Appendix B

Climate Risk Assessment

BURO HAPPOLD

CITY OF LONDON

City of London Adaptive Pathways Study

Climate Risk Assessment

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CITY OF LONDON

July 2020

Preface

Human activity since the industrial revolution has caused environments around the world to change significantly. The impacts of rising sea levels, increasing temperatures and more frequent and intense bouts of extreme weather are increasingly evident. All have implications for our way of life.

To help understand how the climate may change within the City of London, and what this may mean for people, assets and services in the City Corporation area, this document analyses the 2018 UK Climate Projections for central London. This includes presenting future trends in temperature and rainfall patterns considering 'low' and 'high' emissions scenarios, and an analysis of potential extreme weather events. We consider long-term resilience challenges facing the City of London area (the 'Square Mile') and wider portfolio of City Corporation assets from now to 2050, and beyond.

This information can be used to raise awareness of the changes anticipated and assist policy makers, businesses and other organisations and the wider community in taking action to respond to change, as well as directly informing the forthcoming City of London Corporation Climate Action Strategy.

Contents

Adaptive Pathways

01 Our city

The City Corporation today

The City of London Corporation is the governing body of the Square Mile dedicated to a vibrant and thriving City, supporting a diverse and sustainable London within a globally-successful UK.

The Square Mile is the historic centre of London and is home to the 'City' – the financial and commercial heart of the UK. As set out within the Corporate Plan, there are 513,000 workers in the Square Mile, equivalent to 10% of London's total workforce. The Square Mile is home to 23,580 businesses, with nearly 99% of these being SMEs – though large firms (1%) provide over 50% of the Square Mile's jobs.[1]

There are approximately 9,000 residents living in the Square Mile, to whom the City Corporation is responsible for providing services.[2] Attracting 18.4 million visitors in 2017, who spent over £1.7 billion, the Square Mile has a crucial role in supporting the UK and London's tourism economy.[1]

The Square Mile is home to a diverse building stock. Due to its historic importance, much of the Square Mile is a dedicated Conservation Area (**Figure 1-1**). Conversely, it is also home to some of the most iconic new builds on London's skyline.

Beyond the City Corporations statutory duties for the City, London and the UK, the City Corporation are also responsible for a wide portfolio of work and institutions both inside and outside the Square Mile. Beyond the Square Mile this includes the management of public spaces such as Epping Forest and Hampstead Health as well as a number of schools, housing, cultural attractions, markets and ports.

01 Our city

City Corporation aims

The City Corporation has identified three Strategic Aims that will be used as a framework to guide thinking and decision making, ensuring progress toward achieving its vision.

1. **To contribute to a flourishing society:** where people are safe and feel safe, enjoy good health and wellbeing, have access to suitable employment opportunities and housing in cohesive communities and live enriched lives, achieving their full potential.
2. **To support a thriving economy:** maintaining the City's position as a global hub for innovation in financial and professional services, commerce and culture.
3. **To shape outstanding environments:** ensuring that it is physically well connected, sustainable and responsive, resilient to natural and man-made threats, and delivers outstanding buildings, streets, public spaces, and heritage assets.

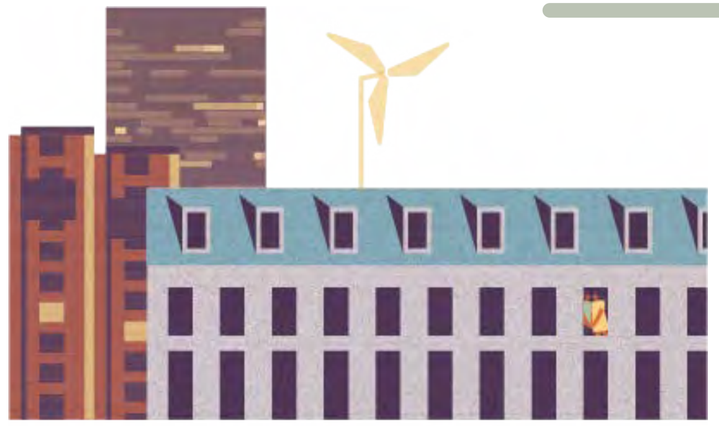
Shaping our future city

The (draft) City Plan 2036[3] sets out the plan for the future development of the City of London, identifying the types of development the City Corporation expects to take place and where.

The Plan outlines the several keys areas of change in its vision for the City of London:

- The Smithfield and Barbican: implementing the Culture Mile initiative, including delivering art and cultural attractions and public realm improvements through the Culture Mile Look and Feel Strategy.
- The City Cluster: accommodate a significant growth in office floorspace and employment, together with complementary land uses, transport, public realm and security enhancements.
- Aldgate and Tower: mixed use area, balancing needs of residents, workers and visitors.
- Pool of London: regenerated through office-led refurbishment and redevelopment of building stock and the delivery of significant public realm improvement.
- Blackfriars: substantial redevelopment or refurbishment of existing post-war buildings.
- Fleet Street: a centre for judicial and related business, a key processional route and shopping centre.
- Liverpool Street: enhance the Moorgate-Liverpool Street area to take advantage of the opportunities presented by the opening of the Elizabeth Line and the redevelopment of the Broadgate Estate.

The delivery of these seven areas of change will support the delivery of the Strategic Aims set out within the Corporate Plan. Through the areas of change the (draft) City Plan 2036 sets out an ambition to increase the residential population to approximately 10,000 people. The City Corporation further hopes to expand office and retail floorspace, by 2 million m² and 196,000m² respectively. It is anticipated that employment within the Square Mile will grow by 116,000 (24%) between 2016 and 2036, with the majority office based. Across the areas of change, urban greening initiatives are a major focus, to support local biodiversity, cooling and Sustainable Urban Drainage (SUDs) infrastructure. For developers, the City has a target Urban Greening Factor score of 0.3.



01 Our city

Committed to climate action

As identified within the Corporate Plan, we are in period of significant change on a global, national and regional level, bringing significant threats, as well as opportunities. The City Corporation is committed to being relevant, responsible, reliable and radical as an organisation. The City Corporation will need to think and act strategically and at pace.

The City Corporation recognises the urgency with which the impacts of climate change must be addressed throughout its operations, as well as positively influencing those it works with externally, for the benefit of current and future generations. Ensuring the Square Mile and the City Corporation's assets across London and beyond are climate resilient environments where people and businesses can thrive for generations to come is critical.

As part of the commitment to developing a Climate Action Strategy, the City Corporation is working to identify thresholds and trigger points by which actions must be taken to ensure that the City Corporation and the Square Mile remains resilient to the impacts of climate change. The outcomes of this work will build on the City Corporation's 2010 Climate Change Adaptation Strategy, 'Rising to the Challenge'. This document is a crucial first step to enabling the City Corporation to understand how the climate is forecast to change, the risks and anticipated shocks and stresses that the Square Mile and its assets beyond this may need to prepare for.

02

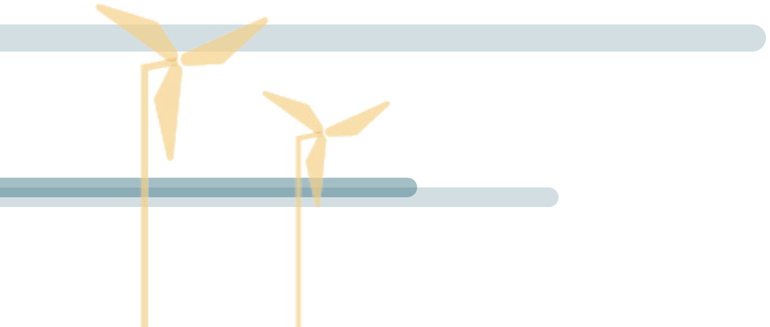
Understanding the Science

GLOSSARY

To understand how the future weather and climate may change in the Square Mile, this study has analysed the 2018 UK Climate Projections (UKCP18). Within this section we provide a non-technical summary of what UKCP18 is, our adopted methodology and a glossary of key terms.

What is the UKCP18?

The UK Climate Projections is a climate analysis tool that forms part of the Met Office Hadley Centre Climate Programme. UKCP18 uses cutting-edge climate science to provide updated observations and climate change projections up to 2100 for the UK and globally. The project builds upon the 2009 projections to provide the most up-to-date assessment of how the climate of the UK may change over the 21st century.[4]



Drought

Defined as 15 days or more with less than 0.2 mm of rainfall.

Heatwave

In London this is defined as 3 or more days with max daily temperatures above 28°C.

Percentile

Representative Concentration Pathways (RCPs) have been tested under multiple climate models. Each model applies its own unique assumptions and variables. As such, each model provides a different outcome. Percentiles represent a particular value within the range of outcomes, indicating the value below which a given percentage of observations in a group of observations falls.

‘Probabilistic’ datasets

Developed by the MET Office, these calculate the average changes over 25 sq.km areas, for different future emissions scenarios (RCPs).

Relative humidity

A variable used to describe humidity. Defined as the ratio of the amount of water vapour in the air to the maximum possible water vapour that could be in the air under the same conditions.

Representative Concentration Pathways

Predicting climate change requires us to forecast future trends in human activities (e.g. population growth, land use change, technology advancement). RCPs make predictions of how concentrations of greenhouse gases in the atmosphere may change as a result of human activities. There are four commonly used RCP's, ranging from RCP 2.6 (low emission pathway) and RCP 8.5 (high emission pathway). There are a range of possible futures within each pathway, so percentiles are used to indicate the likelihood of a particular result happening.

Shocks

Sudden impact events that can immediately disrupt a city and may have wide-ranging and unexpected impacts.

Stresses

Chronic issues that weaken the fabric of a city and can eventually lead to a major shock.

Thermal comfort

whether someone feels too hot or cold. This depends on air temperature, wind, humidity and physiological factors.

02

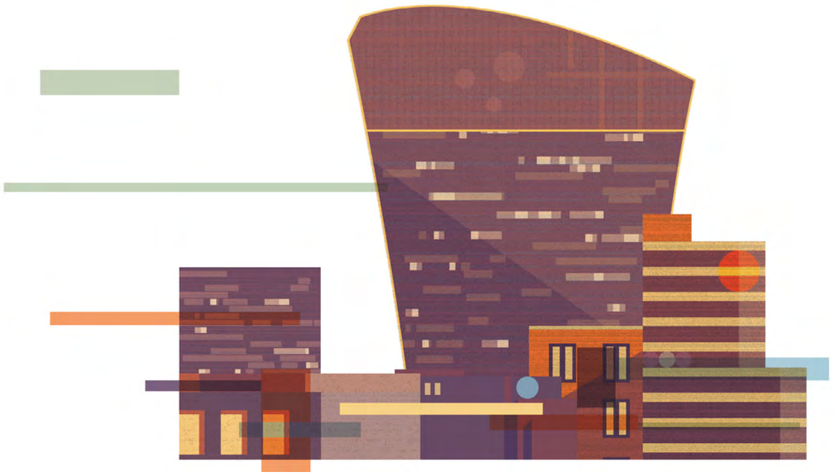
Understanding the Science

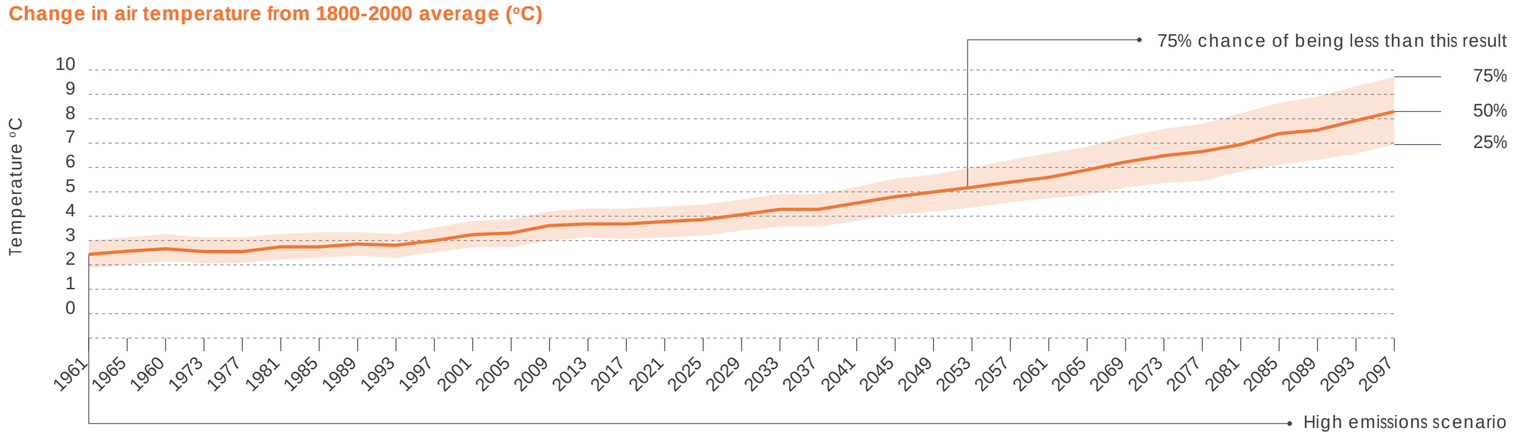
WHAT HAVE WE LOOKED AT?

Many different future climate scenarios have been modelled over recent decades. This analysis focuses on two scenarios from the most recent Met Office analyses. These give an overall picture of possible changes we could see in the Square Mile area and the City Corporation's assets elsewhere in London and beyond.

Section Two: How will the climate change?

We use the Met Office probabilistic datasets to present results for climatic variables, like air temperature, over 25km square areas. In this analysis we present projected changes in future temperature and rainfall patterns for a 'low' (RCP 2.6) and 'high' (RCP 8.5) emissions scenario in the Square Mile and the City Corporation's assets elsewhere. We present the 50th percentile results for the low and high emissions scenarios as well as 25th and 75th percentile ranges. The 50th percentile has been chosen as this represents the median forecast change. The 25th and 75th percentile have been displayed to illustrate a range of potential change.





02

Understanding the Science

WHAT HAVE WE LOOKED AT?

Many different future climate scenarios have been modelled over recent decades. This analysis focuses on two scenarios from the most recent Met Office analyses. These give an overall picture of possible changes we could see in the Square Mile area and the City Corporation's assets elsewhere in London and beyond.

Section Three: What might the worst case look like?

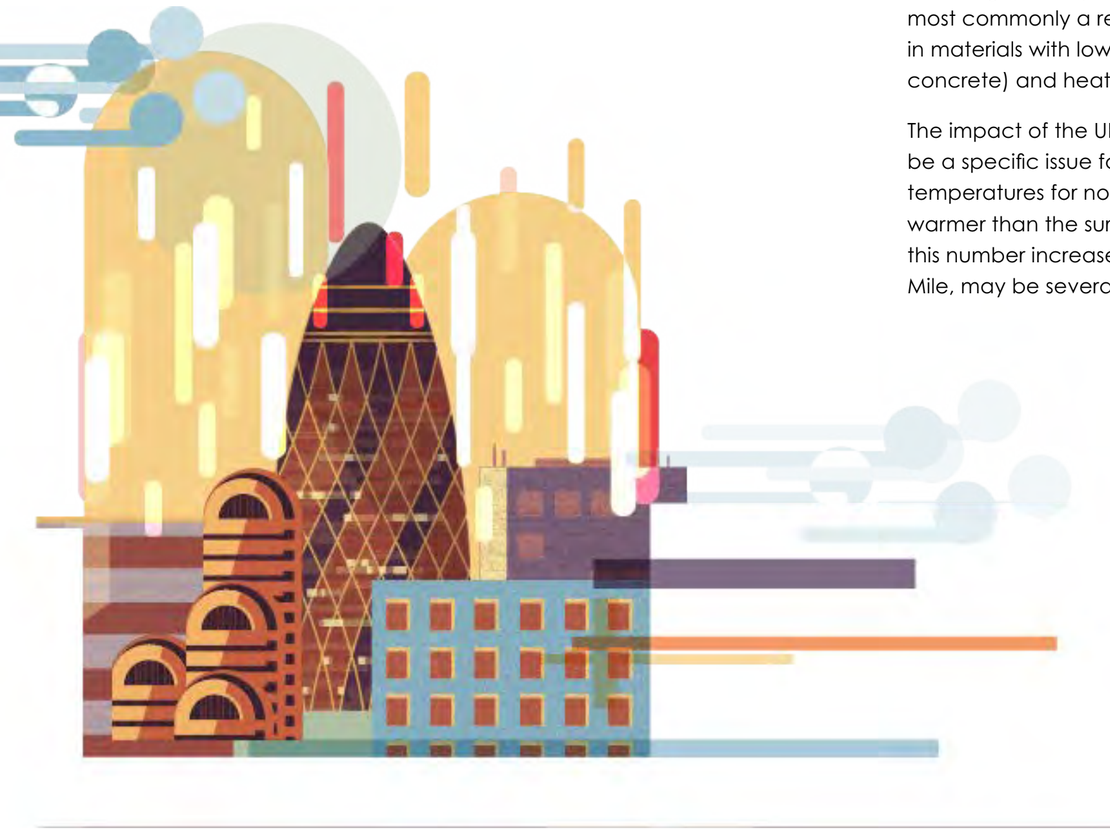
The Met Office 'Global', 'Regional' and 'Local' datasets give daily data predictions for weather variables in future years at different scales. Under the high emission scenario (RCP 8.5), the Met Office data sets contain 12 plausible outcomes for how future daily weather may change. Within this Section, we use the Regional and Local data for the 5km square area over the Square Mile to analyse the possible worst-case weather patterns that the Square Mile may face for the following variables:

- Days of drought;
- Days of heatwave;
- Change in winter snowfall;
- Average summer relative humidity;
- Average wind speeds;
- Maximum five Average -day rainfall; and
- Maximum daily temperatures.

To establish this, we have analysed the data sets for each of the above variables and for each of the 12 plausible outcomes. We have averaged the results to provide an indication of potential future conditions under the 'high emissions' scenario. Although the 'high emissions' scenario is used, since average results are presented it is still possible that worse conditions may occur. Regional datasets were used since they are available for all years to 2080, except in the case of snowfall, which is calculated only in Local datasets.

02

Understanding the Science



What about the Urban Heat Island Effect?

An Urban Heat Island (UHI) typically refers to an urban area that is significantly warmer than its surrounding areas. This is most commonly a result of intensive land use, trapping of heat in materials with low reflectivity and a high thermal mass (e.g. concrete) and heat generated by other human activities.

The impact of the UHI effect is not accounted for within UKCP18 but may be a specific issue for the Square Mile. In London, average night-time temperatures for normal summers are estimated to be around 4.0°C warmer than the surrounding region due to the UHI. In hot summers this number increases[5]. As such, local temperatures within the Square Mile, may be several degrees higher than modelled under UKCP18.

What about flooding and storms?

UKCP18 provides projections for tidal flooding only. However, the Thames brings both fluvial and tidal flood risk.. Moreover, in London, water levels can be controlled using the Thames Barrier. Flood risk is modelled in the Thames Estuary (TE) 2100 Plan, which combines UKCP18 sea level rise projections with detailed modelling of storm surges and fluvial flows. We cover this in Section 4 of the document.

Storms are not directly modelled under the UKCP18. The Met office has reviewed the potential for storm frequency and intensity to change under climate change,[6] and do not find significant evidence that climate change is affecting storms. Increases in wind speeds under climate change are modest compared to natural monthly and seasonal wind variation. Similarly, the influence of climate change on the North Atlantic Oscillation (NAO), which is one of the most important influencers of winter climate in norther Europe, is set to be smaller than natural monthly and seasonal wind speed variation. As wind speed changes in the UKCP18 projections for the City of London have been found to be similarly small, storms are not analysed in this document.

03

How will the climate change?

In this section the key outcomes are presented from the analysis of projected change in air temperature and rainfall patterns in the Square Mile and surrounding areas over the coming decades under high and low emissions scenarios Analysis is presented for annual averages, with seasonal patterns marked.

Temperature

For both high emissions and low emissions scenarios, the Square Mile and the City Corporation's assets beyond this are set to see increasing average air temperatures. By 2080, under the high emissions scenario, summer average temperatures may increase by nearly 5°C, and winter by about 3°C. Under a lower emissions scenario, in 2080, average increases in temperature will be limited to around 1-2°C, more similar to the temperatures we see today. Today, we are seeing summers that are, on average, around 0.5°C warmer than the 1981-2000 average, with comparable winter temperatures. As further explored in Section Four, the level of forecast change is significant for people, assets and services, particularly when the microclimate effects of urban heat island are considered.

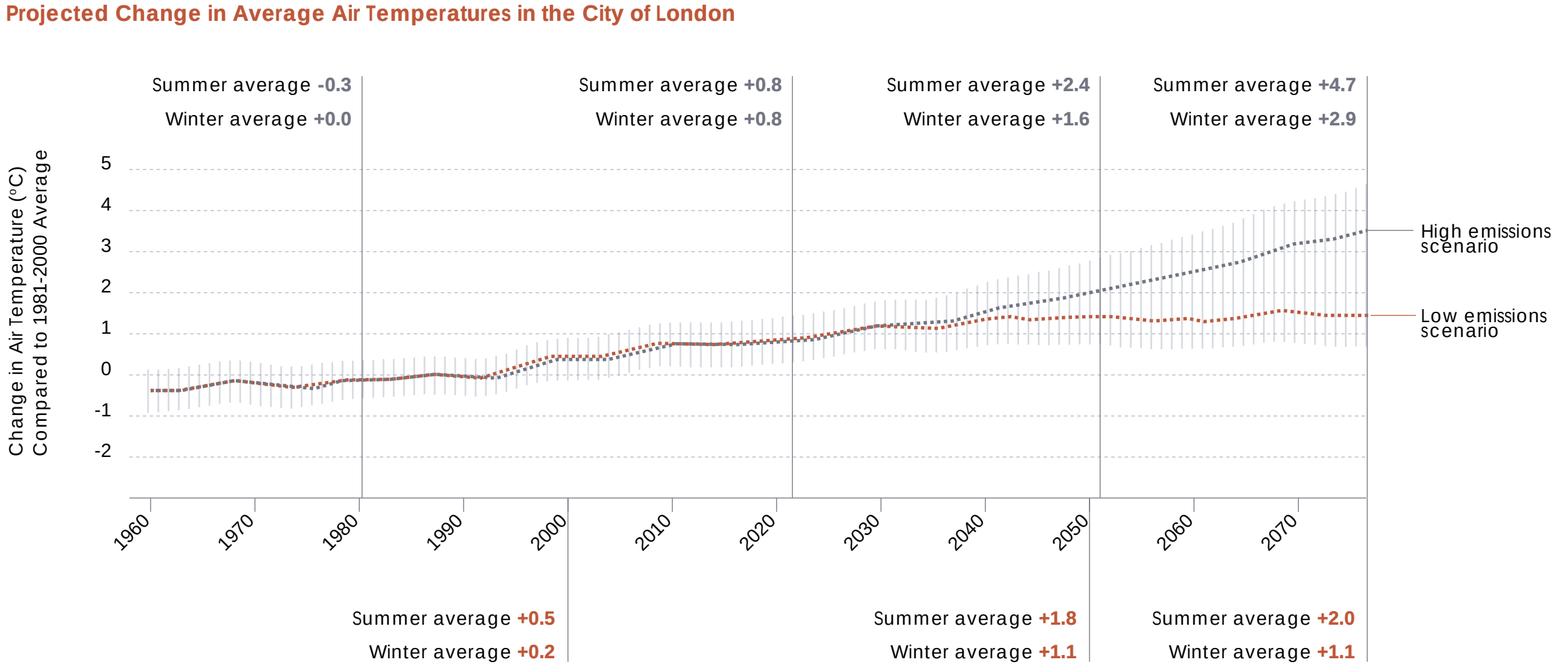


Figure 3-1 Change in average air temperatures under probabilistic UKCP18 projections for low and high emissions scenarios. As described in Section Two, uncertainty in modelling means we could see even higher temperatures. The grey hatching represents a range of possible results for the two scenarios (25th and 75th percentile).

03

How will the climate change?

In this section the key outcomes from the analysis of projected change in air temperature and rainfall patterns in the City of London Borough over the coming decades under high and low emissions scenarios are presented. Analysis is presented for annual averages, with seasonal patterns marked.

Rainfall

Under either emissions scenario, the Square Mile and the City Corporation's other assets are set to see a variation in rainfall patterns by 2080. This is split seasonally, with drier summers and wetter winters forecast.

Both scenarios suggest that summer rainfall is set to decrease by around a third by 2080, and winter rainfall to increase by around 20% by 2080. This links to the findings in Section Four, which indicate that extreme weather patterns (e.g. drought and heatwaves) are set to increase. In 2020, summer and winter conditions are predicted to be around 3% wetter than the 1981-2000 average, though by 2050 the pattern of wetter winters and drier summers will be more apparent.

Projected Change in the Average Proportion of Time Raining in the City of London

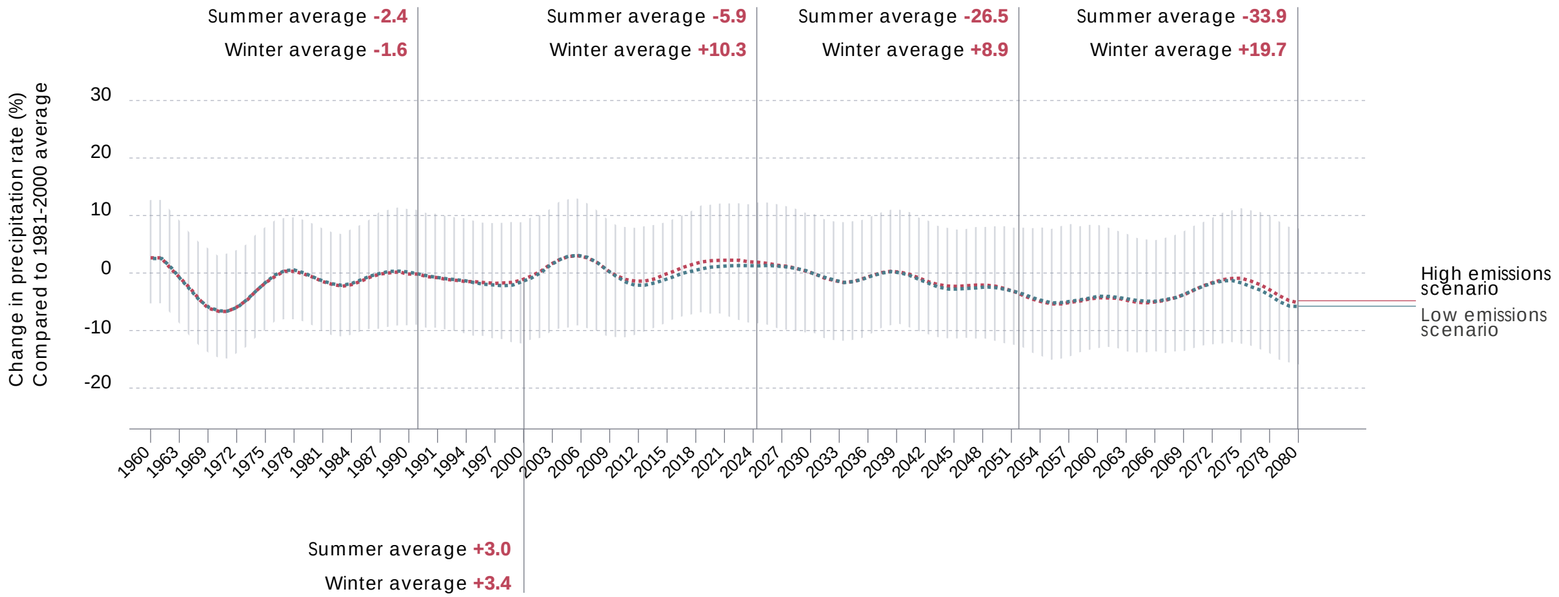


Figure 3-2 Change in average precipitation rates under probabilistic UKCP18 projections for low and high emissions scenarios. As described in Section 1, uncertainty in modelling means we could see more variable rainfall patterns. The grey hatching represents a range of possible results for the two scenarios (25th and 75th percentile).

03

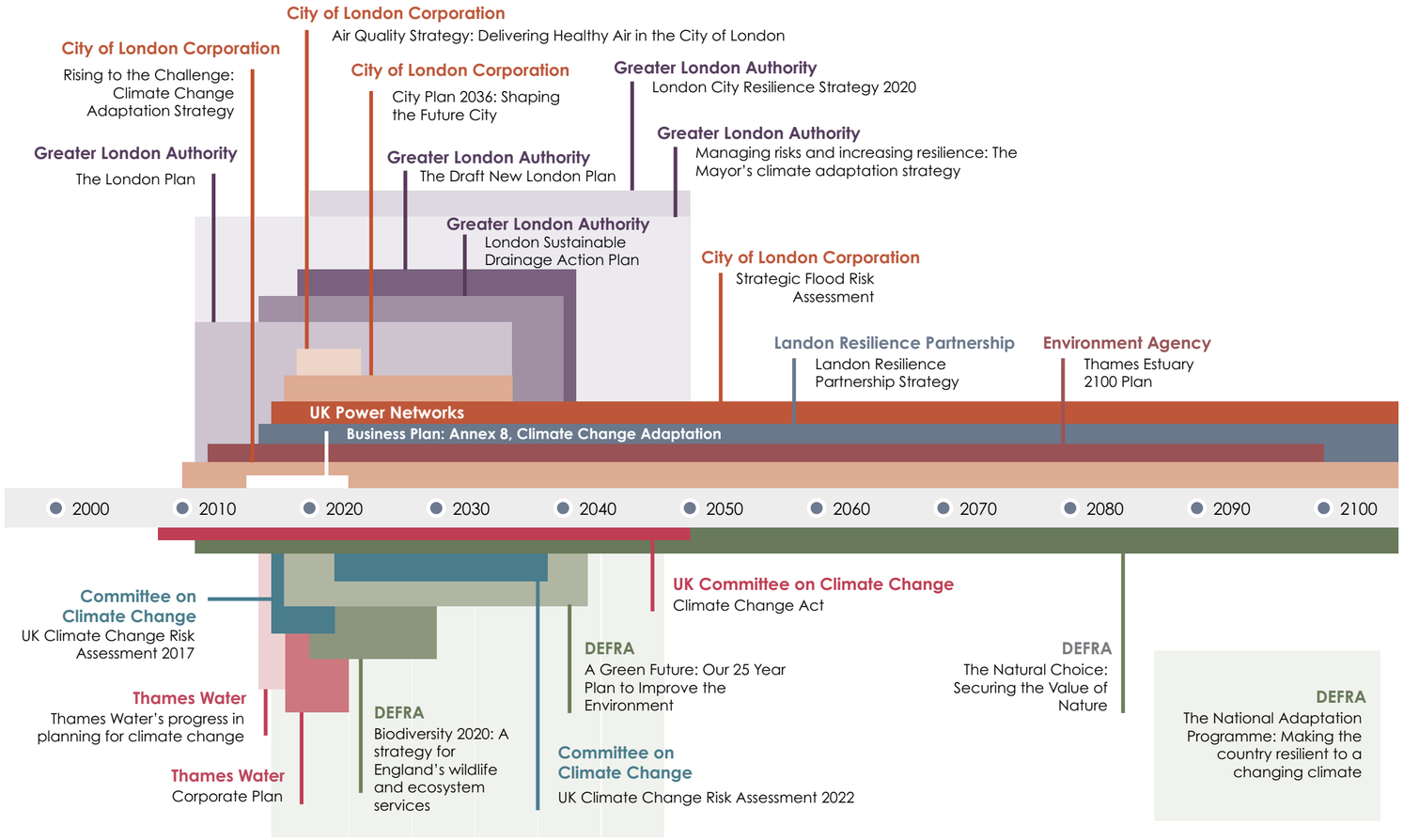
How will the climate change?

In this section the key outcomes from the analysis of projected change in air temperature and rainfall patterns in the City of London Borough over the coming decades under high and low emissions scenarios are presented. Analysis is presented for annual averages, with seasonal patterns marked.

Policy Implications

The results indicate that life in the Square Mile and beyond will have to cope with substantially higher temperatures, drier summers and wetter winters. These conditions will have implications for life in the Square Mile, including the resilience of our infrastructure, the health of workers and inhabitants, and the condition of our natural capital. These implications are explored further in Section Five.

Preparing for, and developing resilience to, the shocks and stresses that will emerge with changes in the future climate will require collaborative action. As illustrated, there are many existing national and regional policies as well as strategies developed on behalf of the public and private sector that are already contributing to building resilience.



04

Local weather patterns under the high emissions scenario

Local weather patterns under the high emissions scenario

This section looks at expected changes in the frequency of extreme weather events for the Square Mile in the coming decades under a high emissions scenario. As far as possible, resilience planning must inform preparedness and future planning for all reasonable future scenarios.

These results indicate that temperatures are set to rise rapidly: by 2080 maximum daily temperatures may increase by around 5°C. This translates into more frequent and longer spells of drought and heatwave, with models projecting an average of 11 days of drought and 56 days of heatwave in 2080. Decreasing relative humidity will help reduce deterioration in thermal comfort as temperatures increase.

Rainfall is also set to increase in intensity in the winter months, with models projecting an average of 20mm more rainfall over the wettest 5 days of winter in future decades compared to 2020. Conversely, snowfall is expected to decrease, as a result of increasing temperatures.

04

What may the worst case look like?

Comfort

Currently, in the summer months, high temperatures combined with high relative humidity and low wind speeds creates humid, uncomfortable thermal conditions. Under UKCP18 projections, while temperatures in the Square Mile are anticipated to increase substantially, relative humidity is set to decrease. This decrease in relative humidity will help to offset some discomfort related to rising temperatures.

Snow

Increasing temperatures will correlate with a rapid decrease in the amount of winter snowfall – up to a two thirds decrease by 2080 in a high emissions scenario. Amount of snow settling is likely to be a fraction of this amount, given rising land temperatures and the Urban Heat Island Effect.

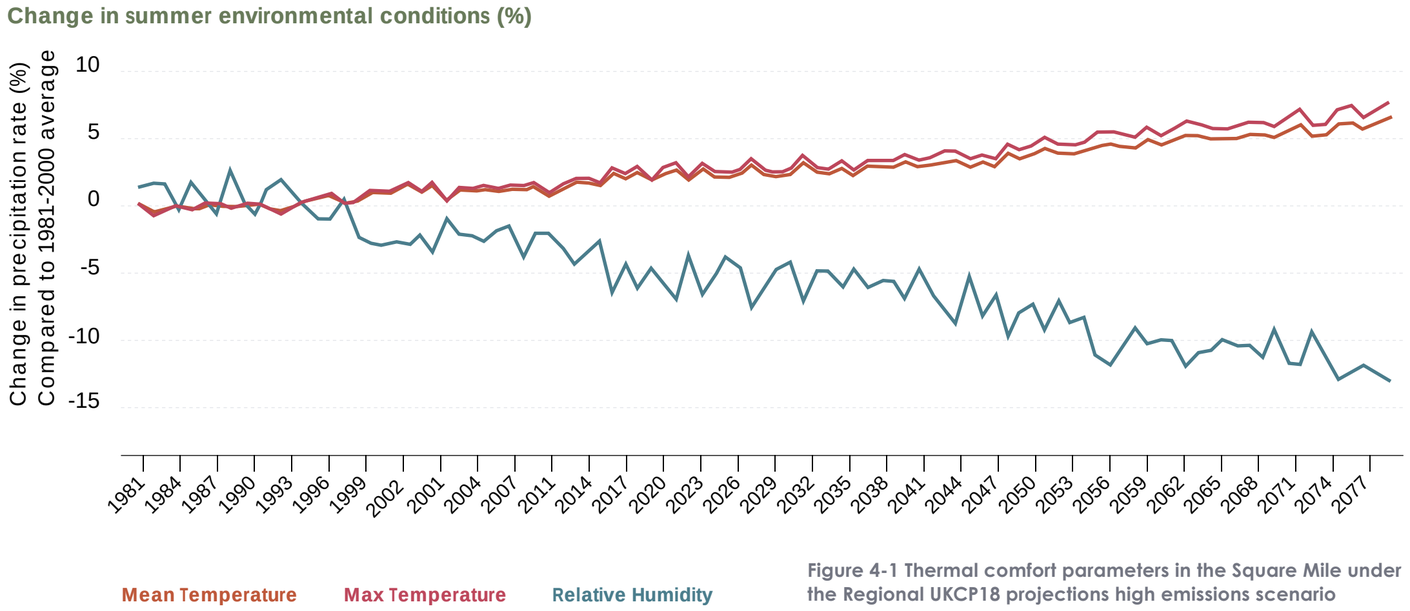
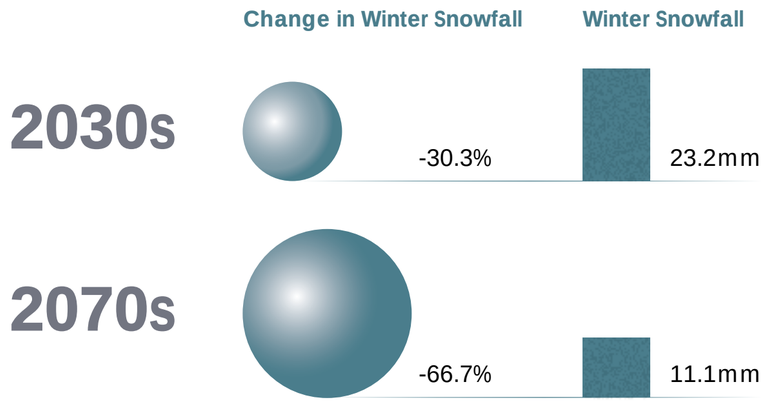
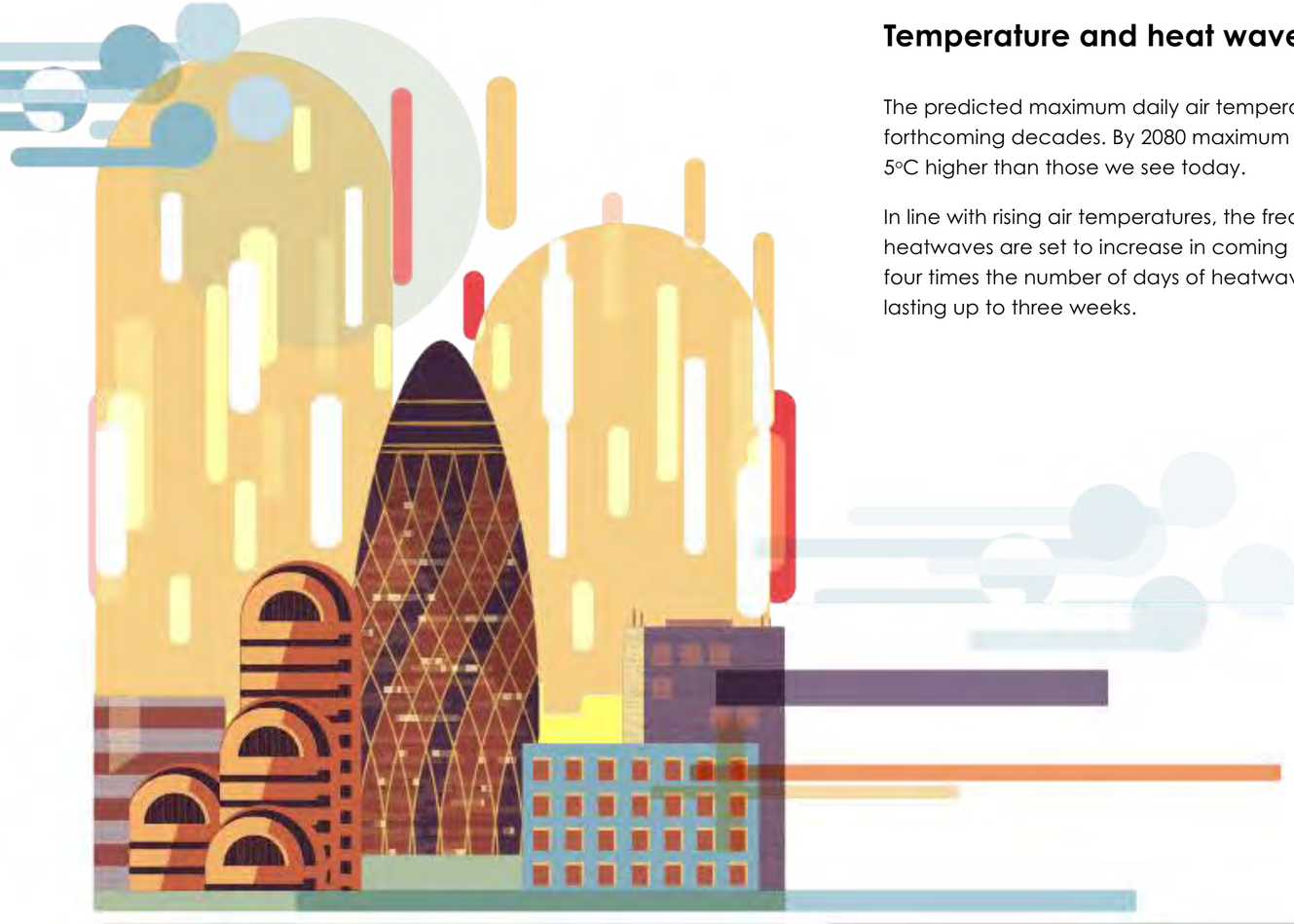


Figure 4-1 Thermal comfort parameters in the Square Mile under the Regional UKCP18 projections high emissions scenario



04

What may the worst case look like?



Temperature and heat waves

The predicted maximum daily air temperature is set to rise steadily in the forthcoming decades. By 2080 maximum air temperatures may be around 5°C higher than those we see today.

In line with rising air temperatures, the frequency and duration of heatwaves are set to increase in coming decades. By 2080, we may see four times the number of days of heatwave compared with today, some lasting up to three weeks.

Rainfall and drought

Rainfall is set to increase in intensity in the winter months, with models projecting an average of 20mm more rainfall over the wettest 5 days of winter in future decades compared to 2020.

Predictions of drier summers (Section Three) align with analysis of future drought. Like heatwaves, droughts are predicted to get longer and more frequent under a high emissions trajectory, with nearly double the days of drought predicted in 2050 compared to 2020. However, there is some fluctuation, as seen by the comparable number of days of drought in 2080 to today.

04

What may the worst case look like?

Max Air Temperature (°C)

The predicted maximum daily air temperature is set to rise steadily in the forthcoming decades. By 2080 maximum air temperatures may be around 5 degrees higher than those we see today.

Days of Heatwave

In line with rising air temperatures, the frequency and duration of heatwaves are set to increase in coming decades. By 2080, we may see 4 times the number of days of heatwave to today, some lasting up to 3 weeks.

Peak 5 Day Rainfall (mm)

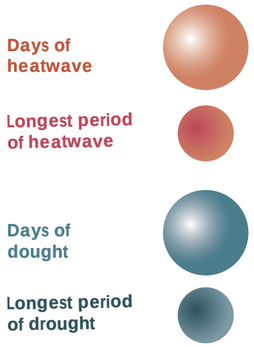
The 5 wettest days of the year are set to get wetter in future periods, with up to 20mm more rainfall in the 5 wettest consecutive days of rain in future years compared to those predicted for 2020.

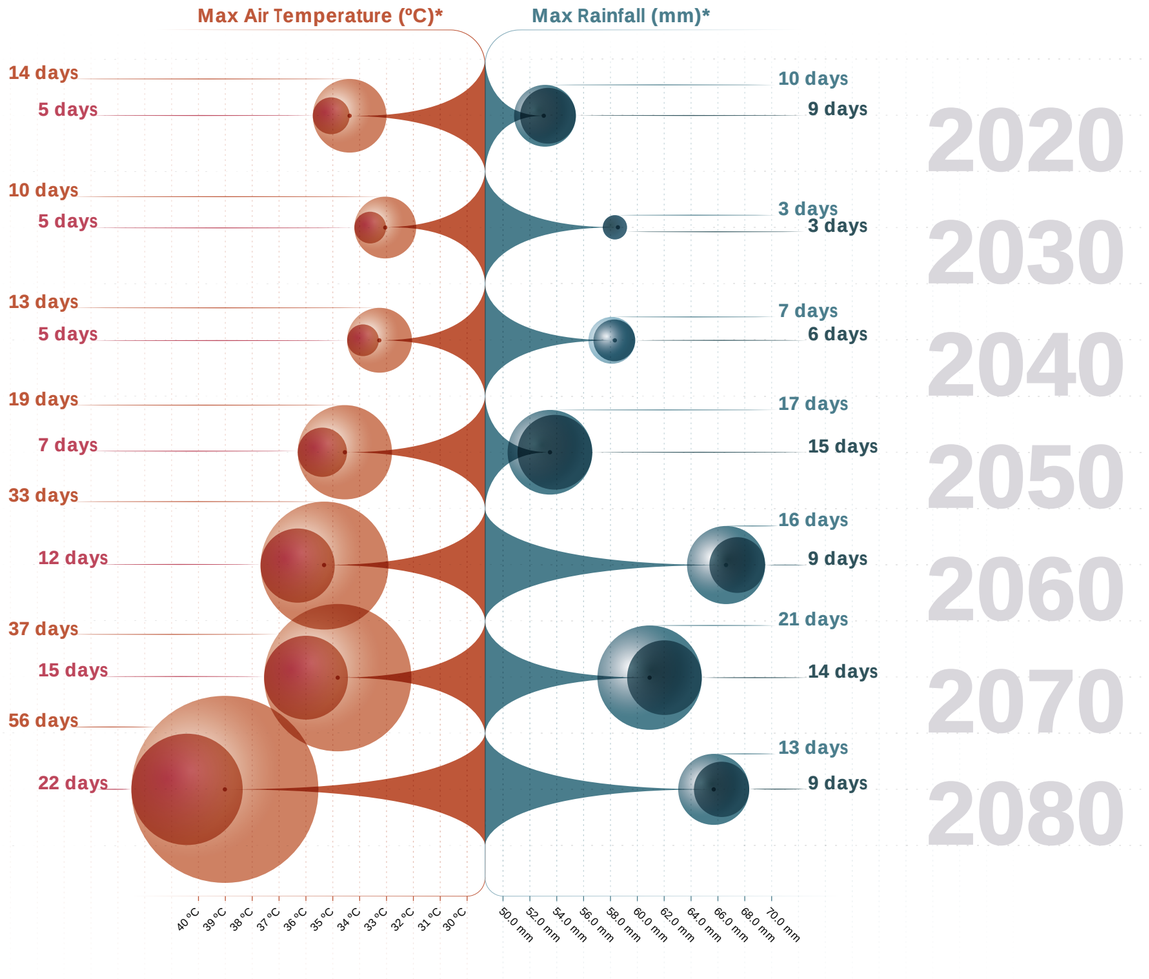
Days of Drought

Predictions of drier summers (Section 2) align with analysis of future drought. Like heatwaves, droughts are predicted to get longer and more frequent under a high emissions trajectory, with nearly double the days of drought predicted in 2050 compared to 2020. However, there is some fluctuation, as seen by the comparable number of days of drought in 2080 to today.

***Note: the change in maximum air temperatures shown here is slightly different to the change in average air temperatures shown in Section Three since the two are different variables, and are calculated using different models, as described in Section One.**

***Note that drought is defined at 15 days or more with less than 0.2mm of rainfall. Periods less than 15 days are listed here since the analysis involves calculating predicted days of drought, using this definition, for 12 separate models under UKCP18. The final number shown here is the average of the models' results. Since some models predict 0 days of drought, this may give a result which is smaller than 15 days.**





04

What may the worst case look like?

Wind

In the London Region, the 12 km UKCP18 projections indicate that wind speeds are anticipated to remain constant in future decades. A slight increase in winter, and decrease in summer, wind speeds can be seen in the projections, at a magnitude of less than 0.5 m/s. The MET Office notes that changes to the North Atlantic Oscillation weather system may also occur, which may influence weather patterns.[6] However, these changes are all 'expected to be much smaller than the natural variability [wind] exhibits from month to month and season to season.'

The analysis presented above is the change in wind speed associated with climate only. It does not account for the impacts for wind speeds associated with the design, construction or retrofit of buildings within the Square Mile as such changes are not an impact of climate change. The combined impact of building design (in particular tall buildings) and any change in wind speed under future climate scenarios, should be considered on a case-by-case basis.

As described in the Technical Appendices document, these extreme values are calculated using the UKCP18 Met Office Global and Regional projections for the City of London. These predict 12 daily datasets for possible conditions under the high emissions scenario (RCP 8.5). Our analysis extracts maximum temperature, five day rainfall, heatwave and drought data for each dataset, with average values present here. Drought and heatwaves are defined against MET Office definitions – see Section Two glossary. It is further noted that experienced comfort is a complex issue, influenced by multiple factors simultaneously. Within this analysis we have studied the outputs of UKCP18 which considers how the multiple factors that may influence comfort are forecast to change overtime. These factors are considered in isolation. In future studies, this analysis may be complimented by analyses using the Urban Thermal Comfort Index, for example, to provide further understanding of how these factors combined may affect experienced comfort.

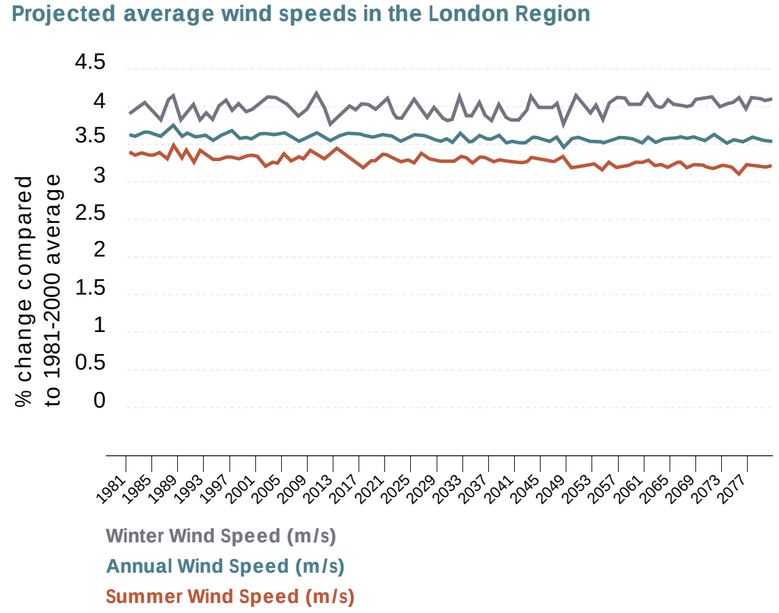


Figure 4-2 Average wind speeds in the Square Mile under the Regional UKCP18 projections high emissions scenario

Risk Assessments

05

Risk One: Flooding and coastal change risks to communities, businesses and infrastructure

The risks

Climate change is set to significantly alter rainfall patterns and increase sea level rise in the UK. This pattern presents an increased risk of severe flooding and coastal erosion. Across the UK, flood risk management will continue to be required to manage risks to our homes and businesses. This includes building structural flood defences, installing mitigation measures and managing surface water build-up and sewer discharge, as well as emergency response coordination in flood events.

An issue for the City of London

As described in the City of London Strategic Flood Risk Assessment (2017),[7] the Square Mile is located on the north bank of the River Thames and contains two historic watercourses: the River Fleet and the River Walbrook, culverted within the sewer network. The City is also underlain by two natural aquifers: River Terrace deposits and Upper Chalk. This positioning, and its highly urban structure, means that there is a risk of fluvial, tidal, surface water, sewer discharge and ground water flooding.

Surface water flooding

Surface water flooding occurs due to sewer overload or high rainfall overwhelming drainage systems. UKCP18 forecasts indicate that that winter rainfall is projected to increase in the City of London under both high and low emissions scenarios. This will increase the likelihood surface water flooding and sewer overflow flooding, which is affected by rainfall entering the sewer network across a wide catchment extending to Hammersmith in the west and Hampstead Heath in the north. A burst water main can also have serious impacts for surface water flooding. Good management of the infrastructure is the key to minimising the threat of flooding from this source. The City SFRA indicates that surface water flooding is the most likely cause of flooding in the Square Mile.

Flood risk from the River Thames

Future flood risk from the river is managed under the Environment Agency Thames Estuary (TE) 2100 Plan.[8] TE2100 describes that pluvial and fluvial flood risk on the Thames will increase under wetter winters and future sea level rise. The Square Mile is protected from this source of flooding through the Thames Tidal Defences, with extreme water levels controlled by the Thames Barrier. The Thames Barrier has seen a small increase in frequency of closures since its opening in 1982,[9] and there are plans to build a new barrier in the later half of the 21st Century.[9] Measures to upkeep these defences are laid out in Chapter nine of the TE2100 Plan, and involve raising defences heights by 0.5m (2065) and 1m (2100). The The City Corporation is developing a Riverside Strategy that will seek to implement these measures, including managing risk of rising water levels and increased likelihood of localised failure - breaches - along the river walls, as a result of hydrostatic loading.

Groundwater flooding

Aquifers beneath the city make groundwater flooding a risk in periods of high rainfall and high tide levels, with 776 properties currently at risk from groundwater flooding according to the City of London SFRA. Higher rainfall across the region predicted under climate change will raise subterranean water levels and increase the risk of groundwater flooding. However, despite the high potential impact, the City SFRA notes that this is a low risk in the Square Mile since groundwater levels are managed and maintained at a low level by the General Aquifer Research Development and Investigation Team (GARDIT).

05

Risk One: Flooding and coastal change risks to communities, businesses and infrastructure

Key impacts in the City of London

The Square Mile will see an increased risk in the frequency and intensity of flood events. This means increasing extents of flooding, and increased water depths. This raises the damages associated with flood events, as well as the numbers of properties and critical infrastructure locations affected. With a study of locations and numbers on the next page, disruption to the following critical infrastructure assets may be expected by different types of flooding:[8]

In the following section, data on properties is presented from the Square Mile SFRA.7 Data on critical infrastructure has been compiled for this report.

Potential impacts on critical infrastructure:	Surface water flooding	Flooding from the Thames	Groundwater flooding
Roads	X	X	X
Railway, DLR and underground	X	X	X
Medical centres and ambulance stations			
Education centres	X		X
Police or Fire stations			X
Electricity sub-stations	X	X	X
Residential and commercial buildings	X	X	X
Waste management (Walbrook Wharf)		X	
Local heat networks[10]			X
Utilities Subways	X	X	X

Sources: (i) Surface Water Flooding using Halcrow 2012 1 in 30y model, (ii) flooding from the river Thames, defence breach modelling to 2100, (iii) increased potential for elevated groundwater.[8]

Note: due to data sensitivity, the location of other critical infrastructure assets such as data centres could not be disclosed. It is likely that data centres and additional assets could be severely affected by flooding, with knock-on impacts to other services within the Square Mile and beyond.

05

Risk One: Flooding and coastal change risks to communities, businesses and infrastructure

Surface water flooding

Surface water flooding occurs 'when intense rainfall is unable to drain away by traditional means such as into drainage systems which may already be overloaded, or infiltrating into the ground',[8] and is the most likely cause of flooding in the City of London. Under climate change, we are due to see increasingly severe weather events and winter rainfall, as modelled by the Environment Agency for a typical 1% Annual Exceedance Probability (AEP) flood event with the risk of 40% increase in rainfall included.[8]

Flood Wof 1.0%

- Flood risk to 35 properties and 73 commercial buildings.
- A total of 217 properties risk lost access due to surface water flooding (91% residential)
- Critical infrastructure affected includes 3 electrical sub-stations, 2 educational facilities and Blackfriars Station.

Flood events with an annual exceedance probability of 1.0% +40% increase in rainfall under Climate Change

- Under 40% rainfall increase, surface water is projected to extend to cover an additional substation, and numerous commercial and residential properties.
- A number of critical utility lines run at a deep level below Farringdon Street. Whilst likely designed with future climate in mind, potential impacts of extreme events on the functioning of these assets should be considered.

City of London Resilience: Surface Water Mapping

05

Risk One: Flooding and coastal change risks to communities, businesses and infrastructure

Flood risk from River Thames

Current Flood Risk

- Direct fluvial flood risk to properties along the river walls in the Square Mile currently amounts to 46 properties and 33 commercial buildings.
- A total of 457 properties are currently at risk of lost access due to flooding, rising to 494 in 2100 (predominantly residential)
- Critical infrastructure affected includes an electrical substation, 1 planned electric vehicle charge point and Blackfriars Bridge station.
- A number of data centres that serve the Square Mile and areas beyond this are located in at-risk areas (locations undisclosed, due to sensitivity).

Future Flood risk

- Direct fluvial flood risk to properties along the river walls in the Square Mile is projected to include 56 properties and 70 commercial buildings.
- Additional critical infrastructure affected includes a fire station, Walbrook Wharf, and additional EV charging infrastructure.

City of London Resilience: Breach Mapping

Note: Flood defence condition grade 1 indicates good condition, and condition grade 5 indicates a failing defence.

05

Risk One: Flooding and coastal change risks to communities, businesses and infrastructure

Ground water flooding

Groundwater flooding events are difficult to map where groundwater levels are unknown, and there is a complex relationship between rainfall events across the region and local geology. In the City of London the risk of groundwater flooding is also low since groundwater levels are maintained artificially low. However, modelling of the London groundwater regime has shown that the following areas could be impacted by groundwater flooding events.[8]

- Flood risk to 81 residential properties and 695 commercial.
- Floods risking access to 700 residential and 291 commercial properties.
- Moorgate, Liverpool Street, Bank and Cannon Street stations at risk, as are 6 educational centres, 1 police station, 3 planned electric vehicle charging points and 3 electrical substations. Projected impacts of flooding at the new Liverpool Street Crossrail site do not account for surface water management measures introduced as part of the scheme. As such, it is likely risk has been identified and mitigated by the development team.
- The large extent of the groundwater flood map means that many tourist destinations are at increased risk of groundwater flooding. This includes historic areas around Bank, the Barbican Estate and Spitalfields Market.

City of London Resilience: Groundwater Mapping

Note: Flood defence condition grade 1 indicates good condition, and condition grade 5 indicates a failing defence.

05

Risk Two: Risks to health, well-being and productivity from high temperatures

The risks

Temperature rise is one of the best understood impacts of climate change. For populations, one of the prominent impacts of rising temperatures is its effect on personal health and wellbeing. The 2012 Public Heath England (PHE) **Health Effects of Climate Change in the UK 2012** report[11] outlines several areas connecting health concerns with escalating temperatures:

1. Temperature effects on human health.
2. Effects of temperature on aeroallergens, pollutants and vector-borne diseases.
3. Temperature and Infrastructure – health and wellbeing risks linked to infrastructure performance under rising temperatures.

1. Increasing temperatures may reduce the high numbers of cold-related deaths in the UK each year, but ill-health and deaths related to heatwaves and high temperatures will rise. UK-wide, some studies anticipate increases in heat-related mortality of approximately 70% in the 2020s, 260% in the 2050s, and 540% in the 2080s, compared with the 2000s baseline of around 2,000 deaths without action.[12]
2. Air temperatures correlate with levels of air pollution, which may trigger respiratory disorders[13]. Seasonal and planting changes will also diversify pollen distributions, with implications for allergens. Pathogen distributions will also be affected by rising temperatures since they show seasonal variation, and rising temperatures may change food preparation and bacterial growth patterns. See also Risk Six.
3. Infrastructure is connected to temperature-related wellbeing, with risks including:
    - Further temperature strain from building overheating, enhanced by overcrowding and poor ventilation.
    - Rising demand on healthcare services, particularly during heatwaves, as well as greater temperature control required to maintain sensitive hospital systems.
    - Effect of heating on roads and access, for example asphalt softening under high solar radiation.
    - Effect on underground spaces, particularly where cooling systems do not exist.

An issue for the City of London

Temperatures in the Square Mile are set to rise in line with national trends, with summer temperatures increasing by around 5°C in 2080 under high emissions scenarios, and the frequency and duration of droughts and heatwaves rising. Heat-related mortality in London will be made worse by the Urban Heat Island (UHI) effect, which can add whole degrees to temperature levels; a study commissioned by the GLA suggests that average summer night-time temperature was approximately 4°C higher in the London city centre than surroundings.[5] As such, overheating, compounded by the UHI effect, is a key risk for the Square Mile.

05

Risk Two: Risks to health, well-being and productivity from high temperatures

Key impacts in the City of London

1 The workday population of the Square Mile amounts to over 500,000 people[1] – composing of residents, tourists and workers. The ability to access **outdoor spaces** is essential to physical and mental health and wellbeing. Increasing outdoor temperatures and deteriorating comfort conditions, combined with the potential for loss of wildlife character (Risk Four) threaten the ability of individuals to access these health benefits. Workers, tourists and other users may be less likely to dwell if they experience thermal stress, which in turn may impact local businesses.

2 The Square Mile has a diverse building stock, many of which are historic or aging,[2] for which there is no single, consistent approach to dealing with increasing temperatures. **Overheating** will contribute to heat-related illness and mortality, as well as decreases in business productivity – for example, one LSE study found that London could experience losses of 0.4% to its Gross Value Added due to heat stress and productivity by 2100, 24% of this within the Financial Sector, a key industry in the Square Mile.[14] Overheating may apply to buildings, infrastructure (e.g. mechanical plant, road networks), outdoor spaces (i.e. public realm) and the underground spaces – including the London Underground, which in summer 2018 saw average monthly evening peak temperatures of over 29°C on some lines.[15]

3 **Heat-related illness and mortality** is a major risk. The City has around 9,000 permanent residents,[16] with many other City Corporation-owned residential sites in Greater London. The elderly are most vulnerable to rising heat (16% of residents in the City are aged 65+). The City has a daytime population of over 400,000[17], consisting mainly of workers in the City district. Amongst professional occupations, around 33% of people have long-term health conditions, which could put them at particular health risk under increasing temperatures.[18] In addition, there is much planned construction in the Square Mile. Increased temperatures may expose those working outdoors to particular risk, notably during extreme events.

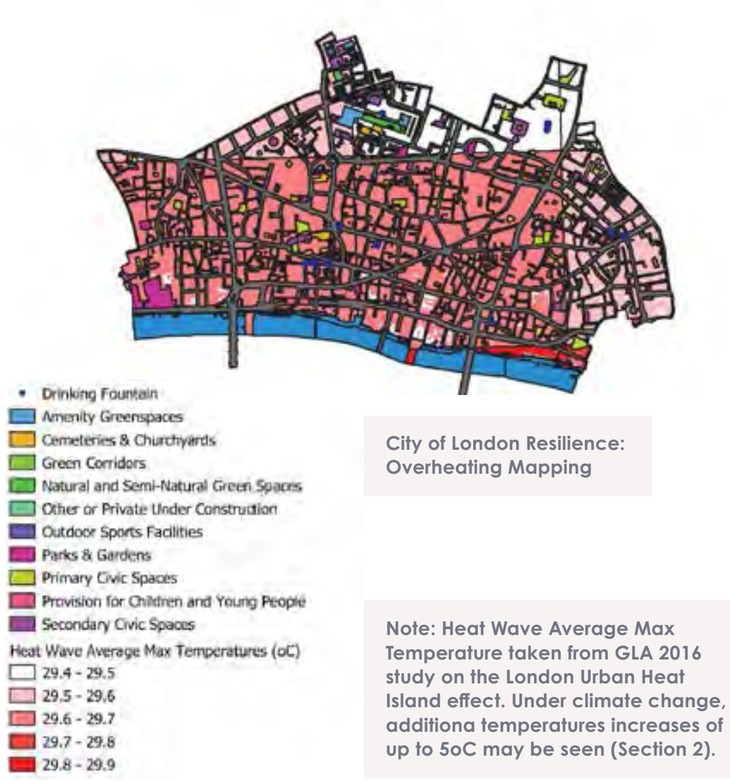
4 **Changes to healthcare requirements** due to rising temperatures will make managing demand on and access to the cardiac centre at St Bartholomew's and A&E services at other local hospitals a key concern for the City. Life-threatening' callouts to the London Ambulance Service increased by 20% during 2013 heatwaves. This may be exacerbated by disruption to local roads, which may impact ambulance passage. Road temperatures can be 35-75% higher than air temperatures, causing melting.[20]

5 **Water, food-borne and enteric pathogen distribution** show seasonal variation, with higher temperatures supporting incubation. Warmer weather will also allow pathogens such as Salmonella to grow more readily in food, and will favour pests that affect food safety. See Risk Six.

6 **Air pollution and allergen distributions** vary seasonally, particularly during heatwaves, suggesting there is a heightened risk to hay fever sufferers, and of well-documented ill-health caused by pollutants. Levels of air pollution in the City of London are high, with locations regularly exceeding EU air pollution limit values.[21] While the City of London Air Quality Strategy aims to improve future air quality in the City, the risk of deteriorating conditions resulting from increasing temperatures must also be considered.

05

Risk Two: Risks to health, well-being and productivity from high temperatures



City of London Resilience: Overheating Mapping

Note: Heat Wave Average Max Temperature taken from GLA 2016 study on the London Urban Heat Island effect. Under climate change, additiona temperatures increases of up to 5oC may be seen (Section 2).

Figure 5-5 urban heat island[5] in the Square Mile, with public space distribution and drinking fountains

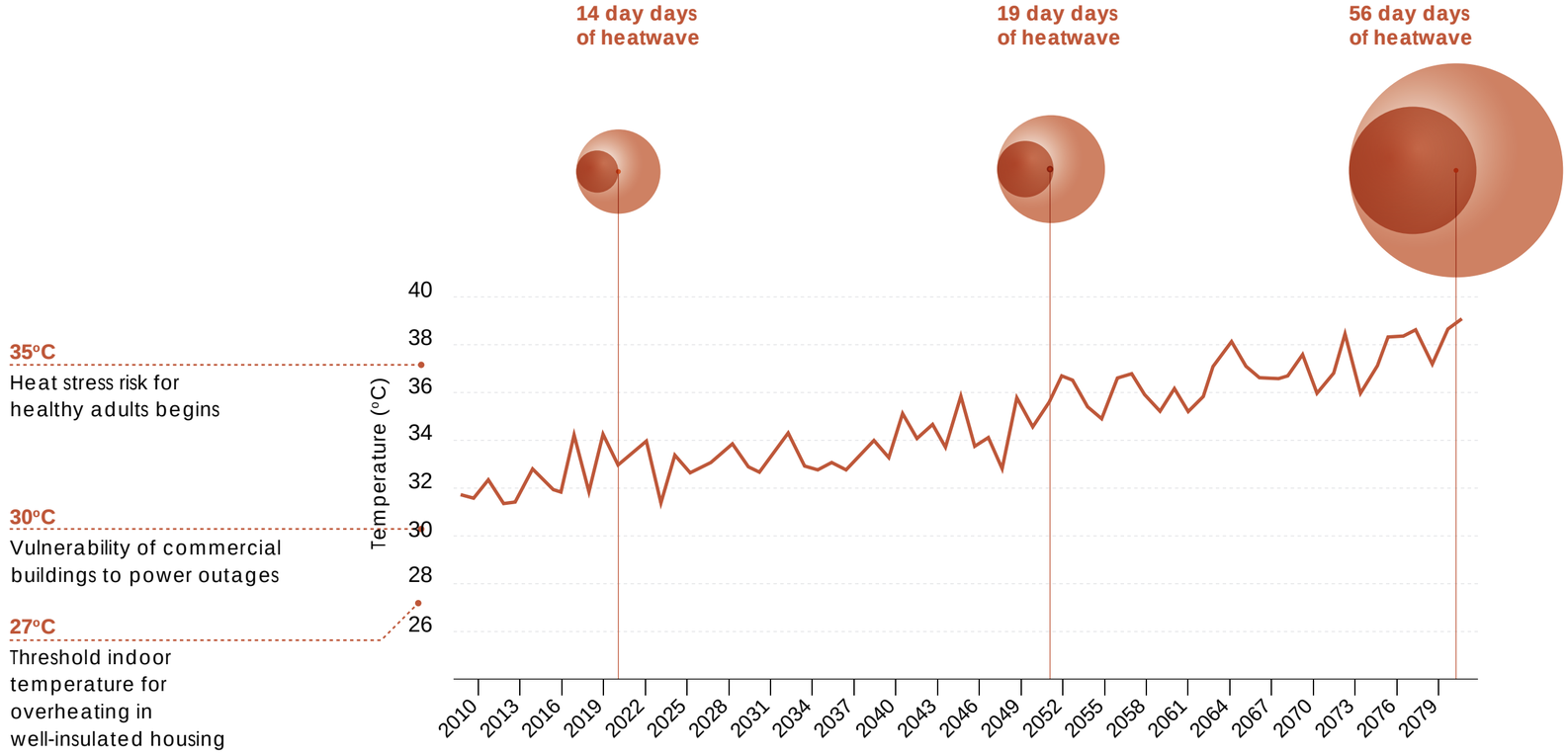


Figure 5-4 maximum daily average temperatures and summer heatwave in the Square Mile under Regional UKCP18 projection high emissions scenarios

05

Risk Two: Risks to health, well-being and productivity from high temperatures

Notable health and infrastructure trends

Issue	2020	Trend	Consequence
Overheating in buildings	56% of domestic EPC ratings awarded between 2017-2018 in the City of London were rated C or lower.[22] The borough has over 600 listed buildings and an aging building stock, so it is expected that many will be challenged to cope with overheating conditions.	**Fluctuating**	New building risk should reduce with tightening energy efficiency legislation. Conversely, aging building stock may see rising risks if not appropriately managed and retrofitted. Large amounts of the City lie in Conservation Areas, meaning that some retrofit measures may not be possible.
Overheating impacts for infrastructure	Anecdotal evidence from City of London officers suggests that peak loads are placed on the UK Power Network during British summer time. This is primarily associated with increased demands for cooling. During previous heatwaves, the existing infrastructure has continued to perform as required. During periods of extreme heat, disruption to roads networks has been observed.	**Fluctuating**	There is a need to consider the potential impacts associated with rising temperature extremes, more frequent and extended periods of heatwaves on the UK Power Network. Hotter, drier summers, followed by warmer wetter winters, may increase the likelihood and scale of damage to road networks. UKPN notes that under climate change there is a significant increase in likelihood of underground cable systems and transformers being affected by increasing temperatures, and a small increase in transformers, substations and underground cables being affected by increasing droughts.[23]
Overheating on the underground	The City has an extensive underground network. GLA records indicate that London Underground lines are subject to overheating. The Central and Northern lines, which service the City of London, both saw temperatures exceed 28°C in 2017.[16]	**Deteriorating**	Increased daytime population numbers are set to increase the overcrowding risk on the underground. Combined with rising temperatures, this increases the risk of overheating on trains. While this risk may be reduced by new transport plans, such as the opening of the Elizabeth Line, there is currently no TfL modernisation plan for the Central or Northern lines.[24]
National projected increases in heat related ill-health	Across England there are approximately 30,000 – 41,500 cold-related deaths per year, compared to around 2,000 heat-related deaths.13 These both particularly affect the very elderly, and those with pulmonary conditions. Heatwaves killed 892 Londoners in 2019, after ~16 days of heatwave.[25]	**Improving**	Heat related deaths expected to rise by between 250-300% by the 2050s (without adaptation). However, the number of cold-related deaths may decline: one study estimates a 12% decline by the 2080s, compared with the 2000s baseline.[13] In the City of London these rates may be conservative given the Urban Heat Island effect. This means healthcare operations may need to shift focus.
Strain on summer hospital capacity	The Bart's Health Trust, of which Bart's Hospital is a contributing hospital, saw occupancy rates of over 88.4 – 92.9% in 2018-2019[26]. Several studies have found associations between high temperatures and increases in emergency hospital admissions, and GP visits have also been shown to increase in hot weather.[13] This may have implications for the cardiac centre at St Bart's as well as A&E services provided by Royal London Hospital. Ambulance services are put under strain during hot events, as seen in the previous section.	**Deteriorating**	Rising populations combined with health strain due to heightening temperatures, rising incidents from pests and diseases (Risk Six), heat wave and air pollution events suggests there will be bed shortages and strain on infrastructure. Disruption to roads, through surface damage and melting in high heat, may put further strain on ambulance services if cool road routes are not available.
Air pollution	In 2010 nearly 10,000 Londoners died prematurely due to long-term exposure to small particles. Between 2014-16, over 4,000 Londoners were hospitalised due to harmful air pollution, and it was responsible for 10% of childhood asthma hospital admissions.[27]	**Improving**	If air pollution reduction measures are successful, pollution-related ill-health should decrease. However, rising temperatures may offset policies designed to reduce current levels.
Impacts of decreased used of outdoor areas	The City Corporation is responsible for the management of 11,000 acres of green space, both in the Square Mile and beyond. These are mainly parkland and forest, and are used extensively for leisure and recreation. They therefore have important physical and mental health benefits.	**Deteriorating**	If temperatures are too high in outdoor spaces, people are likely to reduce time spent outdoors, meaning they will be less able to harness the benefits of time spent outdoors. This may in turn have impacts on local businesses as workers and tourists may be less likely to dwell in the public realm if they experience thermal stress.

05

Risk Three: Risk of shortages in the public water supply, and for agriculture, energy generation and industry

The risks

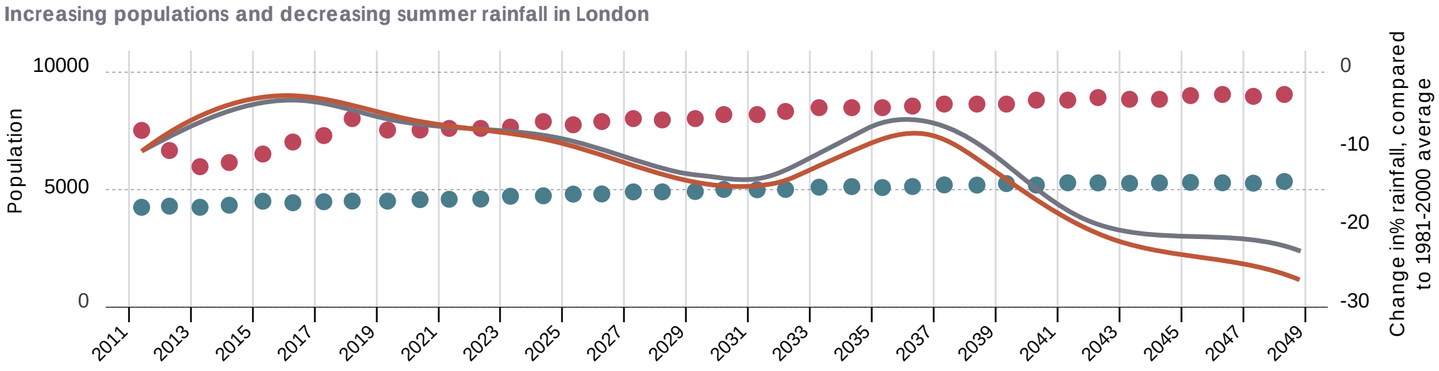
The Climate Change Risk Assessment 2017 Evidence Report[13] establishes that a key risk of climate change it its potential to threaten water supplies: without action, demand for water could be more than 150% of the available resource in many catchments across the UK in future decades. Projected decreases in summer rainfall, combined with population increases, will create a supply deficit. This may be exacerbated by rising temperatures driving evapotranspiration and aridity which lowers reservoir levels, and decreased capacities of water treatment centres. These are vulnerable to flooding, which may also increase in frequency and intensity under climate change. Finally, groundwater abstraction can be ecologically harmful and if not managed sustainably may result in a necessity to reduce reliance on this as a method for meeting demand. Droughts will have implications for public water supply, energy generation and industry, while also feeding into further risks surrounding public health, infrastructure and food supplies.

An issue for the City of London

London's water supplies are dependent on rainfall across the Thames catchment area and surroundings.[28] The climate projections for the area indicate that increases in drought and shifts in seasonal rainfall will follow similar patterns to those forecast for the wider country. Similarly, population and employment forecasts for the area are set to rise. Taken together, without action and appropriate investment it is likely that water supply risks will apply to City of London assets just as across the UK. This is corroborated by literature from WaterUK[29], which indicates that the biggest forecast percentage water deficits in the UK will be seen across London and the South East, and Thames Water, which has stated that 'we can maintain supply… [but] our current assets will be placed under great strain, impacting the robustness of the water system and potentially having a significant detrimental effect on the environment and ecology; and businesses which rely on water'.[30] This is an immediate risk for the City of London.

In addition to drought, Thames Water analysis indicates that further risks for their supply chain – resources, water treatment networks and wastewater treatment – include flooding, temperatures rises and sea level rise.[31] Flood management within the Square Mile is considered in **Risk One**. The City Corporation also owns nine reservoirs, numerous ponds and 4,500 hectares of green space that will play an important part in sustainable urban drainage systems (Figure 5 11), and whose vulnerability is further discussed in **Risk Four**. Finally, the City Corporation is responsible for Rye Brook Dam, a freshwater flood defence asset on Ashtead Common. The dam was restored in 2004,[32] and there is no indication that this poses a risk to major water supply infrastructure.[33]

Figure 5-6 Rainfall and population projections for the Square Mile. Populations calculated using GLA projections. Rainfall data from UKCP18 50th percentile probabilistic analysis, high emission scenario.



05

Risk Three: Risk of shortages in the public water supply, and for agriculture, energy generation and industry

Key impacts in the City of London

Lack of water will exacerbate all other risks described in greater detail in other sections:

- Water to support hospitals and public health during periods of high temperatures (Risk One).
- Water to support emergency services and supplies in extreme events (Risk Two).
- Water as a central part of maintaining natural capital, food production and health systems (Risks Four and Five).

Risk	Time horizon	Impact
Indirect risks through affected infrastructure outside of the City of London boundary	**Long**	Risks to food supply through increased soil aridity and irrigation limitations – around 50% of food consumed is produced in the UK[34], so regional droughts could impact a large proportion of the supply chain. See Risk Five.
	Short	Risks to energy supply – 23% of the UK's energy is generated from power plants cooled from freshwater sources.[35]
	Medium	Risks to local freshwater species, with resulting ecological disturbance also affecting regional agriculture and natural systems. See Risk Four.
Direct risks to City of London operations	**Long**	Risk to household and business water supplies – according to Thames Water projections, by 2100 current water supplies may only meet 76% of demand in London, though some challenges are expected much sooner.[31]
	Short	Linked to the above, buildings typically have approximately one day's worth of water storage. There may be a risk to business continuity if supplies for critical demands cannot be met.
	Medium	Risks to aquifers from saltwater intrusion – if saltwater gets into freshwater supply through the aquifer, there will be a further regional threat to water supplies.
	Short	Risks to irrigation and cleaning regimes – in drought conditions non-essential use of water is limited. However, many of these services are crucial for tourism, public health and maintenance of natural capital and the ecosystem services these provide.
	Short	Risks to air quality – water spray is used to damp down construction dust. Drought limitations on irrigation could result in high local levels of air pollution.

05

Risk Three: Risk of shortages in the public water supply, and for agriculture, energy generation and industry

Estimate of usage in the City of London – Thames Water statistics (2016-17)[36]

% of London users metered	33%
Water wasted through leakage	28%
London per capita consumption	147.2 l/person/d

Approximate water usage in the Square Mile

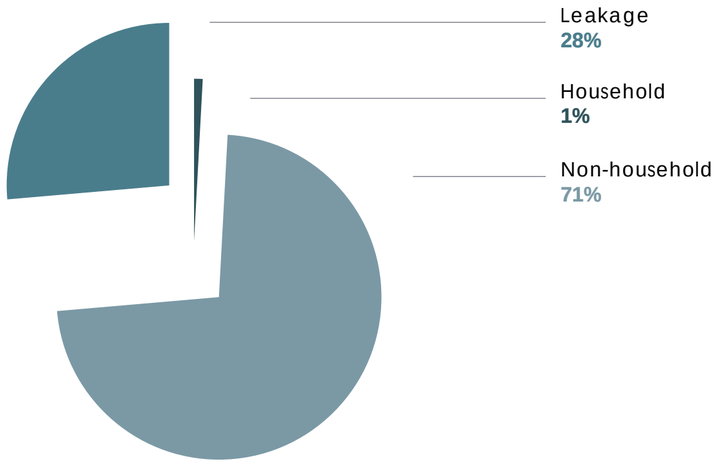


Figure 5-7 approximate water usage in the City of London Borough, based on Thames water leakage, per capita and per non-household properties baseline, using GLA data on residents and non-household property units.

Baseline London supply demand summary (Ml/d) - dry year

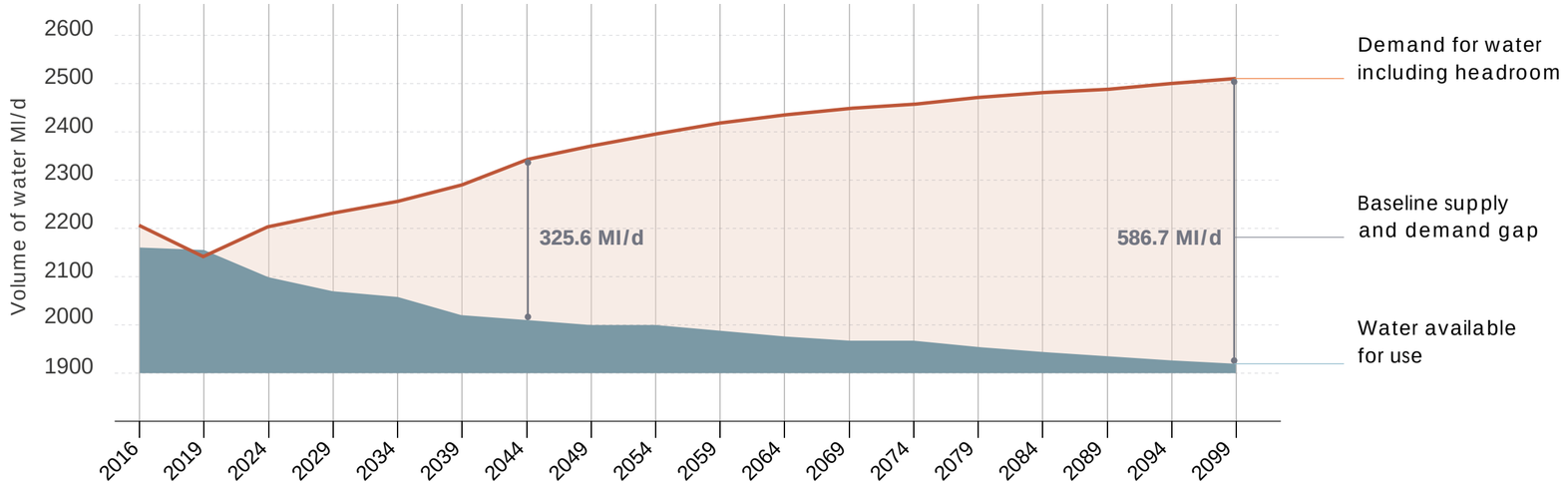


Figure 5-8 Thames Water analysis[30] of supply and demand gap for London indicates that supply could only meet 76% of baseline demand by 2100 in London, if no action is taken

05

Risk Four: Risks to natural capital, including terrestrial, coastal, marine and freshwater ecosystems, soils and biodiversity

The risks

Climatic changes fundamentally alter natural trends and ecosystems, which can impact the natural systems which we depend on for goods and services, as well as causing decline and loss within ecosystems themselves. This can include issues with production of timber, food and clean water, as well as disruption to pollination systems, carbon storage capacity and our dependence on landscapes and wildlife for personal wellbeing. The Climate Change Risk Assessment 2017 Evidence Report also notes that these 'risks are typically exacerbated because the natural environment is already stressed by other non-climate pressures including pollution, habitat loss and fragmentation, and unsustainable use of soil, water and marine resources'.[37]

An issue for the City of London

With only 13.1% of the Square Mile made up of green or blue infrastructure, the consequences of this risk to the Square Mile may be localised, with many indirect impacts through the other issues noted in this study. However, alongside 376 green spaces in the Square Mile, which have important wellbeing and local biodiversity roles, the City Corporation owns or manages almost 4,500 hectares of historic and natural open spaces outside of the Square Mile boundary. These areas include Sites of Special Scientific Interest, National Nature Reserves and Special Areas of Conservation.

The ecosystems in these areas may be described as follows through the National Character Area Profiles:[38]

- The Square Mile – the ecology types in inner London are 'an extensive urban forest of small woodlands and trees in streets, parks, gardens and open spaces.' Including an increasing number of green roofs, these urban green spaces rely heavily on ecosystem services from woodlands, wetlands and parklands in surrounding areas (Figure 5 10). There is also 'a network of rivers, streams, canals, lakes, reservoirs and smaller waterbodies which, together with similar features in outer London, form a strategically important network which provides transport corridors, drainage and flood management, freshwater, diverse wildlife habitats, heritage value, recreational opportunities and important views.'
- Areas outside the Square Mile boundary – the City Corporation is responsible for woodland areas such as Epping Forest and parts of Hampstead Heath. In Inner London, woodland is predominantly broadleaved type, made up of 'ancient semi-natural woodland'. Non-wooded areas are predominantly lowland meadow, with some lowland dry acid grassland.
- Water habitats – the Square Mile contains small freshwater bodies and a portion of the River Thames, which is a National Conservation Area: 'The Thames is important as a migratory corridor for both fish and birds. Aquatic species such as eel, smelt and salmon can be also found'.[39]

05

Risk Four: Risks to natural capital, including terrestrial, coastal, marine and freshwater ecosystems, soils and biodiversity

Key impacts in the City of London

Natural areas in Southern England and the City of London 'are projected to be significantly affected by changes in vegetation composition'[38] in future decades. Without action, lack of connectivity is likely to hasten species decline, while posing as a barrier to new species colonisation, resulting in the potential for a net loss of biodiversity.[39] Landscape character and typology will also be threatened by drought; in the London region this means a likely shift to drought-resilient species and loss of shallow-rooted woodland species, such as beech.[39] The worst affected meadow and woodland areas may be replaced by species-poor acid grassland after the 2050s.[39] A study on climate change impacts on Burnham Beeches, a City Corporation asset, indicated that tree species such as beech and oak would decline in health, while species such as rowan and whitebeam could grow better – resulting in a 'more scrubby and open woodland, with lower tree canopies'.[40] Marine ecosystems may see a decline in species as habitats are threatened by rising water temperatures, low oxygen levels and invasive non-native species.

Risk	Impact
Risks of loss of biodiversity and ecological functionality	Changes in the distribution of plant and animal species and the composition of plant communities leading to habitat loss and fragmentation is likely. Changes in individual species life-cycle timing (knows as phenology) caused by changing temperatures can cause plants to flower/ produce fruit earlier or later than usual. This has a knock-on effect on the insects reliant on specific plants for food which then affects food availability for birds producing young etc. Timing of behaviour is usually linked to the availability of food. While some species will be able to adapt, some of those further up the food chain with longer generation times will struggle and thus are more likely to experience declines in population. This may change the local distribution of species, possibly resulting in local extinctions, and alters the composition and functionality of ecological communities.61
Risks to existing species and habitats due to inability to respond to changing climatic conditions. **Opportunities from new species colonisation – climatic conditions may become suitable to host non-native species.**	There is a high likelihood of changing species composition in the borough's natural spaces. Both animal and plant species are at risk of dying out if they are unable to adapt to changing environmental conditions (Figure 5-5), both new growth and existing mature wildlife. Future conditions in the Square Mile and around are also predicted to be relatively poorly suited to new species colonisation, making loss of biodiversity, and deteriorating habitat connectivity across London, a real risk for the City.[40]
Risk of non-native pests and diseases increasing Risk Six.	Changing climatic and ecosystem conditions risk the introduction and increased transmission of non-native pests and diseases, with numbers of UK Tree Pest and Disease introduction already showing increase since 1900.[42] Inner London has recently seen outbreaks of oak processionary moth, ash die back and Massaria fungal disease on London Planes, and floating pennywort in water bodies.[39] Studies note that urban trees are at particular risk of new pathogens and pest outbreaks, since the global trade in 'plants for planting' is a pathway for their accidental introduction. See more under Risk Six.
Risk to natural carbon stores and carbon sequestration – if biomass decreases, amount of natural capital used as a carbon sink may decrease.	The City Corporation risks losing some carbon sequestration and storage capacity – 4,500 ha of Corporation-owned green space sequesters approximately 27 ktCO_2e/year, ~3% of the Square Mile's annual footprint.[44]
Risks to agriculture forestry, wildlife and heritage from change in frequency and/ or magnitude of extreme weather and wildfire events.	There is increasing risk of extreme weather events in the London Region, which may damage natural capital and its surroundings. Droughts also risk wildfires such as those experienced at Epping Forest in 2018, which, given large numbers of people in the Square Mile and of visitors to parks owned by the City Corporation, and the high value of local infrastructure, would be extremely dangerous. However, existing emergency response services and strategies help to minimise and manage risk.

05

Risk Four: Risks to natural capital, including terrestrial, coastal, marine and freshwater ecosystems, soils and biodiversity

BURO HAPPOLD

CITY LONDON

Key impacts in the City of London cont.

2ºC Climate Scenario

4ºC Climate Scenario

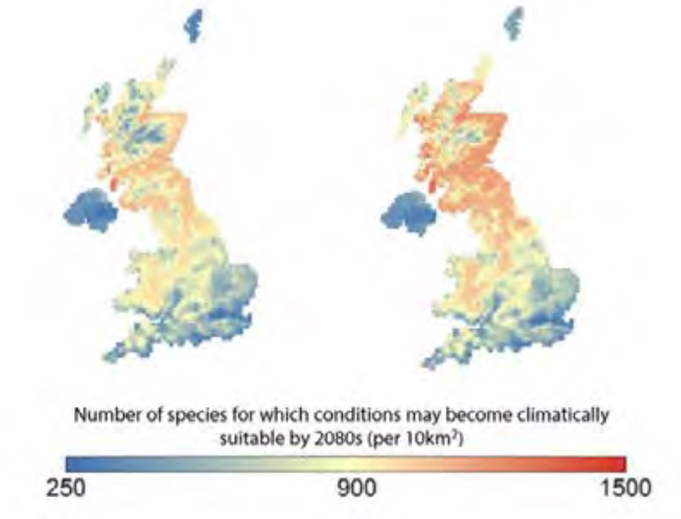


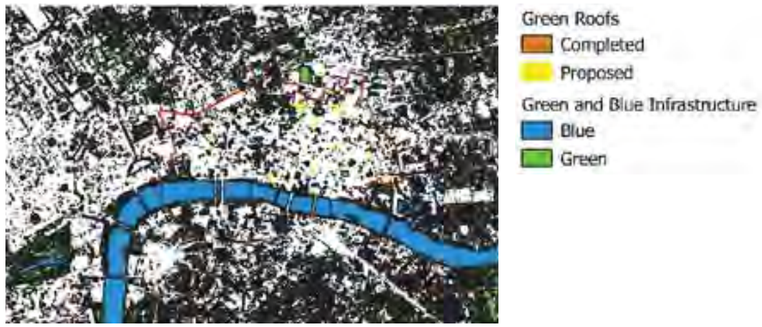
Figure 5-9 maps of national changes to habitat suitability. Source: CCRA Evidence Report 2017. Chapter 3, available online.

Risk	Impact
Risks to agriculture and wildlife from water scarcity and flooding.	While there is some flood risk in the City of London, water scarcity is a key issue (see **Risk Three**), as is regional threat to agriculture.[43] These issues may escalate as irrigation demand, level of disease and temperature all rise under climate change. Since most green space in the Square Mile is parkland, irrigation restrictions are likely during a drought, threatening natural capital and the ecosystem services this provides.
Risks to soils from increased seasonal aridity and wetness – wetter winters and drier summers may change soil compositions. **Risks and opportunities from changes in landscape character – with species turnover and environmental changes, landscape appearance may also evolve.**	As described above, changes to inner London ecosystems, particularly ground flora and drought-sensitive species in shallow soils,[42] as is common in central London, are likely to translate to changes to landscape character in City Corporation green spaces – their appearance, feel, and capacity to deliver wellbeing benefits to visitors through time spent in biodiverse areas. Since urban parks provide important ecosystem services, including wellbeing benefits, this is a key risk for the Square Mile.
Risks to freshwater species from higher water temperatures. **Risks to and opportunities for, marine species, fisheries and marine heritage from ocean acidification and higher water temperatures.**	There are many marine species at risk in the City of London: the Thames and its Tidal Tributaries are listed as Sites of Importance for Nature Conservation in the City of London,[38] and the Port of London Authority reports that the Thames is an 'important freshwater and marine fishery and plays an important role in providing a nursery for juvenile fish', with large numbers of wetland birds, marine mammals and eels integral to the ecosystem.[45] As with land areas, there is a high risk of loss of precious marine habitats in inner London.
Risks of growth and proliferation of harmful algal blooms. This is due to warmer, drier summers increasing risks of low flows, with higher water temperatures improving conditions for the growth of algae.	The Square Mile and the City Corporation's other assets include water bodies, which will be vulnerable to changes in algal phenology. These include the River Thames, a dedicated nature conservation site, the Hampstead Heath ponds, and waterways in Epping Forest (Figure 5-10). Algal blooms can produce toxins, and contain organism that severely lower oxygen levels, damaging marine ecosystems.[46]

05

Risk Four: Risks to natural capital, including terrestrial, coastal, marine and freshwater ecosystems, soils and biodiversity

Biodiversity in the City of London



City of London Resilience: Biodiversity Mapping

Figure 5-10 Blue and green infrastructure in the Square Mile and surrounding areas

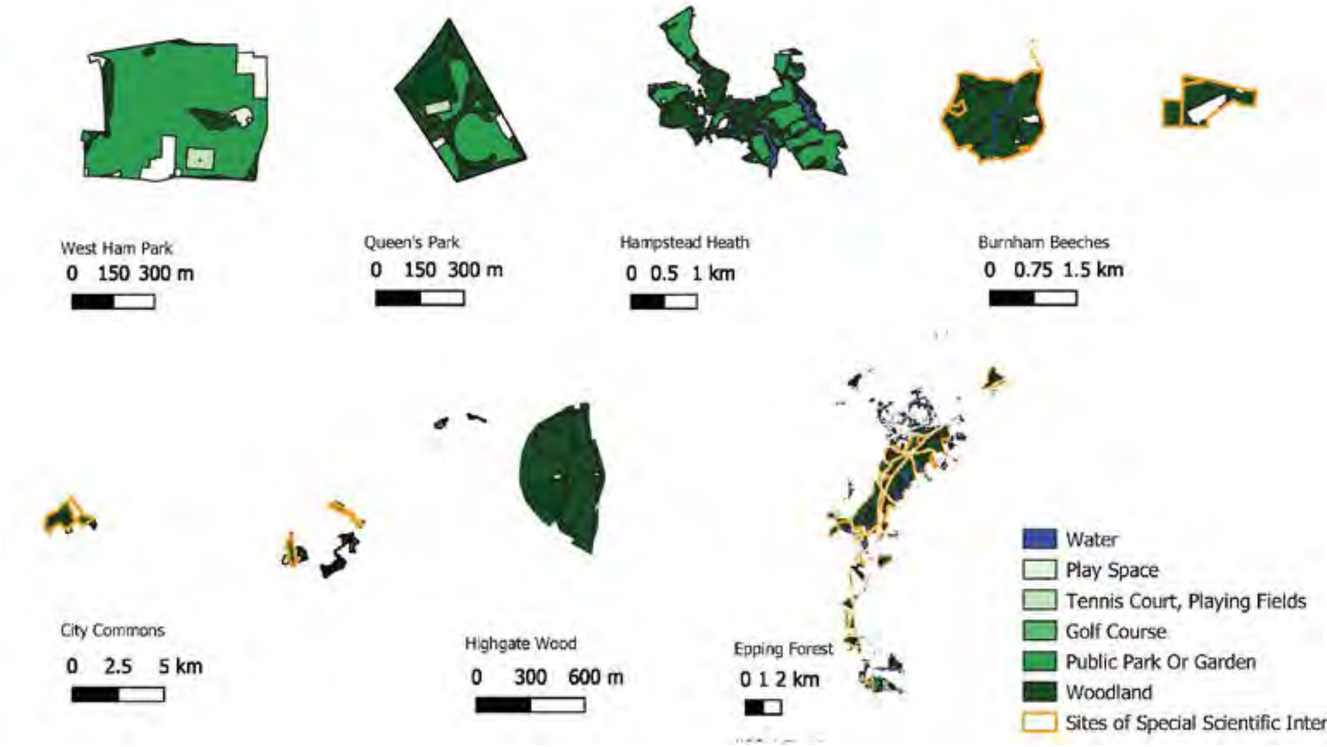


Figure 5 11 Parkland and woodland outside of the Square Mile including Sites of Special Scientific Interest

05

Risk Five: Risks to domestic and international food production and trade

The risks

A recurring consequence of many of the previous risks in this study has been disruptions to food supplies. Food in the UK is 40% imported,[47] with UK food and drink exports annually exceeding £20bn.[35] This combination makes food infrastructure vulnerable to national and international shocks and stresses; food supply has been identified as one of the 13 UK Critical National Infrastructure sectors.[48] The Climate Change Risk Assessment Evidence Report 2017 outlines several connections between climate and food production:

- Weather-related: impacts to agricultural production through short-term weather shocks like drought, longer-term seasonal shifts and rising long-term production constraints, as a result of frequent extreme weather events. For example, droughts in summers and heavy rainfall may cause issues with soil compaction and erosion, altering food production levels and availability. Changing weather patterns may affect crop choices and crop cycles, which in turn may have impacts for pollinators and pollination.
- Legislation: climate change will place additional pressure on international law and governance, which is likely to negatively affect both the production of food and how markets respond.
- Changing aquatic conditions: commercial fisheries and aquaculture are likely to be negatively affected by the combination of ocean acidification and higher water temperatures.
- Political: geopolitical consequences of climate change such as global displacement, conflict and political instability may negatively affect international food production and distribution.

These issues will influence global agricultural supply, with knock-on impacts on trade and domestic prices.

An issue for the City of London

The City of London is heavily dependent on regional, national and international food imports since it contains no major agricultural spaces. This means that food supply vulnerability will be a critical resilience issue for the Square Mile. In particular, the Climate Change Risk Assessment Evidence Report 2017[12] notes that regional food supply is at particularly high risk since 'parts of southern, eastern and central England [are] likely to become unviable for some current farming activity due to their intensive water requirements'. The London Resilience Strategy 2020[49] similarly places food infrastructure vulnerability as a key risk for the London area, and notes that food insecurity is already an issue: 21% of Londoners already live in low or very low food security.[50]

Key impacts in the city of London

The Square Mile is vulnerable to all the food supply risks listed in the UK Climate Change Risk Assessment 2017[12] Evidence Report. Short-term shocks (such as extreme weather, population displacement and conflict) and long-term stresses to food production both nationally and internationally will strongly implicate food infrastructure in the City of London. The infographic in the next page highlights key potential impacts.

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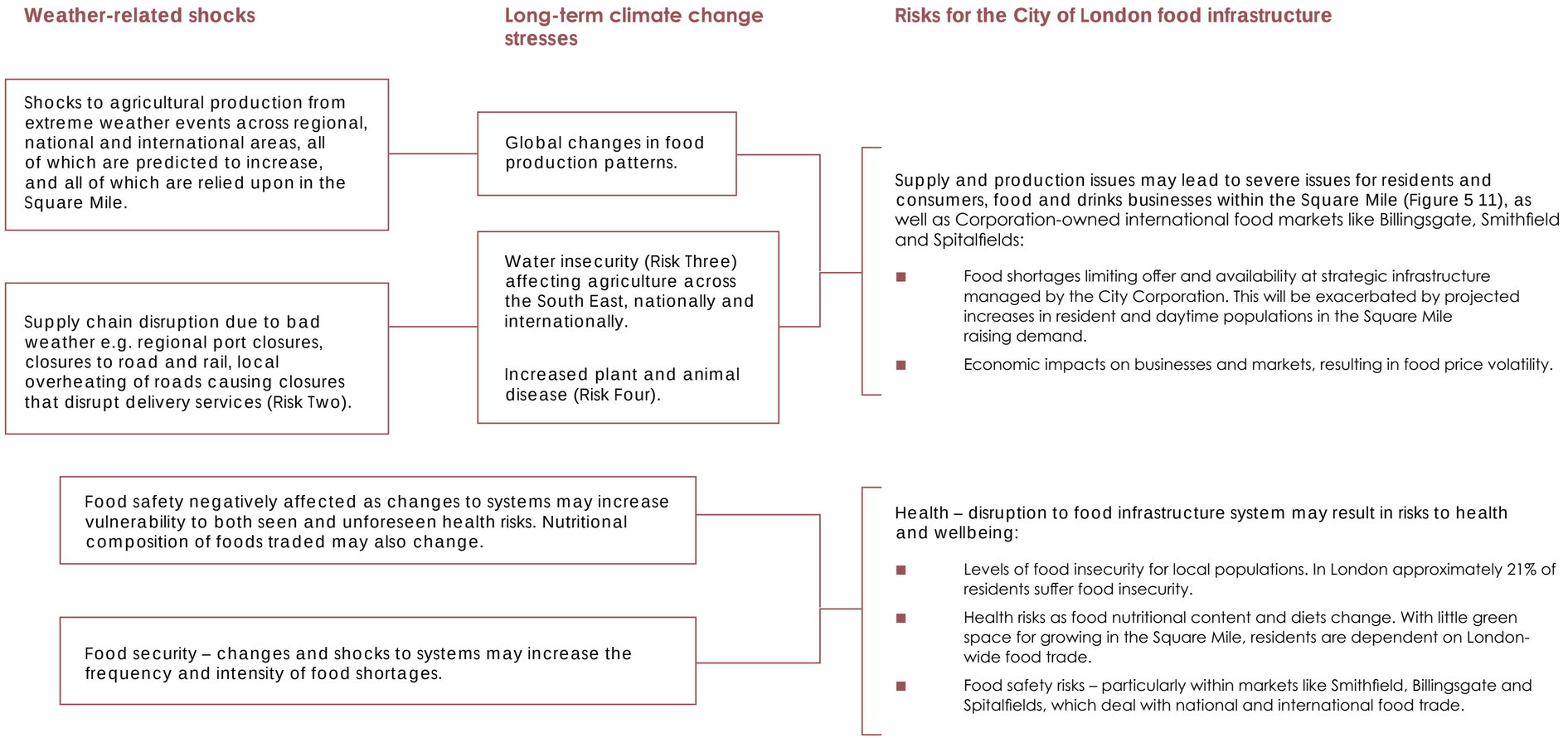
Risk Five: Risks to domestic and international food production and trade



Adapted from the CCRA 2017 Evidence Report, Chapter 7, table 7.2

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Risk Five: Risks to domestic and international food production and trade

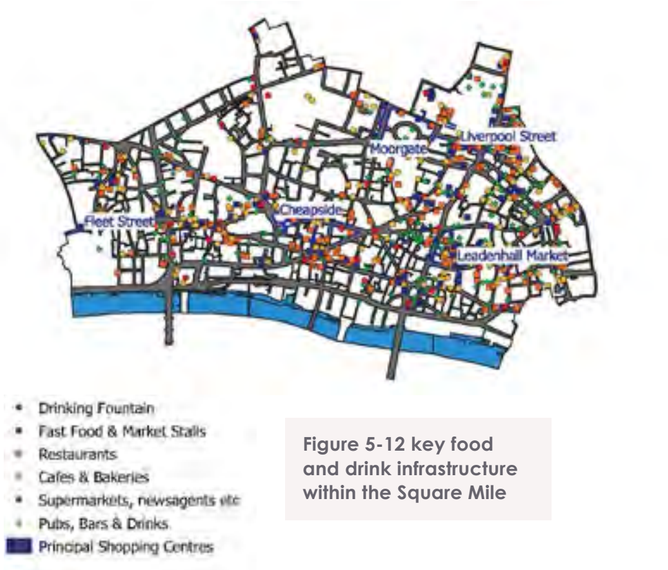

Figure 5-12 key food and drink infrastructure within the Square Mile

	Number of people	Approximate spend on food by residents and workers (£/week)
Working population	513,000	£7,500,000
Square Mile residents	9,000	£388,500

Source: GLA and CoL population data, using typical national data on food expenditure (available online), and daytime expenditure from London worker surveys (available online).

Local pubs, restaurants and takeaways in the Square Mile at risk of disruption	800
Food insecurity levels 2019	21% of Londoners have low or very low food security, rising to 31% low food security in the City & East London Assembly constituency area

Source: GLA datastore

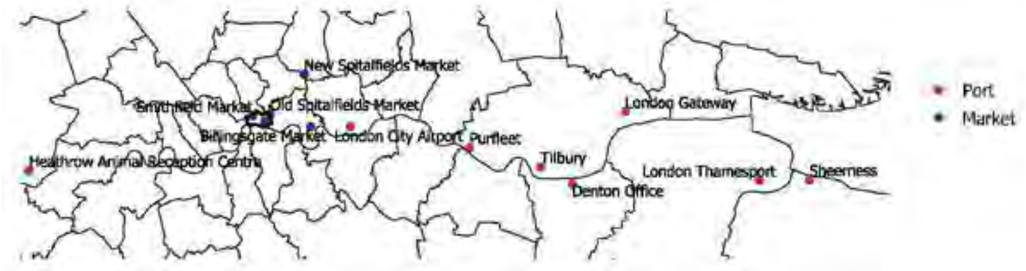

Figure 5-13 ports and markets under City Corporation management that deal with international food imports and exports

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Risk Six: New and emerging pests and diseases, and invasive non-native species, affecting people, plants and animals

The risks

Climate change has the potential to strongly influence the rise in emerging pests and diseases, including non-native species. Listing this risk as a UK-wide research priority, the CCC UK highlights that changing seasonal conditions and global patterns will influence the spread of new and emerging diseases, while pests and invasive non-native species may also 'increase in number and range in a warmer, wetter atmosphere.[48] They highlight the following key concerns:

- Vector-borne diseases may increase and evolve – for example, higher temperatures may allow the survival of new pests, parasites and insects in the UK. Warmer and wetter winter conditions increase overwinter survival rates and the spread of both new and existing parasite, insect and vector animal populations which carry diseases which impact humans, animals and ecosystems.
- Water and food supplies may increase in bacterial and water or food-borne diseases as higher temperatures allow longer survival rates.
- Diseases and changes to agricultural and natural systems may have a further health impact in stressing food and water supplies, and introducing nutritional deficiencies.

An issue for the City of London?

The Square Mile will see the same seasonal condition changes as the wider UK, as evidenced in UKCP18 analysis. This, combined with its high density of people and dense infrastructural systems, makes the likelihood and consequences of disease outbreaks particularly acute, via the mechanisms described above.[51] Additionally, invasive non-native species behave differently in London to elsewhere in the UK. The Urban Heat Island Effect (see Risk Two), complex and international movement of people and trade, variety of available habitats all make the introduction of non-native invasive likely.[34] Studies note that urban trees are at particular risk of new pathogens and pest outbreaks, since the global trade in 'plants for planting' is a pathway for their accidental introduction.[52] The fact that the City Corporation also runs the London Port Health Authority, is a further consideration, since it is responsible for health and infectious disease controls on imports at these locations.

Potential impacts in the City of London

Rise in emerging infections, largely those carried by insects and ticks which will be newly able to survive in rising temperatures in the UK – vectors include mosquitos and ticks capable of carrying vivax malaria, West Nile fever, Dengue fever, Chikungunya fever, tick-born encephalitis.	Strain on medical infrastructure – London hospitals, including St Bart's Hospital in the Square Mile, are world class sites for treatment of diseases. However, rises in the frequency and intensity of outbreaks, and emergence of new ill-health conditions, may put medical systems under strain (see Risk Two).
Rise in climate-sensitive diseases – many diseases, including colds, flus and gastroenteric pathogens, show seasonal variation. Higher temperatures also shorten the incubation period of the pathogen within food, water and animal vectors, increasing their transmission efficiency.	Rise in zoonotic disease incidences – disease-carrying pest populations – such as ants, flies and rats – are set to increase given climatic changes are projected to foster environments favourable to their survival.
Rise in plant and ecosystem diseases – longer growing seasons, moist and warm winters favourable to spore production and increased CO2 concentrations will see more generations of insect pests and tree diseases.	Risks to food production and supply from agricultural pests and rise in invasive species (See Risk Five).

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Risk Six: New and emerging pests and diseases, and invasive non-native species, affecting people, plants and animals

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Key disease management trends in the City of London

Risk	Current data on diseases	Trend	Future
Emerging infections	12 diseases and infections were detected in England for the first time in the last decade, including Swine Flu and Middle East respiratory syndrome. Some vector species, which aid introduction and transmission of new infections, already exist in the UK – including ticks.[54] The high-density nature of London, combined with its position as a centre of international trade and transport makes disease outbreaks a high risk in the capital.		The CCRA evidence report[13] describes that higher temperatures across South East England increase the likelihood of indigenous mosquitos carrying arboviruses. The spread of non-native mosquito species through Europe is expected to reach the UK – carrying viruses of humans and animals like Chikungunya, Zika and West Nile virus. There is also a small risk of malarial transmission towards 2100.
Climate-sensitive diseases	Seasonal variation is currently seen in gastro-intestinal infections like salmonella – infection rates increase 10% per degree over 6°C – and campylobacter.[13]		Rise in bacterial infections is anticipated,[13] though these may be offset by improvements in public health management. As marine temperatures rise, risks of river water pathogens and toxic algal blooms rise in water bodies in the City of London.[54] Heavy rainfall, as which may be seen towards 2100, increase the risk of contamination of drinking water systems.[13]
Zoonotic diseases	The government believes that around 40 zoonotic diseases exist in the UK, including Leptospirosis, streptococcal infections and rabies,[55] to which approximately 300,000 people in a variety of occupations are potentially exposed.[56]		Existing zoonotic disease exposure and transmission rates may increase with warmer, wetter winters: favourable survival conditions for 'nuisance' species such as ticks, ants, flies and rats.[13]
Plant and ecosystem pests and diseases	The UK Plant Health Risk Register contains approximately 1,000 pests and diseases, with around five new risks added every month.[57] This is reflected in recent increase in outbreaks in inner London, such as ash die back and Massaria fungal disease, and floating pennywort in water bodies.[39]		Increase in pest and disease outbreaks across City of London are anticipated, directly contributing to shrinkage and character change of green and aquatic space.[42] Finally, stressed species are more vulnerable to pest and diseases, meaning medium-term ecological deterioration under other climatic pressures (Risk Four) will escalate the risk posed by pests and diseases in later decades.[43]

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Risk Six: New and emerging pests and diseases, and invasive non-native species, affecting people, plants and animals

Key disease management trends in the City of London cont.

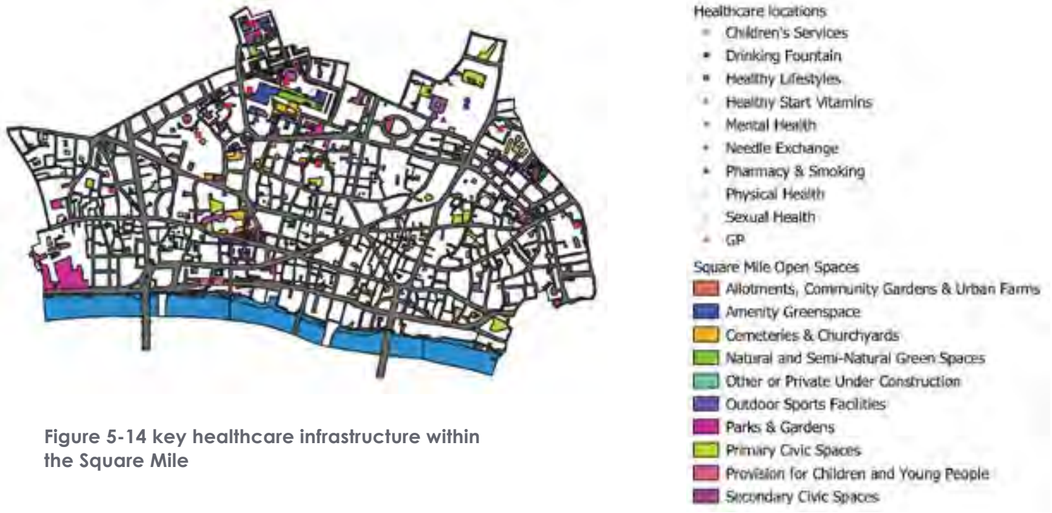

Figure 5-14 key healthcare infrastructure within the Square Mile

Areas outside the City of London Borough Boundaries

As set out within the Corporate Plan, the City Corporation manages many assets outside of the Square Mile area. These have been referenced throughout the document, but this section collates the key risks facing these assets.

The UKCP18 projections for the Square Mile follow the key trends predicted for the broader UK and London Region.[58] This is illustrated for the case of average temperatures in Figure 5-14, where the predicted increases in temperature in future decades are consistent for the full Greater London region. This means that, as a rule, the findings set out in the previous sections of this report are broadly applicable for all City Corporation assets. The following section considers the relevance of each risk to City Corporation assets which lie outside the Square Mile in more detail.

Risk 1: Flooding

Assets across London are protected from flooding under the scope of SFRAs for the local authority areas in which these assets are located. For all areas, surface water and groundwater flood management will rely on the presence of local green spaces and SUDs infrastructure, the implementation of which is required across London under planning policy.[59] For flooding from the Thames, there is an increased risk of flooding to City Corporation assets in south London, which is low lying, around the River Lea and in lowland areas in the Thames Estuary.[60] This flood risk is managed by the relevant defence assets owners, Environment Agency and local authorities, but the risk of flood events are increasing, as for the Square Mile, and these events could have direct impacts City Corporation assets and corresponding services.[61]

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Risk Six: New and emerging pests and diseases, and invasive non-native species, affecting people, plants and animals

Risk 2: Overheating

While there are several City Corporation housing and non-domestic assets in inner London, many also are held in outer London areas. The Urban Heat Island effect is generally less substantial in areas outside the Square Mile,[5] however the weather trends described in Section Two are projected for the full greater London area under UKCP18 (Figure 5-14), meaning all City Corporation assets are projected to experience significant increases in annual temperatures and heatwaves in future decades.[50] Unshaded park areas, and ageing building stock will risk the same issues with overheating as listed in **Risk Two**, with similar difficulties in retrofitting heritage building stock requiring consideration. The City Corporation also holds many assets which have EPC ratings of C and below which may be at particular risk of overheating. For all assets, the high degree of temperatures change may mean that extensive retrofit and mechanical systems installation is necessary in the mid-long term, while mechanical ventilation and passive cooling strategies should be considered for all new builds.

Risk 3: Water supply

As described in **Risk Three**, the whole London region is facing a substantial water deficit, if no action and management is taken by Water Companies. This poses a similar risk to residents and businesses in City Corporation-run assets across London as in the borough boundaries, and a particular risk for the irrigation of the City Corporation's extensive parklands. As described in Risk Four, this poses a significant threat to this natural capital and the ecosystem and user services that they provide.

Risk 4: Risks to natural capital

The City Corporation manages around 4,500 hectares of natural space outside the Square Mile. As discussed in detail in **Risk Four**, these areas are at high risk of loss of biodiversity, invasive non-native species colonisation and change in landscape character. The City Corporation is responsible for a number of large open spaces outside of the Square Mile such as Hampstead Heath and Epping Forest. Such areas may be more susceptible to risk of wildfires than those smaller open spaces managed by the City Corporation.

Risk 5-6: Food infrastructure, pests and diseases

The City Corporation manages several key points of food and health infrastructure outside of the Square Mile, including acting as the London Port Health Authority. The City Corporation is also responsible for running multiple major food markets (Figure 5-12), as discussed in **Risk Five**. Several of these locations are at risk of flooding.[63] Despite effective application of control measures at the border, reducing the risk of known pests arriving to zero will be challenging. As port health authority, at-boarder control will continue to be a priority for the City Corporation however, like in the Square Mile, for open spaces areas such as Epping forest there will be increased need to monitor the control of pests and diseases. Larger open spaces play a vital role in the provision of ecosystem services, without action the spread of pest and diseases may compromise these services.

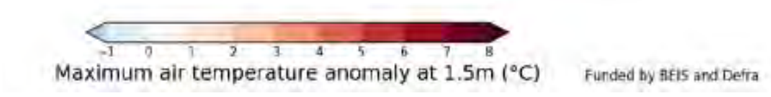
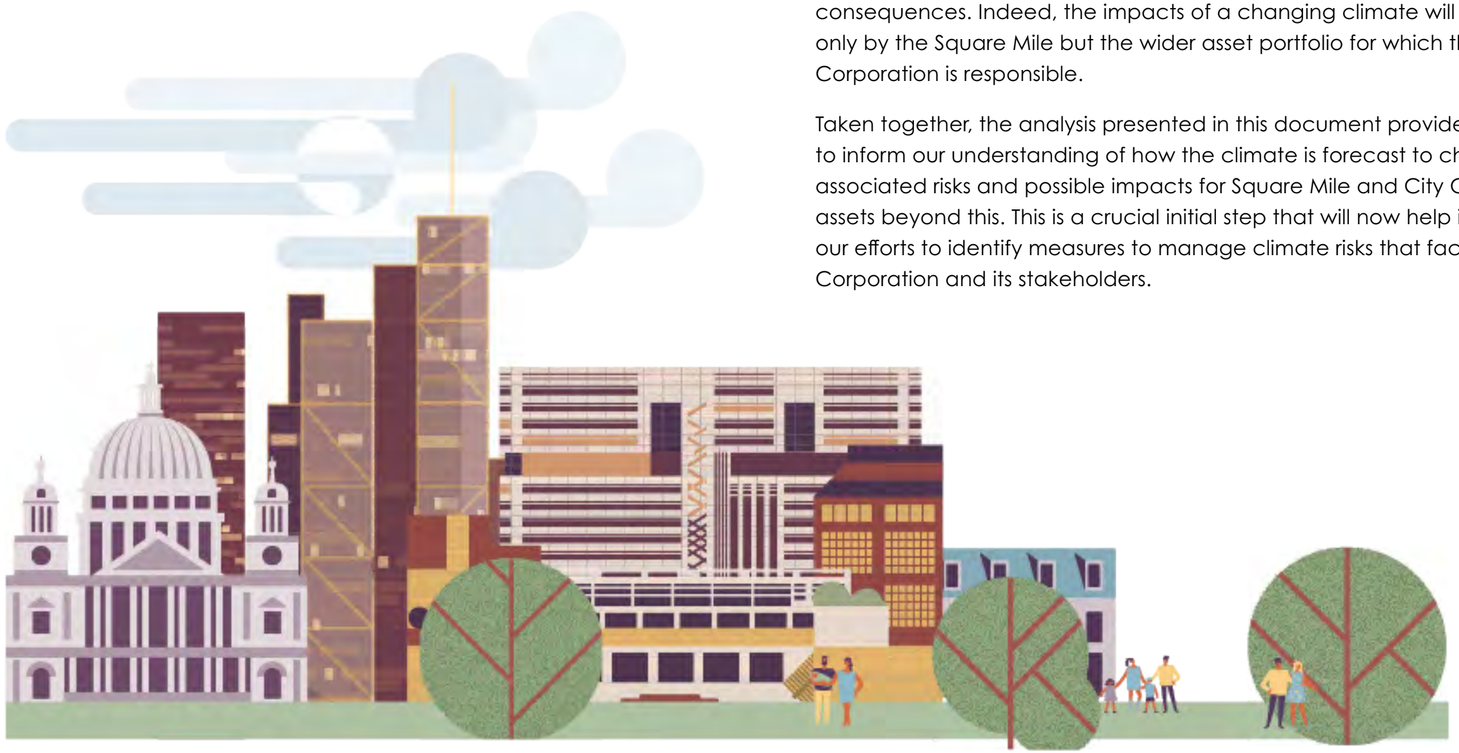


Figure 5-15 Seasonal average max air temperatures anomaly at 1.5 m (oC) for June, July, August using baseline 1981-2000 and 50th percentile scenario RCP 8.5 for years (a) 2020-2039, (b) 2040-2059, (c) 2060-2079, (d) 2080-2099. This demonstrates that projected temperature changes in the region are uniform across City of London assets.

Conclusions



At this point, even the most ambitious carbon reduction scenario will result in climate impacts. For the Square Mile this includes an increased risk of flooding, more frequent heatwaves, water shortages, threats to natural capital, food supply chains and a rise in pest and diseases. These impacts will have implications for all sectors and will often have far-reaching consequences. Indeed, the impacts of a changing climate will be felt not only by the Square Mile but the wider asset portfolio for which the City Corporation is responsible.

Taken together, the analysis presented in this document provides a basis to inform our understanding of how the climate is forecast to change, the associated risks and possible impacts for Square Mile and City Corporation assets beyond this. This is a crucial initial step that will now help inform our efforts to identify measures to manage climate risks that face the City Corporation and its stakeholders.

As outlined within the Mayor's London City Resilience Strategy,[50] "to make a city resilient, it needs systems that can withstand, respond to, and adapt more readily to shocks and stresses". The analysis presented in this document highlights the high level of interconnectivity and key dependencies between the risks and impacts of a changing climate. Public sector decision-makers have a responsibility to ensure that a holistic approach is taken to address these risks, to ensure that adaptation measures in one area do not have unintended consequences elsewhere.

The City Corporation is committed to contributing to a flourishing society, supporting a thriving economy and to shaping outstanding environments. To support us in realising our strategic aims we must take urgent action to ensure resilience to the impacts of forecast changes in the future climate. By doing so we will position the City as a resilient place to do business, to live, to learn and to visit.

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