Climate Change Risks In Nottingham

Nottingham Trent University

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Quality information

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1. Introduction

In November 2018, Nottingham Trent University announced a call for proposals for seed funding with the vision of incentivising and facilitating increased academic involvement in the local area and strengthened engagement with partners and employers through a range of knowledge exchange activities. In response to this call, a joint application between Nottingham Trent University (Dr Marianna Poberezhskaya) and AECOM Ltd (Lizaveta Troshka, Caroline Toplis), supported by Nottingham City Council (NCC), was submitted and successfully accepted to assist NCC with the development of its new Climate Change Adaptation Strategy.

This report has been developed to present the key project findings to date and provides the following information:

- Literature review of global, national and local urban climate change policy and the Nottingham position;
- Review of previous severe weather events and their impacts and response measures;
- UK Climate Projections 2018 (UKCP18) analysis for Nottingham;
- Proposed approach for a Climate Change Risk Assessment (CCRA).

1.1 Purpose of this report

The aim of this report is to allow NCC to understand its current position and unique features with regards to climate change risk and adaptation, and to compare the city's policies and progress with global and national climate change adaptation ambition. The report also enables NCC to have access to modern climate science and data (UKCP18) that can provide a useful insight into what the future may look like and forms crucial piece of information when undertaking a CCRA. Possessing this information will allow NCC to obtain a holistic picture of the climate change risk to its services across the council and be well positioned to develop effective and targeted adaptation measures in response to the identified risks.

2. Methodology

This study comprised the following steps:

1. ***Literature review-*** *a comprehensive literature review covering academic and industry research. Specific attention was given to policies and strategies local to and with relevance to Nottingham.*
2. ***Review of past severe weather events -*** *consideration of observed weather data and events during the 2000-2019 period, including their impacts and any responses to them.*
3. ***Climate data analysis -*** *UKCP18 projections for Nottingham extracted and high level impacts assessed.*
4. ***Conceptual CCRA approach -*** *outline of the key steps required for undertaking a CCRA, with reference to useful data sources, where appropriate.*

The following chapters provide detailed information about each step of this study and outline key findings, limitations of the data used and useful references.

3. Literature review

For several decades, climate change mitigation policies have occupied leading positions among interested policy-makers and scholars (Reckien et al. 2018, Heidrich et al. 2016), however, as the unavoidability of some substantial climatic changes become apparent, more attention is starting to be paid to adaptation policies (see: Carter et al. 2015). The Agenda 21 initiative, a non-binding action plan agreed at the 1992 Earth Summit in Rio, stressed the importance of local governments for achieving sustainable development. However, cities and urban areas were largely absent from much of the subsequent policy debate until 2007, when they entered the Intergovernmental Panel on Climate Change (IPCC) rhetoric via its fourth assessment report (Hebbert & Jankovic 2013). Furthermore, in autumn 2018 the IPCC issued a Special Report (SR1.5) 'on the impacts of global warming of 1.5C above pre-industrial levels and related global GHG emission pathways'. The report was followed by a summary for urban policy-makers published in December of the same year. It emphasised that the SR1.5 'identifies cities and urban areas as one of four critical global systems that accelerate and upscale climate action' (IPCC 2018). The importance of cities is explained by the fact that 'urban areas are home to more than fifty percent of the world's population (a figure that estimates suggest will soon reach 67%), and are the site of most of its built assets and economic activity' (ibid 2018, p. 15). In fact, in some parts of the world this figure is already substantially higher; in England, for example, the urban population has already reached 80% (DEFRA 2013).

3.1 UK stance on climate change adaptation

The United Kingdom has traditionally been presented and viewed as one of the global leaders in its pursuit of an active climate change policy (Harris 2012), leaving behind even its European counterparts in many ways (Heidrich et al. 2016). Adopted in 2008, the Climate Change Act committed the UK to reduce its GHG emissions 'at least' by 80% by 2050. The document contributed to emissions' reduction despite the country's economic growth (Fankhauser et al. 2018). In June 2019, the UK government discussed amendments to the Act which would suggest that it will be first major economy to commit to 'net zero' GHG emissions by 2050 (Harrabin 2019).

As noted, however, climate initiatives need to extend beyond mitigation to include preparing for its inevitable impacts; indeed, the Climate Act introduced the Committee on Climate Change, which advises government on whether and how the targets can be achieved and includes the Adaptation Sub-Committee (theccc.org.uk, 2019). This Sub-Committee feeds information to the regular (every five years) UK Climate Change Risk Assessment report: the latest one (2017) has identified six priority areas and urges stakeholders to 'tackle current and future risks' including flood risks, heatwaves, water shortages, risks to UK ecosystems, domestic and international food production, and the spread of pests and diseases. The National Adaptation Programme (DEFRA, 2013) stated that 'in the wider European context, every £1 spent on adaptation represents four times its value in potential damages avoided'. It also brings up the concept of 'low-regret actions' – adaptation steps that will bring monetary benefits regardless of risk uncertainty (e.g. savings from increased water efficiency, investments in adaptation good and services).

Since 2008, UK legislation requires local authorities to incorporate climate mitigation and adaptation steps into planning documents (Reckien et al. 2018). However, it has been observed that in the UK adaptation policies have mostly stagnated at the planning stage rather than the implementation stage (Fankhauser et al. 2018). This happens despite the Climate Change Risk Assessment report's (2017) predictions that, for example, suggest that, by the 2050s, heat-related deaths in the UK may increase by 250% (compared to the 2000 baseline).

3.2 Adaptation and cities

Climate adaptation is 'inherently more complex than mitigation. This is because adaptation involves a wider array of impacts and climatic variables, as well as a degree of uncertainty in the timing and magnitude of these factors' (Eckersley et al. 2018, p.335). However, whilst mitigation requires a global effort, adaptation has a local angle to it as 'a number of potentially significant climate change impacts are either unique to urban areas or exacerbated in urban areas' (Hunt & Watkiss 2011, p. 14; see also Hallegatte et al. 2009; Reckien et al. 2014; Tu 2018). As a result, local authorities are encouraged 'to develop adaptation responses in advance' (Carter et al. 2015, p.3; Heidrich et al. 2016; Hallegatte & Corfee-Morlot 2011); indeed, in March 2011, the Department of Energy and Climate Change[1] UK signed a 'Memorandum of Understanding' with the Local Government Group to acknowledge 'the pivotal role councils have in tackling climate change' (Gov.Uk 2011). Whilst the memorandum mostly features

[1] In July 2016 it became part of Department for Business, Energy and Industrial Strategy

mitigation policies, it does recognise the importance of local governments in 'protect[ing] and help[ing] the most vulnerable, particularly the fuel poor'.

The concept of adaptation within the urban context has a long history, with humans persistently considering 'local knowledge of wind, sun, humidity and precipitation' in order to increase their chances of survival (Hebbert & Jankovic 2013, p.1334) and at the same time altering the environment and subsequently the climate around their settlements. In fact, Hebbert & Jankovic (ibid) point out that 'city design is the oldest type of anthropogenic climate change' adaptation.

Due to their particularities, urban spaces are more prone to certain climate change affects. For instance, it is projected that the changing climate will intensify the heat island effect, as well as flood risks. Densely populated urban areas are more likely affected by water shortages[2] or problems with local food supplies. Other climate change consequences might include the effect of extreme weather on buildings, an increased rate of weather-related deaths (both due to extreme cold or heat), change in energy use, loss of urban biodiversity, and worsening air pollution (Hunt and Watkiss 2011). Cities' interconnected infrastructure, population density and large numbers of vulnerable groups clustered within a relatively limited space, makes them 'particularly threatened by climate change' (Carter et al. 2015, p.4). Therefore, the social characteristics of cities' inhabitants play an important role in analysis of climate change adaptation policies, as those who have least capacity to withstand climate change adversaries will suffer the most (Lampis, 2013). However, socio-economic considerations bring adaptation policies in line with other urban priorities, for instance, pursuing a poverty reduction agenda will naturally strengthen the population's climate resilience (Hallegatte et al. 2011). Lastly, it should be noted that cities have a capacity to challenge the national climate change policies. Furthermore, evidence suggests that local actors sometimes appear to be more successful in climate change mitigation and adaptation processes than their respective governments (e.g. Hebbert & Jankovic 2013)

3.3 Approaches to urban adaptation

Eckersley et al. (2018, p.340) highlight the idea of **'transformative adaptation'** in which a range of weather or other external events accumulate, focus attention on a problem and trigger a 'fundamental shift in approach and way of thinking'. Another approach would be **'adaptive governance'** which Boyd and Juhola (2015, p. 1235) define as 'decision-making systems comprising formal and informal institutions and social networks that are able to adapt in the face of uncertainty'. The authors further unpack the importance of 'uncertainty' with regards to urban adaptation strategies that cannot solely rely only on historical data but need to be flexible, perceptive and responsive to new information and approaches to ensure urban resilience (ibid). The idea of **'climate urbanism'** takes this discussion to the next level, seeing cities 'as the most viable and appropriate sites of climate action' (Long & Rice 2019, p.992). However, the problem with this approach is that whilst it stresses the importance of urban physical infrastructure, not enough attention is paid to its social justice aspect which, as discussed below, becomes very important in urban climate adaptation policies.

In their comprehensive study of adaptation capacity within Greater Manchester, Carter et al. (2015, p.16) underline the importance of data availability and ability to relate this data to the local context: 'given that climate change projections can vary considerably depending on location, even in a relatively small country such as England, local scale data is especially valuable for adaptation'. Furthermore, they stress the important of the '**holistic' approach** to urban adaptation (ibid) which is echoed by the IPCC (2018, p. 18) and states that the success of adaptation will depend on 'geophysical, environmental, ecological, technological, economic, social, cultural, and institutional factors'. The holistic approach also suggests active collaboration and interdependence with a range of state and non-state actors involved in development and implementation of adaptation policies (Eckersley 2018, Eckersley et al. 2018; see also Heidrich et al. 2013; Leck and Simon 2013; Homsy and Warner 2015). Additionally, cities need to be looked at within the broader regional framework, as habitually they are directly affected by other 'human settlements' and 'ecosystems' (Lampis, 2013, p. 1884, Boyd and Juhola 2015).

3.4 Nottingham City Council: existing policy narrative

The latest estimates suggest that Nottingham city's population is 329,200, with a large young population (29.6% belong to the 18-29 age range) and significant number of vulnerable people, with Nottingham considered to be the '8th most deprived district in England in the 2015 Indices of Multiple Deprivation' (IMD) (Nottingham Insight 2019).

[2] As has been recently illustrated, when extreme water shortage occurred Chennai, India (due to a delay in a monsoon season) numerous local infrastructures has failed to function negatively affecting people's well-being and local economies (BBC News 2019).

Furthermore, it is the youngest and the oldest cohorts who are affected the most by ‘income deprivation’ whilst the worst category for Nottingham in terms of its IMD ranking is ‘Health and Disability’. There is also an income difference between people who live in the city and those who work in it (ibid). Due to this set of metrics, the city is particularly vulnerable to climate change affects and needs to put more emphasis on climate change adaptation. This conclusion is based on the assumption that some parts of the city’s population will be less **resilient** to climate change as they do not have the knowledge or resources to respond easily. For instance, older and very young people, as well as those with disabilities, rely more on public services and infrastructure than other groups. Many of these services are vulnerable to severe weather events, which puts these groups at increased risk compared to the rest of the population. For example, they may have mobility issues that make it difficult to move if there is a risk of flooding, or they may lack the money, skills or relevant knowledge to buy and deploy sandbags. Therefore, as an above average proportion of the population belongs to these categories, the city’s overall resilience is affected.

Overall, Nottingham presents an interesting case study within the UK in terms of its role in national climate change policy and local struggles and vulnerabilities. Over 300 councils signed the ‘Nottingham Declaration’ in 2000, thereby committing to tackle climate change. The Declaration is a political statement rather than a defined policy strategy; nevertheless, it has put Nottingham in a different discursive realm where it has to be seen to match up to its strong environmental ambitions. This was illustrated by the fact that between 2005 and 2009 the city reduced its carbon emissions by 16.79% (NCC 2012) and within subsequent decade this figure was increased to a reduction of 39%. In January 2019, the NCC announced its ambition to become the first carbon-neutral city in the UK by 2028 (Intelligent Transport 2019). As with all early documents and political statements, adaptation does not strongly feature in the Nottingham Declaration. However, Nottingham City, comparatively speaking,[3] has an elaborative set of documents addressing adaptation policy. This includes the Climate Change Adaptation Action Plan (2011) specifically dedicated to the issue, as well as a range of other documents featuring adaptation to different degree:

- The Nottingham Community Climate Change Strategy 2012-2020;
- Local Transport Plan 3;
- Highways Asset Management Plan;
- Breathing Spaces;
- Emerging Greater Nottingham Aligned Core Strategies;
- Emerging Land and Planning Policies Development Plan Document;
- River Trent Strategic Flood Risk Assessment 2010;
- River Leen and Daybrook Strategic Flood Risk Assessment 2008;
- Emerging Preliminary Flood Risk Assessment.

3.5 Preliminary recommendations

- The concept of ‘resilience’ needs to become central to adaptation policy planning in order to better inform decisions aimed at increasing the capacity of the urban system to withstand the negative impacts of climate change (including the degree of uncertainty). It should be noted that resilience at the individual level will vary according to the individuals concerned and, therefore, cannot be understood in the same way as the resilience of the city of Nottingham as a whole. The proposed definition of resilience is ‘the intrinsic capacity of a system, community or society predisposed to a shock or stress to adapt and survive by changing its nonessential attributes and rebuilding itself’ (Manyena 2006, p.446). The more progressive understanding of ‘resilience’ suggests consideration of both the ability to deal with the negative consequences of climate change and, if disaster strikes, to have the ability to ‘bounce back’ by returning to a ‘normal way of life’ or to ‘bounce forward’ by adjusting to new realities and new challenges (Manyena et al. 2011).

- The decisions need to be taken accepting a degree of uncertainty and some contradictory information coming from the consulting bodies. This uncertainty means you cannot calculate the benefits of such initiatives very accurately - which makes it difficult to develop the business case for investing in adaptation solutions and infrastructure. But the costs of ‘doing nothing’ are likely to be very high

- Adaptation planning should involve interested parties at early stages of policy development. Not only will this will help them to understand the risks to their own activities, but it should also highlight how the city-wide systems upon which they rely may be vulnerable and harbour unforeseen risks

[3] Reckien et al. (2018) after analysing 885 urban areas within the EU confirmed that only 26% of them had an adaptation plan; whereas high results for adaptation and mitigation plans in UK cities can be explained by the fact that it was a national requirement in England (see also Reckien et al. 2014).

- The planning process needs to consider the positive and negative co-effects of adaptation/mitigation policies. For instance, densification reduces emissions but intensifies the heat island effect whilst increasing use of air conditioners contributes to additional emissions. Conversely, more sprawling developments could increase the amount of land that is covered with hard, impermeable surfaces, thereby increasing flooding risks

- In this context, the inclusion of green infrastructures and natural systems often leads to 'win-win' mitigation/adaptation scenarios. This also fits within the 'smart urbanism' approach that allows solutions that are environmentally and economically beneficial (Long & Rice 2019).

- Key characteristics of a successful adaptation project (adopted from Power et al 2018):
  - A realistic timetable for development and delivery;
  - Multiple benefits;
  - Early advice from specialists;
  - Develop meaningful collaboration with relevant stakeholders;
  - Monitoring and evaluation should be central for novel and innovative approaches;
  - Bringing together budgets from various partner organisations.

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4. Looking back: observed weather data

Acknowledgement and understanding of past weather events is an important dimension of assessing climate risk. This chapter, therefore, focuses on enhancing knowledge and awareness of weather and climate hazards that occurred in Nottingham between 2000 and 2019. The discussion and findings are based around the Local Climate Impacts Profile (LCLIP) for Nottinghamshire (2000-2010), which was completed to support adaptation planning within the county, and the results of a media search for stories published between 2010-2019.

Box 1: Data limitations

At the time of writing this report, the LCLIP for Nottingham City was not available. Therefore, it was considered feasible to discuss the impacts of severe weather events at the City level based on Nottinghamshire County Council LCLIP data due to its proximity and interlinked services. However, it should be noted that some discrepancies exist (e.g. the Nottinghamshire LCLIP quotes seven major weather-related incidents in the 2000-2010 period, whilst NCC documents mention nine such events[4]). Thus, it can be suggested that the Nottinghamshire LCLIP provides a good indication of the overall trend for the 2000-2010 period in the region but does not provide precise figures in terms of a number of events or the related impacts for the City specifically.

Local authorities and emergency service providers do not typically record weather-related impacts systematically. Therefore, to assess impacts of the most recent (2011-2019) weather-related events within the Nottingham City boundaries, media sources and outlets were consulted. It should be noted that local media is entirely subjective, and coverage of an event can be influenced by many aspects (i.e. level of interest in the weather at the time, and/or the existence (or lack of) other newsworthy events). Therefore, the data obtained through media search should be used with caution.

4.1 Severe weather impacts between 2000 and 2010 – Key findings

The Nottinghamshire LCLIP identified that, between November 2000 and February 2010, the following seven severe weather incidents significantly impacted the county's services:

- Four flooding events (November 2010, July-August 2004, June-July 2007 and January 2008)
- One heatwave followed by a flash flood (July 2006)
- One strong wind/ storm event (January 2007)

One snow and ice event (February 2010)Table 1 provides some details on the effects that the aforementioned events had on key local services:

Table 1 Key impacts of severe weather events in Nottinghamshire for the period 2000 - 2010

Flooding and high winds	Heatwave and drought
• High expenditure, particularly for the Highways Department • Resident evacuation to rest centres (this included evacuation of ill and elderly people) • Road closures, damage, travel delays • Over 1,400 flooded properties • Loss of income to local business • Sewage contamination • Flood damage claims from schools	• Melting roads • Increased risk of fires (including in green spaces) • An increase in anti-social behaviour
Gales	**Severe winter – snow and ice**
• Travel delays due to fallen trees blocking routes • Power lines blown down • Damage to buildings • Local road network damage	• Difficulties for staff reaching their workplace • Increased demand for gritting services (leading to increased cost) • Lost working time (for landscaping team) • A rise in the number of insurance claims related to pot-hole damage

[4] NCC (2011) Climate Change Adaptation Action Plan. Nottingham City Council, Nottingham.

The LCLIP also identified six County services that were most frequently affected by the weather incidents, which led to substantial financial implications (over £2million owning only to flooding):

- Highways
- Children & Young People
- Properties
- Waste Management
- Adult Social Care
- Forestry

Other local players, such as the Nottinghamshire Fire & Rescue Service, Utility companies, Nottinghamshire Police, the Environment Agency, Nottinghamshire Primary Care Trust and Network Rail were reported to experience operational difficulties during these weather incidents.

4.2 Severe weather events between 2010 and 2019 – key findings

The review of media articles and social media posts identified an increase in the number of severe weather events reported since 2011, compared to 2000-2010. Ten events were identified, as follows:

- Five heatwaves and abnormally high temperatures (July 2013, May 2016, July 2016, July 2018 and February 2019)
- Five flooding events (June 2013, July 2013, August 2014, September 2016 and June 2019)

The media articles reviewed suggested that the greatest impacts of the heatwaves were felt by vulnerable groups, and the elderly specifically. In response to the abnormally hot weather in July 2016, Nottinghamshire County Council staff were deployed to make extra checks on people who receive home care. In addition, the police issued an alert to never leave a pet in the car during the hot weather as similar events have proven fatal for pets, with dogs being rescued from vehicles on a number of occasions. In addition to the summer heatwaves, February 2019 was recorded as the warmest February on record.

The impacts of floods were well documented with details available of specific locations and routes being flooded at a particular time. The most severe reported flood occurred in July 2013, when more than 50 homes were hit by flash flooding that followed a heatwave[5]. A month's rain fell in just a few hours in some parts of the region, with the county being reported to be the wettest place in the UK at the time. Major travel disruption was reported in various locations across the city and county with tram and bus service suspended for some time[6][7].

4.3 Discussion

The review of previous severe weather-related events highlights that flooding was the most significant weather-related issue reported over the 20-year timeframe (2000-2019). It appears that NCC's highways and social care departments experienced the highest level of adverse impact from flooding events.

The frequency of heatwaves has noticeably increased over the past ten years with only one recorded during 2000-2010 period and five for 2011-2019 period. This may bring an additional concern and burden on NCC's social care services for years to come.

As highlighted in Box 1, the sources consulted have some limitations regarding their accuracy and level of detail. Therefore, it is strongly recommended that key service providers are consulted individually, to access their local knowledge, experience and expertise in dealing with severe weather events in the past, and their view on potential adaptation options for the future. Specific attention should be given to the financial implications of severe weather events and lessons learnt. Individual interviews or a workshop format event have previously been proven to be useful methodological tools to gather the necessary information and details.

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[7] https://westbridgfordwire.com/police-have-closed-these-nottinghamshire-roads-because-of-flooding/

5. Projecting forward: UKCP2018 findings for Nottingham

Whilst insights into the impacts and consequences of recent weather and climate events can provide a catalyst for action, the UK's Committee on Climate Change Adaptation Sub Committee recommends that such an exercise should also act as a precursor to an assessment of future climate change impacts. Therefore, this chapter focuses on the analysis of cutting-edge climate science that provides an indication of what Nottingham's climate may look like in the future.

The following sections provide an overview of UKCP18 and its outputs and limitations. Detailed climate projections for changes in precipitation patterns and mean temperatures in Nottinghamshire have been extracted through the UKCP18 User Interface and supplement this report.

5.1 UKCP18 Background

The UK Climate Projections 2018 (UKCP18)[8], developed through the Met Office Hadley Centre Climate Programme with support from the Department of Business, Energy and Industrial Strategy (BEIS) and the Department for Environment, Food and Rural Affairs (DEFRA), provide an opportunity to assess the potential impacts of climate change on Nottingham and its built and natural environment and communities. The methodology that the UKCP18 projections are based on reflect leading global scientific understanding of how the climate system operates and how it might change in the future, and it also allows a measure of the uncertainty in future climate conditions to be established.

UKCP18 provides probabilistic projections over land and sea areas. The projections describe the difference between the modelled future climate (up to the end of the century) and the average observed baseline climate. The uncertainties associated with the future climate in probabilistic projections are represented as a range of possible outcomes and probability levels, based on the strength of evidence for different future climate change scenarios.

5.2 Representative Concentration Pathways (RCPs)

Assumptions about the economic, social and physical changes to the environment have been made to model and predict the possible future climate. Representative Concentration Pathways (RCPs) capture those assumptions within a set of scenarios. Specifically, RCPs specify concentrations of greenhouse gases that will result in total radiative forcing increasing by a target amount by 2100, relative to pre-industrial levels. Total radiative forcing is the difference between the incoming and outgoing radiation at the top of the atmosphere and is what contributes to climate change[9].

UKCP18 offers four different RCPs, which result in different ranges of global mean temperature increases over the 21st century (see Table 2).

Table 2 The increase in global mean temperature averaged over 1981-2100 compared to the pre-industrial period (average between 1850-1900) for the RCP pathways (best estimate, 5-95% range). From IPCC AR5 WG1 Table 12.3

RCP	Pathway description and policy requirements	Change in temperature (°C) by 1981-2100
RCP2.6	A pathway where greenhouse gas emissions are strongly reduced. This future would require: • Declining use of oil and low energy intensity • A world population of 9 billion by year 2100 • Use of croplands increase due to bio- energy production • More intensive animal husbandry • Methane emissions reduced by 40 per cent • CO_2 emissions stay at today's level until 2020, then decline and become negative in 2100 • CO_2 concentrations peak around 2050, followed by a modest decline to around 400 ppm by 2100	1.6 (0.9-2.3)
RCP4.5	A pathway that is consistent with a future with relatively ambitious emissions	2.4 (1.7-3.2)

[8] https://www.metoffice.gov.uk/research/collaboration/ukcp
[9] UKCP18 Guidance: Representative Concentration Pathways

RCP	Pathway description and policy requirements	Change in temperature (°C) by 1981-2100
	reductions. This future is consistent with: • Lower energy intensity • Strong reforestation programmes • Decreasing use of croplands and grasslands due to yield increases and dietary changes • Stringent climate policies • Stable methane emissions • CO_2 emissions increase only slightly before decline commences around 2040	
RCP6.0	A pathway that is consistent with the application of a range of technologies and strategies for reducing greenhouse gas emissions. This future is consistent with: • Heavy reliance on fossil fuels • Intermediate energy intensity • Increasing use of croplands and declining use of grasslands • Stable methane emissions • CO_2 emissions peak in 2060 at 75 per cent above today's levels, then decline to 25 per cent above today	2.8 (2.0-3.7)
RCP8.5	A pathway where greenhouse gases continue to grow unmitigated. This future is consistent with: • Three times today's CO_2 emissions by 2100 • Rapid increase in methane emissions • Increased use of croplands and grassland which is driven by an increase in population • A world population of 12 billion by 2100 • Lower rate of technology development • Heavy reliance on fossil fuels • High energy intensity • No implementation of climate policies	4.3 (3.2-5.4)

For this study, UKCP18 projections based on the RCP6.0 and RCP8.5 emissions scenarios have been used. Given today's global policy ambition and rate of industrialisation, economic growth and efforts to curb emissions, approximately 3°C of global warning by 2100 is the most likely scenario[10].

5.3 Timescales and Probability Levels

UKCP18 generates daily, monthly, seasonal and annual projections for 20-year pre-defined periods (e.g. 2020-2039; 2040-2059) and allows for the selection of temporal averages that are of interest to the user[11].

The projections in this study have assessed for the following two time periods and at the summer and winter temporal levels:

- 2020-2039; and,
- 2040-2059.

UKCP18 probabilistic projections also allowed for a range of uncertainties to be considered (expressed in probability terms). To understand the widest range of possible future climate scenarios, the projections have been assessed for three probability levels, as follows:

- The 10 per cent probability level – this demonstrates what the future change is unlikely to be less than. There is a 90 per cent chance the projected change will be more than this.
- The 50 per cent probability level – this is known as the central estimate i.e. what the future change is as likely as not to be.
- The 90 per cent probability level – this demonstrates what the future change is unlikely to be more than. There is a 10 per cent chance the projected change will be more than this.

[10] https://climateactiontracker.org/global/temperatures/
[11] Note that timescales vary depending on the projection type as per Annex 1.

5.4 Climate Variables

At the time of writing, a limited number of variables were available for extraction and evaluation through the UKCP18 User Interface. The following climate variables have been extracted for this project:

- Mean air temperature change;
- Maximum air temperature change;
- Minimum air temperature change; and,
- Precipitation rate change.

It is highly recommended that projections for additional weather variables are extracted and assessed once they become available on the UKCP18 platform (i.e. precipitation on the wettest day).

5.5 Climate Extremes

In late 2019, UKCP18 will release regional projections at a 2.2km special resolution (in a system called Climate Explorer), which will allow for projections relating to the future frequency of extreme weather events to be assessed. When this functionality becomes available, it is recommended that localised risks of heatwaves and flooding are assessed, particularly focusing on the areas of concern and hot-spots identified through the climate change risk assessment (CCRA) exercise.

5.6 UKCP18 findings

UKCP18 projections at a 25km scale within the boundaries illustrated in the Figure 1 have been extracted for this study:

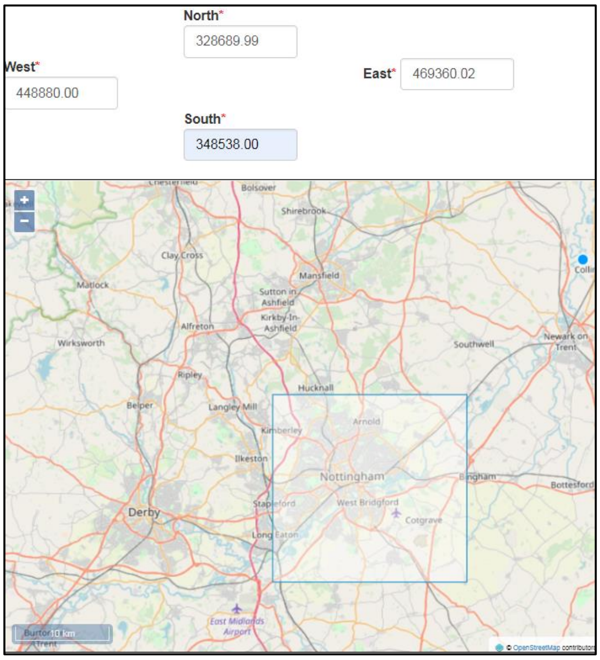


Figure 1 Area of UKCP18 analysis (Nottingham City)

For NCC to be able to understand the possible impacts of climate change on their assets and operations,

Table 3 provides information about the projected changes in mean daily conditions, including temperature and precipitation averages for the baseline (1981-2000), and projections for the 2020-2039 and 2040-2059 time periods[12]. Projections for mean summer (June, July and August) and winter (December, January and February) conditions are included in this summary. These projections represent average weather conditions and do not

[12] UKCP09 probabilistic projections uses 20-year time periods for all future projections.

capture the full range of possible more frequent severe weather events (i.e. dry spells, heatwaves and prolonged heavy rainfall) in the future.

Figure 2 provides guidance on how to interpret the projections in Table 3.

Change in mean daily temperature (summer)	
Baseline (1981-2000)	2020 - 2039
15.9°C	+1.0°C (+0.2°C to +1.8°C)

The central number represents the 50 per cent probability level, indicating that there is a 50% chance the average mean daily temperature in 2030s will be 1.0°C warmer and 50% chance that it will not have increased to such an extent. This probability level is therefore 'as likely as not' to occur.

The figures in brackets show the wider range of probability. In this example, the figures suggest that it is unlikely that mean daily temperature increase will be less than +0.2°C and more than +1.8°C (10 per cent and 90 per cent probability levels respectively).

The baseline figure provides an indication of the average mean daily temperature observed during the period from 1981 to 2000.

Figure 2: How to interpret the projections

Table 3 Key UKCP18 findings for the Nottingham city area for selected weather variables – RCP6.0 and RCP8.5 emission scenarios.

Climate Variable	Season	Baseline (1981-2000)	Projected change (compared to baseline)			
			RCP6.0		RCP8.5	
			2020 - 2039	2040 - 2059	2020 - 2039	2040 - 2059
Mean daily temperature, °C	Summer	15.9	+1.0 (+0.2 - +1.8)	+1.6 (+0.4 - +2.8)	+1.2 (+0.4 – +2.1)	+2.3 (+0.9 - +3.7)
	Winter	4.1	+0.8 (-0.1 - +1.7)	+1.2 (+0.1 - +2.2)	+0.9 (0.0 - +1.9)	+1.6 (+0.4 - +2.9)
Maximum mean daily temperature, °C	Summer	20.4	+1.1 (+0.1 - +2.3)	+1.8 (+0.3 - +3.5)	+1.3 (+0.2 - +2.6)	+2.6 (+0.8 - +4.5)
	Winter	6.8	+0.8 (-0.1 - +1.8)	+1.2 (+0.2 – +2.2)	+1.0 (0.0 - +2.0)	+1.6 (+0.5 - +2.8)
Minimum mean daily temperature, °C	Summer	11.4	+0.9 (+0.3 - +1.6)	+1.4 (+0.5 – +2.5)	+1.1 (+0.4 - +1.9)	+2.1 (+0.9 - +3.3)
	Winter	1.3	+0.7 (-0.2 - +1.7)	+1.2 (+0.1 - +2.3)	+0.8 (-0.1 - +1.9)	+1.6 (+0.3 - +3.0)
Mean precipitation, baseline in mm/projected change in %	Summer	60.7	-7% (-26% - +15%)	-17% (-37% - +5%)	+5% (-5% - +16%)	-20% (-43% - +3%)
	Winter	59	+4%	+6%	+5%	+8%

Climate Variable	Season	Baseline (1981-2000)	Projected change (compared to baseline)			
			RCP6.0		RCP8.5	
			2020 - 2039	2040 - 2059	2020 - 2039	2040 - 2059
			(-5% - +14%)	(-7% - +19%)	(-5% - +16%)	(-5% - +23%)

Box 2 provides a summary of the above projections for future temperature and precipitation change in Nottingham.

Box 2: Summary of projections for future temperature and precipitation change in Nottingham

Projections for the future temperature change highlight the following trends and potential implications:

- The trend of rising annual mean temperatures is forecast to continue. By the 2050s, mean summer temperature could be up to 3.7°C higher than the baseline (1981-2000) average, and mean winter temperature could be up to 2.9°C higher, based on the RCP8.5, 90% probability level.
- Mean daily maximum and minimum temperatures will also increase across Nottingham. The increase in mean daily maximum temperature in summer is projected to be up to 4.5°C; and up to 2.8C increase in mean daily minimum winter temperature compared to 1981-2000 baseline (RCP8.5, 90% probability level).
- The figures shown in
- Table 3 indicate that the city of Nottingham faces threats associated with increasing mean temperatures, particularly in summer. This may negatively affect conditions in buildings and the built environment leading to heat related damage, and also disruption to the council's transport network and energy supply. The 'Urban Heat Island'[13] effect may also become more of an issue, which can cause increased demand for cooling. The comfort of vulnerable citizen groups is of a particular concern and should be considered along with potential implications on demand for NHS services.

Projections for the future precipitation change highlight the following trends and potential implications:

- There will be greater seasonality of rainfall with more in winter and less in summer (when compared to average 1981-2000 baseline conditions). Changes in water availability, particularly reductions in the summer, may lead to increased water shortage, affecting the supply for various services and facilities across NCC's jurisdiction.
- Wetter winters – up to a 23 % increase in precipitation is projected by the 2050s – this may lead to increased flood risk, increased water penetration from driving rain and an increase in subsidence across the city.
- Low water availability during the projected drier summers may have significant effects on all NCC services, and on Highways, Forestry, Properties and Social Care in particular.

Together with observations from the past, UKCP18 probabilistic projections should be consulted when conducting a climate change risk assessment and/ or as a communication tool. The projections help to characterise climate-related hazards and contributes to a multi-faceted risk assessment, which is outlined in Chapter 6.

[13] An urban heat island is a human made area that's significantly warmer than the surrounding countryside — especially at night (Met Office): https://www.metoffice.gov.uk/binaries/content/assets/mohippo/pdf/8/m/mo_pup_insert_health.web.pd

6. Climate Change Risks

To assess the impacts of climate change, the Fifth IPCC Assessment Report (AR5) offers the concept of risk and how it relates to the climate, socioeconomic processes, emissions and impacts (Figure 3).

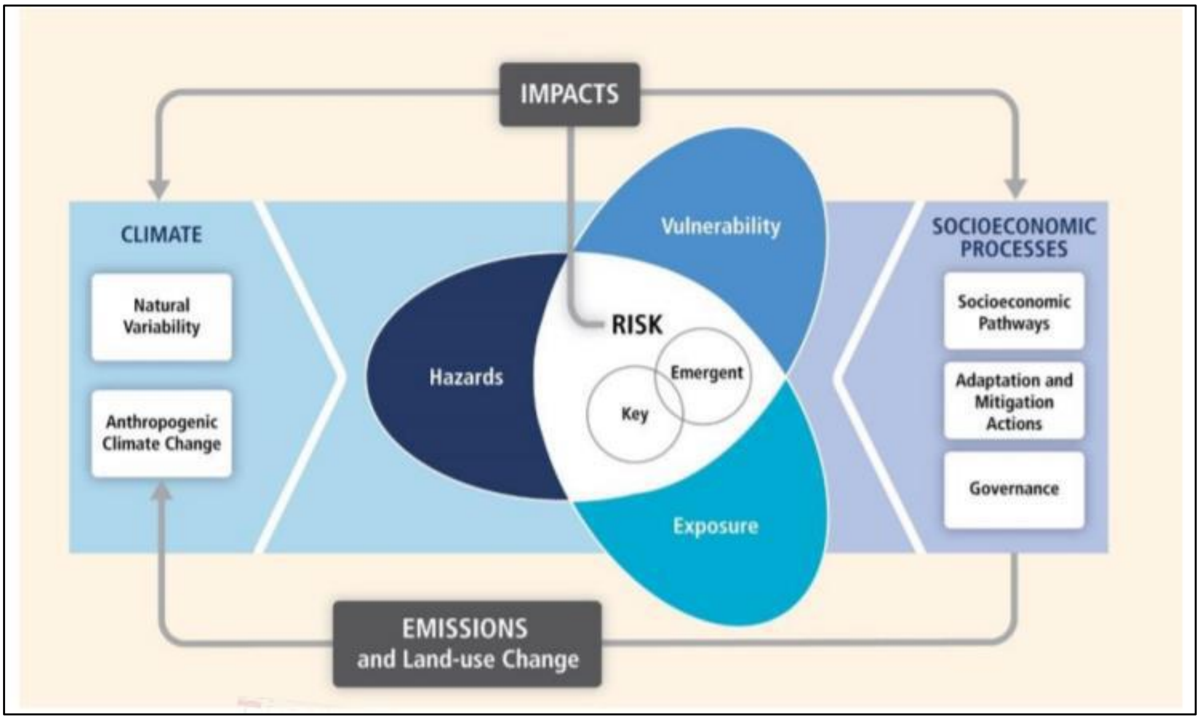


Figure 3 How risk is conceptualised by IPCC[14]

In summary, IPCC AR5 conceptualises climate change risk in the following way:

- **Exposure:** The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected by hazards (e.g. flooding). Typical exposure factors include temperature, precipitation, evapotranspiration and climatic water balance, as well as extreme events such as heavy rain and drought.
- **Hazard**: The potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihood, service provision, ecosystem and environmental resources.
- **Vulnerability:** the propensity or predisposition to be adversely affected, if exposed to the hazard. Vulnerability comprises the following:
  - **Sensitivity:** Susceptibility to harm (if exposed).
  - **Adaptive capacity:** The ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences.
- **Risk**: The potential for adverse consequences where something of value is at stake and where the occurrence and degree of an outcome is uncertain, In the assessment of climate impacts, the term risk is often used to refer to the potential for adverse consequences of a climate-related hazard on lives, livelihoods, health and well-being, ecosystems and species, economic, social and cultural assets, services (including ecosystem services), and infrastructure.

[14] IPCC (2014) *Emergent risks and key vulnerabilities*, in: Climate Change 2014: Impacts, Adaptation, and Vulnerability, http://www.ipcc.ch/pdf/assessment-report/ar5/wg2/WGIIAR5-Chap19_FINAL.pdf.

This means that climate change risk results from the interaction of vulnerability, exposure over time (to the hazard), as well as the (climate-related) hazard and the likelihood of its occurrence. Together these form potential risks, and along with consequences of these, form impacts, as shown in Figure 3[15].

6.1 Assessing climate change risks in NCC context

The IPCC climate change risk concept provides a conceptual understanding of what constitutes risk. However, there is no one-size-fits-all approach to a CCRA. They can differ significantly in their structure depending on scope, the nature of the organisation, and available resources.

In the context of NCC, it is advisable to consider attributes shown in Table 4[16] before attempting an assessment of climate change risks (suggested characteristics for inclusion are provided in the third column 'Proposed for NCC'). Availability of resources, dedication and willingness of key NCC service representatives and other key stakeholders (e.g. energy companies, police, etc) to contribute to the process is critical when undertaking this exercise. Therefore, early engagement is critical for the meaningful output.

Table 4 Attributes of CCRA and suggestions for NCC

Attribute	Key questions	Suggested for NCC
Topic	How many potential climate change impacts are covered?	Change in precipitation patterns, increase in mean daily temperatures
Spatial extension	Which units does the assessment focus on? What is the level of assessment?	Impacts on individual NCC services
	What is the resolution of the assessment?	City level (as defined by UKCP18 resolution 25x25km)
Temporal scope	Over which time periods does the risk assessment focus on?	2020-2039; 2040-2059 (as defined by UKCP18)
Inputs and methods	What methods does the assessment use to acquire relevant information?	A mix of qualitative (measuring and modelling) and qualitative (interviews, stakeholder engagement) methods.

Clearly defined attributes of the CCRA will allow for the assessment to stay focused and achievable.

6.2 Flooding exposure assessment

As described in section Assessing climate change risks in N6.1, the approach to undertaking a CCRA can differ significantly depending on the availability of resources and information to base the assessment on. This report suggests one of the possible approaches for undertaking an exposure assessment that subsequently should be supplemented by vulnerability scoring to establish final risk scores. In the context of this example, risk of flooding or an 'increase in precipitation' is assessed. Publicly available Environment Agency data is a primary information source for assessing the exposure level now and in the future.

To identify the current and future level of exposure of NCC services, assets and operations to fluvial, pluvial and surface water flooding, it is therefore recommended to consult the following Environment Agency data:

Table 5 Recommended data to use to assess flooding exposure level

Flood Zone	Definition	Flood risk timeframe
Zone 3	EA's best estimate of the areas of land at risk of flooding, when the presence of flood defences are ignored and covers land with a 1 in 100 (1%) or greater chance of flooding each year from Rivers; or with a 1 in 200 (0.5%) or greater chance of flooding each year from the Sea.	These datasets provide an indication of the extent of flood exposure at present

[15] https://www.adeptnet.org.uk/system/files/documents/Good%20Practice%20Guide%20ADEPT%202019f.pdf
[16] https://www.adaptationcommunity.net/vulnerability-assessment/vulnerability-sourcebook/

Flood Zone	Definition	Flood risk timeframe
Surface Water 1 in 100 year event	EA's best estimate of the areas of land at risk of surface water flooding. 1% probability of a surface water flood occurring each year.	
Zone 2	EA's best estimate of the areas of land at risk of flooding, when the presence of flood defences is ignored and covers land between Zone 3 and the extent of flooding from rivers or the sea with a 1 in 1000 (0.1%) chance of flooding each year.	These datasets provide an indication of the extent of flood exposure in the future (by the end of the century)
Surface Water 1 in 1000 year event	It is EA's best estimate of the areas of land at risk of surface water flooding. 0.1% probability of a surface water flood occurring each year.	

Box 3 provides further explanation as to why these specific EA data sets are the best sources of information to base the exposure assessment on.

Box 3: Rationale for proposed approach to flood exposure assessment

Currently, the best available data on flood risk is the flood risk for planning envelopes produced by the Environment Agency[17]. This data shows the modelled extents of flooding with annual event probabilities of 3.3%, 1% and 0.1%. A 1% annual event probability is a flood with a probability of occurrence of 1% in any year and is sometimes referred to as the 1 in 100 year event. These extents are based on historic flood and rainfall data and thus represent the current situation without climate change. These datasets do not show the potential effects of climate change.

In the context of local planning and the preparation of flood alleviation schemes for urban areas, the design event of fluvial flooding is usually taken to be the 1% annual event probability flood. Therefore, this is proposed to be taken as the key flood envelope in terms of using the available data to extrapolate to potential future scenarios (2020s, 2050s and 2080s). Climate change allowances for flood risk are set out in UK Government guidance document "Flood risk assessments: climate change allowances"[18].The peak river flow allowances from this document applicable to Nottingham (Humber river basin district[19]) are shown in Table 6 and equivalent rainfall allowances in Table 7.

Table 6 Peak river flow allowances for climate change

River basin district	Allowance category	Total potential change anticipated for the '2020s' (2015 to 2039)	Total potential change anticipated for the '2050s' (2040 to 2069)	Total potential change anticipated for the '2080s' (2070 to 2115)
Humber	Upper end	20%	30%	50%
	Higher central	15%	20%	30%
	Central	10%	15%	20%

Table 7 Peak rainfall intensity allowance in small and urban catchments (use 1961 to 1990 baseline)

Applies across all of England	Total potential change anticipated for the '2020s' (2015 to 2039)	Total potential change anticipated for the '2050s' (2040 to 2069)	Total potential change anticipated for the '2080s' (2070 to 2115)
Upper end	10%	20%	40%
Central	5%	10%	20%

There is not a unique scaling factor between the 1% and 0.1% flood events: it will depend on the nature and location of the catchment for fluvial (river) flooding and on the storm duration and location. In order to quantify the relationship between the 1% and the 0.1% events, Flood Estimation Handbook 2013 rainfall data has been assessed, as presented in Table 8. This shows a scaling factor between +56% and +73%. Given that the climate change allowance for the 2080s varies between 20% and 50% for fluvial (river) events, and between 20% and 40% for rainfall intensity, using the 0.1% flood envelope as a proxy for the 1% flood event with climate change to the 2080s is considered to be reasonable, although possibly slightly conservative.

Table 8 Flood Estimation Handbook 2013 rainfall depths

Duration	Depth		Ratio
(hours)	1%	0.10%	
1	45.41	77.83	1.71
2	57.28	99.13	1.73
4	69.66	119.37	1.71
8	80.21	134.85	1.68
12	85.02	141.15	1.66
24	91.28	147.99	1.62
48	97.29	151.91	1.56

[17] https://flood-warning-information.service.gov.uk/long-term-flood-risk/map
[18] https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances
[19] River Trent falls within boundaries of Humber River Basin District

6.3 Exposure to flooding – adult social care service in NCC

The NCC Adult Social Care Service exposure to flooding is used as an illustrative example to demonstrate the results of the proposed approach. The Adult Social Care Service was chosen due to data availability (locations of the care centres were freely available through the NCC data share website).

GIS shapefiles locating NCC care centres were interrogated with EA flood maps to illustrate the level of exposure at present and in the future. Figure 4 and Figure 5 provide a visual representation of the risk of flooding increasing over time and whether a particular centre is located within a zone particularly exposed to flooding. Table 9 and

Table 10 provide a detailed description for the exposed centre with an indication of the Ward responsible for its operation and the level of expected flood depth.

Table 9 NCC Adult Care Centres exposed to flooding at present

Name	Type	Postcode	Ward	Flood depth
Acorn Resource Centre	Day Centre	NG7 5JD	Arboretum	0.30 - 0.60
Cherry Trees Residential/Respite Care Unit	Residential Care & Day Care	NG5 5TA	Bestwood	0.15 - 0.30
Laura Chambers Lodge	Residential Care	NG11 8HW	Clifton North	0.00 - 0.15
Loxley House	Office	NG2 3NG	Bridge	0.15 - 0.30
Open Door Day Centre	Day Centre	NG8 3GD	Bilborough	0.15 - 0.30
Pakistan Day Centre	Day Centre	NG3 1AX	St Ann's	> 1.20
Spring Meadow Day Services	Day Centre	NG2 3DZ	Bridge	0.30 - 0.60
The Willows Intermediate Care Unit	Day Centre	NG8 3GD	Bilborough	0.00 - 0.15

Table 10 NCC Adult Care Centres exposed to flooding in the future (end of the century)

Name	Type	Postcode	Ward	Flood depth
Acorn Resource Centre	Day Centre	NG7 5JD	Arboretum	Not Available
Albany House Day Centre	Day Centre	NG3 2FP	St Ann's	Not Available
Cherry Trees Residential/Respite Care Unit	Residential Care & Day Care	NG5 5TA	Bestwood	Not Available
JackDawe Team	Office	NG6 8WR	Bulwell	Not Available
Kersall Court (SMART House)	Office	NG6 8WR	Bulwell	Not Available
Laura Chambers Lodge	Residential Care	NG11 8HW	Clifton North	0.15 - 0.30
Loxley House	Office	NG2 3NG	Bridge	0.30 - 0.60
Marcus Garvey Day Centre	Day Centre	NG7 2BY	Radford and Park	0.15 - 0.30
Martin Jackaman Centre	Day Centre	NG8 3LD	Leen Valley	Not Available
Nottingham Emergency Home Care Team	Office	NG6 8WR	Bulwell	Not Available
Oakdene Residential/Short Breaks/Emergency Care	Residential Care & Day Care	NG3 1AZ	St Ann's	Not Available
Open Door Day Centre	Day Centre	NG8 3GD	Bilborough	Not Available
Pakistan Day Centre	Day Centre	NG3 1AX	St Ann's	Not Available
Spring Meadow Day Services	Day Centre	NG2 3DZ	Bridge	0.30 - 0.60
The Oaks EPH	Residential Care	NG3 1GZ	St Ann's	Not Available
The Willows Intermediate Care Unit	Day Centre	NG8 3GD	Bilborough	Not Available
Summerwood Day Centre	Day Centre	NG11 9DR	Clifton South	Not Available

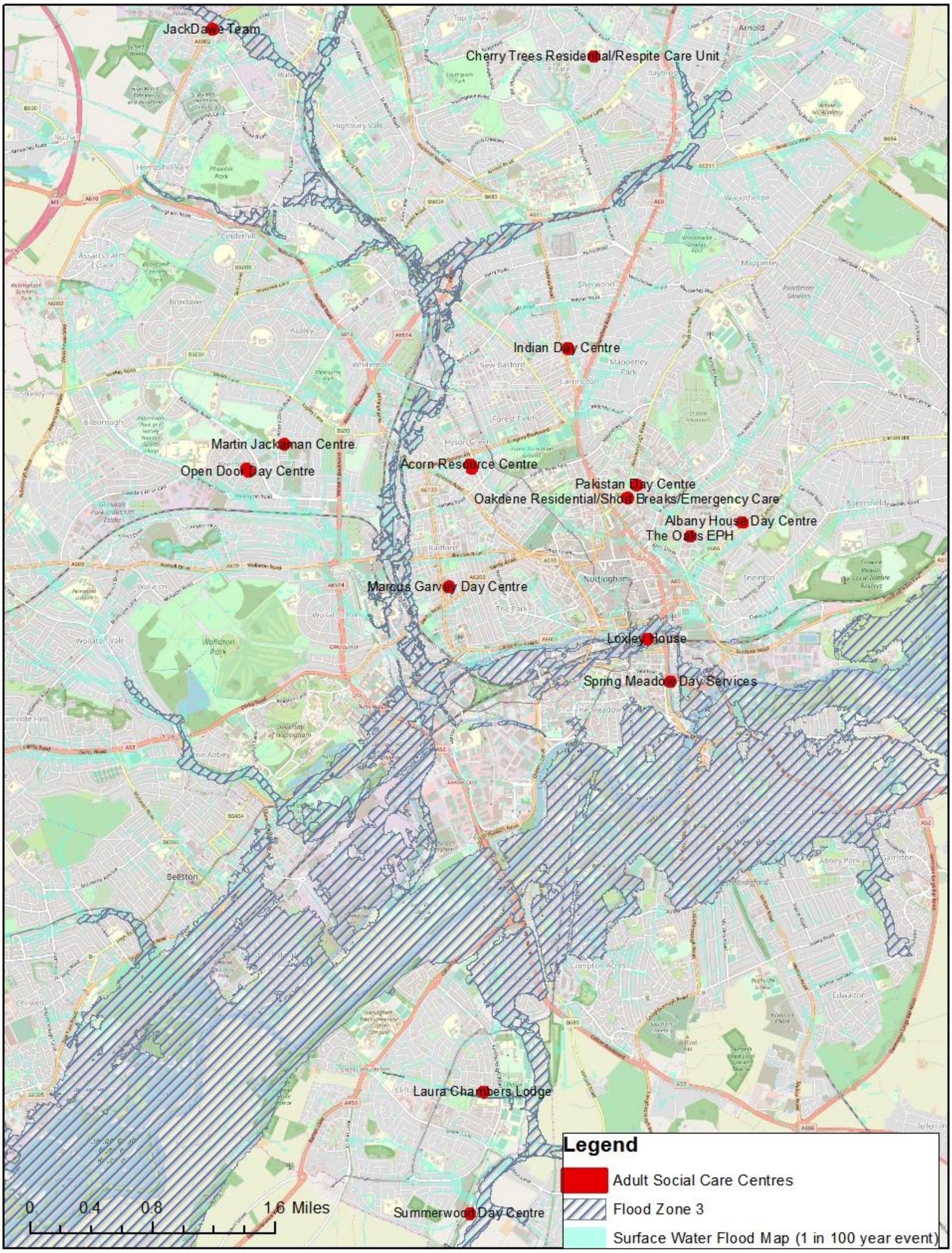


Figure 4 Adult Social Care service exposure to flooding at present

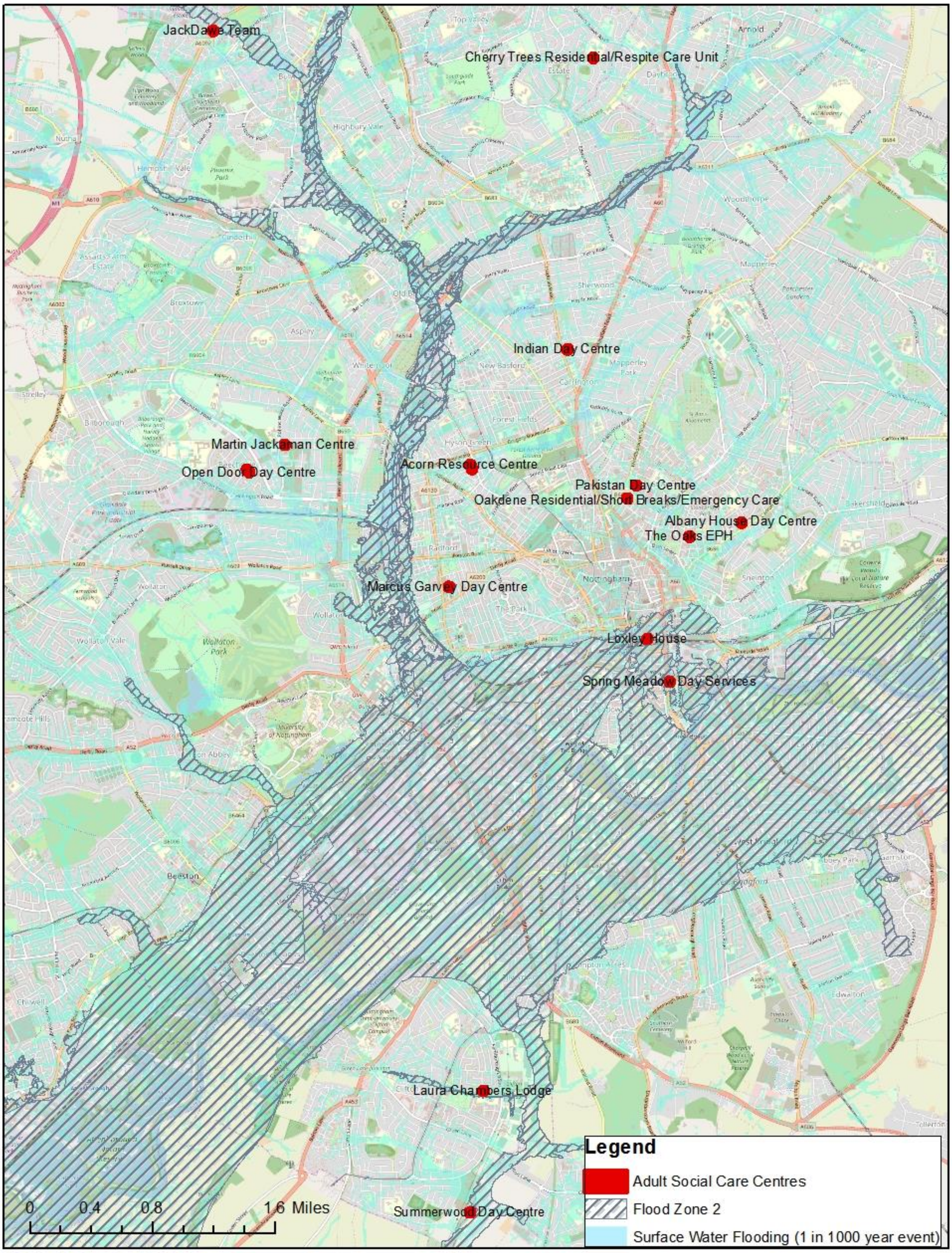


Figure 5 Adult Social Care service exposure to flooding in the future

The depth of a flood (available for surface water flooding only) provides a good indication of the potential severity of the event. Table 11 explains what different levels of flood depth means with regards to property being flooded and the effectiveness of the property-level flood resilience measures.

Table 11 Surface Water Flood depth level explained (Source: EA2013: What is the updated Flood Map for Surface Water?)

Depth (m)	Threshold
<0.15	
0.15 – 0.30	At 0.15m, flooding would: • Typically exceed kerb height (standard kerb height is 125mm) • Likely exceed the level of a damp-proof course • Cause property flooding in some areas
0.30 – 0.60	At 0.30m flooding is likely to cause property-level flooding. This is based on average property threshold levels.
0.60 – 0.90	Property-level flood resilience measures are typically effective up to a water depth of 0.60m above floor level. Above depths of 0.60m these measures are likely to be much less effective and structural damage is more likely to occur. However, as floor levels vary, the maximum flood depth where resilience measures are still effective may be in a range between 0.60m and 0.90m above ground level.
0.90 – 1.20	Very likely to exceed the maximum flood depth where property-level flood resilience measures are still effective.
>1.20	

6.4 Results

The results suggest that there are eight care centres that are currently exposed to flooding. Three of them are at risk of flood water entering the building and causing substantial damage (i.e. Acorn Resource Centre, Pakistan Day Centre and Spring Meadow Day Services). The Pakistan Day Centre is at the highest level of risk with anticipated depth of 1.2m, which can cause structural damage to the building. In similar situations, property-level flood resilience measures are typically not effective, therefore adaptation measures at the Ward-level will mostly likely be required.

Exposure to flooding is anticipated to increase significantly over time. The results of the assessment suggest that 17 of the total of 18 care centres will be exposed to flooding by the end of the century (as opposed to eight currently). EA flood data does not provide flood depth details for all exposed areas in the future, but evidence suggest that the risk of pluvial and fluvial flooding will substantially increase over time. This can potentially have serious implications on the ability of NCC's Adult Social Service to be able to assist vulnerable individuals and communities and subsequently can cause serious implications on health and well-being of the elderly and other vulnerable groups.

Important to note is that this approach assesses exposure level at an asset level and does not take account of any existing flood protection measures, plans and procedures in place. The latter should be considered during the **vulnerability assessment** stage and will therefore increase or decrease the final level of risk. Characteristics such as residents' preparedness for flooding (e.g. awareness, ability to adapt) and physical characteristics of the building should be considered to establish the final risk scores.

6.5 Vulnerability Assessment

As indicated throughout Chapter 6, the exposure assessment is the first element to consider in the attempt to understand climate change risks across NCC operations. This should always be supplemented by a vulnerability assessment.

Vulnerability is defined by susceptibility to harm (e.g. flooding in our example) and the ability of a system (e.g. NCC Adult Social Care Service in our example) to adjust to potential damage, or to respond to consequences (defined as adaptive capacity).

Adaptive capacity can be comprised of different 'ingredients', but the key dimensions are as follows[20]:

- **Knowledge:** general level of education and awareness about issues such as climate change and its impact
- **Technology:** the availability of and access to technological options for adaptation
- **Economy:** GDP, employment/unemployment rate, etc. This can also include budget allowances for adaptation measures
- **Institutions:** multitude of governance, institutional and legal concerns, including the capacities and efficiency of key institutions, transparency of procedures and decision making

Assessing susceptibility and adaptive capacity, therefore, is a multidimensional task that require input from professionals from different disciplines through facilitated targeted engagement. In the context of NCC, a vulnerability assessment should be performed in close collaboration with key service delivery personnel who possess not only strategic knowledge of the services along with key challenges, but also include operational staff and local business and the public who potentially can be impacted by the changes.

A vulnerability assessment is generally a lengthy time-consuming process. Professional external advice and assistance should be considered when performing a vulnerability assessment or an overall CCRA. Alternatively, it is advisable for NCC to appoint a dedicated team or a working group to facilitate the CCRA process.

It was not in the capacity of this project to explore the vulnerability assessment element to complete the CCRA. Considering vulnerability of only NCC Adult Social Services (our example), the task would require significant input from NCC and was not seen as feasible within the scope and timescales of this project.

Section 7, however, provide links to useful information that should be consulted when performing a full CCRA.

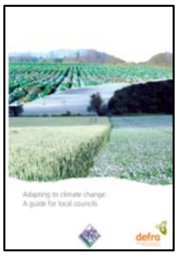
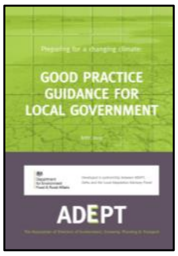
[20] https://www.adaptationcommunity.net/?wpfb_dl=203

7. Conclusion and useful links

Under significant demand to reduce spending and rising demands for its services, local governments tend to prioritise short-term objectives at the expense of the longer-term vision that is required in the context of climate change adaptation. It is important to realise, however, that adaptation can be a linking piece in the puzzle that underpins many core local government activities. Specifically, adaptation can help achieve strategic objectives by ensuring projects, plans and processes are resilient to climate change. Knowledge of the main climate risks allows assets and activities to continue performing without disruption. Many studies now also show that adaptation action is generally cheaper and more effective over time, when compared to the costs associated with the impacts of extreme weather. Early adaptation measures can also help to meet statutory requirements and can deliver co-benefits through careful planning (i.e. improve health and wellbeing, property values, skills and employment, reducing emissions and supporting biodiversity)[22].

A carefully designed CCRA should be a first step in the adaptation journey that provides a useful insight into the most pressing issues, locations and operations, thereby informing adaptation needs. This report suggests one method of looking at climate change risks though assessing hazard, exposure and vulnerability elements of a system. The report also provides an indication of the effort required to complete the task.

There are multiple approaches in existence to guide an organisation through the CCRA process. It is, therefore, strongly advised that NCC consult the following reports and guidance when performing the task:

Document	Brief description
	**The Vulnerability Sourcebook[20] : Concept and guidelines for standardised vulnerability assessment** The document provides a standardised approach to vulnerability assessment covering a broad range of sectors and topics as well as different spatial level and time horizons. It also offers step-by-step guidance for designing and implementing a vulnerability assessment which covers the entire life cycle of adaptation interventions, using consistent methods.
	**Adapting to climate change: a guide for local councils[21]** The guide aims to provide local councils and community groups that are wanting to take action to adapt to climate change, with information on some of the future risks and opportunities. It provides guidance and some practical examples of action, including a number of case studies.
	**Preparing for a changing climate: good practice guidance for local authorities[22]** The guide is designed for a wide range of officers working to implement adaptation within local government. The document is relevant for organisations that are just starting out on adaptation planning, as well as for those who already work in adaptation and are looking for new ways to move the agenda forward in their own area,
	**Adaptation actions in cities: what works? Report of research findings[23]** The report provides a set of case studies depicting climate change adaptation actions in urban areas across the UK. Key characteristics of successful adaptation projects are highlighted for ease of replication.

[21] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/218798/adapt-localcouncilguide.pdf
[22] https://www.adeptnet.org.uk/climategpg
[23] https://www.theccc.org.uk/wp-content/uploads/2018/11/Adaptation-actions-in-cities-what-works-final.pdf

Document	Brief description
	**Sector specific (Roads): Climate change adaptation framework for road infrastructure**[24] The framework provides a consistent approach to analysing the effects of climate change on road networks and helps transport authorities to identify, propose and prioritise the most appropriate measure to mitigate risks associated with extreme weather events.

[24] https://www.piarc.org/en/order-library/23517-en-International%20climate%20change%20adaptation%20framework%20for%20road%20infrastructure.htm