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ARUP

THE CITY WATER RESILIENCE APPROACH

CITY CHARACTERISATION REPORT

GREATER MANCHESTER

ACKNOWLEDGEMENTS

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MARK FLETCHER
Arup Global Water Leader
April 2019

The CWRA project team includes Pilar Avello (SIWI), George Beane (Arup), Kieran Birtill (Arup), James Bristow (Arup), Alexa Bruce (Arup / The Resilience Shift), Louise Ellis (Arup / The Resilience Shift), Sophie Fisher (Arup), Mark Fletcher (Arup), Caroline Karmann (Arup), Richard Gine (SIWI), Alejandro Jiménez (SIWI), James Leten (SIWI), Kathryn Pharr (Venturi Innovation), Oriana Romano (OECD), Iñigo Ruiz-Apilánez (Arup / The Resilience Shift), Panchali Saikia (SIWI), Martin Shouler (Arup) and Paul Simkins (Arup).

CONTENTS

EXECUTIVE SUMMARY

The City Water Resilience Approach (CWRA) helps cities plan and implement actions to build resilient urban water systems. A critical first step in this process is understanding the factors that contribute to, or detract from local water resilience.

This report details research undertaken in Greater Manchester with the aim of

1. Defining the city water basin including natural basin(s), the urban water system and its governance structure, and the interdependencies with other systems; and
2. Identifying the factors contributing to the resilience of the city water system, and those increasing its vulnerability.

This research was undertaken through a detailed review of grey and academic literature and consultation with key Greater Manchester water stakeholders.

Five key functions were identified for the water resilience of Greater Manchester and these functions form the structure of the report.

1. Basic service provision - To provide water, wastewater and other essential services.
2. Risk management - To protect people, assets and systems from water-related hazards.
3. Environment - To support local environment and biodiversity.
4. Economic (Asset) - To facilitate the movement of people and goods and provision of other commercial value.
5. Socio-cultural (assets) – Reflecting and adding to local culture, history and heritage.

CHARACTERISING RESILIENCE

Basic service provision: Two thirds of water from United Utilities—Greater Manchester's water supplier—comes from upland surface water reservoirs in the Lake District, the Pennines and North Wales. The Haweswater Reservoir and aqueduct provides principle supply to the city region and in 2018 United Utilities undertook a significant multi-stakeholder resilience consultation on a Haweswater maintenance strategy. The current United Utilities business plan submitted to OFWAT for approval includes major investment to refurbish the aqueduct tunnels over the periods 2020-2025 and 2025-2030. This is viewed as the best value solution in order to build longer-term water supply resilience locally.

Other potable water actions include a 55km bi-directional large diameter trunk main linking the Greater Manchester water supply with Liverpool and north Wales. This was completed in 2012, building diversity into local supply.

Haweswater also operates within an Integrated Resource Zone where other supply sources (e.g. Ullswater and Windermere) provide support by offsetting abstraction and reducing the demand on this reservoir.

Reducing leakage is a priority and while United Utilities have halved daily leakage since 1992, work is ongoing to further reduce the 457 million litres currently lost per day. This is crucial, with the region coming close to implementing drought emergency measures in the summer of 2018.

The role of independent regulators such as OFWAT and the DWI are crucial for the affordability and quality of water supply to Greater Manchester residents, as is the presence of inclusive consultation processes.

Risk management: The 2015 Boxing Day floods highlighted the interdependencies between water and other urban systems, with that event resulting in £11.5million in infrastructure damage and 31,200 properties left without power.

There is a strong relationship between flooding and urban planning and development control. Strategic plans such as the Greater Manchester Spatial Framework include detailed flood risk analysis. The importance of building on brownfield land and maintaining green space for drainage has been stressed in various strategic documents.

The value of Sustainable Urban Drainage Systems (SUDs) and Green Infrastructure (GI) came through very strongly across the literature as a key approach to Greater Manchester Flood Risk Management, with stakeholder consultations also recognising this, and encouraging further investment.

Environmental Protection: Agriculture and rural land management is behind most reasons for water bodies not achieving good ecological status regionally. This is followed by water industry, urban and transport, domestic, and industry as key categories.

The Environment Agency (EA) conducts testing throughout the Northwest and over 1000 measures have been identified to address water quality failures against the EU Water Framework Directive. The EA is working with GMCA councils to restore local rivers to their natural state, including the renaturalisation of the River Medlock, as well as developing priority habitat in Greater Manchester districts, and protecting sites of scientific interest.

Beyond flood prevention, SUDS and other green infrastructure hold significant environmental value. In Manchester, it is estimated that the physical activity supported by parks may be responsible for cost savings (avoided health care spending) of between £6-10 million per year.

Economic and Socio-cultural asset: In addition to indirect economic savings discussed above, the Greater Manchester water system as a direct economic asset is exemplified by the strategic use of waterfront settings to create sites of business and leisure. This includes 'The Quays' at Salford and Trafford and development of the River Roch in Rochdale. Elsewhere, there are plans to expand the volume of shipping along the Manchester Ship Canal.

Lastly, the Greater Manchester Water System holds great cultural significance. This includes the rich history of the Manchester Ship Canal, 'The Quays' and Roman heritage of the Castlefield area.

Considering all these aspects, appropriate balance can only be achieved through water resilient urban planning with integrated and inclusive multi-stakeholder collaboration, where each of these water resilience functions is acknowledged, promoted and protected.

Beyond coordinated and integrated planning, other key themes and qualities which emerged across water resilience functions included:

- The robust management of critical assets and services.
- Inclusive community organisation and engagement.
- Robust monitoring and mapping of physical and natural water assets for effective management.
- Robust independent water regulation.
- Flexible, integrated natural exposure interventions.

Within this last theme, SUDs and related activity have the potential to create benefits across all five water functions.

1

BACKGROUND

The City Water Resilience Approach (CWRA) helps cities plan and implement actions to build resilient urban water systems. A critical first step in this process is understanding the factors that contribute to or detract from local water resilience.

MediaCityUK Footbridge, Manchester

POPULATION AND ECONOMY

Greater Manchester is a city region in the North West of England encompassing the ten metropolitan boroughs of Bolton, Bury, Oldham, Rochdale, Stockport, Tameside, Trafford, Wigan, and the cities of Manchester and Salford. As of 2018, Greater Manchester has a population of approximately 2.8 million residents, making it the third most populated metropolitan area in the UK.

The region has a rich industrial history, home to a thriving textiles industry throughout the industrial revolution of the 18th and 19th centuries. This industry was supported first by a network of small canal systems constructed in the 1730s to connect Manchester to the Port of Liverpool, and later by the Manchester Ship Canal which enabled the opening of the Port of Manchester at the end of the 19th century (Hobsbawm, 2009). As a result of industrial opportunity, the city population grew significantly in the 1840s.

As with many other major industrial regions, in the 20th century Greater Manchester experienced a significant decline in manufacturing, losing out to cheaper labour, transport and tariffs offered in developing global markets. Nowadays, the region can consider research, manufacturing and advanced engineering, life sciences, energy and environment, financial, professional and business services, real estate, education, creative, digital and technology as key sectors (Invest in Manchester, 2018) and sources of employment. The docks at the Port of Manchester have now been re-developed as 'The Quays', a site of major business, arts and residential offering.

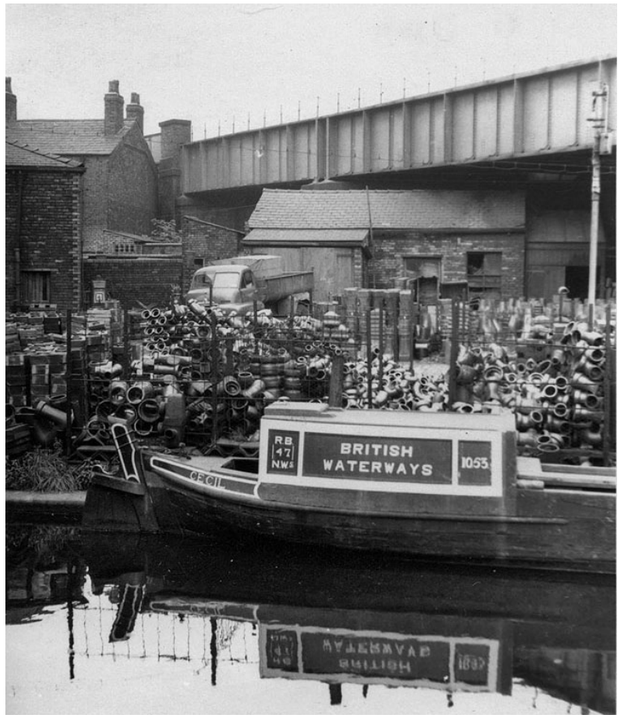
Greater Manchester's unemployment rate of 4.5% is higher than the national rate of 4.2% (nomis, 2018).

Looking at the wider region, around 80% of the Northwest is rural and primarily used for agricultural purposes (CaBA, 2015). Consequently, the relationship between the North West river basin and farming is significant, with water bodies acting as a source of irrigation but also a recipient of agricultural pollution.

Water-related hazards pose a serious risk to the region's economy. According to EA data, there are more than 15,000 properties within the Greater Manchester area that are at medium to high risk of flooding (EA, 2018). Additional economic assets that sit either within, or in close proximity to flood risk zones include road infrastructure, local power stations and city metro stations.

GOVERNANCE

Greater Manchester is unique in the UK as the first (and currently only) combined authority. Greater Manchester Combined Authority (GMCA) consists of ten locally elected council leaders and a mayor of the city region. While the boroughs of Greater Manchester have a strong history of collaborative working, devolution (completed in 2017) has provided GMCA with greater local autonomy with respect to transport, planning, housing, criminal justice, social care and infrastructure investment, as well as greater funding for business development and control over European Union (EU) funding (GMCA, 2018).



Maintenance boats in Dukinfield, Greater Manchester c. 1950 (credit: Jack Lane collection)

Manchester ship canal, looking towards the Lowry Bridge (credit: David Dixon)

2

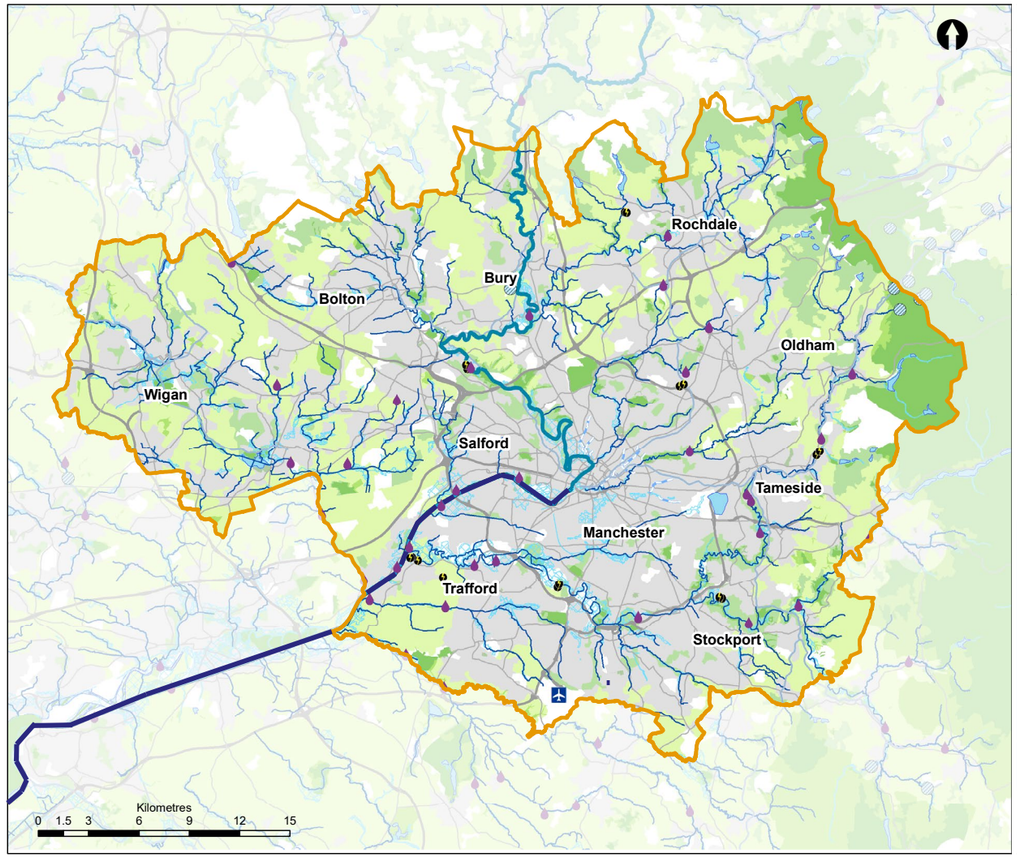
RESEARCH METHODOLOGY

The remote engagement with Greater Manchester consisted of three stages: a desktop study of Greater Manchester water resilience literature, surveys and stakeholder interviews.

STAGE 1	The desktop study aimed at understanding the city's water basin, identifying shocks and stresses that impact the city's water system, and assessing system vulnerabilities.
STAGE 2	Survey and Key Informant Interviews – Wave 2 cities used a stakeholder organogram created during the desk study to identify key stakeholders within their cities. Stakeholders identified in this process were asked to complete a survey or semi-structured interview to share their insights about the local urban water system. While Greater Manchester responses provided a relatively small sample size (10 surveys and 2 in-depth interviews) those who engaged provided unique insights and perspectives into the local water system and all represent organisations who can be considered key stakeholders, as represented in the Greater Manchester Stakeholder Organogram (Section 5). Insights are supported by analysis of desktop literature.
STAGE 3	The desktop phase of this research and identification of key local stakeholders was supported by the knowledge and experience of project colleagues from the Environment Agency and GMCA, who were engaged and participated throughout the duration of the Wave 2 process.
	Engagement with 'Wave 1' cities included a two week field mission, where workshops, focus groups and interviews were conducted. *Engagement with 'Wave 2' cities included remote support to city partners where surveys and interviews were conducted.*

3

UNDERSTANDING GREATER MANCHESTER'S WATER SYSTEM



Waste Water Treatment Plant
Power Stations
Manchester International Airport
Manchester Shipping Canal
Canals
Main Rivers
Underground Rivers
A Road
Motorway
River Irwell
Lakes
Marsh and Wetlands
Flood Risk Areas
Urban Land
Agriculture
Green Spaces
Greater Manchester Area Boundary

Water basin for Greater Manchester

Greater Manchester is home to four river catchments, the Irwell, Upper Mersey, Lower Mersey and Douglas. Thirteen rivers flow through it, including the Irwell, Mersey, and the Tame. The Greater Manchester catchment contains dozens of additional reservoirs including Holingworth Lake in Rochdale. Reservoirs perform various functions including flood mitigation, leisure assets and the provision of water to local canals.

The wider North West basin district covers approximately 13,200 km2 (EA, 2018), more than 10% of the total surface area of England. It stretches from Cumbria in the north to Cheshire and parts of Staffordshire in the south.

BASIC SERVICE PROVISION

Two thirds of water from Greater Manchester supplier United Utilities comes from upland surface water reservoirs in the Lake District, the Pennines and North Wales, a quarter comes from rivers and smaller amount from boreholes (United Utilities 2017). The Irwell, Mersey, and the Tame all rise in the Pennines. There is a network of Wastewater treatment plants across Greater Manchester, (including major works at Davyhulme) where water is treated before discharge into the regions rivers and canals.

RISK MANAGEMENT

The city region has an extensive drainage system, consisting of sewage pipelines, pumping stations and pressurized pipelines. At the perimeter of the Greater Manchester boundary there is significant greenspace and agricultural land providing good drainage. Within the city region much of the land is highly densified, dispersed by strategic blue and green space.

Beyond this, significant hard flood protection measures include two storage basins along the Irwell and reservoirs throughout the city region. Nevertheless, there are significant flood risk areas within each of the ten boroughs and several parts of Greater Manchester are either Zone 2 (1% – 0.1%) or Zone 3 (>1%) flood zones.

ENVIRONMENT

The river, canal and surface water network of Greater Manchester generally achieves moderate Water Framework Directive Ecological status. The urbanised area of Greater Manchester is surrounded by Sites of Specific Scientific Interest to the north and east.

ECONOMIC AND SOCIO-CULTURAL ASSETS

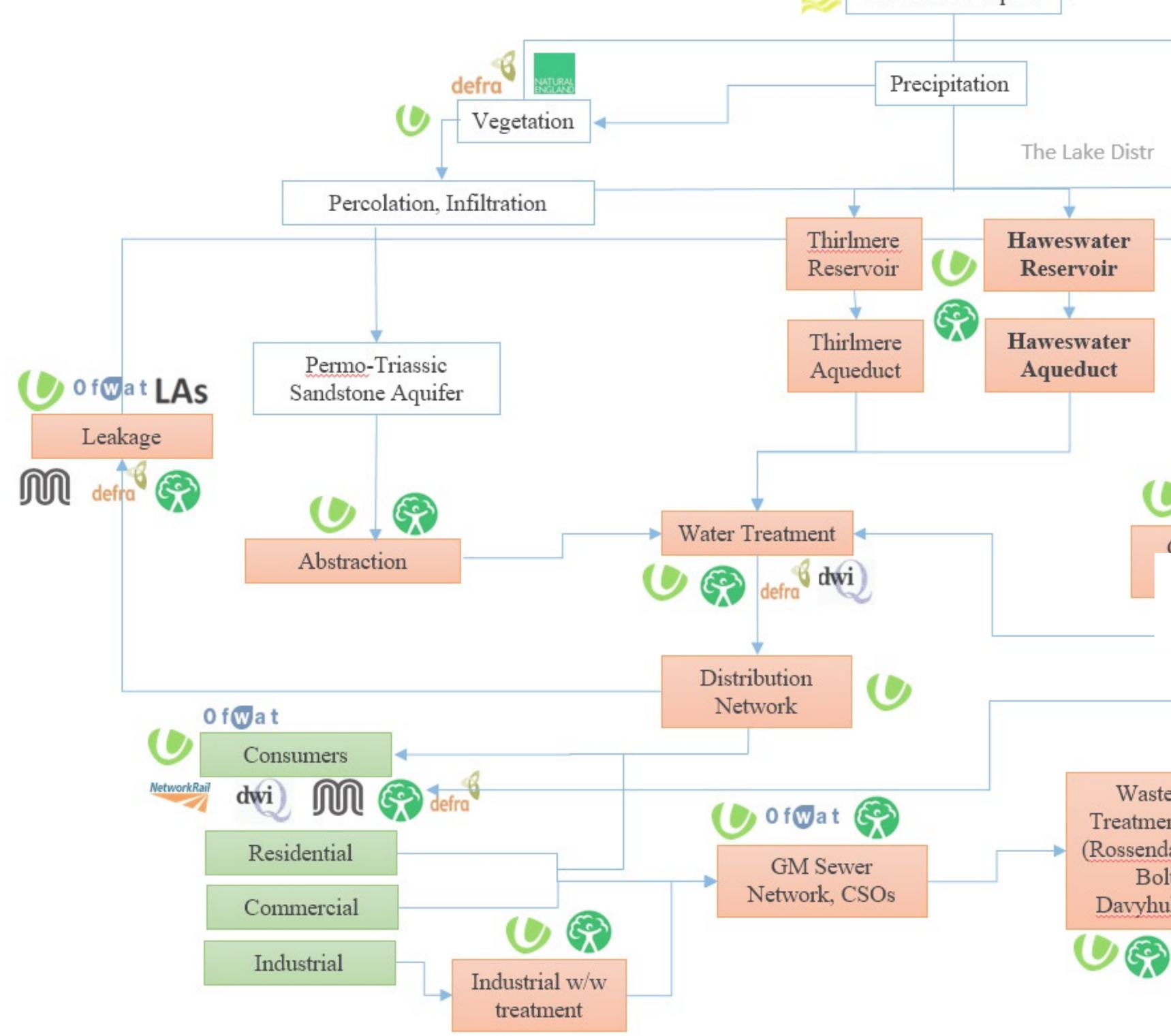
The Greater Manchester region has many canals and branches including the Manchester Ship Canal which stretches from the Mersey Estuary and past the docks at 'The Quays', in Salford and Trafford. (GM Prepared , 2015). Several economic assets within Greater Manchester sit either within, or in close proximity to flood risk zones, including road infrastructure, local power stations and city metro stations.

Metro, Manchester, Credit: Atherton

4

ENGAGEMENT WITH KEY STAKEHOLDERS

The following section describes the Great Manchester water system and key decision-making stakeholders.



For complete diagram see Annex A

STAKEHOLDER COMMENTARY

BASIC SERVICE PROVISIONS

United Utilities is primarily responsible for the provision of potable water and the provision of wastewater management in Greater Manchester and the North West. The water supply comes largely from the Haweswater Reservoir and Thirlmere located in Cumbria. United Utilities have a resilience scheme in their current price review as part of their next spending round, balancing public water charges with infrastructure investments focused on resilience (GMCA, 2018). United Utilities resilience activity is discussed in greater detail in section 5.

The Environment Agency is responsible for regulating water quality and resources.

Before reaching consumers, Drinking Water Inspectorate (DWI) provides independent reassurance that the water supplies are safe and drinking water quality is acceptable to consumers. The Office of Water Services (Ofwat) is responsible for economic regulation of water supply and wastewater. The Department for Environment, Food and Rural Affairs (Defra) sets the overarching policy framework for the water industry.

RISK MANAGEMENT

The Environment Agency (EA) is responsible for the operational management of flood risk from Greater Manchester Rivers and reservoirs. The EA also implement schemes around flood defence and other aspects of water resilience. Funding for these schemes depends on national funding and political decisions. Defra set national policy as well as funding the EA.

United Utilities is responsible for the GM sewer network and therefore the prevention of sewer flooding.

At a planning level, the decisions made by GMCA and the 10 Councils of Greater Manchester affect the permeability and drainage of the city region. Local councils are also Lead Local Flood Authorities with the lead responsibility in managing local flood risks. This includes local flood strategy, localised flood works, asset register management, technical input on surface water drainage to GMCA, and investigating and responding to local flood incidents.

ENVIRONMENT

The EA is responsible for managing water pollution incidents, enforcement actions and maintaining and improving water bodies. Diffuse pollution from agriculture is a primary reason for rivers within the North West Basin not achieving Good Ecological Status.

Defra is responsible for safeguarding the natural environment where they work alongside EA who regulates the use of pesticides near water sources.

The National Farmers' Union is a key organisation through which to maintain dialogue with the farming community.

Pollution, from wastewater and from towns, cities and transport or other key factors is linked directly to urban areas. In this respect the decisions made by GMCA, Local Authorities and Transport for Greater Manchester all influence local water quality.

United Utilities has a key role in the management of wastewater and also monitoring and inspection of installations such as plumbing systems.

ECONOMIC AND SOCIO-CULTURAL

Water transport forms a rich part of Greater Manchester's history with the Manchester Ship Canal a strategic connection to the Irish Sea and beyond. Currently, Peel Holdings privately owns the canal which still ships thousands of containers a year. The waterfront provides a key economic asset to councils within Greater Manchester. For example, 'The Quays' is a critical part of Greater Manchester's economic and cultural attractions. The planning undertaken by GMCA and local councils has a significant influence on the role of water not just as a basic service but as a socio-cultural and economic asset. This includes the strategic provision of green and blue infrastructure versus other planning demands and priorities.

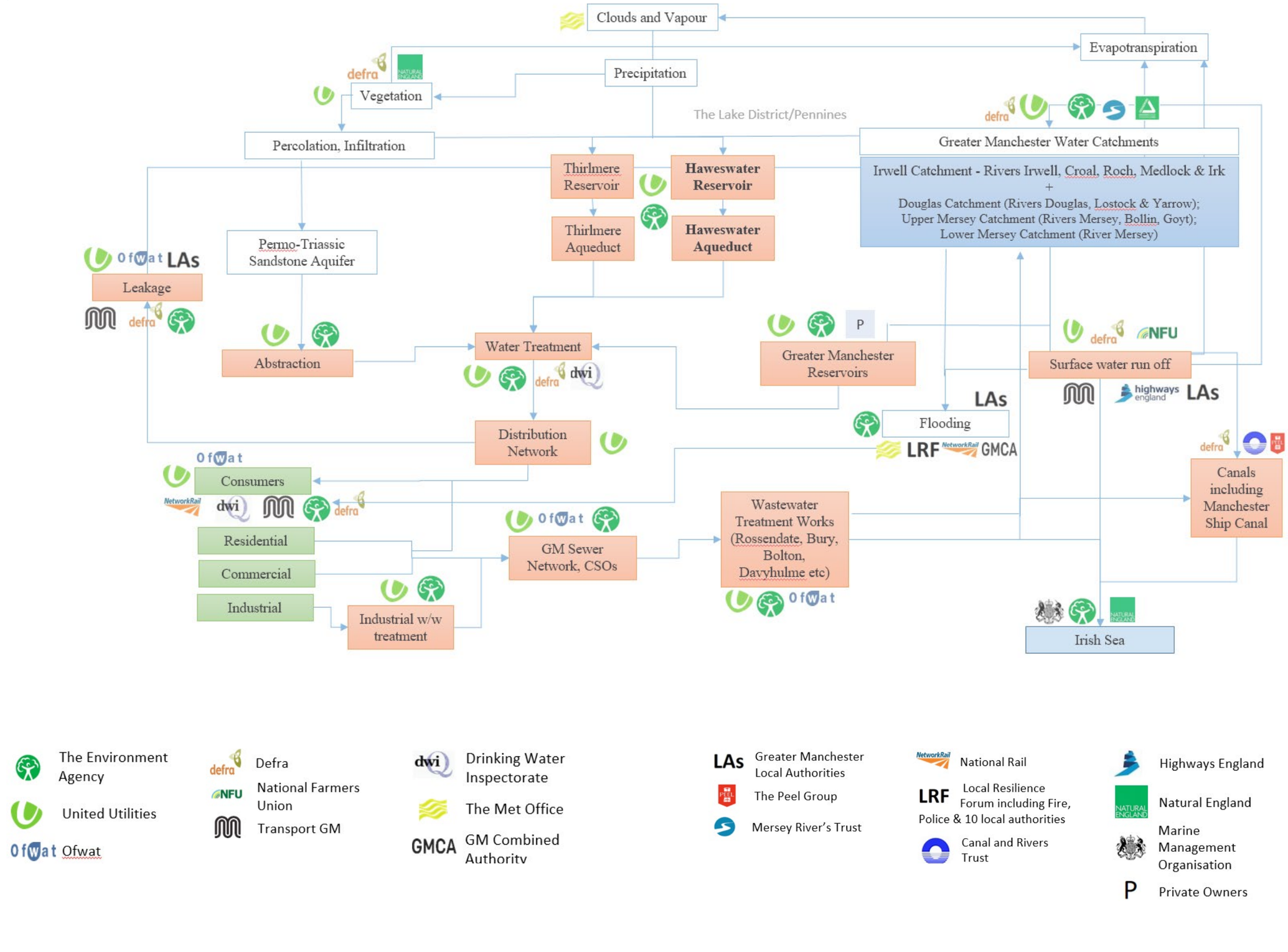
Greater Manchester's water system benefits from strong local engagement facilitated through multi-stakeholder river catchment partnerships, which include local authorities, The Environment Agency, United Utilities, universities and a range of charities such as Groundworks who are active throughout the region.

BOARDS

Greater Manchester has a number of multi-stakeholder boards which support the coordinated and integrated management of various aspects of the city region's water resilience. These include the Greater Manchester Flood and Water Management Board which includes the Environment Agency, United Utilities and GMCA leadership representatives tasked with ensuring that flooding risk management is aligned with infrastructure, investment and regeneration planning decisions (Manchester City Council, 2012).

The Infrastructure Advisory Group is another mechanism offering strategic support and direction. Again, this board includes United Utilities and the Environment Agency.

WATER CYCLE GOVERNANCE GREATER MANCHESTER



KEY ACTORS PER WATER FUNCTION

Function	Key Actors per Water Function								Boards
Basic Service Provision	United Utilities	Environment Agency	Ofwat	Drinking Water Inspectorate					GM Infrastructure Advisory Group
Flood Risk	Environment Agency	DHLCG Department for Homes, Communities and Local Government	GMCA Greater Manchester Combined Authority	10 LAs Lead Local Flood Authorities	LRF Local Resilience Forum actors including Fire, Police & local authorities	United Utilities	The Met Office	Insurance Companies	GM Flood & Water Mgmt Board GM Flood Risk Officers Group
Environment	Environment Agency	DEFRA	National Farmers Union	THE UK WATER PARTNERSHIP	Mersey River's Trust	Greater Manchester Ecology Unit	Natural England	United Utilities	GM Natural Capital Group; Greater Manchester's Local Nature Partnership
Economic	GMCA Greater Manchester Combined Authority	10 LAs 10 Greater Manchester Local Authorities	Highways England	Network Rail	The Peel Group	Transport for Greater Manchester	Private Developers		GM Local Enterprise Partnership
Socio-cultural	10 LAs 10 Greater Manchester Local Authorities	GMCA Greater Manchester Combined Authority	Environment Agency	The Peel Group	Transport for Greater Manchester	Groundwork	Natural England	Canal & River Trust	Planning and Housing Commission Planning Officers Group (POG)

KEY PROGRAMMES

In addition to the actions of key stakeholders, boards and associated mechanisms discussed in the previous section, Greater Manchester has several key recent or ongoing programmes which directly or indirectly concern water resilience:

Natural Course

A ten year (2015-2025 – subject to funding) EU funded project brings together key Greater Manchester and wider North West region water stakeholders.

This project developed an evidence-based integrated water management framework for the River Irwell catchment in Phase 1 and is now expanding this scope in phases 2 and 3.

The project aims to build local capacity to protect and improve the North West water environment. The project brings together GMCA with United Utilities (UU), Environmental Agency (EA), Rivers Trust (NGOs), and Natural England (environmental regulator). It addresses different aspects of water management with a particular focus on risk management and environmental functions of local water resilience.

AMP 7 / PR19

United Utilities reviews investments over a 5 year Asset Management (AMP) period. AMP7 concerns the period 2020-2025. This is linked to a periodic review of pricing (PR), which sets forthcoming prices and determines how income will be invested with respect to water quality and water resilience. There are public consultations throughout this process.

EU Water Framework Directive (WFD):

The WFD came into force in 2000 to ensure all ground and surface waters achieve 'good' status by 2015 or by extended deadlines of 2021 and 2027. Locally, WFD action is coordinated by four catchment partnerships that cover Greater Manchester. The Mersey Rivers Trust, a local NGO interested in the management of the water environment, is proposing to set up a Greater Manchester-wide steering group to coordinate and increase the level and impact of local project delivery. Literature suggests that the water industry is likely to continue to largely follow EU water quality regulations linked to WFD should the United Kingdom leave the EU in some form (Sparkes, 2016) but transposition into UK law presents both opportunities for decentralisation of water quality standardisation and classification , as well as challenges including loss of EU funding for activity around water quality and water resilience (Medupin, 2018).

RESIN - Climate Resilient Cities and Infrastructures:

RESIN is a EU-funded interdisciplinary, practice-based research project investigating climate resilience in European cities. Through co-creation and knowledge brokerage between cities and researchers, the project develops practical and applicable tools to support cities in designing and implementing climate adaptation

Trinity Bridge, spanning the RIver Irwell (credit: Jez Smith)

strategies for their local contexts. In Greater Manchester, several pieces of collaborative research have been undertaken including baseline assessments of climate change adaptation and resilience policy, assessments of the level of available climate change research and data, and into climate change stakeholders. In Greater Manchester, this project has now reached completion.

Greater Manchester Spatial Framework (GMSF)

Greater Manchester is currently developing a strategic spatial plan to identify opportunities for growth across the region through the appropriate development of land for homes and jobs by 2035. GMSF is being produced collaboratively by all 10 district councils. The 2016 GMSF Draft has eight priorities for water quality including drainage, river restoration, SUDs and development control. The content of the final framework will fundamentally impact the future water resilience of Greater Manchester across all five water resilience functions. Stakeholders are tasked with balancing social, economic and environmental priorities and challenges.

5

CHARACTERISING RESILIENCE

Greater Manchester from above

credit: Doc Searls

CRITICAL INTERDEPENDENCIES

Within Greater Manchester there are many critical interdependencies between water and other urban systems. This is evident when examining both the cascading impacts of water-related shocks and stresses, and when exploring both the realised, and the future potential, impacts of water resilience interventions.

CASCADING IMPACTS

Events that disrupt water service provision affect the day-to-day lives of the residents of Greater Manchester impacting livelihoods, economy and other urban systems. The city region has a range of resilience measures to minimise the likelihood and reduce the impact of any such disruption to potable supply. Such measures are discussed in detail in the following sections.

Flood risk management is a top priority and a continual effort for city authorities. In 100 Resilient Cities' Agenda Setting Workshop for Greater Manchester, (GMCA, 2017) participants were asked to explore the relationship between key shocks and stresses and cascading impacts, creating the below 'problem tree'. 'Flooding' was identified as the origin of a total of 22 interdependency links, considerably more than any other problem.

100 Resilient Cities (100RC) workshop participants felt flooding undermined regional resilience through its impact on Greater Manchester's ability to meet basic needs, ensure continuity of critical services and provide reliable communication and mobility. Flooding was felt to significantly impact the public health and economic prosperity of the region amongst other impacts.

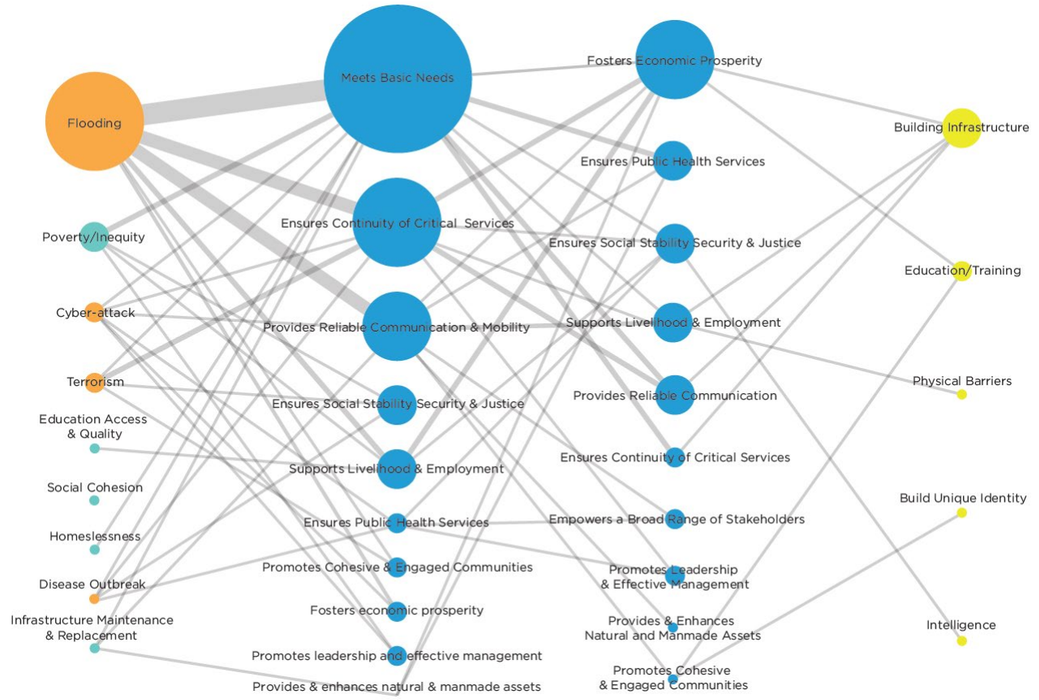
Objective evidence certainly validates those workshop stakeholder concerns. There are notable flood events throughout Greater Manchester's history, including most recently the 2015 Boxing Day (26 December) Floods. This event resulted in:

- Disruption to Metrolink
- £11.5m in infrastructure damage
- Electricity substations damaged
- One Grade II listed building destroyed
- 31,200 properties left without power
- 2,250 properties flooded
- 500 businesses flooded (GMCA, 2017)

The subsequent recovery and future preparedness activity included:

- £11.4m being made available for home flood protection
- £23m+ of capital funding in GM to increase protection to c. 4,000 households
- £22m of Grant-in-Aid funding to improve protection to c. 6,000 households (GMCA, 2017)

Critical interdependecies described by participants during 100 Resilient Cities' Agenda Setting Workshop



INTEGRATED APPROACHES

Examining available literature, within Greater Manchester, many different interventions create benefits to the city region across water resilience functions and to other urban systems beyond water:

- Sustainable Urban Drainage System (SUDS) and Green and Blue Infrastructure programmes demonstrate the potential for water resilience initiatives to positively contribute to all five water functions.

Cascading benefits of such interventions range from transportation access (green corridors) to positive impacts on public health. In Manchester, it is estimated that the physical activity supported by parks may be responsible for cost savings (avoided health care spending) of between £6-10 million per year (Manchester City Council, 2015).

- In April, 2017, in collaboration with Wildfowl and Wetlands Trust / Business In the Community and partners, Arup undertook scenario-based analysis examining the value of strategic retrofit of SuDS in schools across Greater Manchester. This

investigated the time taken to pay back the capital costs through savings made from reduced surface water charges. All scenarios tested demonstrated a positive Net Present Value where the societal benefits were greater than the developmental costs. Benefits were apparent with respect to air quality, wastewater treatment, carbon sequestration, health, education, biodiversity, flood risk reduction, water quality and urban heat island effect (WWT/BITC et al. 2017).

- Water Resilience Research undertaken through programmes such as RESIN, Natural Course and the Blue and Green Infrastructure Strategy are important to fully understand and promote the holistic benefits of water across functions.
- The only way to effectively balance the five functional needs of water is through the effective execution of water resilient urban planning and development control. This appears to be well-acknowledged in the Greater Manchester Spatial Framework, discussed previously.
- Mechanisms for multi-stakeholder collaboration, an integrated catchment based approach within policy, and a supporting governance structure are all key to achieving a holistic approach to water resilience.
- The following sections discuss both challenges and factors of resilience with respect to governance and multi-stakeholder coordination. While Greater Manchester districts have a strong history of partnership working, there has been much change in recent years with devolution and formation of GMCA. While such reform understandably creates technical and administrative challenges it also provides opportunities for even closer partnership working. Other governance challenges discussed by survey participants include the relationship between Greater Manchester and the wider Northwest region of England with respect to certain current and future water resilience issues, notably basic service provision. Participants also stressed the need for greater coordination between key stakeholders engaged in water resilience and those involved in wider urban development, including private developers.

SHOCKS AND STRESSES

The research identified several potential and already realised shocks and stresses which undermine the water resilience of Greater Manchester. These can be articulated as challenges to the key functional aspects of the water system.

FUNCTION: BASIC SERVICE PROVISION

Impact of drought on water supply

In the summer of 2018, United Utilities supplied a record amount of water to pipelines to meet demand during the UK's longest heatwave in 40 years. At that time, Greater Manchester's main supply reservoirs Haweswater and Thirlmere stood at 60% and 46% capacity, respectively. United Utilities came very close to imposing a hosepipe ban, the first since 2012. United Utilities submitted a request to Defra to take additional water from Ullswater, Windermere and Ennerdale Water in the Lake District.

Key informant interviews highlighted a situation of too much water in 2017 and not enough water in 2018, suggesting that response was largely a reactive response, as opposed to proactive planning (GMCA, 2018).

Climate change projections point towards hotter and drier summers across the UK (RESIN, n.d.) and these changes in climatic conditions alongside population growth projections (18% across England and Wales by 2065) (ONS, n.d.) suggest significant future challenges with respect to water supply and demand.

Potable supply pollution

Water treatment and monitoring provides a continual challenge for utility companies and pollution to water supply from external influences poses a genuine risk which requires constant vigilance. In July, 2018 nearly 18000 properties in Bolton were temporarily left without water after United Utilities suffered failures in quality monitoring process. The company has invested significantly in new technology including fail-safe systems at work treatment works to prevent the reoccurrence of such incidents. Independent regulator the Drinking Water Inspectorate fined United Utilities £200,000 (DWI, 2018).

Ageing infrastructure and the need for infrastructure upgrades

Greater Manchester receives most of its water from the distant Haweswater Reservoir. Its aqueduct, a pipeline of almost 100km in length and almost 100 years old, requires maintenance to ensure continued efficient supply (Hidden Manchester Map , n.d.).

United Utilities is currently considering a range of resilience options for the aqueduct in collaboration with GMCA, Ofwat and other key water stakeholders, (GMCA, 2018).

Wastewater challenges include pollution originating from faults in ageing infrastructure; issues around infrastructure meeting evolving environment directive requirements; and ensuring that infrastructure capacity can meet the demands of growing population and industry (Sutton, Kelly, Day, Sergeant, & Bell, 2016). Survey responses anecdotally mentioned the number of combined sewers in Greater Manchester sending clean water through foul drainage networks, as well as the number of wastewater misconnections.

Leakage

Ageing infrastructure, extreme weather events (freeze-thaw) and challenges in monitoring and maintenance mean that leakage places a continual stress on water efficiency. While United Utilities met their Ofwat targets for 2017-18 the utility still lost 133 litres of water en route to households, per property per day—slightly greater than average daily customer usage (CCWater, 2018). Reducing leakage is a continuous challenge with most leaks being underground, making detection and repair difficult.

Domestic usage

Over the past five years, measured water consumption has steadily increased across United Utilities customers from 106 litres in 2013-14 to 122.63 litres for the 2017/18 period (CCWater, 2018). With climate change projections suggesting drier summers within Greater Manchester over the next 100 years, efficient water use will in, all likelihood, become an increasingly important issue for United Utilities, as well as for other Greater Manchester water resilience stakeholders and consumers.

FUNCTION: RISK MANAGEMENT

Reviewed literature, key informant interview and survey data all highlighted flooding as a key shock or stress to the city region. Greater Manchester frequently experiences low intensity flooding which can be considered as a regular stress, but some events come with far greater intensity than usual, over a shorter period of time and can be considered a shock. The 2015 Boxing Day floods discussed below are one recent example. Flooding can erode the resilience of local communities and is especially challenging to those with higher pre-existing levels of vulnerability. Recent research from the University of Manchester points out the relationship between flood risk exposure and levels of economic deprivation within local communities (UoM, 2018).

Fluvial flooding

The previous section (see Critical Interdependencies) highlights the high fluvial (river) flood risk to which Greater Manchester is exposed and how this risk was realised on Boxing Day, 2015. During that flood event 37 of 44 river gauges across Manchester recorded their highest ever levels and properties were affected in eight of the ten Greater Manchester districts (GMCA, 2015).

Current estimates suggest that there are over 52,000 properties in Greater Manchester at risk from fluvial flooding (GMCA, 2017).

Broad climate change projections for the region suggest warmer wetter winters, drier hotter summers and more extreme rainfall (RESIN, n.d.). While at some times of year future rainfall may be less than current levels, other times of year will experience rainfall patterns which will significantly challenge the flow capacity of rivers within Greater Manchester and the wider North West catchment. Environment Agency projections (Environment Agency, 2017) outline a 50% chance of a 30% increase in peak river flow rates within the North West basin for the period 2070 to 2115, but this also includes a more extreme projection of 70% increase in peak flow rate.

Governance

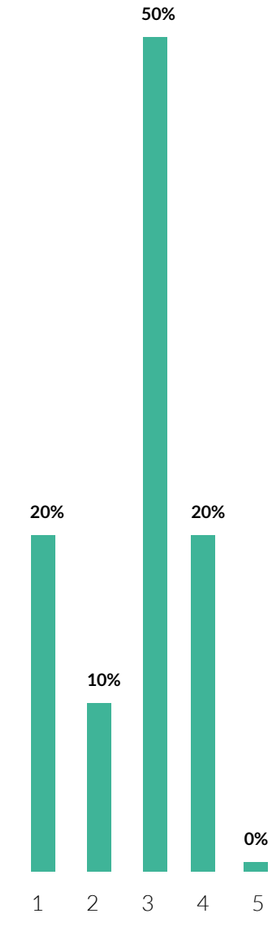
Flooding within Greater Manchester is often influenced by actions upstream. A lack of clear governance structures and coordination on a wider area scale was identified by some stakeholders as a challenge related to flood resilience (UoM, 2018).

Surface water flooding

While 80% of the Northwest is rural, the Greater Manchester area is primarily urban. Larger impermeable spaces naturally present city stakeholders with significant challenges regarding surface water management:

- Over 14.2% of Greater Manchester is susceptible to surface water flooding exceeding 0.1m, and 2.2% is susceptible to surface water flooding of depths over 1m (Ecocities, 2011).
- Costs to residential property from surface water flooding, have expected annual costs of £48 million (Natural Course, 2018).
- 52 listed buildings in Greater Manchester are at high or medium risk of flooding (Environment Agency).
- 35km of Greater Manchester railways and 63km of roads are at high or medium risk of flooding (Environment Agency).
- In addition to fluvial flood damage, the 2015 Boxing Day Floods resulted in 211 homes being damaged by surface water flooding, with a further 25 homes damaged from sewer flooding (GMCA, 2015).
- Large parts of Greater Manchester's Metrolink are located in Environment Agency Surface Water Flood Zone 2 (Ecocities, 2011).

Survey respondents were asked to rate Greater Manchester's water governance from 1 (needs improvement) to 5 (world-leading).



Like fluvial flooding, projected drier summers with periods of intense rainfall means that Greater Manchester can expect to face additional surface water management challenges in coming years.

Urbanisation and loss of green space

The challenges of fluvial and surface water flooding can be compounded by a lack of permeable green space which promotes natural drainage:

- Without careful planning and design, housing growth targets could lead to the release of more protective green infrastructure for development, reducing water catchment ability to store and hold-back water. Over the next 30 years, Greater Manchester is seeking to deliver 227,200 new homes and 5,450,000 m^2 of industrial space. Economic development pressures can sometimes outweigh the pressure of not developing, or incorporating SuDs into design (UoM, 2018). With more than 25,000 new homes set to be within existing flood zones (78% flood zone 2, 22% flood zone 3) (Environment Agency, 2018), authorities face a significant challenge in finding solutions which meet growing demand without increasing environmental and social risk.
- Natural causes of vegetation loss include wildfires with events on Saddleworth Moors during the summer of 2018 creating restoration challenges that will take decades to address.

Wildfires

While drought periods challenge potable water supply, one related problem is a shortage of water to extinguish moorland fires, which are more likely during such climatic conditions (GMCA, 2018).

FUNCTION: ENVIRONMENTAL PROTECTION

The Environment Agency website lists 2744 reasons for North West water bodies not achieving good ecological status Reasons for Not Addressing Good Status (RNAGS).

Pollution from agriculture

Greater Manchester's wider water catchments include significant agricultural land in the Lake District and Pennines.

The top 3 activities connected to agricultural Reasons for Not Adressing Good Status (RFNAGS) were:

- Poor nutrient management
- Livestock
- Poor soil management (EA, 2018)

Quality issues include peat discolouration and pollution into potable supplies from un-restored/ degraded upland peat areas (both peat, and heavy metals).

Pollution from urbanisation

Housing demand in the region poses an environmental risk as well as flood risk. In 2016, 346 Environment Agency RNAGS fell within with the category of urbanisation and transportation. (EA, 2018). Domestic, general public sewer misconnections and discharge were responsible for 106 RNAGS. (EA, 2018).

In the immediate Irwell catchment, diffuse pollution from domestic sources has meant that the majority of water bodies have not met EU Water Framework Directive Standards. (EA, 2018)

Pollution from Industry

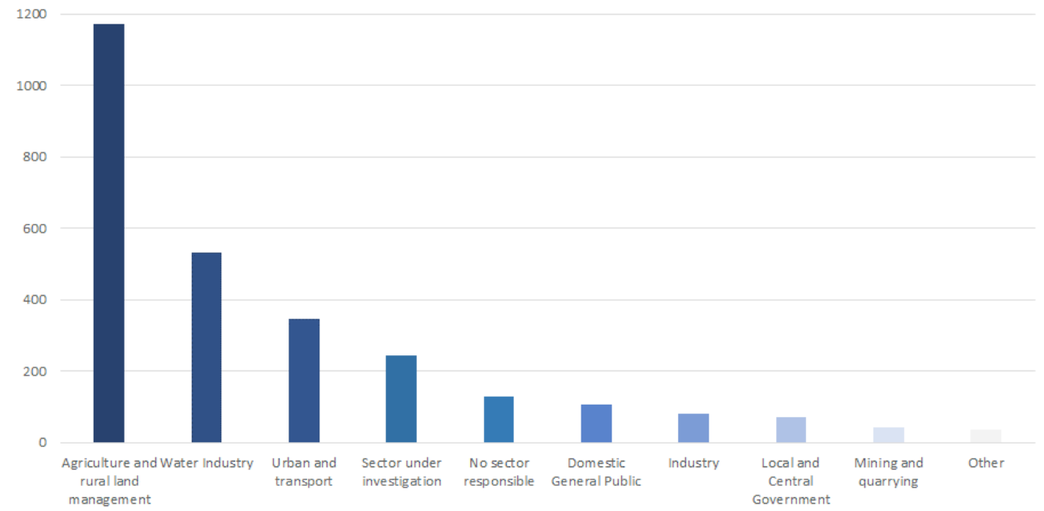
- The Industrial Revolution left a historical legacy of artificial modification which has required significant restoration before biodiversity has started to improve.
- Industry misconnections are responsible for 79 RNAGS largely from discharge and ecological barriers (EA, 2018).
- Mining and quarrying are responsible for a further 41 RNAGS (EA, 2018).

Pollution from utility providers

Beyond agriculture, the category with the most RNAGs associated with it was the water industry with 532. This primarily concerns both continuous and intermittent sewage discharge. In 2014 the Environment Agency prosecuted United Utilities after 21,700 m^3 of sewage polluted the River Medlock, impacting fish stocks and water quality. In this instance, the discharge was caused by a faulty control valve at a wastewater facility.

During 2017 there were a number of serious pollution incidents on the River Irwell. The potential for similar incidents in the future has not disappeared.

Environmental Agency reasons for North West water bodies not achieving good ecological status (2016)



KEY FACTORS OF RESILIENCE

This section presents key water resilience actions and themes which emerged from the desktop literature and primary consultations. These themes are presented with respect to each of the report's five water resilience functions, as well as highlighting cross-cutting actions and themes. This section also identifies the presence of key resilience qualities established by Arup's City Resilience Framework (Arup, 2017) and the role they play in Greater Manchester's water resilience:

The seven "qualities of resilience"

Flexibility	The ability to change, evolve & adapt in response to changing circumstances
Redundancy	Spare capacity purposely within systems to accommodate disruption/demand
Robustness	Well-conceived, constructed, managed
Resourcefulness	People and institutions are able to rapidly find different ways to achieve their goals or meet their needs during a shock or when under stress
Reflectiveness	People and institutions examine and systematically learn from past experiences, and leverage this learning to inform future decision-making
Inclusivity	Participation, engagement and ownership by all in-cluding most vulnerable
Integration	Alignment between stakeholders/plans/interventions - mutually supportive to a common outcome

FUNCTION: BASIC SERVICE PROVISION

Management of critical assets and services

The robust maintenance of critical assets emerged as a key theme for continued provision of water as a basic service.

- In 2018 United Utilities undertook a significant multi-stakeholder resilience consultation on a maintenance strategy for its main reservoir and aqueduct, Haweswater. The current PR19 business plan submitted to OFWAT for approval includes a major water resilience scheme worth over £750million over the 2 asset management periods 2020-2025 and 2025-2030. This includes plans for targeted refurbishment of Haweswater aqueduct, including replacement tunnels. This is viewed as the most likely best value solution in order to build long-term water supply resilience locally (WWT, 2018; United Utilities, 2018a).
- Diversity (flexibility, redundancy) of water supply during times of insecurity or maintenance is another key quality. In 2012, a new 55km bi-directional large diameter trunk main linking the Greater Manchester water supply with Liverpool and north Wales was completed (GMCA, 2018).
- United Utilities is also investing £280million to improve Davyhulme, Oldham and Royton Wastewater Treatment Works (United Utilities, 2018b).
- While supply leakage is still a significant problem United Utilities is working to improve this situation. The company reported having halved leakage, from 945 million litres per day in 1992 to 457 million litres per day in 2015, with 160 inspectors looking for leaks, as well as sniffer dogs, drones and satellites (United Utilities, 2015).

Inclusive engagement and community consultation

Provider United Utilities has several mechanisms to ensure the inclusive provision of key services:

- Community engagement came through strongly within reviewed literature as important for the continued provision of potable water. Examples include increased communication between United Utilities and the general public during times of drought regarding updates and responsible wastewater practices.
- The Manchester and Pennine Resilience Project consultation process was supported by 100 Resilient Cities, YourVoice and independent academics to ensure a rounded and rigorous engagement process.
- United Utilities has financial support schemes for low income communities and a robust mechanism and performance targets for customer complaints (United Utilities, 2017).

Monitoring and mapping

Continued provision of water supply cannot be realised without robust, regular monitoring of the performance of assets and current supply conditions.

- United Utilities monitors reservoir levels and Environment Agency monitors both river levels and water quality. This informs supply conditions and highlights any need to deviate from regular service (e.g. drought conditions) (United Utilities, 2018c; Environment Agency, 2015).
- The DWI inspects and monitors the quality of drinking water supply (DWI, 2017).

Independent regulation

The role of OFWAT and DWI are crucial for the affordability and quality of water supply to Greater Manchester residents.

OFWAT reviews and challenges water company business plans including upcoming PR19. They also set leakage targets to which United Utilities must comply.

Water resilient urban planning

This theme includes the proportionate consideration of potable and wastewater infrastructure capacity in urban planning and development control activity. Capacity considerations need to be in line with historic and projected population growth and local plans for infrastructure and housing development. This should take place as part of integrated and holistic development strategies that involve local authorities, utility providers, The Environment Agency and other interested stakeholders.

- Greater Manchester is currently developing a spatial plan to identify opportunities for growth across the city through the development of a Greater Manchester Spatial Framework (GMSF) with water resilience currently integrated within this planning (GMCA, 2016).

- United Utilities reviews investments in five year Asset Management Periods with a corresponding business plan that considers current supply and projected demand, as well as emergency measures. This provides an opportunity to develop more sustainable and integrated solutions for the next investment period.

- Diversity and redundancy of supply is another key aspect of water resilient planning and operation. Haweswater operates within an Integrated Resource Zone where other supply sources (e.g. Ullswater and Windermere) provide support by offsetting abstraction and reducing the demand on Haweswater and reducing the likelihood of implementation of drought powers. This diversity of supply also includes the West East Link Main, which enables the transfer of additional water from the south of the Integrated Resource Zone towards Manchester (United Utilities, 2018d).

FUNCTION: RISK MANAGEMENT

Risk sensitive urban planning and development control

The relationship between urban development and flooding has been discussed in the shocks and stresses section and robust, integrated water resilient urban planning and development control is crucial for future risk management. It was identified by 50% of survey respondents as key to managing shock/stresses including flooding:

- Strategic plans such as the Greater Manchester Spatial Framework have previously, or are currently undergoing detailed flood risk analysis.
- The importance of building on brownfield and maintaining green space for drainage has been stressed in various documents. The draft Greater Manchester Spatial Framework has brownfield redevelopment and minimisation of Green Belt construction as key features (GMCA, 2016).

Strategic planning for natural flood risk management has been articulated in several pieces of literature including the Manchester Blue and Green Infrastructure Strategy (Manchester City Council, 2015) (RESIN, n.d.) and documentation coming out of the EU-funded RESIN project.

Multi-stakeholder collaboration for integrated approaches

A key theme within the literature concerns the importance of coordinated, multi-stakeholder integrated approaches in order to truly address flood risk. Six out of ten survey respondents identified this as a key 'help' in managing city shocks/stresses including flooding:.

- Various mechanisms and specific programmes to support and generate multi-stakeholder coordination across Greater Manchester were identified across the literature. This includes flood management groups multi-stakeholder programs such as the EU-funded Natural Course project and clear, coordinated arrangements for multi-agency flood response, as evident during the Boxing Day floods, and regular preparedness activities through the local resilience forum (GMCA, 2017).
- While the previous section highlighted challenges of wider area coordination, key informant interview data suggested that collaboration across the ten local authority districts that make up Greater Manchester was generally effective and supported by structures and mechanisms (UoM, 2018). There needs to be a governance structure which facilitates effective horizontal and vertical coordination and collaboration. This is an area in which research in Greater Manchester is currently taking place and will need continued attention should the United Kingdom leave the EU in some from (Ravetz & Connelly, 2018). Coordination is key not just across local and national government but also other stakeholders including consistent flood risk design standards between asset owners (100RC, n.d.).

Monitoring and mapping

Greater Manchester has a range of actors collecting flood data and undertaking monitoring and mapping activities.

- There is a national partnership between the Environment Agency and The Met Office to combine their respective expertise in hydrology and meteorology, monitor flooding and provide forecasting and warning services (Flood Forecasting Centre, 2018).
- Other stakeholders include the University of Manchester and University of Salford, which undertake research and provide data on various aspects of flood risk mitigation and expert knowledge for decision-makers to draw upon (UoM, 2018) (SIRC, n.d.) (UoM,

2017).

Natural exposure reduction interventions

The value of Sustainable Urban Drainage Systems (SuDs) and Green Infrastructure (GI) came through very strongly across the literature as a key approach to Greater Manchester Flood Risk Management. SuDs provide additional drainage and offers a degree of redundancy during times of high rainfall. Such schemes also provide the opportunity to develop inclusive and integrated interventions, providing flexible spaces which have social, economic and public health benefits beyond flood risk management:

- Within Manchester green and blue spaces covers 58% of the city. SuDs assets include five river valleys, three canals, over 160 parks, street trees, woodland, private gardens, and other areas of natural environment (Environment Agency, 2017).
- The region has released a Green and Blue Infrastructure Strategy in 2015.
- United Utilities current Business Plan aims to introduce sustainable drainage schemes to around 1400 homes.
- Non-domestic customers are penalised or rewarded by United Utilities according to the m^2 of hard surfaces connected to the site and mains sewer connections, creating a financial incentive for SUDS (Business in the Community, 2018).
- Stakeholders noted a lack of national regulation regarding green infrastructure use, with developers currently entitled to connect to mains sewer system (UoM, 2018).

River Roch, Rochdale © Gerald England Creative Commons Licence.

FUNCTION: ENVIRONMENTAL PROTECTION

Water resilient urban planning and development control/ multi-stakeholder collaboration for integrated approaches

Like flooding, stakeholders must find a coordinated, multi-stakeholder integrated approach that effectively balances the demands of urban development with environmental sustainability and water quality.

- Sustainability and strategic environmental assessments are key components of the Greater Manchester Spatial Framework (GMCA, 2018).
- The above SuDs related development incentives and penalties are important in order to realise environmental benefits.

Monitoring and mapping

Robust monitoring of the quality of water bodies is essential for regulation.

- The Environment Agency conducts testing throughout the Northwest as well as the rest of the UK. Over 1000 identified measures have been identified to address water quality failures against the EU Water Framework Directive (EA, 2018).

Natural exposure reduction interventions

- The SUDS initiatives discussed in the previous section hold substantial value from an environmental perspective. Across Greater Manchester there are a whole host of initiatives at different scales ranging from large scale integrated projects to individual green-façade retrofitting of buildings.
- The region has a historical legacy of river modification and pollution from industry.

The literature discusses various projects and initiatives involving the Environment Agency and GMCA councils working to restore rivers to their natural state, including the renaturalisation of the River Medlock. Other Environment Agency activity includes:

- 22 SSSIs with aquatic interests, > 74% recovering condition.
- Plans to create 15 ha of priority habitat in Wigan in 2017 / 18.
- In 2016/2017 8ha of priority habitat was created in Salford.

As investment is brought forward the situation will improve and EA “reasons for not achieving good ecological status” (RNAGs) will be tackled.

FUNCTIONS: WATER AS ECONOMIC AND SOCIO-CULTURAL ASSET

Water resilient urban planning / multi-stakeholder collaboration for integrated approaches

ECONOMIC

Greater Manchester water as an economic asset is exemplified by the strategic use of waterfront settings to create sites of business and leisure:

- Tourism contributes £13billion to the North West economy. Access and use of water bodies is a key part of the tourism offer in the North West.
- 'The Quays' development in Salford and Trafford, is a major site of economic growth and a key asset to the region. Along the Quay and Wharf there are key leisure facilities and commercial space including Media City a hub of creative and digital industry.
- There has been recent development of the River Roch to create a tourist and leisure attraction in Rochdale.
- From a transportation perspective, the Manchester Ship Canal has a historic role in the economic development of the region and as discussed elsewhere there are plans to increase volume of shipping along this. Literature talks about the economic opportunities of Port Salford as the UK's first tri-modal port.
- Healthcare cost savings of protecting green and blue space are discussed in the interdependencies section. This is one of many interdepedenscies with significant economic implications, with risk management and flood protection another key theme.

CULTURAL

The water system of Greater Manchester also holds great historic and cultural significance:

- The literature acknowledges the socio-cultural value of water infrastructure in creating sense of place. The Manchester Blue and Green Infrastructure Strategy acknowledges both the 160 parks which serve local communities, and residential development that has taken place within the Irk Valley.
- The Manchester Ship Canal holds a rich history as a Victorian feat of engineering and key part of the economic history of the region.
- 'The Quays' are not only an important economic asset but provide key landmarks and sites of local cultural significance.
- The Castlefield area of Manchester has a rich cultural history as the site of the Roman era fort of Mancunium which gave the city its present day name. The site, chosen by the Romans due to the strategic protection provided by the Rivers Irwell and Medlock was designated as a conservation area in 1980 and became the UK's first Urban Heritage Park in 1982. Today it is a key tourist location for the city (Manchester City Council, 2018)

Greater Manchester strategic plans and frameworks (e.g. Greater Manchester Spatial Framework) acknowledge the need to balance the differing priorities of water as a potable supply, its role in risk management, its importance enviornmentally and its role as a social and cultural asset.

As with all other functional priorities, appropriate balance can only be achieved through water resilient urban planning with integrated and inclusive multi-stakeholder collaboration where each of these functions is acknowledged and protected.

SUMMARY

A range of actions have been identified in this report as contributing to the water resilience of Greater Manchester. Key themes and qualities which emerged across city water functions include:

- The robust management of critical assets and services
- Inclusive engagement community consultation
- Multi-stakeholder collaboration for integrated approaches
- Robust monitoring and mapping of physical and natural water assets for effective management
- Robust, integrated and inclusive planning and development control for water resilience
- Robust independent regulation
- Flexible, integrated natural exposure interventions.

The research suggests that assets such as Sustainable Urban Drainage Systems and processes such as multi-stakeholder collaboration enable the various water resilience demands of Greater Manchester to be managed in an integrated and inclusive fashion - two key water resilience qualities. While stakeholders identified collaborative action as a factor of local water resilience, there was also wide consensus that coordination and cooperation amongst key stakeholders (EA, UU, GMCA, private developers) can still be improved.

Actions which reduce flood risk and improve water quality can have significant cross-cutting social, environment and economic benefits. The above themes, initiatives and qualities must continue to be promoted and implemented across future city planning and development activity.

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