Greater Manchester Fellowship Report

Assessing the cost of failing to adapt to flooding

April 2025

HOWDEN | GMCA GREATER MANCHESTER COMBINED AUTHORITY | United Utilities Water for the North West

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Executive Summary

Purpose

To effectively respond to flood risk both now and in the future, it is vital to understand the impacts of flooding caused by severe storms and heavy rainfall on assets, services and livelihoods. Over the last decade, Greater Manchester has experienced several severe flood events that have damaged homes, businesses and infrastructure, causing millions of pounds in economic losses. Considering this, the Fellowship project assessed Greater Manchester's flood risk exposure. It also considered **the cost of United Utilities – the city-region's water supplier – failing to adapt to flooding** and the related impacts for water provision in Greater Manchester.

Methodology

This report presents a **5-step Climate Risk Assessment methodology** developed to assess the cost of flooding to United Utilities' facilities. The approach combines market leading flood risk data and analytics, insurance loss models, climate consulting, and analytics expertise. Throughout the Fellowship project, key stakeholders were engaged to guide its direction and capture diverse perspectives. These key stakeholders were the Local Government, Government representatives, infrastructure providers, insurers, and flood consultants and flood modellers.

Key Outcomes

The Fellowship project and this report will strengthen the understanding of United Utilities, Greater Manchester Combined Authority (GMCA) and their key partners of the vulnerability of Greater Manchester's water infrastructure to flood, the cost of this exposure, and the investment required to reduce it. Below is an overview of the specific outcomes that have been identified for each key stakeholders:

- **Greater Manchester Combined Authority** has developed a deeper understanding of the impacts of flood risk on the city-region, which will enable it to build a fuller picture of the costs and impacts of climate change. Additionally, it is more aware of United Utilities' flood risk exposure, United Utilities' capacity to respond, and the related potential impacts on the provision of water services in the region.

- The Fellowship project provided **United Utilities** with a methodology for assessing the impacts of flood on its assets that is informed by insurance data and risk assessment approaches. This methodology will support United Utilities' existing approach to assessing the impacts of climate risk on its asset portfolio, including potential enhancements to it 2024 Climate Risk Assessment.

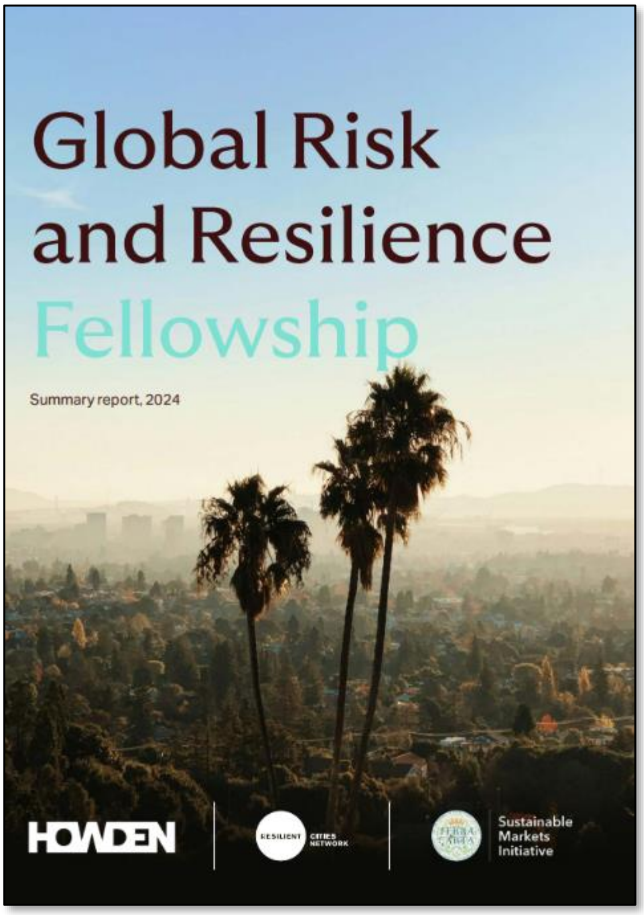
- The **Cabinet Office** and **Ministry of Housing, Communities and Local Government** (MHCLG) – both of which were involved in consultations throughout the project – have a better understanding of the approaches used by the insurance sector to assess the costs of climate risk, as well as the relevance of these approaches for climate risk assessment in cities. The learnings from the project can be drawn on in the development of other municipal resileince plans, as well as any updates to the UK Government Resilience Framework.

The Global Risk & Resilience Fellowship Programme

The Global Risk and Resilience Fellowship ("the Fellowship") is a pioneering program delivered through a partnership between Howden, the Resilient Cities Network and the Sustainable Markets Initiative (SMI), the objective of which is bolster city resilience by collaborating with city leaders to utilise insurance and private sector tools and knowledge to address urban climate challenges.

It is a unique partnership between the public and private sectors that places insurance professionals – Fellows – within city leadership teams in member cities of the Resilient Cities Network. The Fellowship, alongside a network of experts, will seek to bolster city resilience by providing access to various tools for addressing risks. By integrating insurance professionals into cities' resilience planning, the Fellowship will transform insurance into a comprehensive tool that accelerates de-risking and resilience-building efforts – ultimately contributing to sustainable growth.

City officials receive practical risk consulting advice from the Fellows that will amplify existing efforts to build long-term resilience and minimise vulnerabilities. The cities also benefit from risk transfer expertise to understand and manage volatility. The program also enables insurance professionals to develop expertise in climate risk and city resilience, and to better understand how risk mitigation and risk transfer can be leveraged to effectively address long-term climate change risks in the public sector. Both the city officials and the Fellows will join a cohort of thought leaders equipped to implement innovative solutions that incorporate risk consulting and risk transfer into cities' resilience agendas.



About the Fellowship Partner Organisations

Resilient Cities Network

Resilient Cities Network is the world's leading urban resilience network. It brings together global knowledge, practice, partnerships, and funding to empower its members to build safe and equitable cities for all. Its unique city-led approach ensures cities drive the agenda to benefit the communities they serve. At work in over 100 cities worldwide, the Resilient Cities Network supports on-the-ground projects and solutions to build climate resilient, circular and equitable cities while also facilitating connections and information-sharing between communities and local leaders.

For more information, please visit: sustainable-markets.org

Howden

Howden is a leading global insurance group with employee ownership at its heart. Founded in 1994 it provides insurance broking, reinsurance broking, and underwriting services and solutions to clients ranging from individuals to the largest multinational companies. The group operates in 55 countries across Europe, Africa, Asia, the Middle East, Latin America, the USA, Australia, and New Zealand, employing 20,000 people and handling $38bn of premium on behalf of clients.

For more information, please visit: howdengroup.com and howdengroupholdings.com

Howden Climate Risk and Resilience

Howden's Climate Risk and Resilience team provides climate advisory and risk transfer solutions to help accelerate and de-risk the move towards a low carbon economy, build societal resilience, and mitigate the impacts of climate change. The team comprises more than 70 world-class experts globally. A blend of specialists in all facets of climate science, and professionals with a deep understanding of the inner workings of the insurance and financial markets.

For more information, please visit: howdengroup.com/uk-en/climate-risk-and-resilience-howden-uk

Sustainable Markets Initiative

Founded by His Majesty King Charles III in 2020, as Prince of Wales, the Sustainable Markets Initiative has become the world's 'go-to' private sector organization on transition. Launched in 2021, the Terra Carta serves as the Sustainable Markets Initiative's mandate with a focus on accelerating positive results for Nature, People and Planet through real economy action.

For more information, please visit: sustainable-markets.org

Introduction

As the main water provider for Greater Manchester, it is important for United Utilities to understand the impacts of severe storms, heavy rainfall, and significant flooding on its facilities, as well as the consequences of these impacts on society. The urgency to gain this understanding was highlighted in December 2015, when Storm Desmond, an extratropical cyclone, caused financial losses to United Utilities of approximately £19.5 million.[I]

The climate across Greater Manchester is changing. Average annual rainfall in the region has increased by about 7% from 1961 to 2004, while winter precipitation has risen by as much as 50% during the same period.[II] According to the UK Climate Projections 2021 (UKCP21)[III], extreme rainfall events are expected to occur with greater frequency, with winter precipitation potentially increasing in intensity by up to 30% by the 2050s. Modelling indicates that peak river flows could rise by 70% by the 2070s under high emissions scenarios.[II] Given these climate changes, it is essential for the Greater Manchester Combined Authority (GMCA) and United Utilities to have a shared understanding of their interlinked evolving risk profile.

This report outlines the methodology developed to assess the cost of flooding to United Utilities' facilities.

Project Focus & Objectives

1 The primary goal of this Fellowship project was to support the **Greater Manchester Combined Authority** in assessing the potential impact on their water services if the region's water supply company, United Utilities, does not take sufficient measures to adapt to future flood risk under a range of climate scenarios.

2 The secondary goal of this Fellowship project was to provide **United Utilities'** Climate Adaptation Manager with language to engage with United Utilities' risk manager to help build a compelling investment case for enhancing resilience and investing in climate adaptation.

3 The third goal of the Fellowship project was to provide the **Cabinet Office and the Ministry of Housing, Communities and Local Government** with a private sector methodology for assessing the costs of climate risk, to inform local and national level resilience investment strategies and potentially contribute to the National Resilience Review.

Stakeholders

A range of stakeholders were engaged through the Fellowship project to guide its direction and capture diverse perspectives. These included:

The Local Government, to ensure the Fellowship is embedded within the local city context and framed within the political landscape.

Government representatives to ensure the Fellowship provides valuable information that feeds into the UK Government's Resilience Framework.

Infrastructure providers from across Greater Manchester, to develop a deeper understanding of the cascading impacts of climate risk in the region.

Insurers, to gain insights into how insurance policies can be structured in response to adaptation actions and to better understand how insurance can be used to de-risk investment in facilities.

Flood consultants and flood modellers, to provide United Utilities with loss estimates and a better understanding of flood risk, combining climate consulting with expert advice.

GMCA GREATER MANCHESTER COMBINED AUTHORITY

Cabinet Office

Ministry of Housing, Communities & Local Government

United Utilities

electricity north west

Transport for Greater Manchester

JBA risk management

Rebalance EARTH

Methodology

Defining Risk

To align with the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report's (AR6)[IV] definition of 'risk', the risk assessment integrates the following elements:

Hazard x Exposure x Vulnerability

- **Hazard**: How likely is a hazard event to occur, and what is the intensity?
- **Exposure**: What are the characteristics, functions, and financial values of exposed facilities?
- **Vulnerability**: How damageable are the exposed facilities? What adaptive capacity measures are in place to reduce risk?

To ensure that the methodology was robust and aligned with current industry standards, the Fellowship project team undertook a comprehensive literature review of industry best practices. Some of the key literature identified and used as the foundation of the methodology includes: *'Water UK: A Climate Change Adaptation Approach for Facility Management Planning' (2007)*[VI], *'ISO 14091: Adaptation to Climate Change — Guidelines on vulnerability, impacts and risk assessment' (2021)*[VII] and a recently published synthesis of physical climate risk assessment by ARUP titled *'A Universal Taxonomy for Natural Hazard and Climate Risk and Resilience Assessments' (2024).*[VIII] Other key literature was reviewed to ensure the Fellowship builds upon existing work in the context of urban resilience in Greater Manchester such as *"The Cities Water Resilience Approach"* by ARUP (2019)[IX], which aids cities in planning and implementing actions to build resilient urban water systems.

A Methodology Rooted in Industry Best Practice & Research

Climate Risk Assessment: A 5-step Approach

To evaluate the cost of flooding on United Utilities' facilities, this Fellowship project outlines a method for conducting a detailed site-specific Climate Risk Assessment (Figure 1). The approach consists of five steps to quantify risk and provide recommendations for preliminary resilience actions, which will aid in decision-making regarding investments in resilience measures (Figure 2). The approach combines market leading flood risk data, analytics and insurance loss models with climate consulting and analytics expertise. Key stakeholders listed in the above section were actively engaged throughout the entire process.

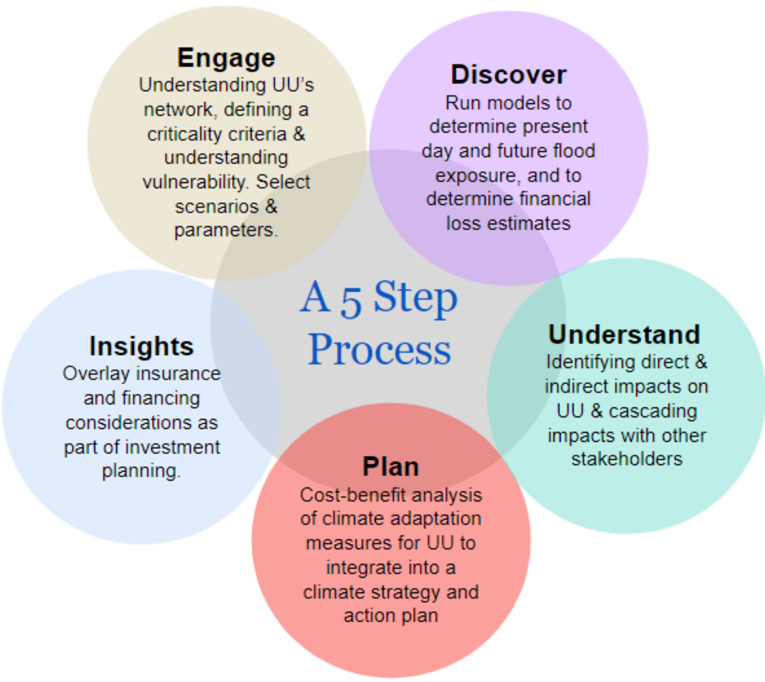


Figure 1: The methodology for the Climate Risk Assessment

Figure 2: The five steps in the methodological approach for the enhanced physical Climate Risk Assessment

Key steps in the process

Rationale and Outputs

Step 1: Engage and Scope

(1) Map the service provider's portfolio of facilities & network, including location, function, facility value, connectivity, network criticality etc.
(2) Conduct a Vulnerability Assessment to develop an understanding of the vulnerabilities of the service provider's various facility types, e.g. electrical equipment, presence of staff on-site etc.
(3) Apply a Criticality Criteria review of the most important facilities to the local authority's water supply.

To narrow down the list of facilities, a criticality criterion is used to identify the top five most important facilities for the local authority's water supply. These top five facilities are taken forwards to Step 2.

Step 2: Discover Hazard Exposure

(1) Select the relevant scenarios and parameters.
(2) Obtain present day and future flood exposure to better understand the spatial distribution of flood risk at a site-level.
(3) Obtain present day and future financial loss estimates to better understand the financial losses at a site-level.

Simulate industry-class models to illustrate the estimated and evolving costs of flooding for the top five most important facilities under various scenarios. The facility that contributes the most to the total loss and is of significant interest to other major infrastructure providers will be selected for Step 3.

Step 3: Understand the Risk

(1) Identifying direct and indirect impacts of flooding on the most important facility to the local authority's water supply under all scenarios.
(2) Engage in dialogue with critical major infrastructure providers to identify cascading impacts.
(3) Develop a risk matrix to align with the service provider's risk appetite.
(4) Score the likelihood and consequence for each risk for each facility.

Engage with United Utilities to identify several types of risks, including operational, environmental, legal, and reputational risks during flood events. Also, engage with other critical infrastructure including electricity providers, transport providers etc. to identify cascading impacts from this facility.

Step 4: Plan

(1) Compile a list of adaptation measures across various categories.
(2) Cost-benefit analysis and identify potential adaptive characteristics.
(3) Identify a short-list of adaptation measures relevant to the service provider.

It is important to consider a variety of adaptation actions and assess the associated costs, risks, and potential co-benefits of each action to identify the most effective actions and avoid the risk of maladaptation. Recommendations around sequencing the options into a realistic timeline will aid the service provider in building an investment case.

Step 5: Insights

(1) Insights on financing considerations for investment planning.
(2) Recommendations and key insights for the service provider.

Consider viewpoints from different stakeholders, including an insurer, an investor, and a risk management consultant, to gain insight into how to continue shaping the conversation around resilience-building for United Utilities and for the local authority.

The Methodology Applied: A Climate Risk Assessment for United Utilities

Step 1: Engage & Scope

Key tasks under this first step included:

(1) **Map United Utilities' facility portfolio** of water and wastewater network, including location, function, facility value, connectivity, network criticality etc.

(2) Conduct a **Vulnerability Assessment** to develop an understanding of the vulnerabilities of United Utilities' various facility types, e.g. electrical equipment, presence of staff on-site etc.

(3) Apply a **Criticality Criteria** to identify the most important facilities to Greater Manchester's water supply.

The initial task was to develop a comprehensive understanding of United Utilities' network of facilities across Greater Manchester. United Utilities oversees a portfolio of more than 3,000 facilities throughout Greater Manchester, with a total insured value exceeding £3 billion. Below is a list of the 19 distinct facility types (Figure 3).

In order to select five important facilities for Greater Manchester's water supply from the 3,000-facility portfolio, a two-step process was applied; (a) first, a Criticality Criteria was applied to a list of 19 facility types, and (b) a facility-level Criticality Criteria was applied to identify the top five facilities. The purpose of a Criticality Criteria is to assess the relative importance of facilities / facility types that are included as part of the scope of an assessment.

Facility Types Criticality Assessment

As part of the Criticality Criteria, it was decided that water treatment works were of greater concern than wastewater treatment works. This decision was informed by the UK's Critical National Infrastructure (CNI) List [V], which designates water infrastructure facilities as essential for society to function and, therefore, as more critical than wastewater facilities.

The table below provides further details on the high-level Criticality Criteria applied to the list of 19 facility types, including whether a facility type is deemed critical for the functioning of the water network, and whether the facility type has a degree of vulnerability to flooding (i.e. if it was to be flooded, operations at the facility would be impacted).

The table below details the criteria requirements (High Priority to Low Priority), the facility types (e.g. Booster Pumping Station), the number of facilities under each facility type (#) and whether the facility could be classed as CNI by the UK government.

A **Vulnerability Assessment** was conducted to understand facilities' vulnerability to flooding. United Utilities provided additional insights into considerations such as the operability of a facility if submerged, insured content value[1] as a proxy for flood vulnerability, number of on-site employees, and dependencies on supporting infrastructure.

An Impact Assessment categorised United Utilities' facility types based on the potential impact of facility operations stopping. It considered impact on water supply in Greater Manchester, population served, interdependencies and impact on other infrastructure providers, and facility value.

Note: The five facilities on which the Fellowship project was focused on fell under the water facility-types highlighted in blue below, all of which were then taken forward to the facility-level Criticality Criteria.

Figure 3: Outcomes of the criticality assessment

⬆ High priority: High criticality, AND vulnerable to flooding	➡ Medium priority: Medium criticality, AND vulnerable to flooding	⬇ Low priority: High or low criticality, BUT NOT vulnerable to flooding
Booster Pumping Station (107)	Detention Tank (176)	Borehole Pumping Station (114)
Intake Water Pumping Station (5)	Private Pumping Station (140)	CSO (779)
Service Reservoir (72)	Secondary Dosing (43)	Concession Supply (3)
Sewage Network Facility (574)	Sludge Pumping Station (9)	Network Pumping Station (385)
Site Support (1055)	Sludge Treatment Facility (8)	Raw Water Main Facility (5)
Water Treatment Works (16)		Sea Outfall (2)
Wastewater Treatment Facilities (54)		
Dam and Impounding Reservoir (43)		
Potable Trunk Main Facility (254)		

It was determined that the following facility types are most important for Greater Manchester's water supply: Booster pumping station; intake water pumping station; service reservoir; water treatment works; dam and impounding reservoir; and potable trunk main facility. This brought the total number of facilities under consideration down to 497 facilities. These facilities were then assessed using a facility-level Criticality Criteria to identify the top five that are most crucial for Greater Manchester's water supply.

Facility Level Criticality Assessment

From each of the six facility types, the top ten facilities with the highest total insured values – which is a factor of each facility's content (electrical, instrumental, and mechanical), rather than civil infrastructure – were selected. This approach was based on the assumption that facilities with higher content value are more vulnerable to flooding. This brought the number of facilities under consideration down to 60.

All 60 facilities were then assessed for flood risk exposure using the UK Government's Flood Maps. Discussions were held with United Utilities to identify the strategic importance of each remaining facility for Greater Manchester's water supply. Additional discussions addressed dependencies and interdependencies with Transport for Greater Manchester and Electricity Northwest Limited. Consideration was also given to the total facility value, the number of employees on site (both permanent and temporary), and historical flooding records. This process reduced the facilities under consideration down to the five that were the focus of the Fellowship project.

The top five most critical facilities are listed below, with a combined total facility value of £114.8 million (Figure 4).

[1] *The methodology presented in this report is informed by insurance data and methods and therefore insurance metrics and values were considered.*

Figure 4: The top five most important United Utilities facility to Greater Manchester's water supply

Facility ID	Facility Type	Facility Total Insured Value (TIV)	% Value of Civil	% Value of Content
UUW TW nr 2	Water Treatment Works	£13,900,000	7%	93%
UUW TW nr 85	Water Treatment Works	£26,500,000	52%	48%
UUW TW nr 68	Water Treatment Works	£55,000,000	53%	47%
UUW BP nr 492	Booster Pumping Station	£2,900,000	3%	93%
UUW TW nr 82	Water Treatment Works	£16,500,000	57%	43%

To enhance our understanding of each facility, the Fellowship project team shared a facility-specific questionnaire with United Utilities, the aim of which was aims to gather information about the site's operations, its vulnerabilities to flooding, and the potential impact of flooding on United Utilities and other major infrastructure providers. The questions included were:

- Specify the number of individuals served by the facility to assess its criticality to GMCA.
- State the total number of employees on-site, including both permanent and temporary staff.
- Provide details about any historical flooding incidents at the facility.
- Describe any existing flood protection measures in place, such as basements, floor types, or ground-level machinery.

Step 2:

Discover Hazard Exposure

Key tasks under this step included:

(1) Select the relevant scenarios and parameters.
(2) Obtain present day and future flood exposure to better understand the spatial distribution of flood risk at a site-level.
(3) Obtain present day and future financial loss estimates to better understand the financial losses at a site-level.

Note: Site-specific results cannot be disclosed in this report. United Utilities have been provided with a separate Technical Report with the detailed findings of this Step of the Fellowship project.

To quantify flood risk exposure at a site-level across the five most important facilities for Greater Manchester's water supply, the Fellowship team used market leading flood risk data and analytics, and insurance loss models, combined with climate consulting and analytics expertise to demonstrate the estimated and evolving costs of flooding. The modelling considered facility specific vulnerabilities and existing flood protection measures.

High resolution flood modelling capabilities were provided by JBA Risk Management[2] for fluvial and pluvial flooding for present day and future flood extent, and for both flood depths and geospatial extents across the sites. The resolution of the outputs was modelled at a granular five metre resolution. The return period that was simulated was the 1 in 1,000-year return period. Time horizons consisted of baseline (present day), 2030s (near-term), 2050s (mid-term), and 2080s (long-term). The considered emission scenarios consisted of RCP2.6/SSP1 (Paris Agreement aligned) and RCP8.5/SSP5 ('Business as usual').

Theory: Return period

Flood classifications in the insurance sector traditionally follow return periods. These enable the market to quantify the likelihood with which a certain magnitude of flood will occur.

The return period is a way of expressing the likelihood of an event happening in any given year, for example:

- A 1 in 50-year flood means that there is a 2% chance of flood occurring in any given year.
- A 1 in 500-year flood has a statistical likelihood of 0.2% of occurring in any given year.

It is important to remember that these are statistical likelihoods and not absolute terms. Therefore the 1 in 500-year event could happen next year, and then again, the year after; for example, southeast Texas experienced 1 in 500-year floods for five consecutive years starting in 2015. Likewise, we could experience a 10-year period without any significant events at all. These numbers sound very exact, and in theory can be if enough resources, expertise and data are used to determine them; however, they can also serve as an easy framework to assess risk. This is why it is often better to think in terms of likelihood or probability, and the typical scale of the flooding events associated with each return period. The table below sets out the relationship between return period and chance of occurrence.

[2] *JBA Risk Management provide market-leading, high-resolution global flood maps providing flood extents and depths for multiple return periods across a range of scenarios. Data derived from JBA's Great Britain (GB), Northern Ireland (NI) and Republic of Ireland (ROI) 5m Flood Map.*

Return periods and probability

Return period (years)	Probability	Chance of occurrence
10	0.1	10%
25	0.04	4%
50	0.02	2%
100	0.01	1%
500	0.002	0.2%
1000	0.001	0.1%

Effective return periods were provided utilising JBA's change factors[3] to provide an indication of future hazard intensity under various climate scenarios and time horizons (Figure 5). Results show that for a present day 1 in 1,000-year return period, river flow is projected to have a higher probability of occurring in any given year. Here are examples of JBA's change factors for one of the assets assessed through this Fellowship:

- For fluvial flooding, today's 1 in 1,000-year return period becomes 1 in 509-year event by 2080 (RCP8.5)
- For pluvial flooding, today's 1 in 1,000-year return period becomes 1 in 472-year event by 2080 (RCP8.5)

Figure 5: Effective time periods

Fixed Effective RP (1 in 1,000 year)	RCP 4.5			RCP 8.5		
	2030	2050	2080	2030	2050	2080
River	997	848	611	969	781	509
Surface Water	883	802	700	811	679	472

Insurance industry standard loss models were used to quantify the financial impact of flooding on the five United Utilities facilities most important for Greater Manchester's water supply. Loss Estimates[4] were used to identify which facilities drive the loss for United Utilities, as well as to provide a focus for the remainder of the methodology.

The Average Annual Loss (AAL)[5], a proxy for calculating the cost of insurance premium, was calculated and shown to increase by 23% by 2100 relative to present day across the five facilities. Existing flood protection measures were shown to mitigate the AAL across the top five facilities by ~10%.

A loss probability curve for the extreme tail risk (Aggregate Exceedance Probability[6]) was calculated for a range of return periods, including a 1 in 200-year (as a proxy for Storm Desmond), a 1 in 100-year (a return period United Utilities are expected to be defended against), and 1 in 25-year (a return period United Utilities are expected to be defended against).

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[3] JBA's Climate Change Flood Maps are created using change factors, created from climate change data, to create effective return periods alongside DTM, hydraulically modelled flood maps with known return periods. The hydraulically modelled flood maps are then adjusted to the effective return periods.
[4] Projections of future claim costs based on historical data and previous losses experienced by an insurance entity.
[5] The AAL is the mean value of a loss exceedance probability (EP) distribution. It is the expected loss per year, averaged over many years.
[6] The Aggregate Exceedence Probability (AEP) curve represents the annual likelihood that the aggregation losses from multiple events will exceed a specified loss threshold.

Step 3: Understand the Risk

Key tasks under this step included:

(1) Identifying direct and indirect impacts of flooding on the most important facility to Greater Manchester's water supply under all scenarios.

(2) Engage in dialogue with critical major infrastructure providers to identify cascading impacts.

(3) Develop a risk matrix to align with United Utilities' risk appetite.

(4) Score the likelihood and consequence for each risk for each facility.

Climate Risk Narratives and Scoring

Through engagement workshops with United Utilities, the Fellowship project team identified a range of direct, indirect, and cascading risks resulting from flooding of United Utilities' facilities (Figure 6). The relevant risk categories are outlined below. Climate Risk Narratives capture the transmission of risk from the hazard to the impact on United Utilities and are useful engagement tools intended to describe climate related risks which are meaningful for communities and decision makers in a specific context.

Figure 6: Relevant risk categories

- Operational and performance failures leading to the disruptions to the supply of water.
- Risk of chemicals contaminating the watercourse leading to biodiversity risks and risk of breaching environmental regulation.
- Damaged infrastructure and on-site flooding limiting movement on-site and leading to health and safety risks on-site staff.
- Disruption to critical supply chain leading to disruption to operations due to insufficient supplies (e.g. chemicals).
- Risk of contaminated water entering the system leading to public health and safety concerns.
- Disruption to site workforce due to difficulty / inability to conduct usual tasks leading to the disruptions to the supply of water.
- Disruption to site access road and transport routes impacting staff's ability to reach the site.
- Damage and disruption to key dependencies (e.g. energy, telecommunications) leading to disruptions to water supply.

A risk matrix was designed to align with United Utilities' risk appetite across the relevant risk categories to capture different consequences because of flooding. These include:

- The financial impact on United Utilities (£)
- Operational impact measured through total downtime (e.g. hours or weeks)
- The number of customers impacted (number, thousands)
- The reputational impact on United Utilities (e.g. potential for adverse publicity)
- The extent environmental damage (e.g. slight damage / easy clean-up)
- Severity of injury arising from health and safety breach (e.g. minor injury or death)

Insight provided by other key infrastructure providers, such as Transport for Greater Manchester and Electricity North West, deepened the Fellowship team's understanding of the potential cascading risks on their facilities resulting from the flooding of United Utilities' facilities. Figure 7 below shows an example of one of the risk matrix that the Fellowship team used to score each of the risk narratives considered with United Utilities (Risk Matrix = Likelihood Score x Consequence Score, with results ranging from 'Very Low' to 'Very High').

Figure 7: An example of a risk matrix used with United Utilities to score each risk narrative

Likelihood	Very high	Medium	High	High	Very High	Very High
	High	Medium	Medium	High	High	Very High
	Medium	Low	Medium	Medium	High	High
	Low	Very Low	Low	Medium	Medium	High
	Very low	Very Low	Very Low	Low	Medium	Medium
		Insignificant	Minor	Moderate	Major	Catastrophic
		Consequence				

Step 4: Plan

Key tasks under this first step included:

(1) Compile a list of adaptation measures across various categories.

(2) Cost-benefit analysis and identify potential adaptive characteristics.

(3) Identify a short-list relevant to United Utilities.

Cost-benefit of Adaptation Solutions

Adaptation options are strategies and measures that are available and appropriate to prepare for and adjust to the current and projected impacts of climate change. Adaptation options range from actions that build adaptive capacity (e.g. knowledge creation and sharing of information) or establish management systems and supportive mechanisms (e.g. insurance mechanisms), to adaptation actions implemented on the ground (e.g. physical or ecosystem-based measures).

A comprehensive list of adaptation options was provided to United Utilities for future reference. The list included adaptation options across various categories including: (i) Governance and Institutional, (ii) Economic and Finance, (iii) Physical and Technological, (iv) Nature-based Solutions and Ecosystem based Approaches, and (v) Knowledge and Behavioural Change.

Each adaptation option has been given a cost-complexity score to provide United Utilities with an understanding of the cost and time it would take to implement the option, and the perceived level of complexity associated with implementing the measure. Literature and desktop-research was used to identify the relevant information for the range of adaptation options.

Co-benefits of each action were identified for United Utilities to tie into its wider environmental, social and governance (ESG) strategy. Co-benefits of adaptation include the positive effects on biodiversity, air quality, water management, greenhouse gas emission reductions, and health and well-being from the implementation of an adaptation measure.

To guide United Utilities' consideration of the most suitable adaptation options, the Fellowship project team applied the UK Climate Impacts Programme's (UKCIP) Identifying Adaptation Options criteria for assessing the impacts of adaptation interventions. The approach classifies the impacts of interventions in four categories related to the potential for 'regretting' the implementation of the intervention. These are 'no regrets'; 'low regrets'; 'win-win'; or 'flexible/adaptive'. The approach uses the UKCIP 'Identifying Adaptation Options' criteria:

- **No regrets (NR):** Response option is worthwhile whatever the extent of future climate change.
- **Low regrets (LR):** Although benefits may be uncertain, relative costs are low, and relative benefits are large.
- **Win-win (WW):** Response option has other social, environmental, or economic benefits, possibly including climate change mitigation, as well as adaptation.
- **Flexible or Adaptive Management (FA):** This option reduces the risk of over-adaptation and allows new information to inform responses as it becomes available.

Adaptation options with a risk of maladaptation were flagged for United Utilities' awareness. Maladaptation is any changes in natural or human systems that inadvertently increase vulnerability to climate change (e.g., an adaptation that fails to reduce vulnerability but rather increases it). To provide United Utilities with a view of the adaptation measures at work, the Fellowship project team highlighted examples of effective implementation in other cities.

Finally, discussions were had with United Utilities to refine the list of adaptation options under consideration, both generally and in relation to each of the five focus facilities.

The table below provides examples of adaptation options the team presented to United Utilities (Figure 8).

Figure 8: Examples of adaptation options the Fellowship team presented to United Utilities

Adaptation Key Type Measures	Examples relevant to United Utilities
A: Governance and Institutional	• Draft emergency response plans and crisis management procedures for staff to follow during all extreme weather events • Mainstream adaptation into policies
B: Economic and Finance	• Create / revise insurance schemes and products • Revise the level of contingency funds for emergencies
C: Physical and Technological	• Install pumps to allow faster evacuation of flood water from basements • Move location of electrical controls, cables and appliances to a higher-than-normal level • Replace impervious pavement that has deteriorated or impeded storm water management with permeable pavement (in the form of porous asphalt, rubberized asphalt, pervious concrete or brick/block pavers) to filter pollutants, recharge aquifers and reduce storm water volume entering the storm drain system
D: Nature Based Solutions and Ecosystem based Approaches	• Riverbank reforestation • Wetland restoration • Managed Retreat
E: Knowledge and Behavioural change	• Engage with peers across the industry to share experiences on how to reduce risks • Develop alternative route plans for critical transport routes • Improve monitoring of extreme weather events

Step 5: Insights

Key tasks under this step included:

(1) Understanding **cascading risks** at a city-level.

(2) Assessing financing options for investment **planning.**

(3) **Recommendations and key insights** for United Utilities.

A system-level view of flood impacts

When flooding strikes a city, it initiates a complex chain of events that profoundly impacts economic resilience. The initial impact is seen in widespread infrastructure failures, where floodwaters disable critical systems such as power stations, transport networks, water treatment facilities, and connectivity hubs. These failures are interconnected, creating a domino effect where the breakdown of one system triggers the collapse of others, amplifying the overall disruption across the city. Figure 9 illustrates the cascading effects of flood risk on various stakeholder groups at the city level, highlighting the connections between their impacts.

While the Fellowship project initially focused on considering the impact of flooding on United Utilities' facilities – and as a result the provision of water to communities and businesses in Greater Manchester – it quickly became apparent that this analysis also needed to include views from other stakeholders as well as impacts beyond United Utilities' individual facilities. An important missing voice was from the private sector – in particular businesses and corporates in Greater Manchester who are likely to be both impacted by flood disruptions, and are well placed to contribute to how they are managed or mitigated.

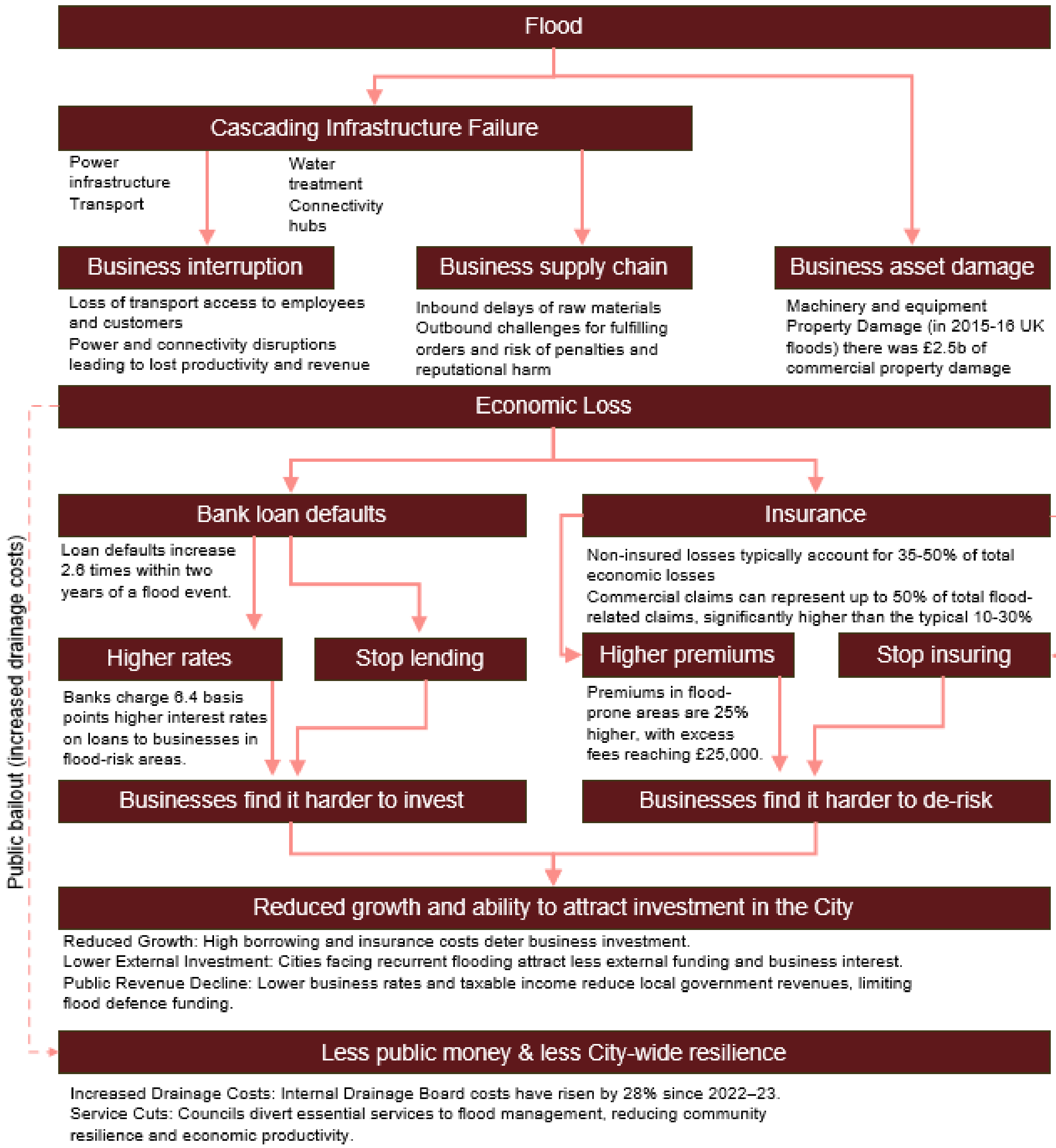
There are three critical ways that businesses bear the brunt of the cascading effects of flooding: (i) business interruption; (ii) supply chain disruptions and; (iii) property and facility damage. Business interruption occurs when power outages, transport disruptions, and restricted access prevent employees and customers from reaching premises. Additionally, connectivity disruptions and power cuts cause lost productivity and revenue. Supply chain disruptions exacerbate the challenges, with delayed deliveries of raw materials and outbound logistical failures resulting in contractual penalties, reputational harm, and further economic strain. Meanwhile, direct property and facility damage—such as to machinery, equipment, and facilities—adds substantial costs. For instance, estimates suggests that there was £1.6-2.3 billion in economic loss due to Storms Desmond and Eva, with insured losses of £900 million - £1.2 billion.[X]

The economic ripples of these impacts are far-reaching. Businesses facing operational losses and recovery costs often struggle to repay loans, with research showing that defaults increase by 2.6 times within two years of a flood event.[XI] This, in turn, prompts banks to raise interest rates; research shows rises of 6.4 basis points for businesses in flood-prone areas or, in some cases, banks stopped lending altogether.[XII] Similarly, insurers respond with significant adjustments. Non-insured losses typically account for 35-50% of total economic damages[XIII], while commercial claims can represent up to half of flood-related claims.[XIV] This leads to higher premiums - 25% above average in flood-prone areas - and excess fees reaching £25,000[XV], making it more difficult for businesses to manage risks and recover.

The systemic risks extend to financial institutions and insurers. The growing number of defaults and escalating claims can destabilise financial operations, weakening the overall capacity of institutions to support economic recovery. These cascading effects undermine a city's ability to attract investment and businesses, eroding its long-term economic resilience.

To address these challenges, cities must adopt holistic strategies that integrate both traditional and nature-based solutions (NbS). NbS, such as wetland restoration, river rewilding, and urban green spaces, absorb floodwaters, reduce surface water runoff, and protect infrastructure. Beyond flood mitigation, these solutions enhance biodiversity, improve carbon sequestration, and often prove more cost-effective than grey infrastructure.

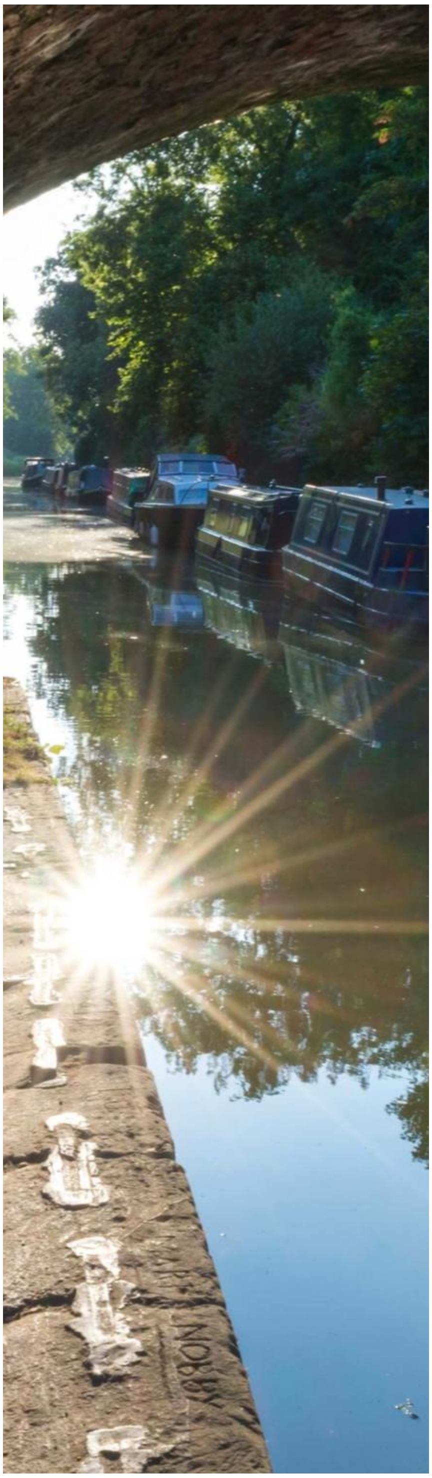
Figure 9: A diagram illustrating the cascading effects of flood risk on various stakeholder groups at the city level, highlighting the connections between their impacts.



Key Insights for United Utilities

This report outlines a methodology for United Utilities that is intended deepen decision makers' understanding of United Utilities' flood risk profiles – both in the present and under future scenarios – at a facility level across five facilities that are important for water supply in Greater Manchester.

Three key insights and considerations for United Utilities from the Fellowship project are:



1 **There are insurance and other benefits to United Utilities applying this methodology across its portfolio of facilities**: The methodology developed through the Fellowship project demonstrates the heterogeneous nature of flood risk. Applying the analysis across United Utilities' entire portfolio would provide a quantitative flood profile of each facility, enabling United Utilities to discuss and structure a bespoke coverage programme with its insurance partners (e.g., grouping facilities by risk-profile, excluding or reducing coverage for facilities with lower risk profiles and securing higher coverage for facilities with higher risk profiles). Additionally, by evaluating flood risk at the facility level, United Utilities can attain a more comprehensive understanding of its risk profile and make better informed decisions regarding where to focus adaptation investments.

2 **The need for a quantitative cost-benefit analysis**. This report (i) provides United Utilities with an analysis of the cost of inaction, (ii) highlights gaps in the current understanding of climate risk, and (iii) proposes a qualitative cost-benefit analysis of potential adaptation solutions. The next step in building on this work is to quantitatively model the proposed adaptation solutions. This will help United Utilities determine which solutions to implement. United Utilities could also explore discussing high priority adaptation measures it intends to implement with its insurer to demonstrate the value of these adaptations and how they can support a stronger insurance programme.

3 **The importance of collaborative adaptation**. The report demonstrates the interdependencies across key infrastructure providers in the North West. For adaptation to be effective it is essential United Utilities understands how other major infrastructure providers depend on United Utilities' water supply and facilities, and vice versa, and each provider's adaptation strategies. A focused approach to data gathering and the establishment of a collaborative group with other major infrastructure providers would be the most effective mechanism to facilitate ongoing dialogue regarding these matters.

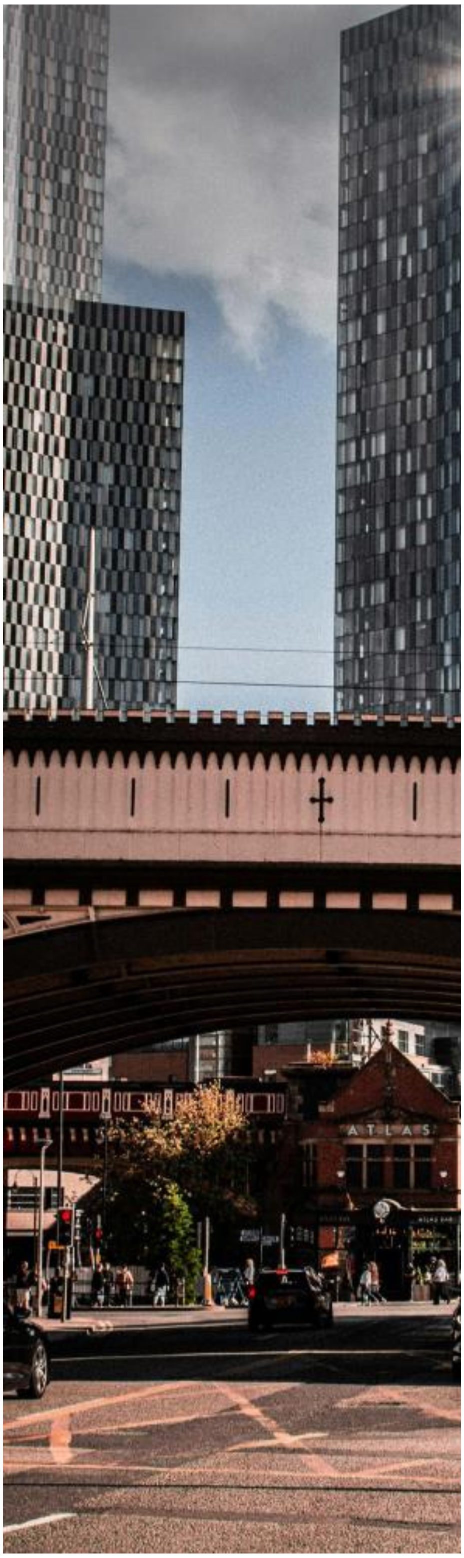
Key Insights for Government

1 The Fellowship project emphasised the importance of knowledge sharing and strategic engagement between private and public sectors stakeholders to enhance understanding of climate risks and their impacts in the UK and strengthen collaboration to address these risks.

2 The Fellowship project highlights a lack of corporate involvement in general conversations around climate risks to major infrastructure providers and recommends the inclusion of the corporate perspectives to ensure effective decision-making regarding water demands and future development.

3 Accurately quantifying the impacts of climate risks is challenging. As a result, there is a credible risk that stakeholders across the public and private sector in the UK are underestimating the true impact of climate risks in the UK. Multi-stakeholder discussions facilitated through the Fellowship project highlighted the vital need to improve knowledge sharing and collaboration and establish mechanisms for data sharing among agencies and infrastructure providers to facilitate a better understanding of cascading risks and their impacts.

Value of the Fellowship to GMCA



1. Public-Private Collaboration: Through the Fellowship project, GMCA leveraged its convening power to enable stakeholders with varying perspectives and interests to (i) build a shared understanding of flood risk and (ii) understand that flood risk is simultaneously owned by multiple stakeholders - including the regional authority and other public bodies, businesses, utility and infrastructure providers and property owners themselves. As a result, effectively managing flood risk requires collaboration and a deep understanding of flood risk related interdependencies. Critically, engagement across a diverse range of stakeholders highlighted flood risk related interdependencies.

2. Critical need to strengthen understanding of cascading risks: There are critical gaps in the understanding of cascading climate risks across other major infrastructure providers in Greater Manchester. As a result, there is a risk that the true extent of climate change impacts in the city-region is underestimated and not accurately captured. This Fellowship project found that GMCA would benefit from a more granular understanding of the severity of climate risks in the city-region.

3. Demystifying insurance: The project has demonstrated the strategic value of insurance sector data, tools and expertise for informing urban resilience building strategies.

4. Enhanced understanding of climate change impacts to water supply in Greater Manchester: Climate modelling conducted during the project accelerated GMCA's understanding of how communities and facilities will be adversely impacted by flood related disruptions to water supply in the city-region. It provided a view of the costs of United Utilities failing to adapt water infrastructure to future flood risks, providing a robust evidence base for increased climate action and investment.

5. Development of a blueprint for other utility companies or major infrastructure providers to follow to better understand their climate risk, and a methodology that can be applied to other hazards beyond flooding.

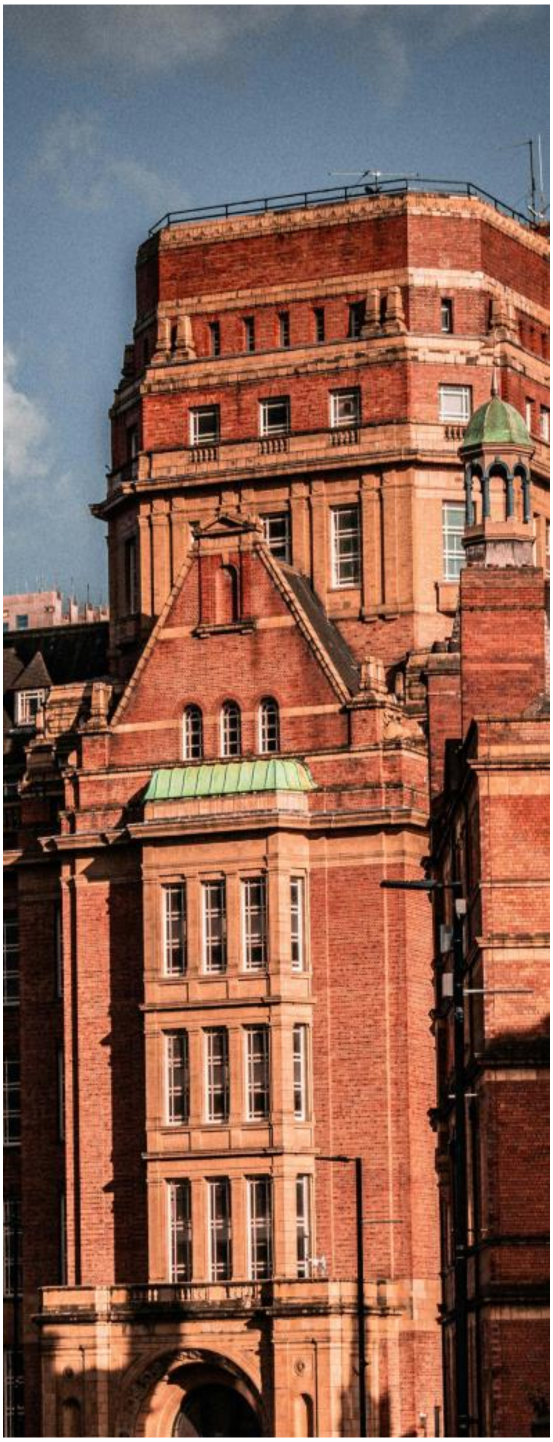
6. Global Urban Resilience: The methodology is beneficial for other cities helping to support improved global urban resilience.

Conclusion

1 The Fellowship project – and this report – will support the Greater Manchester Combined Authority to understand the existing status of climate risks in Greater Manchester and key gaps in relation to United Utilities' readiness to address flood risks, as well as how other infrastructure providers understand interdependencies and cascading risks. Understanding these gaps can enable GMCA to start building a fuller picture of the costs and impacts of climate change in the city-region.

2 For United Utilities, the report offers guidance on enhancements that could be applied to their 2024 Climate Risk Assessment to evaluate climate risks and resilience measures. It provides their Climate Adaptation Manager and wider resilience teams with the necessary tools to work effectively with risk managers and insurance representatives, promoting better discussions with insurers and informed decisions on investing in resilience.

3 This report provides the Cabinet Office and the Ministry of Housing, Communities and Local Government with an understanding of a combined insurance and wider private sector methodology for assessing the costs of climate risk, which can inform local and national level resilience investment strategies. Key methodologies and insights developed through the Fellowship project are well-placed to be amplified in the UK Government Resilience Framework or other resilience frameworks for municipalities in the UK. The Fellowship project demonstrated that cabinet and other national government stakeholders have an important role to play in areas including: (i) setting enabling policies and standards that support closer collaboration among infrastructure providers that share risk – who at present face barriers in sharing data and collaborating closely to implement the solutions to manage risks (ii) amplifying resilience best practices across communities in the UK; and (iii) convening senior private and public sector decision makers to align incentives for resilience building.



Appendices

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Glossary

Adaptation	An adjustment in natural or human systems in response to actual or expected climatic stimuli (variability extremes and changes) or their effects which moderates harm or exploits beneficial opportunities.
Average Annual Loss (AAL)	AKA Pure Premium, Expected loss, Burn Cost. The long-term average that RMS predict will be lost on an annual basis.
Aggregate Exceedance Probability (AEP)	The Aggregate Exceedance Probability (AEP) curve represents the annual likelihood that the aggregation losses from multiple events will exceed a specified loss threshold.
Climate Scenario	Climate Scenarios, or climate change scenarios, relate to standardised, hypothetical future states of the world defined by the extent to which climate change mitigation (i.e. the reduction of CO_2 emissions) is adopted.
Exceedance Probability	The exceedance probability is the reciprocal of the return period specified as a number of years.
Gross Loss	Is the total loss to each site from a peril, minus the policy financials i.e. deductible, limit, attachment and before reinsurance is applied. The gross loss can be displayed at location, account and portfolio level.
Occurrence Exceedance Probability (OEP)	The Occurrence Exceedance Probability (OEP) curve represents the annual likelihood that losses will exceed a specified loss threshold, from a single event.
Peril or Hazard	Refers to climate, weather or geological events or circumstances in the natural environment that may cause loss, damage or interrupt the normal functioning of business.
Return Period	The Return Period refers to the probability of a given event occurring within the next year and often used interchangeably with exceedance probability. For example, a 1/100-year return period has a 1% chance of occurring in any given year.
Tail Value at Risk (TVaR)	AKA Tail Conditional Expectation (TCE). The expected loss given that a loss at least as large as the return period loss or value at risk has occurred. i.e. if a loss above a specific return period does happen, this is how large it is likely to be (on average).
Value at Risk (VaR)	AKA Return Period Loss or RPL. The loss corresponding to a point on a loss curve that describes the likelihood of exceeding a loss threshold from the single largest event (OEP) or an aggregation of events (AEP).

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