 40cm in the same time frame (*Met Office, 2019b*). Combined with exposure to strong tides, sea level rise may pose a significant flood hazard to the city, its infrastructure and its communities.

Winter precipitation is projected to increase, meaning milder and wetter winters in Bristol. Under RCP8.5 scenario winter precipitation could increase by up to 50% by 2080 (*Met Office, 2019b*).

Though summers are expected to be drier and hotter on average, there is also an increased probability of storm surge and intensity of summer rainfall events.

This considerable increase of winter rainfall and a change in pattern of summer rainfall events exposes Bristol to fluvial (river) and pluvial (rainfall) flood risk of both greater extent and frequency of occurrence. Given the projected impacts of climate change on precipitation and sea level rise, flooding is considered to be the greatest physical hazard facing the city.

The greater the duration of a flooding event, the greater the impact on the city. For example, where a flood event impacts transport infrastructure, access to facilities, such as healthcare, or the movement of supply chains would greatly be impeded. This has knock on effects on the population's way of life, which would only increase in severity with duration.

	RCP4.5	RCP8.5
By 2050, winter precipitation rate in Bristol is projected to increase by up to	↑9%	↑28%
By 2080, sea level on Bristol's coastline is projected to increase by up to	↑+42cm	↑+72cm
By 2080, winter precipitation rate in Bristol is projected to increase by up to	↑17%	↑48%

Hazard	Likelihood in 2050	Confidence
Flood	H	Very certain

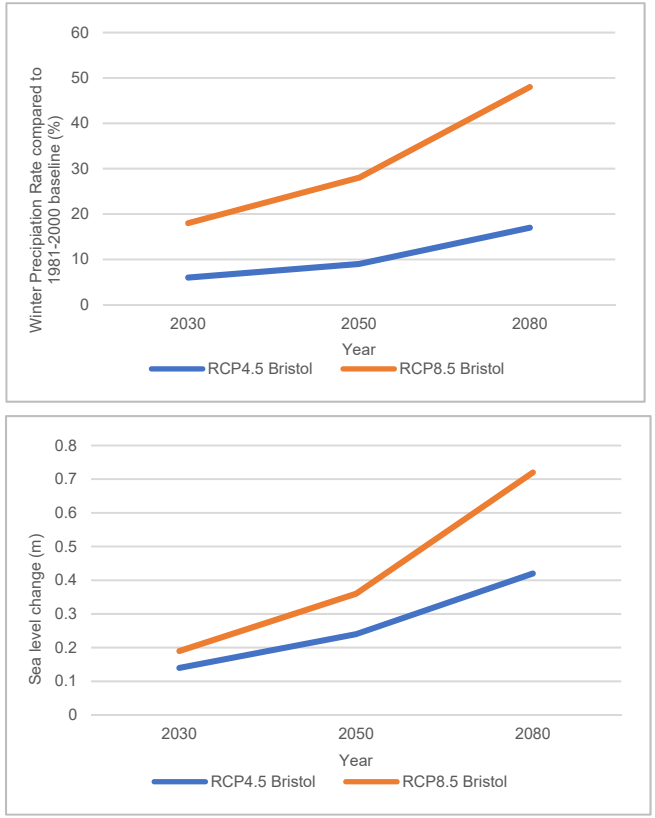


***Figure 10**. Illustrative winter precipitation and sea level change predictions for Bristol*

Historic hazard case studies:

- 2007 Flooding events, UK. Flooding inundated 40,000 hectares of land, causing £50 million worth of agricultural damage (*DEFRA, 2010*).
- The flooding in England and Wales in 2013/2014 caused £230- £310 million in total damages to businesses, with an average of £82,000 in damage per business asset (*CCC, 2017*).
- Flooding in Thailand in 2011 impacted the international hard drive market causing prices to double (*CCC, 2017*).

All of these different impacts could affect Bristol in the future.

Flooding and sea level rise

We have used Bristol City Council's flood modelling and flood maps to consider the specific areas of Bristol that may be impacted by flooding now and in the future.

These flood maps consider a flood which is a combination of fluvial river flows, pluvial rainfall and tidal projections for present day and 2080.

The maps in Figures 11a and 11b represent 1/200 year tidal flooding events and 1/100 year fluvial and pluvial events. They use UKCP09 data with a scenario of RCP 8.5 and 90th Percentile. This is equivalent to our RCP8.5 Bristol by 2050 scenario, using previous data.

These maps include take into account the protective impact of future proposed flood defences at Avonmouth, Floating Harbour flood gates, Cumberland Road Flood Wall, Totterdown flood wall, Eastville Sluices, Malago and Brislington Brook relief tunnels.

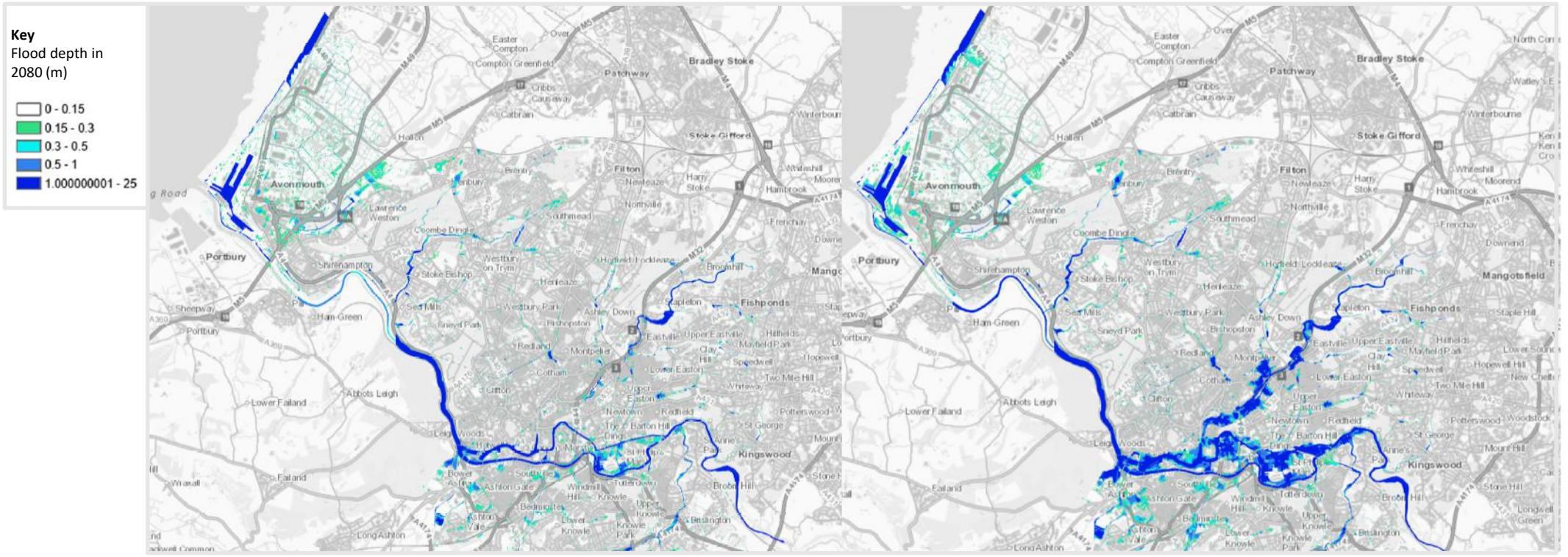


Figure 11a. *Present day flood extent map (BCC 2020)*

Figure 11b*. Flood extent map for Bristol by 2080 when today's school children retire (BCC,2020)*

3. Bristol's climate hazard exposure

Hazard	Likelihood in 2050	Confidence
Extreme heat	H/M	More certain than not

Extreme heat

Extreme heat is defined as two or more consecutive days where the maximum daily temperature exceeds 30°C.

Over the last 10 years, Bristol has experienced maximum temperatures ranging between 29.2°C – 34.1°C (*Bristol Weather, 2018*).

The UKCP18 data projections show that the frequency of hot spells or extreme heat conditions is projected to rise from occurring once every four years (in the period 1981-2000) to approximately four times a year by 2070.

Hotter summers are expected to become more common: by 2050 there is a 50% chance of summers as hot as 2018 (the equal-warmest summer on record). In 2080, the maximum summer temperature in Bristol is projected to be over 9°C hotter than in the baseline period (*Met Office, 2019b*).

An extreme heat event is likely to have greater impacts over a longer duration in particular where it affects food and water supplies and impedes the ability of the population to function.

	RCP4.5	RCP8.5
By 2050, summer maximum temperature is projected to increase by over	+2.2°C	+4.9°C
By 2080, summer maximum temperature is projected to increase by over	+3.5°C	+9.2°C

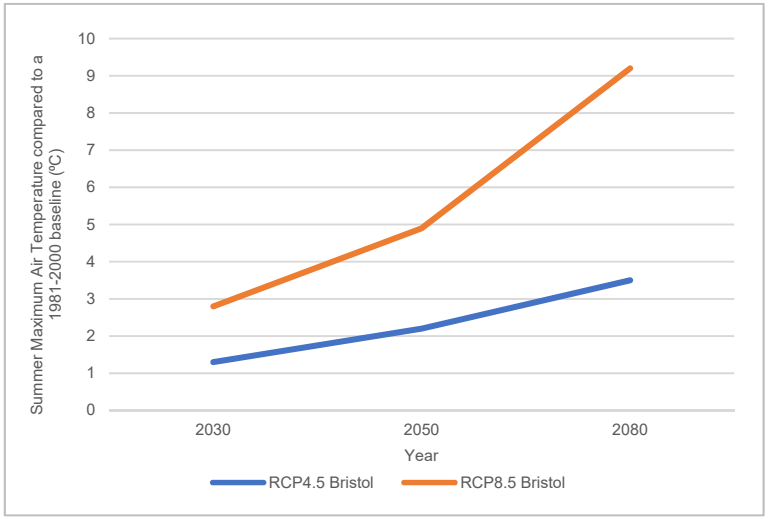


Figure 12: *Illustrative projected change in summer maximum air temperatures in 2030, 2050 and 2080 compared to a 1981-2000 baseline (Met Office, 2019b)*

Historic hazard case studies: 2018 heatwave

- In 2018, rail services in Bristol were disrupted due to high temperatures (ITV, 2018).
- The hot weather over summer 2018 caused difficulties for UK farmers who had to request support from the UK government (*Arup, 2019*). This caused significant increases in vegetable prices (the cost of onions increased by 41% between March and July).
- Dairy production also suffered in the summer of 2018 from reduced grazing and dairy cows were impacted directly by the hot weather reducing milk yields (increasing butter prices by 24% between March and July). As a whole, this period of hot weather was thought to increase wholesale food prices by 5%, estimated to cost UK consumers £45 million per week (*CEBR, 2018*).

The likelihood of the city experiencing another summer like this by 2050 is 50%.

3. Bristol's climate hazard exposure

Hazard	Likelihood in 2050	Confidence
Drought	H / M	More certain than not

Drought

There are many different types of drought but here we are focusing on meteorological drought. This is defined in the UK as 15 or more consecutive days where precipitation does not exceed 0.2mm (*WO, 2019*). This only considers projected changes in precipitation and does not consider changes in water demand.

In the last 10 years, maximum annual consecutive days of no rainfall in Bristol have ranged in length from 12 – 22 days (*Bristol Weather, 2018*).

Summer precipitation is projected to decrease under all emissions scenarios. UK climate projections suggest that the rate of summer precipitation could decrease by 26-68% between now and 2080 (*Met Office 2019b*).

The realisation of this change would significantly increase the risk of drought in Bristol. Though drought conditions are defined by level of rainfall, the impacts of drought are exacerbated by extended periods of hot temperatures. More frequently occurring hot and dry periods also provides less opportunity for post-drought recovery.

Given the projected changes in precipitation rates and maximum temperature increases, drought is considered to be a substantial risk to Bristol during the summer months.

This means hotter, drier summers in Bristol which over the longer term would have greater effects on the ability of the city and its citizens to function.

	RCP4.5	RCP8.5
By 2050, summer precipitation rate in Bristol is projected to decrease by up to	↓ 18%	↓ 45%
By 2080, summer precipitation rate in Bristol is projected to decrease by up to	↓ 26%	↓ 68%

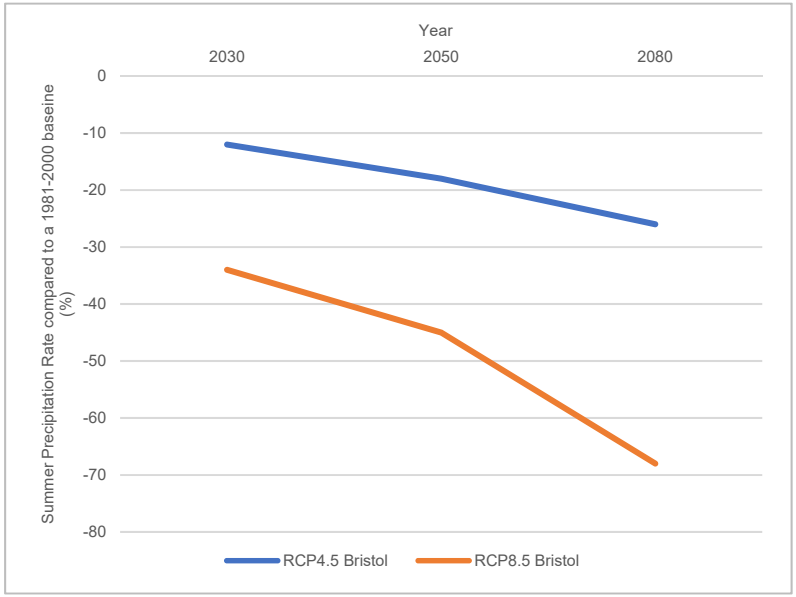


Figure 13: *Illustrative projected change in summer precipitation in 2030, 2050 and 2080 compared to a 1981-2000 baseline (Met Office 2019b)*

Historic hazard case studies: Cape Town Day Zero

- In Cape Town's drought between 2015-2018, the city contemplated turning off parts of the reticulation system (a network of pipes used in irrigation and water supply). This prospect became known as Day Zero. Preparations for Day Zero included collaborative planning for the emergency response that would be required. (*100 Resilient Cities, 2019*).
- As an example of the potential impact, the city of Cape Town's Day Zero preparations had the business community preparing for an extreme scenario, recognising the impact on their supply chains and employees (*100 Resilient Cities, 2019*).

This may be more extreme than we expect to see in Bristol, but the knock on impacts of drought across society and economy should not be underestimated.

3. Bristol's climate hazard exposure

Extreme cold

Extreme cold from a public health point of view are temperatures below 2°C (*PHE, 2018*). An extreme cold day for physical assets could be defined as a day with sub-zero temperatures as low as -3°C. This is the temperature defined by the Community Risk register (*LRF, 2014*), which may impact the rail services (*Network Rail, 2018*) and at which building design technical standards rate extreme for heating systems (*ASHRAE, 2017*).

Though the influence of the Atlantic Ocean keeps Bristol's air temperature above freezing for most of the year, freezing temperatures and winter frosts do occur.

The last 10 years in Bristol have seen minimum temperatures as low as -7.5°C (*Bristol Weather, 2018*). This means that even if the most extreme average winter temperature increase of 4.8°C is realised by 2080, extreme cold conditions may still be observed (*Met Office, 2019b*).

Given the impact that extreme cold can have on infrastructure, communities and businesses, it is considered a hazard for the city.

Though the risk of extreme cold days is projected to decrease over time, days of extreme cold are still likely to occur and the impact of these conditions on assets should still be considered.

Storms and high winds

In general, it is expected that the frequency and intensity of storms and storm surges is likely to increase due to climate change. This is largely influenced by increasing oceanic and ambient temperatures causing a shift in the concentration of water vapour in the atmosphere and patterns of marine and wind currents *(IPCC, 2014)*.

Storms, storm surges and high winds can have potentially significant impacts on physical assets by causing issues such as power outages, damage from fallen trees and contribution to flooding *(CCC, 2017)*. Storms, storm surges and high winds are particularly difficult to predict given their dependence on a large number of conditions, especially when discussing conditions in 2080 *(UKCP18, 2018)*. As such, this hazard has not been directly addressed on an individual asset group basis (storm surges are partly addressed through coastal flooding).

However, it is recognised that steps must be taken to improve the city's resilience against storms across all asset groups. Similarly, it is recommended that a more detailed study is undertaken to address the city's exposure to storm hazards.

	RCP4.5	RCP8.5
By 2080, minimum winter temperatures are projected to increase by	↑1.9°C	↑5.2°C

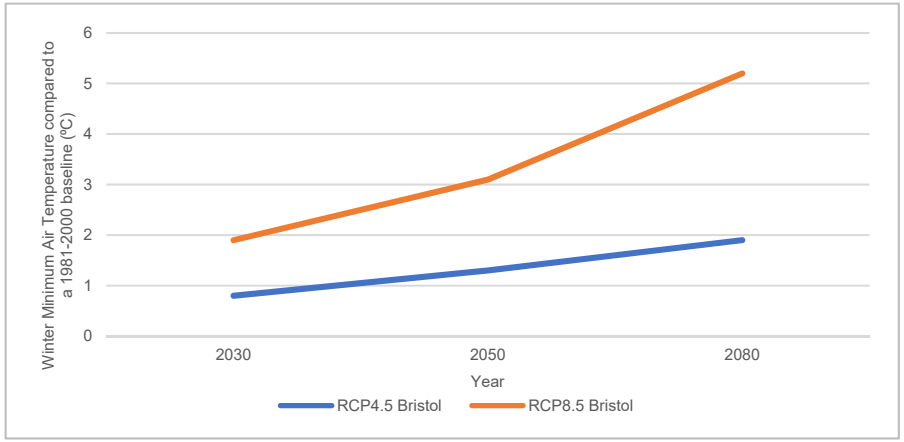


Figure 14: *Illustrative projected change in winter minimum air temperature in 2030, 2050 and 2080 compared to a 1981-2000 baseline (Met Office 2019b)*

Historic hazard case studies: Beast from the East, 2018

- Bristol and the rest of the UK was hit by freezing conditions in early 2018.
- Travel was disrupted across the UK, causing disruption to road, rail and air travel. March 2018 saw Bristol Airport being close temporarily and roads were closed with police advising avoidance of routes in the West of the UK. The Severn Bridge partly closed due to high winds. Trains were delayed and cancelled with South Western Railway reported freezing temperatures were causing many point failures (BBC, 2018).
- Schools across Bristol were also forced to close for two days (Bristol Post, 2018)

While the overall risk of extreme cold may decrease we may still experience extreme cold periods.

4. Bristol's key city assets

We are focussing on three key asset types: physical, social, and business and economy. A breakdown of the asset groups within this is shown below.

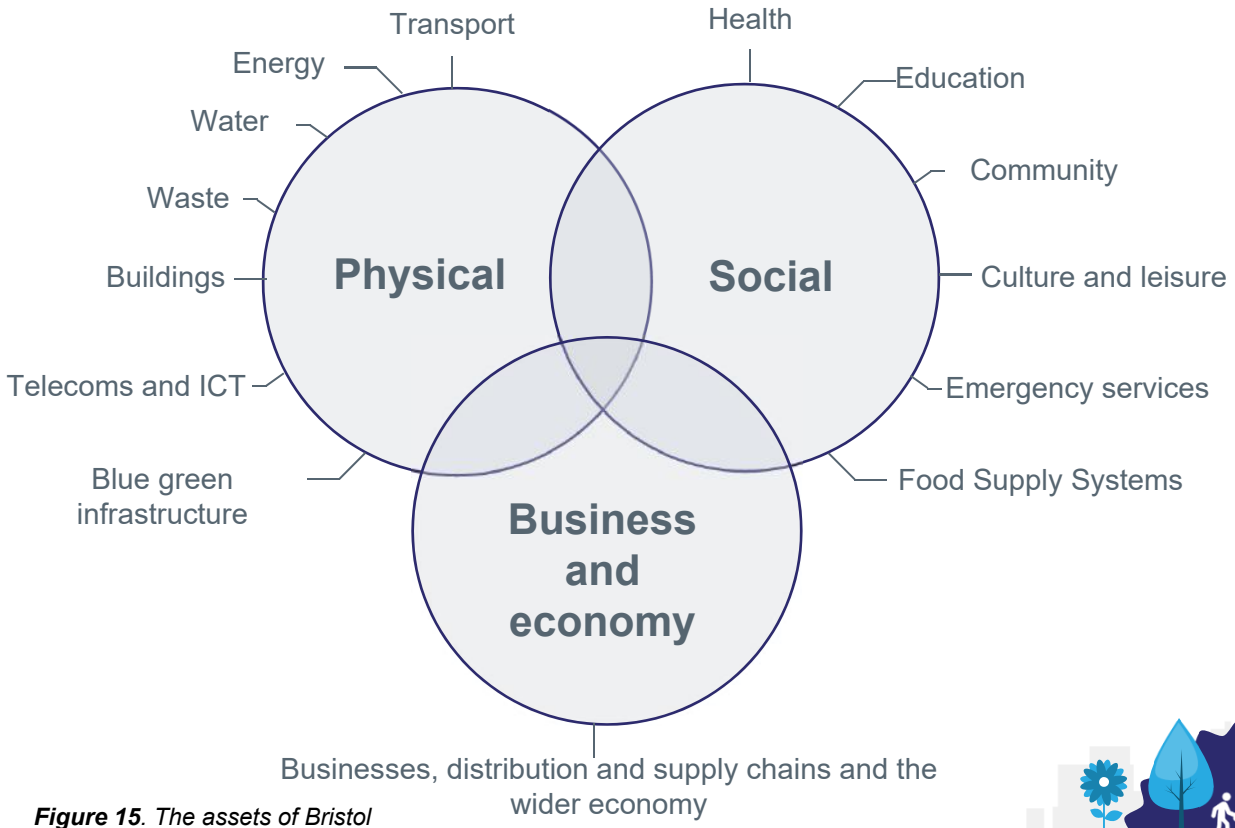


***Figure 15**. The assets of Bristol used for this assessment*

Physical assets

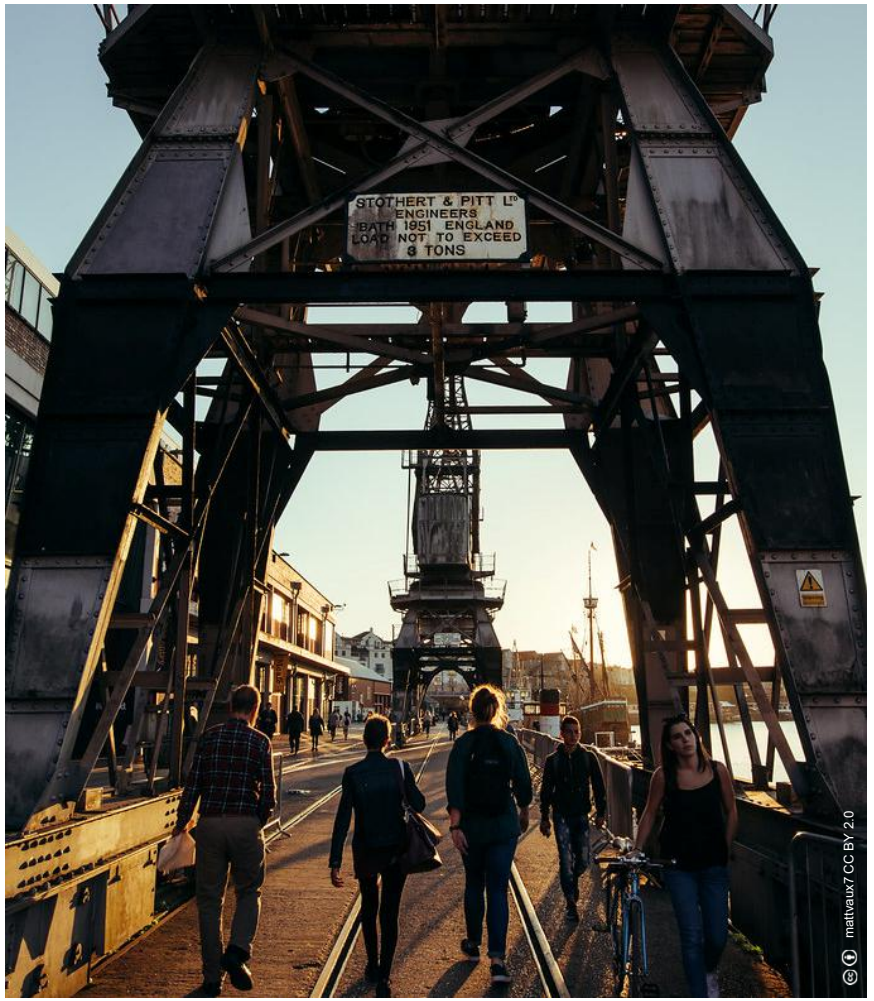
Physical assets cover the grey, green and blue infrastructure and buildings across the city. We have considered the following asset groups in this section:

- Transport
- Energy
- Water
- Waste
- Buildings
- Telecoms and ICT
- Green Infrastructure

Table 1 provides a summary of the sensitivity of the physical assets, with more detail in the pages that follow.

Physical asset	Flood	Extreme Heat	Drought
Transport			
Energy			
Water			
Waste			
Buildings			
Telecoms and ICT			
Green Infrastructure			

***Table 1**. The hazard / sensitivity rating of the physical assets to each of the key hazards.*



5. Physical assets

Transport

Hazard	Consequence in 2050	Confidence
Flood	M	More certain than not
Extreme Heat	M	More certain than not
Drought	M	More evidence required

Introduction

Transport networks are key to support Bristol citizens' access to vital facilities and to support the local economy. When extreme weather causes disruption to this network it can cause knock on effects across the city by preventing access, which in turn could have significant impacts for the operation of the city and the wellbeing of its citizens.

Bristol has an extensive portfolio of transport assets, comprising infrastructure, fixed assets and rolling stock. Transport infrastructure in Bristol includes a complex network of roads, cycle lanes, railways and public footpaths. Highways England has ownership and control over the portions of the M32 (11.5km), M49 (4.7km) and M5 (17.4km) that fall within the Bristol local authority boundary. All non-motorway roads fall under the responsibility of Bristol City Council.

There are six major bridges used for transport in Bristol and many other smaller bridges. Ownership and operation of these assets is governed by the classification and use of the bridge (e.g. rail bridges are controlled and owned by Network Rail and Avonmouth Bridge is controlled and owned by Highways England).

All 15 train stations and eight railway lines in Bristol are managed by Network Rail with major service operators (and owners of relevant rolling stock) including Great Western Railways, CrossCountry and South Western Railways. Network Rail also owns and operates a portfolio of rolling stock for operations and maintenance purposes. There are two park and ride hubs within the Bristol boundary: Portway (operated by Wessex Bus and First West of England) and Bath Road (operated by First West of England).

There are ten major bus routes in Bristol, each with a series of bus stops and used by rolling stock operators including MetroBus, First West of England, Travel West, National Express, Bristol Airport Flyer, ABus, Megabus and Stagecoach South West. The Bristol bus and coach station is operated by First West of England and is the only major coach station in the city. National Cycle Routes 3 and 4 run through the city. Both are maintained by Sustrans. Privately owned transport assets include individual private vehicles (1.04 cars are owned per household (*BCC, 2019b*)), car clubs (enterprise city car club, zipcar and co-wheels), YoBikes (docks and bicycles),and car parks (some owned and operated by Bristol City Council).

Sensitivity

Transport networks include multiple transport modes, which are reliant on each other to provide multi-mode journeys and allow supply chains to run smoothly (*CCC, 2017*). An extreme climate hazard event could result in major disruption over the short to medium term resulting in knock-on effects to the health and wellbeing of the population and the economy.

Future flood extent maps indicate that various transport assets are projected to be impacted by flood events. Roads, railway lines and cycle lanes run through both current and future flood zones. In particular, major transport hub Bristol Temple Meads railways station is projected to be impacted by flood by 2080. This flooding is also projected to impact roads in the city centre such as Cumberland Road, Victoria Street, Baldwin Street and Prince's street. In the northwest, railway lines and stations (Avonmouth and Sea Mills) that follow the Portway are projected to be impacted by flooding. The Portway itself, Hotwells and other major routes into the city in that area may also be impacted by flooding.

Extreme heat directly impacts transport infrastructure. For example, in high temperatures the steel tracks of railways expand causing buckling, leading to safety risks and delays (*Network Rail, 2012*). Road tarmac can rut and soften during hot weather. This was predicted to occur in extreme high temperatures in summer 2019 although this did not happen. Additionally, the risk of subsidence may increase, affecting transport infrastructure foundations and causing potential damage (NERC, 2015). In 2018, rail services in Bristol were disrupted due to high temperatures (*ITV, 2018*). With projections set to see temperatures increase further in the next 60 years, these instances of transport disruption and asset damage are likely to occur more frequently without adaptation action. Overheating of rolling stock such as buses and trains during periods of extreme heat can cause safety concerns for both function of the assets and passengers.

Drought conditions do not necessarily impact the ability of transport systems to function. However, extended periods of dry conditions may impact the structural integrity of foundations and earthworks increasing the risk of collapse or landslips (*NERC, 2015*). For example, 8% of the UK transport network is at risk of landslide disruption (*CCC, 2017*). This risk is particularly pertinent for high retained walls such as those in the Avon Gorge.

Extreme cold conditions and cycles of freeze-thaw can impact the stability of earthworks and embankments that support transport infrastructure (*CCC, 2017*). Furthermore, freeze-thaw can cause road surfaces to buckle and crack, exacerbating the extent of potholes and increasing the need for maintenance. Warming winter temperatures are likely to decrease occurrences of significant freeze thaw, thus relieving some pressure on maintenance and repair of major infrastructure assets.

The disruption of one transport mode, can impact the functionality of the network. This in turn can have a knock on effect to other sectors in the city, impacting productivity and causing isolation. Weather disruption often effects multiple transport modes, so substitutions of alternative modes may not always improve the resilience of network and critical weakness in the network can cause wide impacts (*CCC, 2017*).

5. Physical assets

Energy

Introduction

The energy system is vital to provide Bristol with power for homes, businesses and public services. Many sectors and other infrastructure assets rely on a continuous supply of energy for their continued function.

The gas transmission network is owned and controlled by National Grid Gas Transmission. The only portion of the National Grid gas transmission network that crosses the Bristol local authority boundary is near the Seabank Power Station and Avonmouth energy recovery centre in the northwest corner of the local authority boundary.

National Grid Electricity Transmission operates the electricity transmission network in Great Britain. Physical assets within these networks include: underground cables, masts, substations and overhead lines of varying voltages.

Western Power Distribution control electricity distribution for the midlands, south Wales and the south west (including Bristol). Within the city of Bristol local authority are 17 substations and one power station (*BCC, 2019a*). Physical assets also include electricity distribution cables.

Wales & West Utilities control gas distribution within Bristol and the wider south west region. The physical assets in their network consist of underground distribution pipes.

Power generation infrastructure in Bristol includes the Seabank Power Station (SSE and CK Infrastructure Holdings Ltd), Avonmouth Energy Recover Centre (Viridor) and privately owned, small-scale solar energy generation (individual panels on private roofs etc.). There are four turbines at Avonmouth (Thrive Renewables) as well as a growing heat network in the City, owned and operated by Bristol City Council.

Sensitivity

The energy system is designed and operated under a range of weather conditions experienced in the UK. However, extreme weather events exceed these design standards and could result in disruption and long-term chronic changes which impact the long term performance of the energy systems (CCC, 2017).

Flooding is considered a key risk for power stations and substations. In the UK 18% of power stations are within flood zones (*CCC, 2017*). High-level analysis of flood mapping indicates that the two power stations in Bristol do not fall within the impact zone of a 2080 1/200 flood. However, a number of substations do fall within the flood zone such as Feeder Road 33kv and Feeder Road B. Should the mapped flood event occur, inundation of these substations could impact power distribution within the city, having a knock on effect for emergency service, residents and businesses.

There may be direct impacts to energy as a result of extreme heat. Hot conditions pose a risk of overhead power lines sagging and impacting the performance of mechanical and electrical systems that are sensitive to temperature (*CCC, 2017*), and potential issues with subsidence impacting pylons and underground cables and pipelines (*NERC, 2015*). Extreme heat conditions projected to impact the city by 2050 may also place increased demand on Bristol's energy supply where air conditioning or refrigeration systems are in place e.g. supermarkets, hospitals and schools.

Drought does not pose a direct impact on the function of energy assets but may impact the structural integrity of supporting earthworks and foundations. Low rainfall can disrupt earthworks, causing shrink/swell around pipework and pylons (*NERC, 2015*). While there is no large energy generation in our study area, water scarcity can impact energy generation and the subsequent access to energy across the city (*CCC, 2017*).

Hazard	Consequence in 2050	Confidence
Flood	M	More certain than not
Extreme Heat	M	More evidence required
Drought	L	More evidence required

Cold temperatures can have direct impact on energy infrastructure by snow and freezing rain impacting powerlines. The most significant impact of cold weather events is not on the physical infrastructure but is caused by the increase in domestic demand for power which can impact the availability of energy supply in Bristol.

Disruptions to the energy systems can have knock on impacts across the city. These can be direct, for example causing lack of heating for elderly residents in the city, or indirect by removing supply to a water treatment works, causing cascading impacts in the water system or impacting the ability to operate flood gates. It should be noted that some organisations, such as the City Docks, may have response procedures for these occurences.

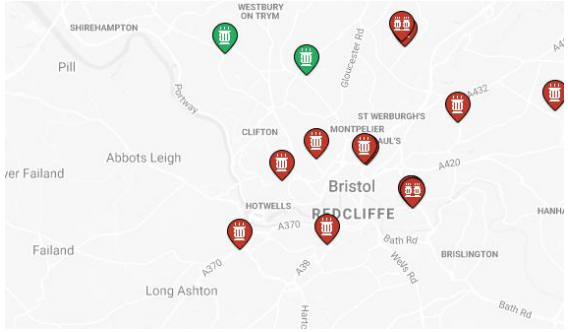


Figure 16: *Electricity distribution substations in Bristol showing network constraints. Red icons show substations where connections may be possible but there might be a requirement for significant network reinforcement (WPD, 2019).*

5. Physical assets

Water

Hazard	Consequence in 2050	Confidence
Flood	M	More certain than not
Extreme Heat	M	More certain than not
Drought	H	Very certain

Introduction

Water is a basic human need and access is vital for all, especially for vulnerable citizens. Bristol Water and Wessex Water operate and maintain the water and waste water supply assets respectively in Bristol.

Bristol's drinking water is provided by Bristol Water and assets include water sources, water treatment works, pumping stations, service reservoirs, water towers and water mains. No water treatment works or pumping stations fall within Bristol city's boundaries. Much of Bristol's potable water is from outside Bristol, shown in Figure 17.

Wastewater assets, run by Wessex Water, include underground sewers, sewage treatment works and sewage pumping stations. Within the Bristol boundary there is one sewage treatment station.

Water and waste water pipes and connections that fall within private property boundaries are under the responsibility of the respective property owners.

With a coastal border and rivers running through the city centre, Bristol also hosts water assets and infrastructure such as Avonmouth Docks, Royal Portbury Docks, Bristol Floating Harbour and Bristol Marina. These infrastructure assets host ferry terminals, import/export distribution centres, museums, cultural centres and various privately owned businesses and homes.

Other water assets in Bristol include a network of rivers and waterways, a portion of coastline on the northwest border of Bristol, sustainable urban drainage systems and storm overflows. Bristol Water supply zones and sources are depicted in Figure 17. The quality and health of water assets in Bristol are closely linked to the prevalence and health of green infrastructure (GI) assets. By improving drainage and protecting against extreme heat and subsidence, GI can support a more resilience network of water assets.

Sensitivity

Rainfall and evapotranspiration are climate sensitive processes and therefore the amount of water available can be impacted by climatic changes, with wider reaching effects on the health of the population and the infrastructure it depends on.

Flood mapping suggests that for a 1/200 flood in 2080 no water or wastewater treatment works fall within the flood impact zone. However, flooding can place great stress on water and waste water networks by overloading pipes and stormwater storage beyond capacity. This is particularly true in Bristol where the flood zone covers a densely built up area of the city where surface water flow is high and natural drainage low.

An increase in temperatures may cause direct impacts to water infrastructure through increasing the risk of subsidence on engineered slopes and foundations which could impact assets such as flood defences (*CCC, 2017*). High temperatures can also impact the level of water treatment required, increasing the release of pollutants, like soil nutrients and dissolved organic carbon into water courses and reducing water quality (WW, 2018). Generally, high temperatures place a greater demand on the water supply system due to higher consumption of the public.

Drought can cause impacts to the availability of water resources and can decrease water quality by reducing the dilution of pollutants. This places increased demand on water resources and water supply and treatment infrastructure (WW, 2018). Drought may also disrupt earthworks, potentially causing pipes to dislodge or get damaged (*NERC, 2015*). Should drought cause water course levels to significantly deplete and prohibit navigation, boats and businesses that rely on the water ways may be impacted (*CRT, 2019*).

The combination of freezing temperatures and demand on water supply systems can lead to greater occurrences of pipe bursts and supply interruptions (*Bristol Water, 2018*). With aging assets, this risk increases due to the depreciating structural and material integrity of water and waste water distribution assets.

Disruption to water infrastructure can have significant impact on residents, communities and industry that rely on continuous access to water. A lack of water can affect vulnerable people the most. Interruptions to water supply can be caused by drought or supply network damage through flooding, subsidence or freeze thaw.

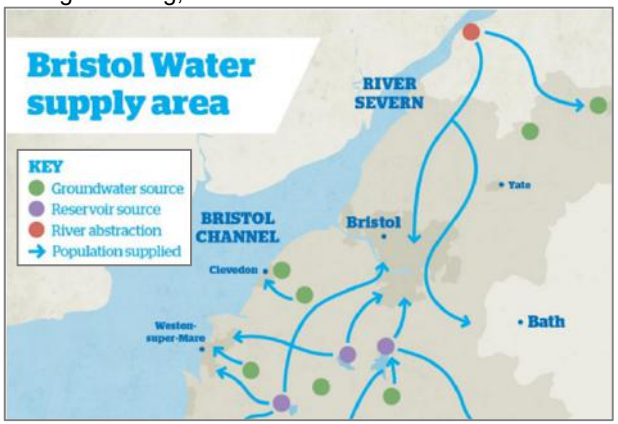


Figure 17: *Bristol Water's supply zones (BCC, 2018b)*

5. Physical assets

Waste

Introduction

Waste systems are key to reducing pollution and contamination of air, soil and water and reducing disease carrying pests. Therefore, preventing negative impacts to human health, and the natural environment (*CCC, 2017*).

The greatest density of waste management assets in Bristol is in the Avonmouth area. This industrial area hosts recycling centres, collection hubs, energy recovery plants and specialist plants for removal and disposal of hazardous waste associated with major infrastructure developments. These sites are:

- Veolia waste management
- Bristol and Avon Transport and Recycling Ltd (specialist construction waste collection, recycling and disposal)
- SUEZ recycling and recovery (two other sites are also located in Blackfriars and St Philip's)
- Bristol Waste's household waste recycling centre (Bristol Waste's only other household waste recycling centre is in St Philip's)
- Biffa waste management plant
- GENeco bioresources and renewable energy park (collection, treatment, recycling and disposal of food waste, liquid waste and compost)
- Viridor waste-energy recovery facility

In the wider local authority area, Bristol Waste operates three street cleansing depots (Hartcliffe Way, Albert Road and Lewin's Mead). There are 42 recycling banks spread throughout the city with a concentrated mass around the city centre and in the residential areas along the north and eastern boarders with South Gloucestershire (*BCC, 2019a*). Each of the organisations operating in this region of Bristol also own and operate a portfolio of rolling stock to support collection and disposal of waste. No landfill sites fall within the Bristol local authority boundary.

Sensitivity

An effective waste management city is essential to ensure citizen wellbeing and remove potential public health hazards. A failure in this system may put the citizens of Bristol at risk.

2080 flood mapping suggest that transport routes leading to and from Avonmouth could be slightly impacted by flooding. However, fluvial flood risk may directly impact some of these waste management facilities such a Veolia waste management and Bristol and Avon Transport and Recycling Ltd as they are located in the EA's flood zone 3, see Figure 18 (*BCC, 2018a*). Therefore, the function of Bristol's largest concentration of waste infrastructure could be directly impacted. This could impose potential long term impacts (due to recovery time) on waste management in Bristol. Flood zones in the city centre indicate that Bristol Waste depot in St Philip's (Albert Road) and Broadmead (Lewin's Mead) could be impacted by a 2080 1/200 flood (BCC, 2020) Additionally, approximately four recycling banks could be impacted by the same flood extents. Given the number of recycling banks in the city, flooding of a small number of banks is unlikely to impact the ability of citizens to recycle using these small depots. However, collection of waste from the city centre recycling banks may be hindered by flooding.

There are few likely direct impacts of waste infrastructure in extreme high temperatures, though waste may become odorous in high temperatures and require more frequent collection. There may be indirect impacts from failures across other interconnected systems.

There are few likely direct impacts of drought conditions, however there may be some impacts of subsidence causing indirect impacts from failures across interconnected systems.

Hazard	Consequence in 2050	Confidence
Flood	M	More certain than not
Extreme Heat	L	More evidence required
Drought	L	More evidence required

There are few likely direct impacts of extreme low temperatures, however there may be indirect impacts from failures across other interconnected systems such as the impact of icy roads on waste collection.

Disruption of other infrastructure causes impacts to the waste systems, especially the energy and transport systems. Also, disruption of waste systems can impact other systems such as energy from waste assets (*CCC, 2017*) like the Avonmouth Resource Recovery Centre.

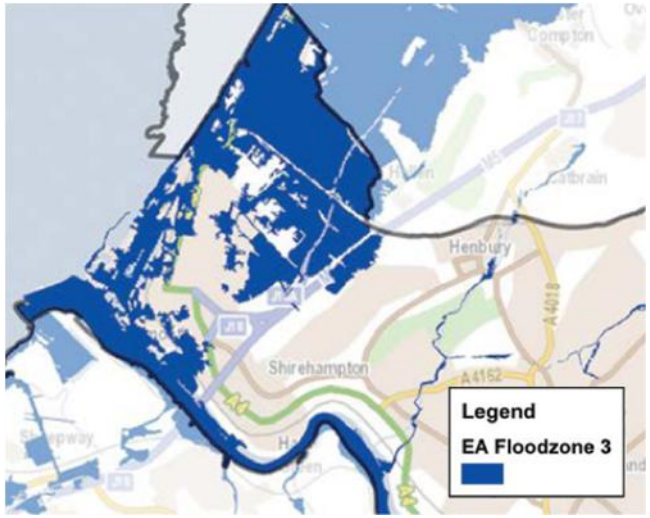


***Figure 18**: Map of the EA flood zone 3 fluvial flood risk in Bristol at Avonmouth, the location of many waste assets, reflecting a more extreme flood event than in the 1/200 flood (BCC 2018a)*

5. Physical assets
Buildings

Hazard	Consequence in 2050	Confidence
Flood	M	More certain than not
Extreme Heat	M	More certain than not
Drought	L	More evidence required

Introduction

With the 10th largest urban population in Great Britain (*BCC, 2019b*), Bristol is home to a combination of public and privately owned buildings with a wide variety of uses. Bristol has a portfolio of essential buildings expected in any major city such as hospitals, schools, police stations, community centres, healthcare centres, transport hubs and public service centres (e.g. job centres). The impact on the social functions of these buildings is covered in more detail in the subsequent section on social assets.

Buildings in Tyndall's Park, Broadmead, the City Centre, Old Market, Finzels Reach, Redcliffe, St Philip's Marsh and Canon's Marsh are predominantly commercial. These areas surround the Floating Harbour and are near to Bristol Temple Meads and major transport links. The commercial district comprises businesses, restaurants, shops, other commercial organisations and is also home to the Bristol Temple Quarter Enterprise Zone. Commercial areas can also be found on the outskirts of the Bristol local authority such as in Avonmouth, Hengrove, Brislington and Stoke Park/Frenchay (*OSM, 2019*). The impact on the economic functions of these buildings is covered in more detail in the subsequent section on business and economic assets.

Areas such as Cotham, Bedminster, Southville, Montpelier, Redland, St George, Knowle, Clifton and Hotwells comprise the residential areas that immediately border the city centre commercial district (*OSM, 2019*). Good quality affordable housing is a key part of health and wellbeing, in Bristol over 75% of citizens are happy with their current housing, with the most deprived 7% less satisfied than the Bristol average (*BCC, 2018b*).

The historic nature of Bristol means that its buildings are an eclectic mix of medieval, Tudor, Stuart, Georgian, Victorian, 20th century and modern structures.

Sensitivity

The quality of and climate change impacts on buildings in the city have the potential to impact the heath, wellbeing and productivity of the citizens across the city.

The city centre in Bristol is the area at most risk of tidal and fluvial flooding. It is also the most densely built up area within the City of Bristol. If realised, this flood risk would have a severe impact on commercial, residential and public buildings and services. Currently there are approximately 1,000 properties at risk of fluvial and tidal flooding. This is projected to increase to 2,600 by 2060. In the St. Philip's area, 2080 1/200 flood could impact the commercial district and severely restrict access to the rest of Bristol (*BCC, 2016*).

The built up areas of Broadmead and Redcliffe would see major damage to commercial real estate while Canon's Marsh, Hotwells, Wapping Warf and Spike Island are also projected to be impacted in a 2080 1/200 flood. Critical buildings that may be impacted include: Temple Fire Station, Bridewell Police Station and a number of GP surgeries. Several 'community places of safety', community centres, food banks and residential areas also fall within the defined flood zone. Though no major hospitals fall within the mapped flood zone, key transport links to major A&E centres such as the BRI and Southmead Hospital are projected to be impacted.

Key proposed development sites also lie in areas at risk of flooding including Western Harbour, Temple Quarter Enterprise Zone and the Frome Gateway development.

Extreme heat places a strain on the cooling requirements and energy consumption of buildings, especially those with inefficient insulation, poor ventilation or extensive glass facades. Hot conditions may cause buildings to be unsafe for use. Currently 20% of homes in England experience overheating even in cool summers, with 1960-1970s dwellings and offices being particularly prone to overheating (*CCC, 2017*).

Drought does not pose an immediate risk to the function of buildings and structural assets in Bristol. Knock-on effects from the strain of drought on other asset groups such as water infrastructure may impact Bristol's buildings. Severe drought induced subsidence may impact the structural integrity of buildings on earthwork foundations. This risk is particularly pertinent for buildings on high retained walls such as those in the Avon Gorge.

Extreme cold places a strain on heating systems within buildings. This is more likely to have an impact on energy demand rather than the function of buildings themselves. Knock-on impacts of extreme cold on other asset groups could effect buildings in Bristol.

Flooded buildings can result in devasting impacts to lives and livelihoods. Buildings in the centre of Bristol are at high risk. Overheating and cold homes and offices can have an impact on health, wellbeing and productivity of the citizens of the city. Students in overheated schools are more prone to fatigue and bad behaviour and office workers productivity decreases (*CCC, 2017*).

5. Physical assets
Telecoms and ICT

Introduction

ICT and data services support every aspect of a functioning economy from controlling other infrastructure systems, emergency systems and financial and personal data. Disruption of these systems can have significant impacts to a variety of sectors across the city.

ICT and communications infrastructure includes a vast portfolio of assets owned, maintained and operated by a large range of private organisations. Given the private nature of these organisations, it has not been possible to collate sufficient data regarding the type and extent of existing ICT infrastructure in Bristol.

However, it can be assumed that these assets will include:

- Data centres
- Internet service provider networks
- Telephone fixed line networks
- Mobile phone network infrastructure
- Physical infrastructure including cables and ducts
- Transport network telecoms systems
- Emergency control rooms (e.g. emergency service control centres and the Environment Agency national incident room)
- Television and radio masts

There are also a number of publicly owned and operated assets in the form of B-Net and Bristol is Open.

Critical data and communication centres in Bristol include: Temple Street Operations Centre (covering Traffic Control Centre and Community Safety (CCTV) and Bristol City Council's Emergency Control Centre), emergency service hubs and the Environment Agency national incident centre.

Sensitivity

ICT networks often are quite resilient as they have redundancy and diversity of systems. Failure of one part of the network often has little impact outside the area directly served by the failed asset or component. However, disruption to the network over the longer term can cause loss of communications for thousands of homes, businesses and public services (*CCC, 2017*).

Flooding is considered a key climate risk for ICT infrastructure given the impact it can have on causing failures and major damage to data and communications centres. This is especially true for fibre to cabinet networks as cabinets can be flooded making full fibre networks more resilient. Flood mapping indicates that the low lying areas of the city centre are at greatest risk of flooding during a 2080 1/200 flood. Given that this area of Bristol is the most densely populated with residences, businesses and public services, it is also likely to be the area most heavily connected to and reliant on ICT and communications infrastructure. In the event of a flood, ICT and comms infrastructure could be caused to fail leaving residencies, businesses and public services without access to internet or telephone service. ICT and comms infrastructure impacted by flooding in the city centre could also have impacts in the wider supply area.

Increase in maximum temperatures may cause direct impacts due to increased risk of overheating in data centres, exchanges and base stations (*Fu et al, 2016*).

Though drought is unlikely to directly impact the functioning of ICT and communications assets, it can have potential impacts on the stability of earthworks ad foundations stations (*Fu et al, 2016*). Subsidence reduces the stability of communications towers and networks, the movement or collapse of which would cause major disruption to ICT systems in Bristol.

Hazard	Consequence in 2050	Confidence
Flood	M	More certain than not
Extreme Heat	M	More evidence required
Drought	L	More evidence required

Extreme cold can have a negative impact on the function of ICT systems. Increases in minimum temperatures are likely to reduce the costs of space heating in assets. Warmer winters will also lessen the likelihood of snowfall and subsequent impacts on masts and antennae, reducing maintenance stations (*Fu et al, 2016*).

There is limited information on the location and protection for most ICT assets, making it difficult to understand their vulnerability (CCC, 2017).

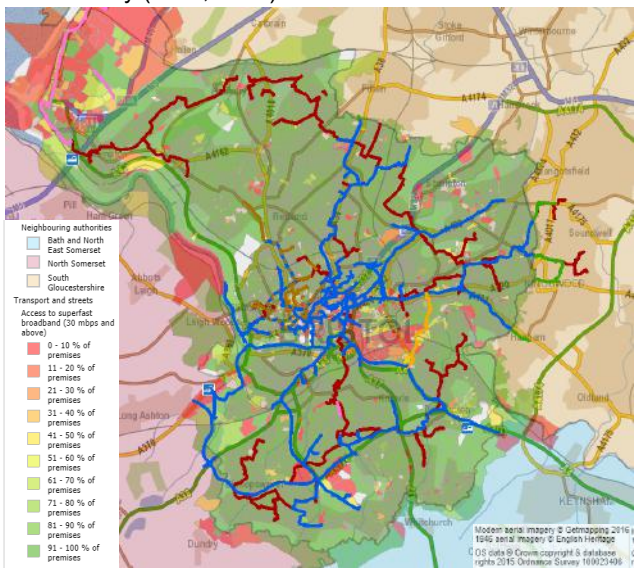


Figure 19: Known extent of the fibre optic network in Bristol and indication of community access to superfast broadband (*BCC, 2019a*)

5. Physical assets

Blue green infrastructure

Introduction

Blue green infrastructure is the network of natural and semi-natural areas. These are a key support to improve resilience to climate threats and therefore need to be protected and enhanced.

Blue green infrastructure (BGI) in Bristol managed by Bristol City Council comprises public realm, parks, greenways, wildlife corridors, trees, allotments, school outdoor sports facilities and cemeteries. There are also large sites of Nature Conservation Interest (SNCIs) and Special Scientific Interest (SSSIs). Special Areas of Conservations (SACs) and Special Protection Areas (SPAs) bordering Bristol on its coastal margin.

Private green infrastructure includes four golf clubs (Filton, Henbury, Shirehampton and Knowle), residential gardens and agricultural land on the outskirts of the local authority boundary.

There are four charity run city farms in Bristol: St Werburghs City Farm, Windmill Hill City Farm, Hartcliffe Community Park Farm and Lawrence Weston Community Farm.

The impact on the food system is considered in more detail in the section on social assets that follows.

Sensitivity

Green infrastructure provides a significant life support system in cities by providing physical protection, improved health and wellbeing and benefits for biodiversity and the natural environment. Without green infrastructure the city may experience impacts such as reduced soil stability, increased flood risk or negative health and wellbeing impacts for citizens.

Green infrastructure is not likely to be permanently damaged by flooding. For a time after a flood event, parks and other open green spaces may be water logged and some trees may be lost to rot. However, green infrastructure provides a useful pathway to reduce the impact of flooding on more vulnerable assets by increasing drainage and helping to minimise the accumulation of surface runoff. Any unstable or weak vegetation (e.g. young shrubs or saplings) may be destroyed during a flood.

Extreme heat can significantly impact the health of green infrastructure. Trees may become parched and open green spaces and leaves can suffer from scorching (*UoMA, 2019*). Even if short lived, exposure to extreme heat can have long term impacts on the health and strength of vegetation. Urban areas tend to be between 1-2°C warmer than bordering rural areas (the urban heat island effect) due to the heat absorbed and slowly released by urban infrastructure. Green infrastructure can be used to reduce the urban heat island effect. Studies have shown that temperatures under tree canopies are lower than that of the surrounding environment. Furthermore, there is a direct link between the size of green spaces and variety of vegetation within them and the positive impact they have on cooling temperatures (*Monterio et al, 2019*).

In periods of dryness and drought, green infrastructure can be severely damaged. Short term impacts of drought on green infrastructure include wilting, scorch and defoliation of bushes, trees and shrubs. In the longer term, exposure to drought can cause trees to shed large branches (*ITV, 2018*) leading to dieback of the overall tree canopy and potential death of plants. Drought can also impact the stability of vegetation as soil structures become less cohesive and shrinkage occurs around roots. This is a particular risk for young shrubs and plants that do not have an established root system (*UoMA, 2019*).

Freezing conditions can have long and short term impacts on green infrastructure. In the long term, frost damage can reduce the ability of plant life to photosynthesise and grow (*Krause et al, 1988*). In the short term, freezing plants can suffer from dehydration and cell death (*Pearce, 2011*).

Hazard	Consequence in 2050	Confidence
Flood	L	More certain than not
Extreme Heat	M	More evidence required
Drought	H	More evidence required

Warming temperatures in Bristol may reduce likelihood of these impacts being realised, however, it may also have an impact on the essential cooling needed to trigger flowering and seed production and eradication of pests.

Extreme weather and climate stress can cause a cumulative impact on BGI and the biodiversity it supports. As the climate changes, some species may struggle to evolve and diversify causing shifts in spatial distribution and species interactions (*Ohlemuller, 2011*), and potential spread of disease from continental Europe and elsewhere. Making space for nature in cities is therefore vital.

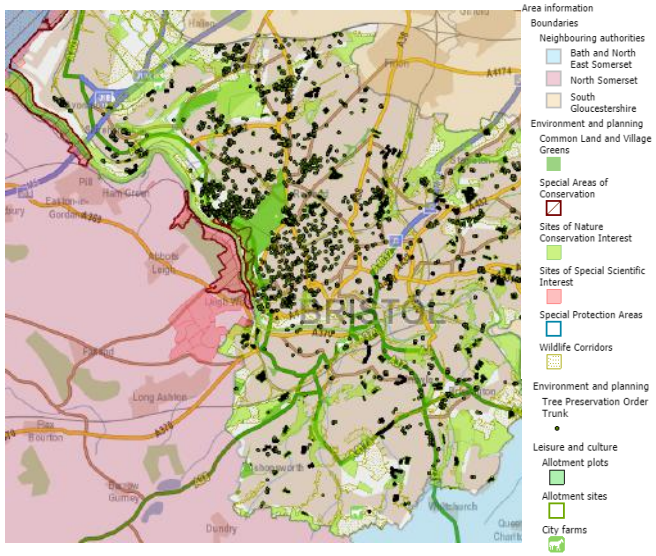


Figure 20: *The common land, village greens, SNCIs, SSSIs, SACs, SPAs, wildlife corridors, allotment plots, city farms and tree cover in Bristol (BCC 2019a)*

5. Sensitivity of assets

Social assets

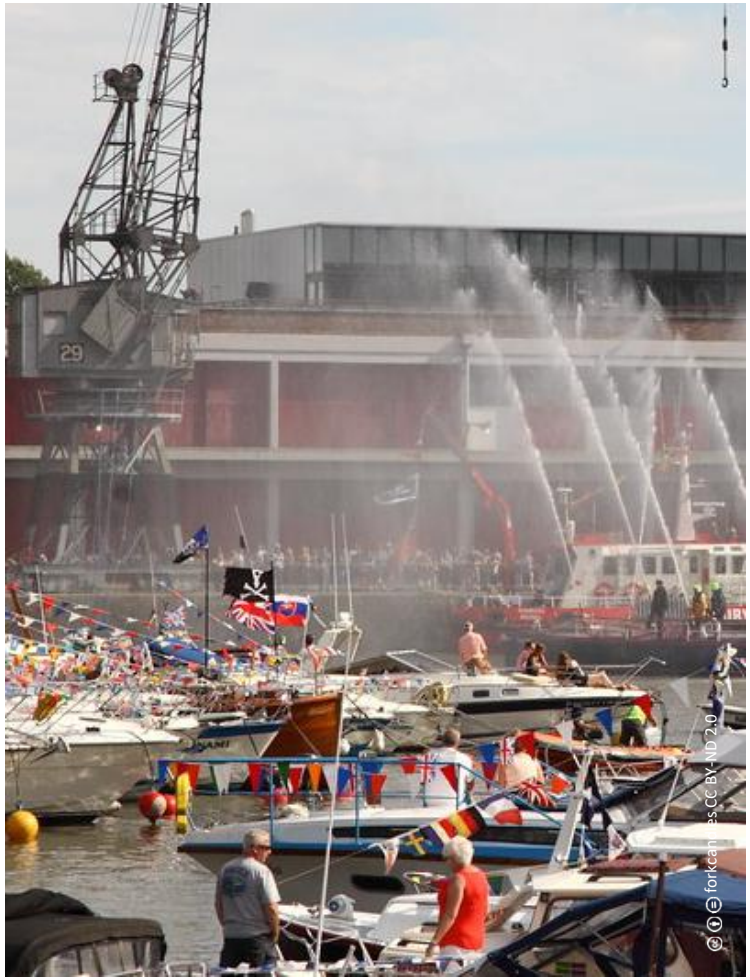
Social assets include the health, education and community assets. We have considered physical assets as well as human and social capital. We have considered the following asset groups in this section:

- Health
- Education
- Culture and leisure
- Community
- Emergency services
- Food supply systems

Table 2 provides an overview of the sensitivity of social assets.

Social asset	Flood	Extreme heat	Drought
Health			
Education			
Culture and leisure			
Community			
Emergency services			
Food supply systems			

***Table 2**. The hazard/ sensitivity rating of the social assets to each of the key hazards.*



5. Social assets

Health

Hazard	Consequence in 2050	Confidence
Flood	M	More evidence required
Extreme Heat	M	Very certain
Drought	M	More evidence required

Introduction

Health assets comprise both the physical infrastructure and services provided by health organisations which support the general wellbeing of the population. Bristol is an active city, with 72.5% of adults claiming to be physically active, it is the highest of all English core cities (*Sport England, 2019*). Over two thirds of residents are satisfied with life. However, inequalities are apparent through health data, with just over half of the population in the most deprived areas satisfied with life (*BCC, 2018b*).

The life expectancy for both women and men in the city is below the national average at 82.8 and 78.7 years respectively (ONS, 2015-17), and the inequality gap between the most and least deprived areas is 7.1 and 9.6 years respectively (PHE, 2015-17).

Bristol has 12 hospitals with six of these located in the city centre and others located near to key arterial routes out of the city (*BCC, 2019a*). The responsibility of Bristol's hospitals lies with the North Bristol, University Hospitals Bristol and Avon and Wiltshire Mental Health Partnerships Trusts. Other health assets including GP surgeries, care home facilities, and dental surgeries are distributed throughout Bristol.

The biggest causes of death in Bristol is cancer, followed by cardiovascular diseases, respiratory diseases and liver disease (BCC, 2018c).

The Bristol One City Plan sets out an objective for mental health to become as important as physical health in Bristol (*BOCP, 2019*). Currently, 1 in 5 people in Bristol report below average mental wellbeing, this rises to 28% in the most deprived communities. The number of people who have been diagnosed with depression in Bristol is 10% which places it slightly above the England average, alongside the rate of suicide which is also higher than average (BCC, 2018c).

Sensitivity

The UK's health and social care system operates close to its limits and is therefore vulnerable to climate threats (*CCC,2017*).

High-level analysis of 2080 1/200 flood extent maps indicate that Bristol's 12 hospitals will not be immediately impacted by flooding (*BCC, 2016*). However, those located centrally which fall under the responsibility of the University Hospitals Bristol NHS Trust are near to areas of 2080 1/200 flooding, and their operation could be impacted in terms of access for staff, patients, emergency vehicles and other supplies by road.

Flooding events have the potential to result in health effects both during and after, including injuries, infections, mental health problems and in some cases death. Surface water flooding would impact lower income households to a greater degree due to the likelihood of less flood-resilient properties, inability to insure / relocate, and associated insecurity which could lead to anxiety and stress (*Lindley et al. 2011*). Flood events would result in greater demand for health services due to these impacts. This demand could be exacerbated due to limits on access to these services.

Extreme heat could directly impact on health service infrastructure including risk of building subsidence, overheating of building services including power supply, and limited water supply to hydrate staff and patients.

Hot conditions may cause buildings to be unsafe for use. Currently 20% of homes in England experience overheating even in cool summers, with 1960-1970s dwellings and offices being particularly prone to overheating (*CCC, 2017*). Heat waves and conditions in buildings can have impacts on health through dehydration, heat stroke, and aggravated cardiovascular and respiratory illnesses thereby leading to greater pressure on public health services. This could disproportionately impact on the health of those who are socially isolated or those without personal independence in nursing homes. Warmer temperatures exacerbate urban pollution, and associated problems with asthma, allergies and other respiratory diseases. It has been linked to an increased risk to preterm birth (*NIH, 2016*). Extreme heat in work environments, which are not adapted to it, can decrease worker wellbeing and productivity in hospitals thereby creating a cyclic effect in the ability of health services to perform.

Drought conditions could impact on public health and public health services due to increased rates of dehydration. This could have a cyclic effect in patient care if public health services have limited water supply to hydrate patients and staff. Drought conditions could have an impact on food supplies thereby contributing to malnutrition if supply chains are severely impacted and food prices rise (see food). This would place further dependency on health services.

Extreme cold conditions and cycles of freeze-thaw can impact the stability of earthworks and embankments that support health services infrastructure (*NERC, 2015*). In England and Wales, an average of 24,000 deaths occur over winter, with elderly patients and those with chronic health conditions most at risk (Office for National Statistics, 2019). According to research, an extra 1 degree drop in temperature was associated with 1.1% increase in deaths (*Tammes et al., 2018*). Warmer winter temperatures overall would improve this, however cold days would still occur.

5. Social assets

Health

Severe weather may cause acute increases in demand for health and social care services and directly damage health infrastructure (CCC, 2017). Increasing instances of hazardous events has the potential to impact on mental wellbeing and could contribute to rising rates of stress, anxiety and depression. Eco-anxiety has been defined as a source of stress caused by “watching the slow and seemingly irrevocable impacts of climate change unfold, and worrying about the future for oneself, children, and later generations” (BBC, 2019). A rise in eco-anxiety could place a greater demand on mental health services. Changes in climate are also linked to emerging diseases, several vector borne diseases have emerged in recent years, such as dengue fever and West Nile virus, and these may start to effect the UK in the future (CCC, 2017).

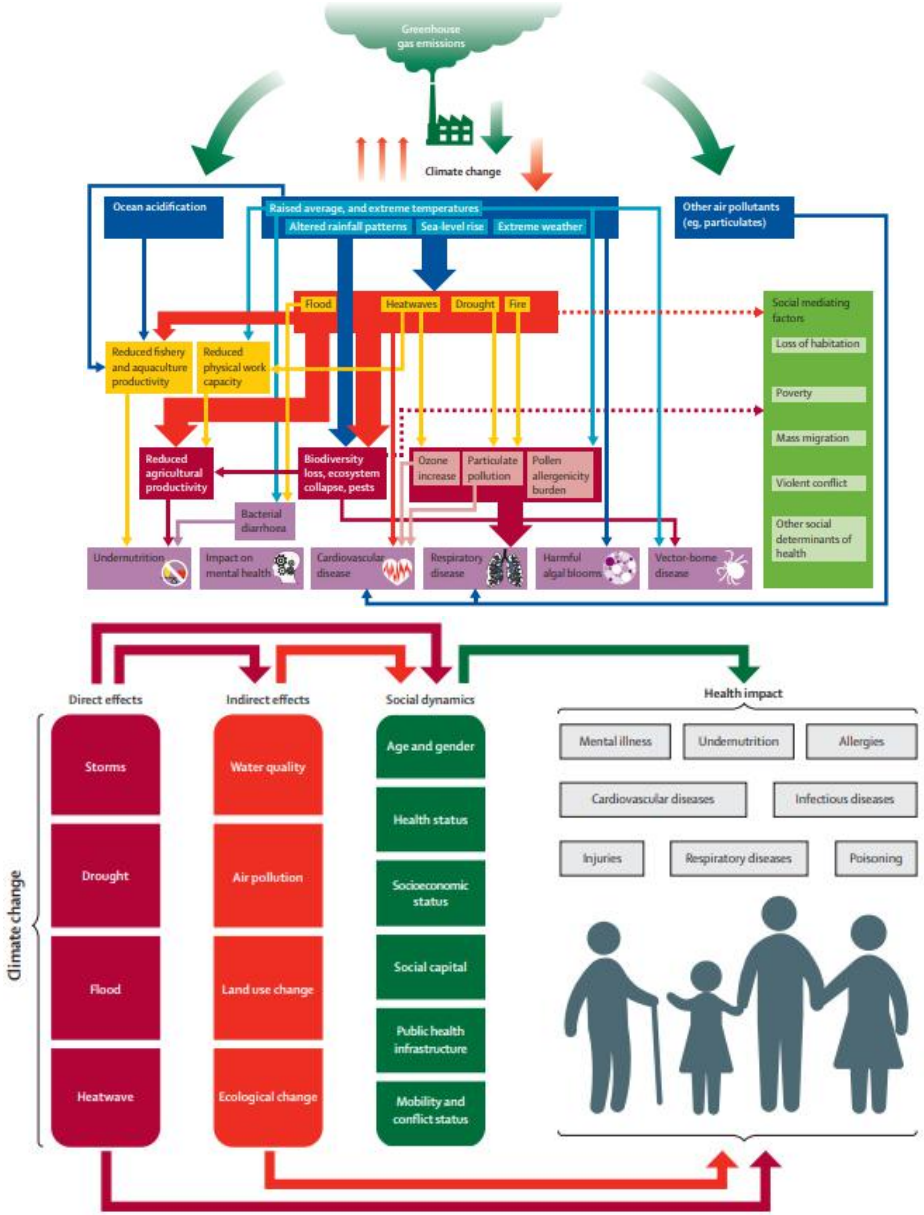


Figure 21: *a) An overview of the links between greenhouse gas emissions, climate change and health & b) the direct and indirect effected of climate change on health and wellbeing (Watts et al, 2015)*

5. Social assets

Education

Introduction

Educational assets include both the levels of education in the city's population and the educational institutes themselves (nurseries, schools and higher education).

Bristol has a high proportion of higher education students in the city, although significantly fewer young people growing up in Bristol go on to higher education than the national average, with three of the five worst performing neighbourhoods in England currently situated in Bristol (*HEFCE, 2018*). There are three universities with some facilities within Bristol City Council's boundaries; the University of Bristol, the University of the West of England (although this is predominantly in South Gloucestershire) and the Open University.

A key barrier to higher education in the city has been found to be a lack of A-level or equivalent qualifications offered at schools in particular areas, with post-16 centres and colleges concentrated in limited geographical areas and with a lack of effective public transport (*UoB, 2018*). City of Bristol College has four campuses throughout Bristol and South Gloucestershire including one situated centrally, one in north Bristol and one in south Bristol (*City of Bristol College, 2019*).

Bristol has 204 educational establishments in total with 70 of primary and secondary schools maintained by the local authority, 84 classed as academy/free schools and are therefore governed by non-profitable charitable trusts, and 15 independent schools.

The number of primary school children in Bristol has grown by 29% over the last decade which is one of the highest rates in the country (BCC, 2019b). This is expected to increase over the next decade with a projected population increase higher than any of the other English Core Cities (*BCC, 2019d*).

Sensitivity

Flood events have the potential to limit access to schools, disproportionately impacting those who travel further distances to school or whose schools are in areas more prone to flooding. With more frequent flooding events, this could result in more frequent disruption to education for those disproportionately impacted. 2080 1/200 flood maps indicate that schools in and around the city centre (including Ashton) could be most affected by flood events, both in terms of flooding of buildings and flooding of access. There are some risk areas in north-west Bristol which could impact schools in Southmead, Brentry and Henbury. Access to City of Bristol College's College Green campus could be affected by flood events affecting central Bristol (*BCC, 2016*).

Extreme heat events have the potential to restrict access to education if they occur during term-time. There are currently no legally prescribed maximum temperatures for school premises or other educational institutions in the UK. However, without air conditioning systems to cool buildings, it may be deemed necessary to close during periods of extreme heat. Many schools, especially Victorian era and those built post-war, are prone to overheating and poor indoor air quality. In the UK many classrooms experience temperatures over 24ºC causing poor behavior and cognitive performance (CCC,2017). If schools were to remain open during an extreme heat event, this would impact on children and teacher ability to focus and absorb/relay information. Though most extreme heat events are more likely to occur during the summer months when educational institutions are already closed, warm weather is occurring early in the year and even slightly elevated heat can cause uncomfortable conditions in poorly insulated buildings.

Hazard	Consequence in 2050	Confidence
Flood	L	More certain than not
Extreme Heat	L	More certain than not
Drought	L	More certain than not

Drought conditions would also result in an inability to focus and absorb/relay information especially with a combination of heat and limited water supply. Drought can have an impact the stability of earthworks and embankments (*NERC, 2015*) that support school buildings and infrastructure.

Extreme cold has the potential to limit access to educational institutions. The temperature in school buildings should be at least 16ºC (*NEU, 2019*) and cold events have the potential to close institutions due to both safety of access and health and safety within educational sites. During ice and snow conditions in 2018, at least 100 schools in Bristol were closed during these events and many others opened later in the day to enable safe access (*Bristol Post, 2018*).

As with public health, extreme heat and unsafe conditions in schools could lead to negative health impacts for students, especially in schools that lack quality outdoor space. Furthermore, school closure resulting from a combination of these events could disproportionately impact children who rely on free school meals during term time and when considered cumulatively over the course of a year this could lead to enhanced inequality through access to education, food and the pastoral care provided by schools.

It should be noted that there is an opportunity to deliver enhanced community engagement and sense of shared responsibility around the cause and impacts of climate change through the national curriculum.

5. Social assets

Culture and leisure

Hazard	Consequence in 2050	Confidence
Flood	M	More certain than not
Extreme Heat	L	More evidence required
Drought	L	More evidence required

Introduction

Bristol's local identity and culture is key to citizens feeling a sense of belonging in the city. The city's thriving culture and creative scene helps to drive economic growth and tourism in the region, with the tourism economy alone in Bristol and South Gloucestershire worth £1.4 billion annually, supporting 29,000 jobs.

Bristol was named Museum Destination of the Year in 2018, and its museums, galleries and archives alone, operated by the Council, attracted over 1.3 million visitors 2018-19 (*BCC, 2019b*). Other tourist attractions include the SS Great Britain which is the city's top tourist attraction (run by the SS Great Britain Trust), and the Arnolfini and We The Curious which are both registered charities.

Bristol's cultural venues include cinemas (e.g. Watershed), Colston Hall, the Bristol Old Vic, the Hippodrome which are all centrally located, amongst many others (*Visit Bristol, 2019*). Bristol also holds a number of outdoor festivals throughout the year including Bristol Balloon Festival, Upfest, and the Harbourside Festival.

Bristol houses 27 public libraries which are distributed throughout the city, including Central Library by College Green (*BCC 2019a*). The libraries provide community access to free learning and community spaces and are operated by Bristol City Council (BCC, 2019g).

The city is home to two football clubs including Ashton Gate stadium in south Bristol which is also home to Bristol Rugby Club, and Memorial Stadium in north Bristol. The home of Gloucestershire County Cricket Club is also situated in North Bristol (*GlosCricket, 2019*).

Sensitivity

Bristol's thriving cultural scene may be significantly impacted by climate change, from outdoor festivals being called off, to direct damage to historic assets and creative spaces. Many of Bristol's cultural assets are housed within heritage buildings which are often more effected by climatic change.

Flooding events have the potential to cause major disruption to some of Bristol's biggest tourist attractions and cultural venues due to their central location surrounding the floating harbour. Heavy downpours and storms have disrupted cultural events in Bristol in the past. 2080 flood extents suggest that access to Ashton Gate Stadium would also be susceptible to increased flood risk. Impacts on these venues could include damage to structural foundations of buildings, exhibits, car parks and access routes. In turn, the effects on these venues could result in a loss of visitors to these venues and a loss of revenue for the city.

The impacts of extreme heat on Bristol's tourist attractions and cultural venues are unknown. Heat events could result in fewer visitors if buildings are not adequately prepared for the heat event, or more visitors should people choose to escape from the heat by spending more time inside well-cooled public buildings. Furthermore, outdoor events could also be over-subscribed during sunny, hot weather creating pressure on infrastructure and support services

Drought conditions would result in conservation of water which could affect the operation of tourist attractions and cultural venues. For example, the SS Great Britain is covered by a layer of insulating water, saving the Trust £20,000 on annual energy bills (*SSGB, 2019*), and the current football and cricket pitches require irrigation. This could also affect community spaces such as public parks and gardens which provide important areas for community gathering and cohesion. Drought conditions would impact green infrastructure, increasing the risk of fire where parks, grassland and woodland are dry, and reducing the appeal and cooling effect of grass parks where they are scorched brown.

Extreme cold events could impact access to these venues and reduce visitors as people may prefer to stay at home rather than travel in unsafe conditions. Cold events could also damage the physical infrastructure and services to tourist attractions and cultural venues for example through freezing pipes.

Culture and leisure in Bristol may be significantly impacted by climate change in a range of ways. There is significant flood risk to some of the city's cultural assets around the harbourside, in particular.

5. Social assets

Community

Hazard	Consequence in 2050	Confidence
Flood	M	More certain than not
Extreme Heat	M	More certain than not
Drought	M	More certain than not

Introduction

Bristol has more than 250 community buildings managed by and for local communities, and more than 1,500 different voluntary and social economy organisations. Bristol's voluntary and community sector is thriving, with over two thirds of Bristol residents volunteering or helping out in their community at least three times a year, and 59% of residents in the most deprived areas (B*CC, 2018b*).

There are 11 advice drop-in centres throughout Bristol which are registered charities providing guidance and support relating to benefits, housing, debt, employment and immigration concerns (*CAB, 2019*).

As a local authority, Bristol ranks 5th in the number of people sleeping rough, with 82 rough sleepers in a single night in 2018 (*Homeless Link, 2018*). There are over 1,430 night shelter/ supported housing beds available in Bristol (*BCC, 2019b*).

There are at least 45 religions in Bristol, with faith centres distributed throughout the city. Bristol ranks 7th in England and Wales for the proportion of people who state they have no religion. Whilst Christianity remains the largest religion, this has seen a decrease over recent years (*BCC, 2019b*).

The 2018/19 Quality of Life survey found that 86% of the population of Bristol were concerned about climate change, with 30% changing the way they travel due to climate change concerns, and 25% doing so in deprived communities. 18% of residents agreed that they could influence decisions affecting their local area, a decrease on previous years (*BCC, 2018b*).

Sensitivity

Key community buildings, services and places impacted by extreme events. Disruptions to these services will impact the most vulnerable and isolated citizens disproportionally.

2080 1/200 flood events have the potential to impact on community buildings and buildings used by voluntary/charitable organisations, in particular those situated in the city centre. Aside from the city centre, community centres in St Paul's including the Malcolm X Centre, Eastville, Southmead and Ashton Gate are located in areas at risk of 2080 1/200 flood. These buildings may be more at risk due to a lack of investment available to ensure they are equipped for flood events. These buildings and organisations are particularly important to maintain community cohesion and contribute to reducing social isolation. As noted under 'physical assets', several 'community places of safety' and food banks fall into the defined flood zone. For households that are affected by flooding, greater demand may be placed on public services and local charitable organisations as people may lose their homes and possessions and require shelter and support.

Extreme heat could impact the operations of organisations to fully perform. There would likely be an increased reliance on air conditioning which would result in not only an increase in building operation costs but a greater contribution by the organisation to carbon emissions. The heat could also affect the number of willing volunteers to provide their time and skills during uncomfortable weather conditions and particularly if building services are not up to the standard required. There could be a greater demand for shelter and support, in particular from those who are homeless or deprived.

Drought conditions could place greater demand on organisations, in particular those which provide shelter and pastoral care to those in need, due to limited water supply available and potential impacts on food supply.

Extreme cold conditions could impact the operation of buildings and buildings used by voluntary/charitable organisations, reducing their ability to perform to their fullest. This may occur at a time when demands on their services are increasing, in particular for those organisations providing shelter to those experiencing homelessness. Demand on community buildings may be reduced during these conditions as people tend to stay indoors, but this may contribute to greater rates of social isolation and higher risk of associated health conditions.

Changing climatic conditions may place a greater demand on both public services, as detailed in the health section above, and also charitable/ voluntary organisations, for example those supporting homelessness, social isolation and mental health.

There are significant numbers of people displaced by natural disasters, for example there were 24.2 million people displaced by disasters in 2016 (IDMC, 2017). Bristol is a 'City of Sanctuary', a place that is publicly committed to include people seeking sanctuary. Climate migration and the increasing city population may cause some additional stress to community facilities and services. Therefore international climate events can have an impact to the city's communities. Communities and services will need to adapt (with support from government policies and frameworks regarding climate migration) and prepare for population change in line with Bristol's values (*Forum, 2019*).

5. Social assets

Emergency services

Introduction

Emergency services include ambulance services operated by South Western Ambulance and Avon Ambulance Services NHS Trusts, fire services operated by Avon Fire and Rescue, and police services operated by Avon and Somerset Constabulary, along with HM Coastguard.

The Avon and Somerset Local Resilience Forum includes emergency services, health services, Maritime and Coastguard Agency, Environment Agency, voluntary agencies, utility companies, transport providers and the five Councils of Bath and North East Somerset, Bristol, North Somerset, Somerset and South Gloucestershire. The LRF aims to enable the community to be better prepared to cope during an emergency and to recover more quickly. The Met Office works with the LRF to support the understanding of the impact of climate change on the risks managed.

There are two ambulance stations which serve Bristol, one in Lawrence Hill and one in Avonmouth. The ambulance services respond to 999 calls across the city and provide patient transportation to hospitals (*NHS Providers, 2019*).

There are five fire stations in Bristol including two at Avonmouth, and four police stations including one in the city centre (*BCC, 2019a*).

The Coastguard does not have a specific base in Bristol, but will respond in the case of an emergency (*MAC, 2018*).

Sensitivity

Emergency services are vital for the city to be abele to deal with extreme events and protect the city's citizens. If the function of these services were negatively impacted there is the potential for loss of life.

The city centre of Bristol and land adjacent to the tidal river would be at risk of 1/200 flood by 2080 (*BCC, 2020*). This could affect central Bristol emergency police and fire services both in terms of the infrastructure and access to emergencies, thereby affecting their operations (as covered under 'physical assets'). Flooding would also increase the demand on emergency ambulance, fire and rescue and police services. Services based outside of the city centre would be less impacted in terms of operational access, but would experience a demand on their services to support those who have experienced flooding and any associated health impacts.

Extreme heat events would increase demand for emergency services, in particular ambulance services due to a greater likelihood of heatwave and other health impacts. Heat wave events have been found to increase levels of anger and associated domestic abuse which may increase demand on police services or emergency social services. Suicide rates are also higher with warm weather, which could contribute to an increased demand for emergency services (*Standford, 2018*). There have been warning to the general public to take care when swimming during heatwaves, following a number of drownings in 2018 (Independent, 2018).

Hazard	Consequence in 2050	Confidence
Flood	M	More certain than not
Extreme Heat	M	More evidence required
Drought	M	More evidence required

Drought conditions could impact on ambulance services due to higher rates of dehydration and health impacts. These conditions could also hamper the efforts of the emergency fire service to respond to fires due to water shortages.

Colder weather conditions are less likely to happen in the future extreme cold days are still likely to occur. Emergency Services are vital response to this cold weather Emergency services will be particularly key to deal with cold weather alert level 4, a major emergency incident (*PHE, 2018*). Therefore extreme cold days are still likely to put strain on to emergency services.

Emergency services are vital to support the systems of Bristol to deal with the impact of severe events and to serve communities across the city. Therefore a failure in emergency services could impact the responses of many other key city systems. Furthermore, the projected increase in frequency and intensity of climate hazards, combined with the impacts on the cities assets pose a significant increase in pressure on Bristol's emergency services when compared to current conditions (which already place them at high capacity).

5. Social assets

Food supply systems

Hazard	Consequence in 2050	Confidence
Flood	M	More certain than not
Extreme Heat	M	More certain than not but more evidence required
Drought	M	More certain than not but more evidence required

Introduction

Food supply networks are dynamic and complex international, regional and local supply systems which can be disrupted extreme climate events.

The assets included in the food supply systems include farms, food manufacturers, processors, wholesalers, wholesale markets, supermarket distribution centres, suppliers and distributors, supermarkets, independent retailers and street markets. These are international, national and local. The number of registered food businesses within Bristol's boundaries are shown in Figure 22.

While some food growing occurs on Bristol's allotments (3,851 allotments on 108 sites), most is produced outside the city and brought in. The UK as a whole imports 50% of its annual food requirements and 30% is from the EU. The UK spends the most importing fruit and vegetables- spending £11.1 billon in 2017(*DEFRA 2018*).

Bristol's reliance on external food supply systems is reflected by the split of Bristol's food business with 74% catering, and 21% retail, and only 3% processor or manufacturer, and 2% being wholesale distribution in 2010 (*Carey, 2011*). The majority of retail supply chains have between one and four weeks of stock (*DEFRA 2018*). Only 46% of UK firms have sight of their suppliers' contingency plans for environmental disruptions (*Arup 2019*).

There are no overarching food security legislations or national responses for food disruption. The UK has signed and ratified the International Covenant on Economic, Social and Cultural Rights Treaty, which recognises that everyone should have adequate standard of living including food (*UN 1966*).

The British Government does have responsibility to feed people in schools, hospitals, prisons, armed forces and government agencies. There are 653 public educational and care premises in Bristol, see Figure 22 (*Carey, 2011*).

In Bristol there are already 43,000 people considered 'food insecure', measured in 2016 (*BCC 2019b*). There are 15 food banks within Bristol's boundaries (*BCC, 2019a*).

Sensitivity

While Bristol's food supply chain is resilient to some extent due to diversity of suppliers, it has a 'just-in-time' nature with limited stockpiling of products from retailers. Therefore severe weather within Bristol's boundary can cause significant disruption mainly over a few days or weeks (*Grecksch & Stefan 2018*).

2080 1/200 flood projections suggest that a flood like this may impact food business particularly in the center of the city. Within Bristol the distribution and wholesale facilities are clustered in two main areas: St Philip's and Avonmouth/Royal Portbury (*Carey, 2011*). These areas are currently within 2080 1/200 flood risk areas (BCC, 2020). This could impact the strategic food distribution of St. Phillips Market both within Bristol and further afield (*BCC, 2016*). Flooding Avonmouth would affect the largest area of agricultural land in the city boundary (*Carey, 2011*). Bristol City Council and Southmead Hospital aim to buy food locally and regional suppliers have already stated they are vulnerable to flooding events. Flooding outside Bristol's boundaries also impacts food production and therefore availability within the city. For example the 2007 floods, which inundated 40,00 hectares caused £50 million worth of agricultural damage (*DEFRA, 2010*).

The projected increase in extreme heat events will likely impact the production of food, most of which occurs outside Bristol City's boundary. For example the hot weather over summer 2018 caused difficulties for UK farmers who had to request support from the UK government (*Arup, 2019*). This caused significant increases in vegetable prices (onion prices increased by 41% between march and July in 2018). Dairy production suffered from reduced grazing and dairy cows were impacted directly by the hot weather reducing milk yields (increasing butter prices by 24% between march and July). As a whole this period of hot weather was thought to increase wholesale food prices by 5%, estimated to cost UK consumers £45 million per week (*CEBR, 2018*).

Category	Number in Bristol
Food distributor/distribution centres/cold stores/ wholesaler	90
Food manufacturers	27
Farms/city farms	6
Abattoir and cutting facilities	9
Caterers (catering companies)	543
Hospitality/eat out (hotels, restaurants, takeaways etc)	1058
Public, educational and care premises (catering))	653
Specialist retail (including bakers, butchers, fishmongers, delis, health food shops, greengrocers)	183
Other retail (including supermarkets	520
TOTAL	

Note: Excludes all other categories listed under registered food businesses and excludes registered businesses trading in alcohol, confectionery and non-food.

***Figure 22**. Registered food businesses in Bristol City Region dealing with staple foods in 2011 (adapted from Carey, 2011)*

5. Social assets

Food supply systems

Sensitivity

The projected increase in summer drought may not have a significant direct impact on food within Bristol's boundaries it does impact crop yields around the country and increases costs due to irrigation needs. For example the 95% of our potato consumption is grown in the UK but only half the crops have access to irrigation which can reduce yields in droughts (*The Grocer, 2018*).

Extreme cold: While winters are becoming warmer, extreme cold events with freezing weather can impact national crop growth. The freezing spring temperatures in spring 2013 stunted wheat growth and prevented planting of other key cereal crops. There were similar issues for livestock farmers with 20,000 more sheep and 5,000 more cows dying in spring 2013 compared to spring 2012. This caused a knock on effect of needing to import significantly more food (*Telegraph, 2013*).

If these extreme weather events result in food shortages this has the potential to affect the whole population, with the most vulnerable likely to be the most affected due to the rising food prices that would ensue with reduced supply. Similarly, there is the potential for gradually rising food prices as the climate changes irrespective of extreme events which would have a major impact on low income families.

International impacts affecting Bristol's food systems

Climate impacts outside Bristol's boundaries impact the food system within the boundaries. In the past the major risk to food supply has been the interruption on transport of food supplies instead of the food supplies themselves. However, due to the uncertainty of future climate patterns, the future may not follow these past patterns.

International weather and climate significantly impact agriculture, leading to greater variability and poorer yields. An example of this impact in practice is the Russian heatwave in 2010 which was linked to the doubling of global wheat prices (*MOD 2018*).

There are eight crops that provide 74.2% of the worlds calorie consumption, these are produced in five main areas. This means we are highly dependent on a small number of crops. These area are 'breadbaskets' of the world: Latin America (soya and sugar), US (soya and maize), Europe (wheat), Asia (rice) and South East Asia (palm oil). Climate change increases the likelihood of simultaneous failures in these crops causing significant impacts on the global food market. This can have knock on impacts on food prices and social stability of these growing areas (MOD 2018).

It is also worth noting that future policy relating to food supply may change, for example, as a result of Brexit.

5. Sensitivity of assets

Business and economy

Introduction

Bristol contributed £14.2bn to the UK economy in 2017 (*BCC, 2019b*). The city's economic strength is knowledge-rich businesses and entrepreneurial activity, especially high tech, creative and digital industries (*100 Resilient Cities, 2016)*.

There are 22,170 business units in Bristol (2018). The city has many start-ups and small and medium enterprises (SMEs) with the second highest number of the core cities (*BCC 2019b*). There is a strong independent retail sector in the city with some areas of particular strength around Gloucester Road and North Street.

Bristol has a highly skilled workforce. In 2018 there were 268,000 employee jobs in the city and an average wage of £28,000/ year. Over half of employment is in managerial, professional and technical occupations (*BCC 2019b*). Most jobs are in health and social work (16% of city jobs) followed by wholesale, retail trade (14% of jobs) and professional, scientific and technical advisory (11%) (*Nomis, 2018*). The unemployment rate in 2019 of 3% below the national average (*BCC 2019b*).

The West of England is focusing on three sector strengths; advanced engineering and aerospace; creative, cultural and digital industries; financial, business and legal services (*WECA, 2019*).

There are two enterprise zones in the city; the Temple Quarter Enterprise Zone (TQEZ) is situated in the centre of Bristol and the Avonmouth Severnside Enterprise area is partly in the Bristol area. The focus for TQEZ is for creative, high-tech and low carbon industries. Avonmouth has many warehousing and distribution companies currently including Tesco, Asda and Co-op.

Table 3 provides an overview of the sensitivity of business and the economy to climate hazards.

Asset	Flood	Extreme heat	Drought
Business networks and the economy			

***Table 3**. The hazard/ sensitivity rating of business and the economy to each of the key hazards.*

5. Business and economy

Hazard	Consequence in 2050	Confidence
Flood	M	More certain than not
Extreme heat	M	More certain than not
Drought	M	More evidence required

Sensitivity

The key impacts to business will be felt as direct impacts to the assets from hazards, impacts to the supply chain and impact to exports. The direct impact from flooding and extreme weather events cause damage to assets and disrupts business operations. This poses one of the greatest risks to English businesses now and in the future (*CCC, 2017*). Climate change will also impact the shape of Bristol's economy through opportunities for growth in goods and services related to addressing climate risks (the adaptation economy).

Extreme weather can impact labour productivity across sectors by preventing workers from accessing sites, working remotely, or causing them to leave to deal with issues related to these events (*CCC, 2017*). Jobs that require physical labour especially outdoors will become more challenging and have more health and safety risks associated with them.

Avonmouth and Severnside Enterprise Area and Temple Quarter Enterprise Zone are situated in within some of the areas at highest flood risk. Flood risk in Bristol centre is projected to increase. Currently TQEZ is at risk of 1/200 flooding, this risk will likely increase by 2080 (BCC, 2020). This flood is projected to impact access to the Redcliffe area, where many businesses are located and the Wapping Wharf retail and restaurant area. There may be impacts to the A4032, a main artery into the city, and the A38 a key route through the city, both potentially impacting businesses (*BCC, 2020*). The flooding in England and Wales in 2013/2014 caused £230- £310 million in total damages to businesses, with an average of £82,000 in damage per business asset (*CCC, 2017*).

As the likelihood of Bristol experiencing extreme heat events increases this will likely have a knock on impact on businesses in lost productivity, decreased cognitive functioning and damages to public health. Rising average temperatures also may have long-term impacts on productivity growth (*DFID, 2017*). For example, Horowitz (2009) predicted that a temperature increase of 1ºC would lead to a reduction of 3.5% in world Gross Domestic Product (GDP). It is also estimated that worker productivity decreases by 1.7% for each 1ºC in daily average temperature above 15ºC (*Deryugina & Hsian, 2014*). It is estimated that the 2003 UK heatwave caused business losses of £400-500 million (*CCC, 2017*).

As the likelihood of drought in Bristol increases in the future it is likely that this will have an impact on water-intense industries with implications for other sectors across their supply chains and production processes (*CCC, 2017*).

Extreme cold can have significant impacts on business and the wider economy, while winter temperatures are generally increasing, this does not mean that extreme cold snaps will not occur. The 'beast from the east' extreme cold weather in 2018 impacted multiple industries across the UK with the construction industry losing an estimated £2bn over three days. It impacted retail, reducing footfall in shops, leisure faculties and restaurants. It also had a knock on impact on supply chains, delaying shipments of raw materials to manufacturing firms. It was estimated that it cost the UK economy over £1bn per day. The December 2010 cold weather had the worst impact on the economy, knocking 0.5% off GDP growth (*The Guardian, 2018*).

Often, to deal with extreme events, staff work remotely, which highlights business' dependency on resilient ICT and electricity infrastructure. It is essential that businesses have undertaken robust business continuity management (BCM) planning. Smaller businesses, of which there are many in Bristol, are less likely than larger companies to prepare for climate change or to have BCM plans in place (*CCC, 2017*).

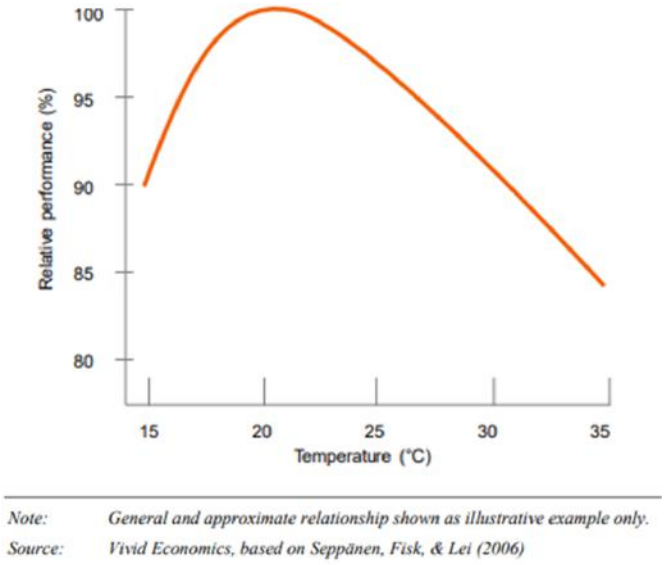


***Figure 23**. Impact of temperature on workforce productivity, showing the optimal temperature is 20ºC (DFID, 2017)*

5. Business and economy

Sensitivity

Distribution networks and supply chains

Bristol's businesses rely heavily on national and international supply chains. Extreme weather events have the potential to disrupt these supply chains, causing challenges for businesses to get resources and materials. This can prevent businesses in Bristol being unable to complete projects and fulfil orders which can lead to breach of delivery contracts, loss of revenue and reputational damage. To some extent the climate resilience of local infrastructure, described in the physical asset section of this report, will affect how severe the impact felt by Bristol businesses is.

These extreme weather events already impact these supply chains and distribution networks and such disruptions could become more frequent as hazard exposure increases in the future. For example, drought can impact Bristol businesses' supply chains, impacting water availability for manufacturing products or for washing, cooling or heating during production processes. Severe drought may also cause a shortage of crops used for food, clothing and other products. During the Barcelona extreme drought in 2007 and 2008 it was estimated to cost the Barcelona region €1,605 million (*Grecksch & Stefan 2018*).

There may be some sectors where only a few companies provide key services (for example ICT and haulage) and therefore the resilience of these businesses is key for many businesses across the city and country (CCC 2017). Due to these interdependencies it is essential that companies understand their own supply chain resilience and the resilience of the companies within their supply chain. There is also a need for companies to build requirements on climate risk and resilience into procurement processes.

Through international supply chains Bristol's businesses are exposed to the risks of extreme weather across the world. As a proportion of GDP, UK international trade (imports plus exports) was 57% in 2015.

Supply chains in countries which are particularly vulnerable to climate impacts such as in South and South East Asia and sub-Saharan Africa may be particularly disrupted (CCC 2017).

There may also be wider indirect impacts of changes in climate on impact through changes in customer demands; changing their need for goods and services and increasing the public pressure to prepare for climate risk and reduce their environmental impact.

Climate migration may also fundamentally may impact resource availability, supply chains and the workforce within the city. An increase to the city's population would require businesses and supply chains to adapt to support this change to ensure that all citizens are provided for in terms of decent work, healthcare, education and basic provisions.

***Figure 24**. Clothes, food and electronic equipment are especially at risk from climate risk In their international supply chains (CCC, 2017)*

5. Business and economy

Sensitivity

Some of the key impacts, both direct and to their wider supply chain, for five of the 10 key business sectors have been highlighted in Table 4.

Service area	Amount of Bristol's economy	Potential impact to Bristol's business sectors due to extreme weather events and climatic change
Wholesale and retail services	15.1 %	**Production of goods and raw materials (mostly outside Bristol's Boundaries)** • Physical risk to water supply (and availability of water for irrigation), crops and raw materials. • Greater risk of animal infections (e.g. avian flu), insect infestation, plant disease, wildlife damage, etc. • Decreased production for rain fed crops and reduced reliability (and quality) of supply of fresh produce. • Equipment and other investments, including expertise of workforce, are linked to specific crops which may no longer be viable. • Interrupted access to sites and land during extreme events impacting food production and processing. **Distribution of goods to Bristol** • Disruptions to transportation systems and operations. • More refrigerated distribution and storage required and problems with livestock transportation in heat. **Direct impact to wholesale and retail** • Exposure of workforce to increased heat. • Buildings directly impacted by extreme events.
Construction	9.7%	• Extreme weather events may disrupt transport for site deliveries and affect site work (e.g. muddy site conditions or excessive heat), restricting work-days. • Insurance may be more expensive or difficult to obtain for existing buildings, new buildings, and during the construction process.
Transportation and storage	4.2%	• Damage to roads, bridges & rail systems disrupting companies' ability to ship product and/or receive supplies.
Manufacturing	4.1 %	• Supply chain interruptions and vulnerable transport systems. • Process environment will become hotter with increased need for cooling—particularly important for comfort/health of workforce and performance of production processes.
Finance and insurance services	3.6%	• Weather-related losses could stress property and casualty (P&C) insurers to the point of impaired profitability, consumer price increases, withdrawal of coverage, and elevated demand for publicly funded compensation and relief. • Potential climate-related impairment of the value of securities into which insurance firms invest as part of their asset management activities could leave companies unable to cover future losses.

***Table 4**. Potential impact of extreme events on sectors of Bristol's economy (BCC, 2019c) adapted from Sussman & Freed, 2008*

6. Current adaptive capacity

Context

The Climate Change Act 2008 put in place a policy framework to promote adaptation in the UK. The second National Adaptation Programme (NAP) sets out the UK government's response to the second Climate Change Risk Assessment (CCRA), showing the actions government is, and will be, addressing the risks and opportunities posed by a changing climate. It forms part of the five-yearly cycle of requirements laid down in the Climate Change Act 2008 to drive a dynamic and adaptive approach to building our resilience to climate change.

The Civil Contingency Act 2004, along with accompanying regulations and non-legislative measures, provide a framework for civil protection in the UK capable of meeting the challenges of the twenty first century. The Act sets out the requirements of category 1 and 2 responder organisations. The Avon and Somerset Local Resilience Forum (LRF) which is a partnership comprising all organisations needed to prepare for an emergency in the area, including emergency and health services, utility companies, transport providers and the local authorities

As a local authority, Bristol City Council is a category 1 responder ("core responder") and the Act sets the provisions to plan, respond and recover from major incidents including emergency control measures, the 24 hour control room, multi-agency plans and Bristol specific plans.

The LRF is required under the Act to produce a Community Risk Register to enable the community to be better prepared to cope and recover quickly in an emergency event.

For organisations in Bristol, the Business Resilience Handbook developed by the Bristol Resilience Network provides guidance to support businesses in understanding their current resilience, framing long-term thinking and decision making and encouraging collaboration for a more resilient future (*Bristol Resilience Network, 2015*).

Adaptive capacity

Adaptive capacity is the ability of systems, organisations or people to adjust to events, respond to consequences or take advantage of opportunities (ISO 14090:2019).

A city's adaptive capacity is comprised of a range of knowledge, capabilities, capacity across individuals, organisations and systems. This breadth makes a rapid assessment of a city's adaptive capacity challenging.

For the purposes of this study, a review of some of the key corporate, governance and planning indicators of the existing adaptive capacity of Bristol's assets to climate hazard events has been undertaken. Existing indicators of adaptive capacity include published plans and strategies relating to operations in the event of an emergency or climate hazard event which shows that an organisation is prepared to respond. An example of this is Bristol Water's Drought Plan, or the city council's green infrastructure plan which contributes to the adaptive capacity of communities. Indicators also include major capital or investment projects which improve resilience to climate risks for example the Bristol Flood Risk Strategy. These are provided in more detail on the following pages. These have focused on indicators relating to preparedness for specific climate hazards.

There are some emergency response plans (some triggered or informed by Met Office severe flood and weather warnings) which provide adaptive capacity across multiple hazards and an important part of developing Bristol's adaptive capacity will be for multiple agencies to work together to respond. The scope of standalone emergency plans at present is likely to be too limited to manage and mitigate some climate risks.

Bristol's Emerging Local Plan will set the future trajectory of the city over the next 20 years. A consultation was held in March 2019 and the draft policies are currently under review. Draft Policy CCS3: Adaptation to a changing climate sets out that new development will be expected to include site and building-level measures to be resilient to future climate change impacts and that these should be integral to the layout and design. It requires development proposals to provide an adaptation strategy which demonstrates how they will address issues such as minimising the overheating of buildings, providing comfortable external spaces in hot weather and conserving water supplies.

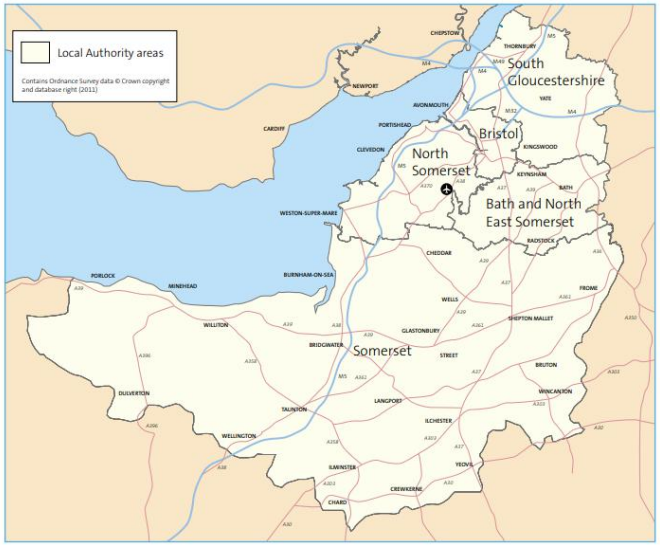


***Figure 25**. Avon and Somerset Local Resilience Forum area*

6. Current adaptive capacity

Flooding and sea level rise

A series of studies have been conducted to better understand the extent and exposure of infrastructure and communities to future flooding scenarios in Bristol. The emergency services, local authorities and other agencies work together to develop flood response plans and procedures and the Local Resilience Forum has been working to communicate with developers to incorporate flood mitigation measures in new developments (*LRF, 2017*). However, there is less evidence to show that there is public understanding of this flood risk.

Some of the key sources of operational adaptation employed in Bristol include:

Strategy and planning:

Local Flood Risk Management Strategy (FRM) *(BCC, 2018a)*

The strategy builds on the extent of flood risk to Bristol and sets out objectives for managing flood risk, measures to achieve those objectives and an action plan that explains how and when those measures are to be implemented. The FRM strategy addresses climate change by evaluating the extent of climate induced fluvial and tidal flooding and the approximate number of properties at risk. This analysis has informed a catchment-based and community-focused approach to flood risk management that has been adapted to account for the impacts of climate change.

Bristol Avon Catchment Plan *(BACP, 2016)*

This plan outlines a catchment-wide approach to management of water and flood risk, land and sustainable agriculture, waste water, rivers, access to recreation and investment opportunities. All recommendations and partnership actions in this plan take into account the challenges that climate change presents on each of the associated systems.

Action:

To assist in delivering and monitoring the FRM strategy, improved flood monitoring and measuring systems have been developed such as BCC SWIM flood report and the BCC flood monitoring network. There are some ongoing operational programmes to manage flood risk, such as the gully and culvert maintenance and clearing programmes (*LRF, 2017*).

Developments to improve Bristol's resilience against future flood scenarios include:

Avonmouth & Severnside Flood Defences:

The new flood defences (planning permission has been granted and the design phase is underway) is set to protect the Avonmouth Severnside Enterprise Area (ASEA) from future flooding (*SGN, 2019*). The development will also work to protect and enhance local ecology by creating 80 hectares of wetland habitat *(SGN, 2017)*.

The current plans for these defences are shown in Figure 26.

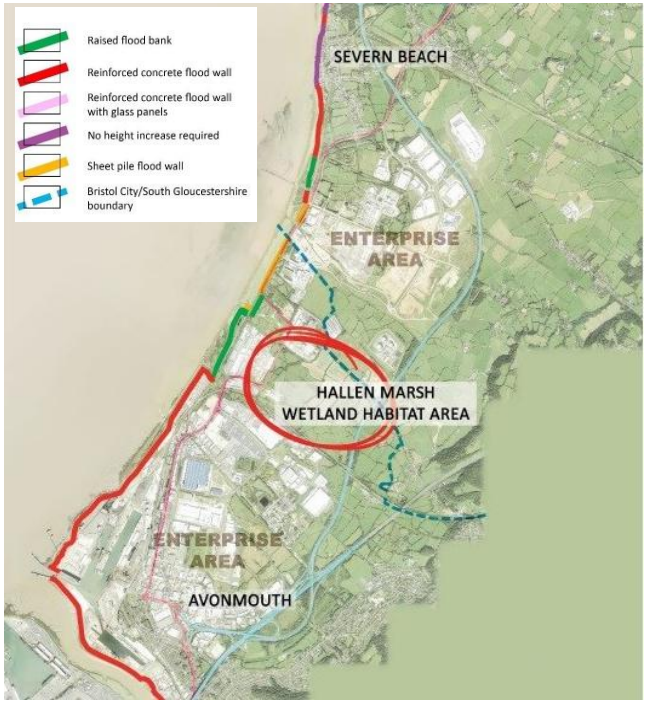


Figure 26: *Avonmouth Severnside Enterprise Area (ASEA) ecological mitigation and flood defence project (BCC, 2019f)*

6. Current adaptive capacity

Drought

Some of the key sources of adaptation in Bristol include:

Strategy and planning:

Bristol Water: Water Resource Management Plan (WRMP) *(Bristol Water, 2019)*

The WRMP is Bristol Water's long-term plan to balance water supply with projected future water demand. The current approach to water resource management takes into account modelling of the impacts of climate change. Using the modelling approach for Bristol's Water project shows that while there will be some reductions in water available for public supply, their integrated supply network and range of water sources will mitigate this impact. This will be coupled with plans to reduce leakage and customer water demand. Only half of the water supplied by Bristol Water is from within the supply area with the rest transferred from outside. In periods of dry weather the transfer of water into the area is maximised to conserve water reservoirs within their supply area.

Bristol Water Drought Plan *(Bristol Water, 2018b)*

Bristol Water has worked to make the water supply system resilient to droughts experienced within their historic record, through scenario modelling and testing. However, it has been identified that the company is less resilient to specific drought types particularly long-duration droughts, of over a year, and drought in early winter. This plan sets out the actions that would occur in the event of a severe drought.

Additional planning

Some work (for example in the EA Drought Response Framework) has been undertaken to understand the drought impacts wider than the water supply, in areas such as green infrastructure, agriculture and wider industry.

Extreme heat

Bristol City Council has commissioned work to map the city's current surface temperatures, so to some extent understands the current areas of heat risk. However, more detailed work is necessary to assemble a detailed evidence base at a variety of scales that also consider ambient air temperature variance. One of the key adaptation plans employed in Bristol includes:

Strategy and planning:

Public Health England's Heatwave Plan for England *(PHE, 2014)*

This is a national plan to support NHS, local councils, public services and communities to know how services can work together to deal with the impacts of heatwaves. This plan details a heat-health watch alert system which runs from 1st June to 15th September each year. Based on Met Office forecasts this is made up of five main levels (0-4) which covers long-term planning for severe heat to a major national emergency. The Plan is due to be replaced by a severe weather plan which combines cold weather and heatwave plans.

Extreme cold

Many of the extreme cold plans (such as Bristol City Council's severe weather plan) are dealing with the response to an event. The main current adaptation plans in the city include:

Strategy and planning:

Public Health England's Cold Weather Plan for England *(PHE, 2018)*

This is a national plan to support NHS, local councils, public services and communities dealing with the impacts of cold weather. This includes a five level severe cold weather alert service from 1st November to 31st March. Each level triggers a series of appropriate actions to deal with the impact. The plan provides specific actions for individuals, community and voluntary sectors and healthcare providers.

Local Resilience Forum and multi-agency plans

There are multi-agency emergency plans and training exercises many of which are coordinated by the Local Resilience Forum (*LRF, 2017*). There are specific national plans for specific situations such as the Severe Weather Emergency Protocol for engaging rough sleepers (*Homeless Link, 2019*). At a local level there are also community snow wardens to support the community in a cold snap.

Infrastructure asset owner plans

There are specific plans for some infrastructure assets such as Bristol Water's Severe Weather Task Force to prepare for and deal with the impact of, cold weather (*Bristol Water, 2018c*) and Highways England Severe Weather Plan (*Highways England, 2018*).

6. Current adaptive capacity

Adaptive capacity matrix

The current major plans and actions that provide Bristol with adaptive capacity to extreme events have been mapped to support identification of future opportunities to provide Bristol with improved climate resilience. Only those plans which directly support climate adaptation have been included.

This is shown in Figure 27.

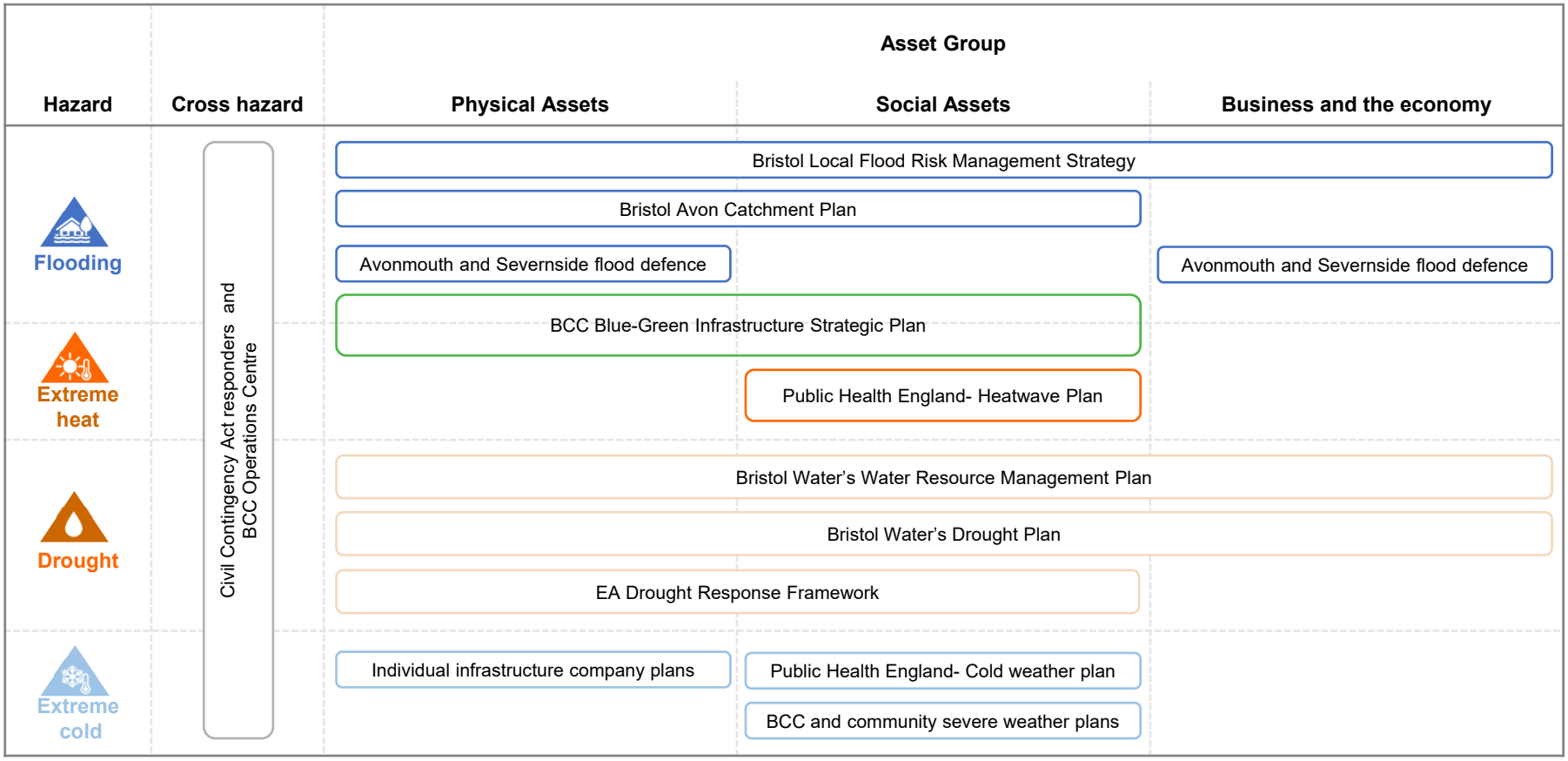


***Figure 27**. Bristol's current adaptive capacity matrix*

7. Conclusions and recommendations

In this report, we have explored the potential impact of specific climate hazards on Bristol's assets and the current adaptive capacity of these assets, based on existing and currently proposed adaptation plans and policies.

There is a clear need for a joined-up approach across the city to build Bristol's adaptive capacity which will maximise efficiencies and minimise risk. Governance and institutional arrangements will be key to enable city players to collaborate and communicate.

There are interdependencies between both different climate hazard impacts (for example, extreme heat would place greater demand on public water supply as the public try to stay hydrated which, coupled with a drought period, would further exacerbate water supply issues) and between impacts associated with a climate hazard (for example, flooding could impact the road network which could affect the ability of emergency services to operate).

An assessment of interconnectivities is outside the scope of this report. However, it is recommended that further work is undertaken in order to inform a joined-up adaptive response.

Cumulative impacts of climate hazards have also not been included in detail in this study. In particular, increased climate hazard events could result in rising levels of eco-anxiety in the population.

Climate hazards which affect other geographical regions may in turn impact on Bristol. Food supply networks, for example, could be affected, and there could be increased in-migration caused by climate hazards that take place elsewhere which could create additional pressure on Bristol's infrastructure, public services and communities. This has also been outside the scope of this assessment.

Recommendations for immediate action

We have identified areas where immediate action can and should be taken based on our current knowledge of the risks, whilst recognising that the action will need to be adaptive and evolve over time. These have been listed below.

Flood risk management

Flooding (both fluvial and surface water) is a major risk to the assets of Bristol. The spatial impacts of flooding are reasonably well understood and the assessment results indicate that the emerging flood management strategies for Avonmouth and Severnside and the City Centre and - crucially - their implementation, is a key priority for the city and will assist in providing a fundamental level of adaptation to all asset groups. It will be important that these plans are adaptive, enabling us to evolve the detail of what is delivered in response to improvements in our knowledge and understanding of climate risk.

Extreme weather event response and recovery

Emergency response plans exist which are assisting in preparation for climate hazard events. However, as we prepare for an increasing number and intensity of extreme weather events, there are opportunities to continue to enhance our planning. This could include additional multi-agency exercises and planning. For example, public transport providers including bus and rail providers should collaborate to create future adaptation plans based on updated flood risk management plans. This would include rerouted services and a specified place for sharing this knowledge to users during climate events. Additional and collaborative planning would help to ensure that the city remains accessible and navigable for citizens, incoming goods and essential public services during extreme climate events/

Green infrastructure networks

Whilst we don't yet have a full understanding of the city's baseline, we know that green infrastructure can have two-fold benefits in responding to climate change impacts;

- Green infrastructure provides a useful pathway to reduce the impact of flooding on more vulnerable assets by increasing drainage and helping to minimise the accumulation of surface runoff.
- Green infrastructure can be used to reduce the urban heat island effect, and provide cooling,

We recommend that green infrastructure is maximised now. However, there is also a need for improved knowledge; we recommend that environmental data and modelling is collated across the city in order to assist in the development of a green blue infrastructure strategy, building on work that has already been undertaken such as the Landscape Enterprise Networks (LENS) pilot.

Preparing buildings for extreme conditions

There is a lack of climate resilience in the current building portfolio and an opportunity to support climate resilience of future developments. We recommend that residential and non-residential properties are retrofitted to adapt to future climate hazards, in particular heat, flooding and storm impacts. Retrofit efforts for lower carbon buildings should include considerations of resilience against climate events.

Co-ordination and governance of climate resilience

There is an opportunity for a greater shared understanding of the vulnerability of the city's assets. Whilst the Local Resilience Forum exists to bring together all organisations needed to prepare for an emergency, data is not actively shared between asset owners and operators such as National Rail, ICT providers, water and energy providers. Greater collaboration would support sharing knowledge through, for example, a shared data resource. The secure Cabinet Office information sharing platform, Resilience Direct, supplemented by Bristol City Council's proposed Climate Atlas Tool is considered a robust combination for better knowledge sharing and improved understanding of climate resilience.

6. Conclusions and recommendations

Making better use of these platforms would assist in creating more efficient adaptation measures, as a shared understanding of the challenge could support different providers in sharing costs, risks and benefits of joint solutions with less disruption to the city.

Improving our knowledge and understanding

Alongside our recommendations for immediate action, this report has highlighted the need for us to continue to improve our understanding of climate risk and resilience.

We have identified opportunities to understand how the city can better prepare for climate hazard events. These have been set out below.

Climate hazards

We recognise that drought conditions affect more than just water supply and have reverberations on assets across the city. Due to data and time constraints, this study has only considered meteorological drought. We recommend a wider drought study, building on existing work undertaken to date, to provide a better understanding of risk. In particular, this should involve a more detailed assessment of wider drought hazards, including water demand, engaging in particular with the Environment Agency and academics.

Bristol Water's Drought Plan and the complementary Water Resources Plan provides an overview of water resources and the management of water resources during a period of drought. A wider drought study with a detailed evidence base would support the development of a Bristol focussed strategy to manage non-drinking water supply, such as water supply for green infrastructure. The combination of existing drought and water resource management plans with a more detailed evidence base and drought study would help to establish a holistic approach to water management during a drought period.

Mapping of the city's current surface temperature is underway however there is a gap in knowledge of the future surface temperature of the city. Future heat mapping would support in determining appropriate spatial interventions to prepare the city for extreme heat events.

We recommended filling gaps in our understanding of additional hazards, for example we recommend a study of the potential for future storms and high winds in Bristol.

Asset sensitivity

Further assessment could be undertaken from the perspective or individual assets or assets groups in order to identify adaptation initiatives at a local, or individual system scale. An example of what this could look like the flood maps shown in appendix A, but with a particular focus on an asset group such as Bristol's bus routes. This may be partly covered by BCCs proposed Climate Atlas Tool which intends allow users to investigate vulnerability to climate risks using a combination of climate hazard information, maps of city assets and socio-economic data.

There is currently a lack of publicly available knowledge and data over the resilience of the food supply network to future climate hazards. Funding and guidance would support businesses and producers to develop their own contingency plans and therefore adapt to climate hazards.

Sharing this information would help Bristol City Council to map existing food supply chains and ensure the city is prepared in the event of a climate hazard. An assessment of climate hazard events on local food supply has been undertaken however it is noted that supply is dependent upon events outside the city boundary. Further work could be undertaken at a national scale to determine how food supply systems could be affected in order to determine priority adaptation measures.

There is currently a lack of understanding at a community level of how climate hazards may impact people and communities. A wide ranging community-level programme of engagement, building on existing initiatives would support building resilience for communities. This would support community preparedness for action when a climate hazard event occurs.

There is a gap in understanding of the quantified economic impacts of climate hazards at a local level. We recommend quantification of economic impacts of climate hazards in Bristol is undertaken to help build a business case for action. This includes the direct impacts, impacts on revenues and sales, impact on productivity, and impacts on resources, production and supply chains. This would aid understanding of the economic viability of climate adaptation and assist in stimulating funding for climate adaptation measures.

Interdependencies

Interdependencies between assets exist, but an overarching understanding of cascading impacts is lacking. It is recommended that work is undertaken to develop greater understanding of interdependencies between physical and non-physical systems. This should build on research done at a national level, for example by the National Infrastructure Commission and as part of the Climate Change Risk Assessment 3.

We recommend a study to understand the potential climate risks through supply chains for organisations in the city.

Future resilience

It is recognised that this report provides an assessment of the risk of climate events on existing hard and soft infrastructure. Similarly, it is understood that to achieve the twin goal of a zero carbon and climate resilient city, retrofitting existing assets whilst also building climate resilience into new infrastructure is essential. An assessment of climate events on future planned infrastructure and identifying adaptation pathways that will need to be implemented is recommended to support Bristol in reaching its net zero and climate resilience goal.

Appendix A

Spatial data: an example

To understand how specific assets in the city may be impacted by extreme events further mapping can be undertaken so that interventions can be planned to support the most vulnerable local areas or sectors.

For example, Figure 28 shows how the bus network might be impacted by a 1/200 flood.

This suggest that much of the bus network and metrobus is not likely to be directly impacted by tidal, river and surface water flooding. However, under both present day and future flood risk scenarios, the city centre routes are projected to be impacted. This could have critical impacts on the accessibility of the whole network.

The impact is projected to be significantly more severe by 2080. New routes or methods of crossing between south and north Bristol would be needed in this event.

This mapping provides an example of the type of data and analysis that could form part of Bristol City Council's Climate Atlas tool and shared between all city stakeholders.

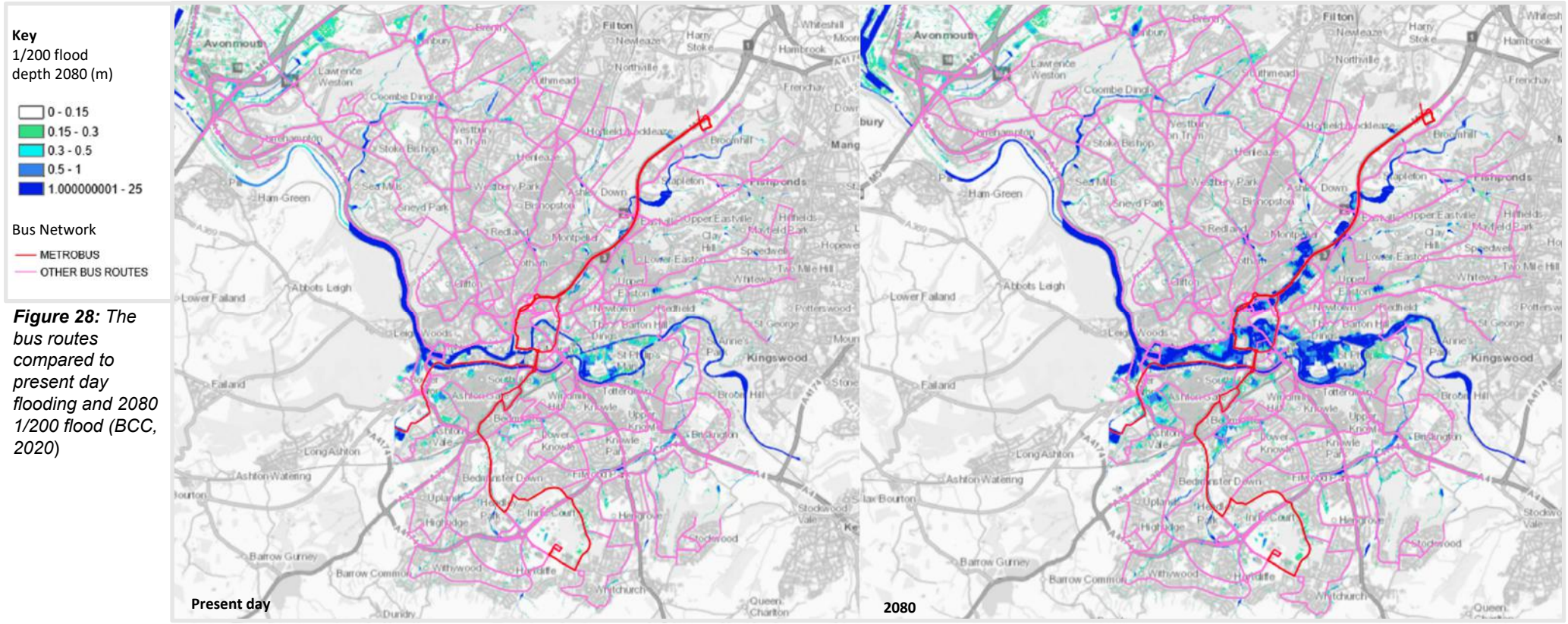


Figure 28: *The bus routes compared to present day flooding and 2080 1/200 flood (BCC, 2020)*

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