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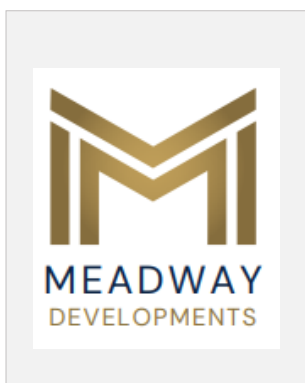
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Commercial St, Manchester - Flood Risk Summary

Final

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Meadway Developments

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This report describes work commissioned by Steven Carnes, on behalf of Meadway Developments by an instruction dated 7th of May 2025. The Client's representative for the contract was Steven Carnes of Meadway Developments. Tom Keene and Guy Dixon of JBA Consulting carried out this work.

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Abbreviations

1D	One Dimensional (modelling)
2D	Two Dimensional (modelling)
AEP	Annual Exceedance Probability
AONB	Area of Outstanding Natural Beauty
CC	Carbon Calculator
CS	Cross Section
CSO	Combined Sewer Overflow
DEFRA	Department of the Environment, Food and Rural Affairs (formerly MAFF)
DS	Downstream
DTM	Digital Terrain Model
EA	Environment Agency
FEH	Flood Estimation Handbook
FEH22	Flood Estimation Handbook 2022
FMfP	Flood Map For Planning
FRM	Flood Risk Management
ID	Identifier
mAOD	metres Above Ordnance Datum
NRFA	National River Flow Archive
QMED	Median Annual Flood (with return period 2 years)
ReFH	Revitalised Flood Hydrograph method
ReFH2	Revitalised Flood Hydrograph 2
SFRA	Strategic Flood Risk Assessment
TUFLOW	Two-dimensional Unsteady FLOW (a hydraulic model)
US	Upstream

1 Introduction

1.1 Overview

JBA Consulting (JBA) was commissioned by Meadway Developments in May 2025 to produce a flood risk summary for a site on Commercial Street, Manchester. Land use on the site is currently an office building with car parks to the south and eastern areas. It is understood that the site is to be redeveloped to provide residential properties which would encompass the entire of the site. As part of this study the existing Environment Agency (EA) flood product data has been reviewed and updated to provide a site-specific assessment of flood risk for the site.

1.2 Location

The site is located in the centre of Manchester City Centre, to the East of Deansgate and covers an area of approximately 800m². The site is accessible from all directions, with vehicular access from Commercial Street or Little Peter Street. At the closest point the River Medlock is located to 30m to the north-west of the site, flowing in a westerly direction where it joins the River Irwell. The River Medlock is designated as 'Main River' by the EA, who carry out maintenance or improvement work to manage flood risk as part of its statutory duties. The site location plan is shown in Figure 1-1.

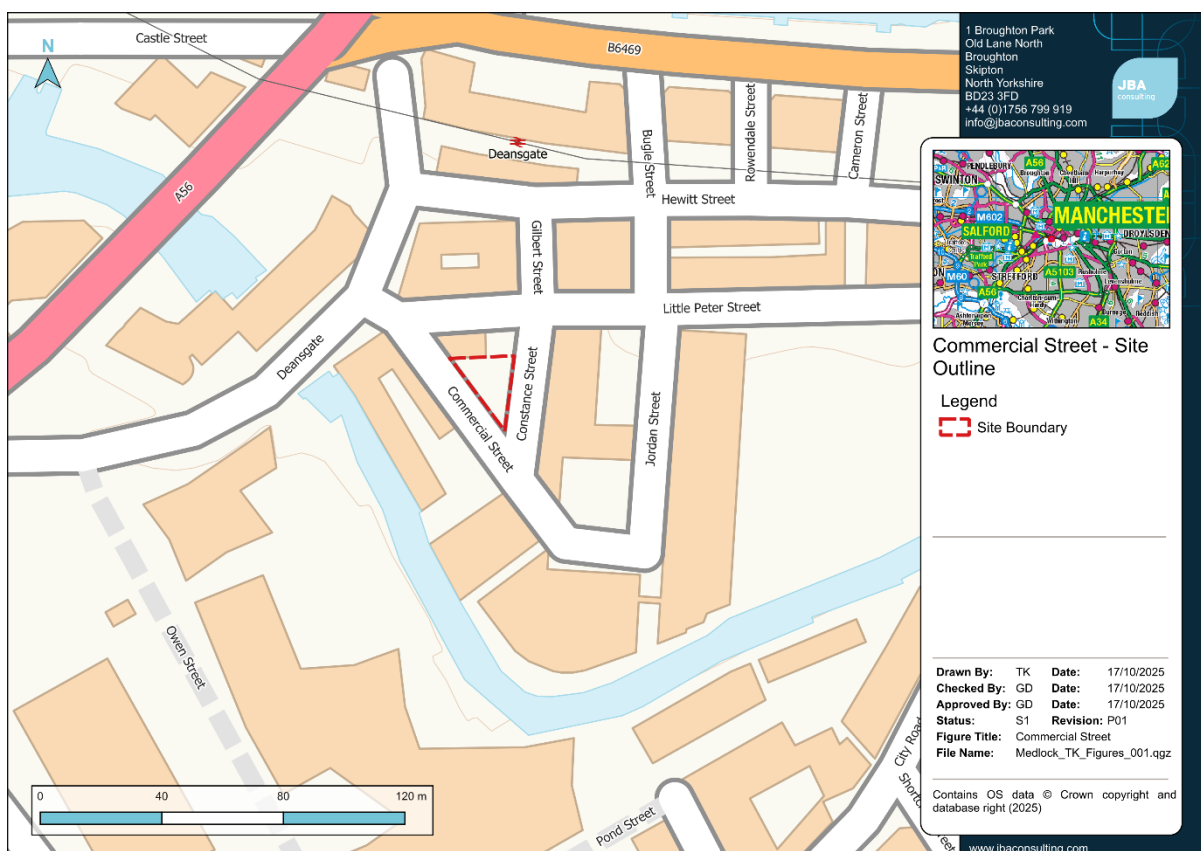


Figure 1-1: The Location of the Commercial Street site.

1.3 Study Aims

Based on a review of available information and discussion of the work completed to date, the following project aims and objectives were agreed with the client:

- Review and update the current EA's River Medlock hydraulic model.
- Undertake local hydrological analysis / checks
- Map present day flood risk and establish potential future risk through climate change scenarios. Propose Flood Zones for the site.
- Assess the sensitivity to flood risk on site by completing analysis on roughness, flow, downstream boundary, building representation and spill representation.
- Produce a summary report of the work undertaken for engagement with the EA.

2 Environment Agency Data

2.1 Light Detecting and Ranging Data (LIDAR)

The latest available version of EA's LIDAR was downloaded from the Department for Environment, Food and Rural Affairs (DEFRA) data portal¹. The LIDAR downloaded and used in this study was flown in 2020 and is available at a 1m resolution. The LIDAR was downloaded in four separate tiles and merged; this merged dataset is visible in Figure 2-1 below.

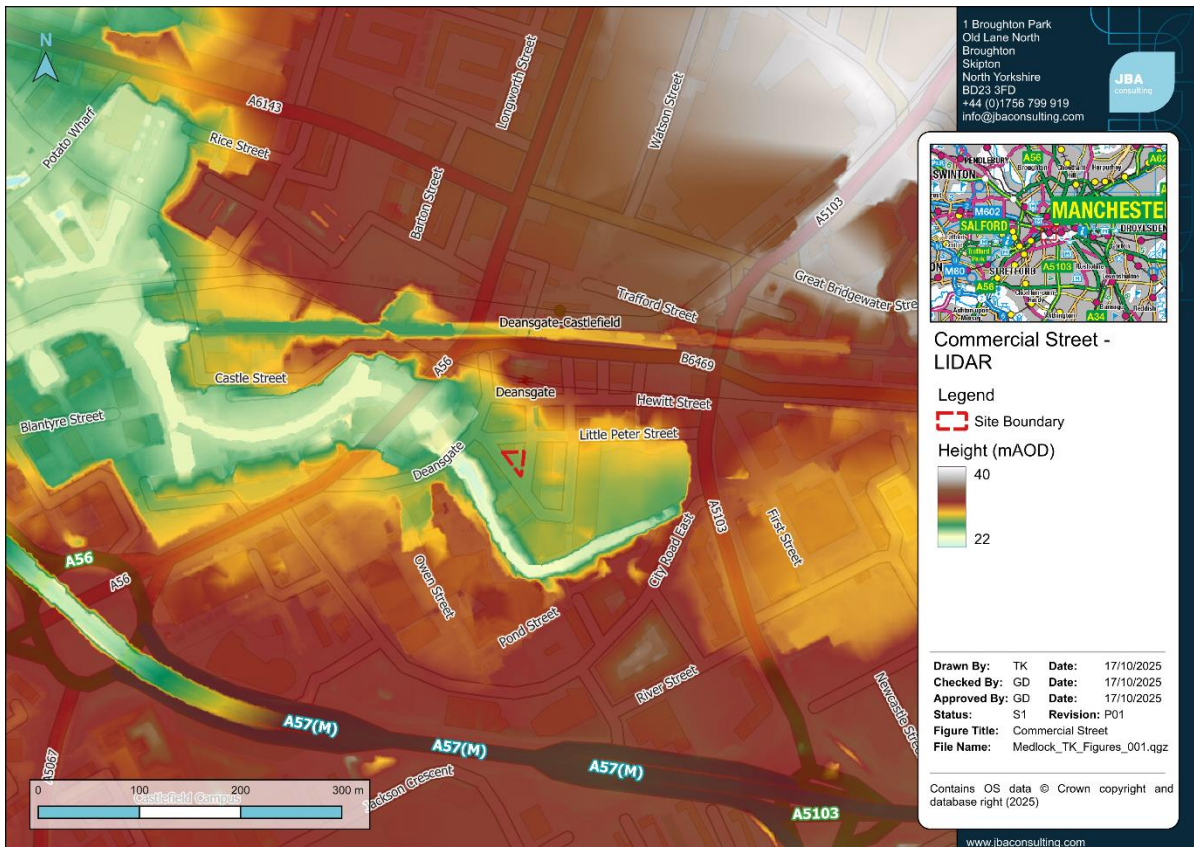


Figure 2-1: EA LIDAR.

2.2 Environment Agency Flood Zone Classification

The EA's Flood Map for Planning (FMfP) indicates that the site lies within Flood Zone 3, as shown in Figure 2-2, which is considered to have a high probability of flooding. A review of the supplied detailed EA Product Data suggests that the site would be located with the 3.3% Annual Exceedance Probability (AEP) flood extent, which is typically used to designate Flood Zone 3b (Functional Floodplain). The current EA FMfP does not include any data relating to defence representation.

¹ [DEFRA Survey Download](#)

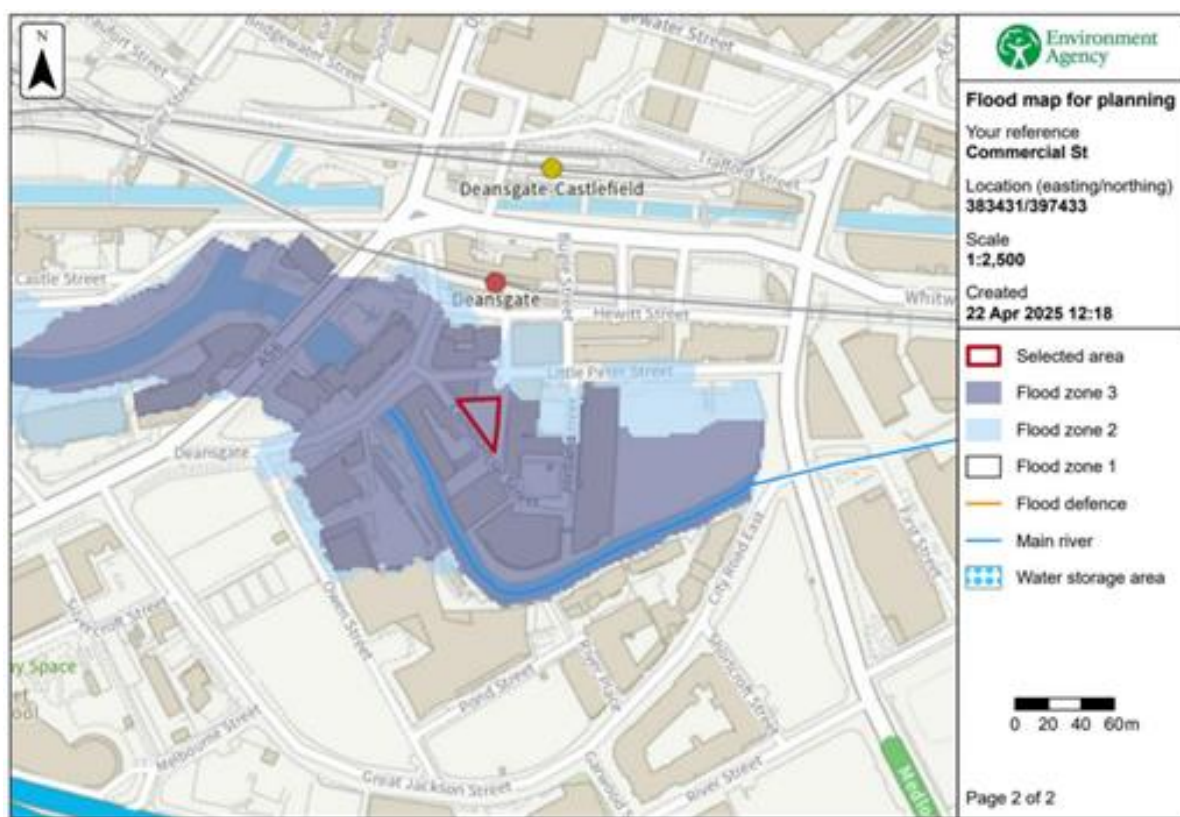


Figure 2-2: The EA's FMfP Outputs for Commercial Street, Manchester.

The risk of flooding from rivers and sea data, which was updated on 28th January 2025 as part of the EA's National Flood Risk Assessment (NaFRA), considers the site to be at high risk of flooding both now and in the climate change scenario. This information can differ from that presented in the EA's Flood Zones maps as the longer-term risk data includes local flood defence infrastructure. JBA Consulting also sought to compare the FMfP outlines to recorded flood outlines or historical flood outlines for this area. At present there is no outlines available for comparison.

2.3 Hydraulic Modelling

The EA's flood modelling dataset suggests that the following studies adjacent to the site have been used to map flood risk:

- Manchester Ship Canal Study 2018
- River Medlock Flood Map Study 2011

The EA's product data response received on 19th December 2024 provided the report, outputs (including MapEdit) and model files for both studies. The information received is also referred to as (Product 5, Product 6 and Product 7).

A high-level overview of both EA historic studies is provided in the sections that follow.

2.3.1 EA 2011 River Medlock Flood Mapping Study 2011

This study created a linked 1D river, 2D floodplain hydraulic model through the study area, primarily using data captured from cross sectional survey collected in 2008. This approach offers an improved representation of floodplain hydraulics as it can simulate direct overbank flooding but also captures complex overland flooding mechanisms where the flood source and receptor may not be adjacent to one another. As the floodplain in the immediate area around the site has been formally represented, the outputs from this study are considered an appropriate starting point for a site-specific assessment. For completeness the hydraulic model was formally reviewed as part of this commission prior to recommending design flood levels, to confirm that the model setup and outputs are sufficiently detailed to support a comprehensive assessment of flood risk at the site.

2.3.2 EA 2018 Manchester Ship Canal Study

The Manchester Ship Canal study follows a similar linked 1D river / 2D floodplain hydraulic modelling approach to that used on the River Medlock study but critically, only in targeted areas of the canal. The role of the River Medlock and other large tributaries represented in this hydraulic model was to route flows into the Manchester Ship Canal so that the timing and shape of the inflow hydrographs was appropriate at key mapping locations. The site does not sit within one of these key mapping locations. Whilst there are river sections directly adjacent to the site, which are taken from the 2011 River Medlock study, the floodplain is not formally represented. This would overestimate flood levels as water can only rise vertically in the channel as opposed to spreading into the floodplain. Based on this assessment the Manchester Ship Canal hydraulic model is not considered suitable for a site-specific assessment at this location.

2.4 Incoming Model Review

As outlined in EA modelling for Flood Risk Assessment guidance 2, it is our responsibility to check the suitability of an existing model for use in a site-specific assessment of flood risk. This section of the report covers an initial model review completed on the Mott MacDonald 2010 River Medlock Model Update Study for the purpose of the site-specific flood study at Commercial Street. The investigation was limited to checks that could be made using the data available to the project team and customised according to the sites perceived level of flood risk.

2.4.1 Hydrology

The hydrology in the original model is taken from the Medlock FRM study (Atkins, 2009) which utilised a Flood Estimation Handbook (FEH) CD Version from 1999. This study applied calibrated ReFH methods to derive the hydrology. Since this period, FEH hydrological methods have undergone significant improvements, the most recent of those being in 2022. Several updates to the Revitalised Flood Handbook (ReFH) method have also since been made, with the most recent in 2023 (ReFH2.3) which utilises the FEH22

design rainfall. As the previous hydrology is significantly out-dated, this should be updated to follow current methods.

2.4.2 Ground Model

The main limitation in the Light Detection And Ranging (LIDAR) data used to represent the floodplain is that it was flown in 2009. Given the potential for change across the catchment since that time, it is suggested that the LIDAR data is updated to the most recently flown data available from the DEFRA data services portal. Upon this update building levels and bank levels should be checked to confirm levels are still representative.

2.4.3 Channel data

The model built in 2010 uses survey collected from differing time periods, ranging from November 1997 and July 2008. All the channel survey utilised in this model is therefore greater than 15 years old. Manchester has undergone significant redevelopment in that time, and with that, there is a potential for changes to structures and river channels. Collecting new survey throughout the model reach is beyond the scope of the current study.

According to commentary stored within the 2010 model, channel roughness values were derived from photographic evidence as suggested in Chow (1959). At the time of writing, JBA Consulting does not have access to the River Medlock 2009 SFRA and as such cannot verify this information. It is noted that large proportions of the model have been given what is typically quite generic with a bed roughness of 0.04 and bank roughness of 0.06. It is also noted that various River Medlock restoration schemes have taken place since 2009 although not in the immediate area around the site.

2.4.4 Buildings

The 2010 Medlock model follows one of the acceptable methodologies for building representation in an urban area as outlined in the EA Fluvial Modelling. This employs what is known as "stubby buildings" to the model by applying a 300mm threshold level to each building in the model domain. This approach encourages water to initially route around buildings. The previous modelling used an underlying mean average ground level for each building footprint which was based on LIDAR data. This was reinforced in the model to smooth each footprint, prior to the 300mm addition. These average ground levels could be updated using the newer LIDAR data.

Since Manchester has undergone significant development since the original 2010 model, it is suggested that the building layer should be updated to reflect this. For this site-specific study, it is considered acceptable that a localised assessment can be made.

3 Hydrological Analysis

3.1 Overview

This section summarises the hydrological calculations used to update the inflows in the hydraulic modelling. AEPs of 3.3%, 1% and 0.1% were estimated as these events are used, potentially in combination with historic or recorded flood outlines to define the Flood Zones. In addition, the impacts of climate change were also considered as these simulations are used to inform the site design. The Irwell Management Catchment peak river flow allowances, which the site sits within, give flow uplifts of 35% and 46% for the 2080s Central and Higher estimates respectively. These uplifts were applied to the 1% AEP. Typically, the central estimate (35% flow uplift) would be used as the 'design flood' but the Higher estimate (46% flow uplift) allows the potential sensitivity of the site to climate change to be assessed. The 1% plus climate change scenarios will be referred to as 1% AEP +CC35% and 1% AEP + CC46% throughout the report.

3.2 Catchment

The site is 30m from the River Medlock, which is a tributary of the River Irwell. The catchment of the Medlock is well represented by the flow gauge which is less than 3km upstream (London Road Gauge). The catchment draining to the gauging station is 57km² (adjacent to the site the catchment area is 64km²) and is almost entirely urban in its lower reaches. Upstream there is a combination of urban and improved grassland cover. The catchment area to the gauge is located in Figure 3-1.

The hydrometric gauge on the River Medlock (NRFA reference 69020), is less than 3km upstream. The gauge is located where the London Road crosses the River Medlock. The gauge is categorised as suitable for both pooling and QMED and has over 50 years of digital flow record. The catchment average annual rainfall (1991-2020) was 1083mm and the potential evapotranspiration (PET) over the same period was 592mm. Typically, assuming a correctly specified catchment area, this should result in a mean flow of approximately 1m^{3/s} at the London Road gauge.

3.3 Hydrograph Generation

Both FEH and ReFH2 methodologies were considered for this study, and further details are provided in the flood calculation record, in Section A. For the upstream estimation point, the Enhanced Single Site method at the London Road gauging station is the final method applied. A downstream flow estimation will be used to understanding the remaining contribution of flow in the intervening area between the gauging station and the site. This method is discussed further in Section 3.4. The peak flows for the 3.3%, 1% and 0.1% events are available in Table 3-1.

Table 3-1: Peak flows for the 3.3%, 1% and 0.1% events.

Site code	3.3%	1%	0.1%
MedlockUS	49	62	95
MedlockDS	55	70	107

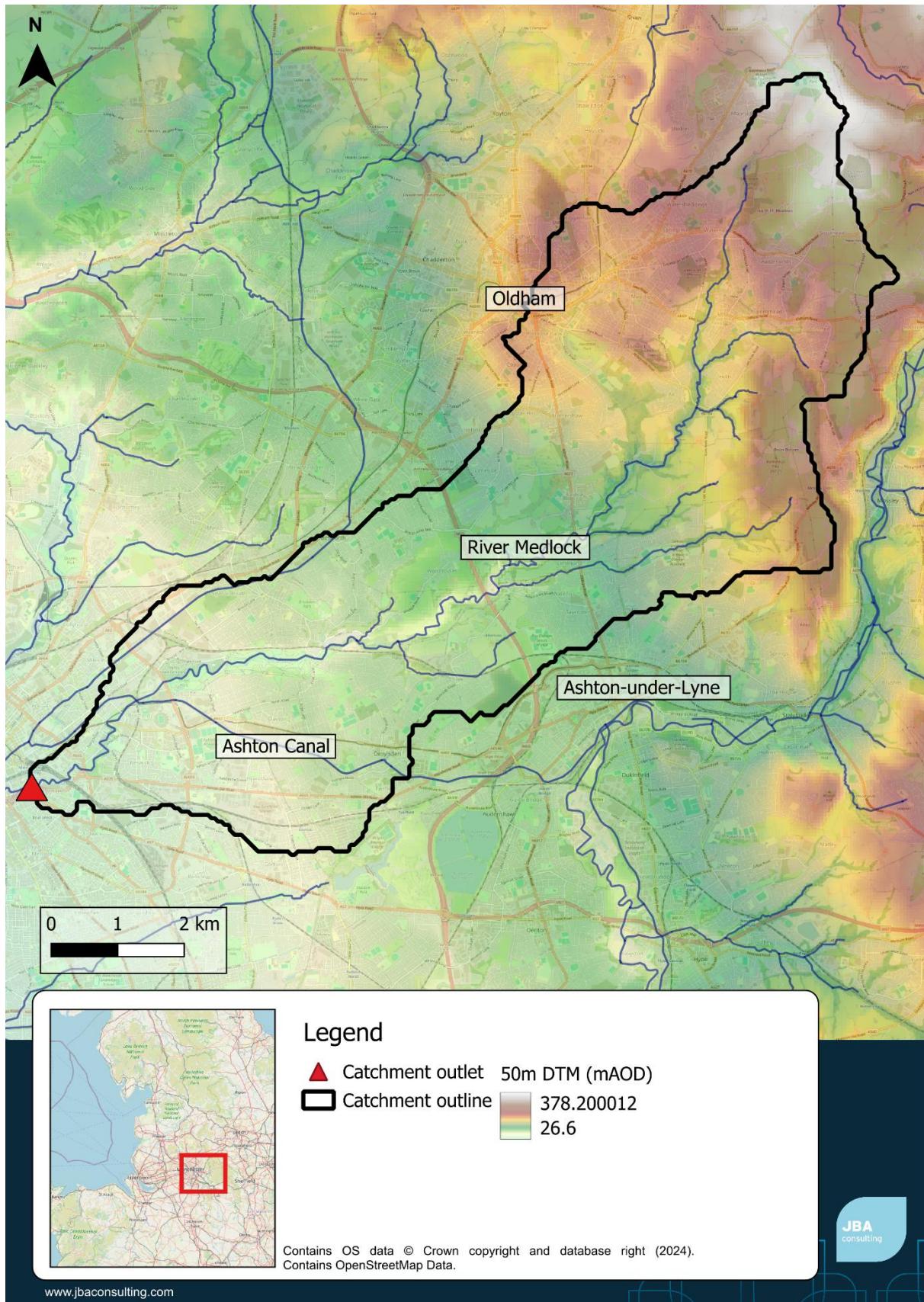


Figure 3-1: The River Medlock catchment for this assessment.

3.4 Lateral Flow Application

In the site-specific hydraulic model, a lateral inflow, which represents the change in catchment area between the gauging station and the site has been added. Conceptually this represents the flow that would enter the watercourse in between the two lumped flow estimates. A conservative approach has been taken in that all the flow for the lateral inflow has been added a single point a short distance upstream of the site

Further adjustment to the lateral inflow was then made to reconcile the peak flows to the design estimates at the site. Locations of the lumped inflow and Medlock DS measurement point is in Figure 3-2.

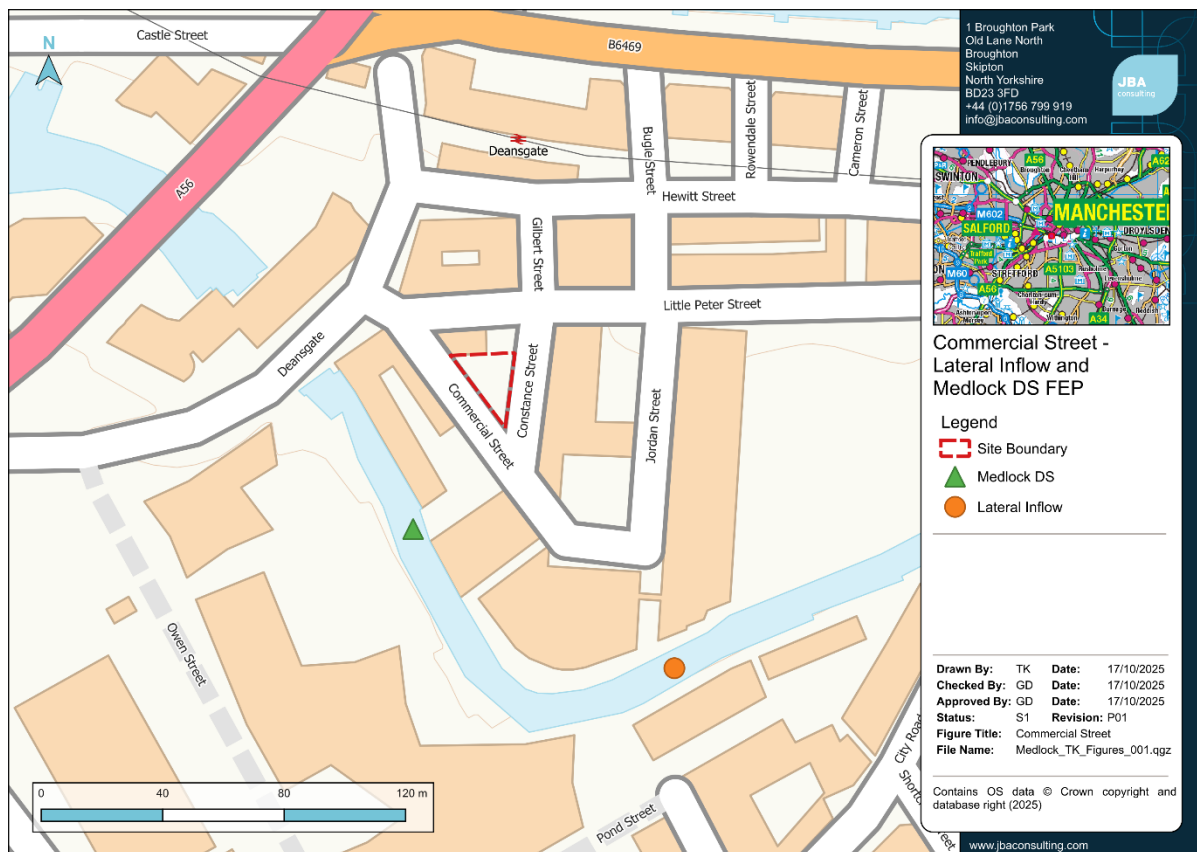


Figure 3-2: Locations of the lumped lateral inflow and Medlock DS measurement point.

3.5 Climate Change Allowances

Table 3-2 summarises the climate change flow uplifts relevant to the study. These are based on the Irwell Management Catchment peak river flow allowances. The 2080s central flow estimate (highlighted in bold) should be used for more vulnerable developments in Flood Zone 2 or 3a, according to EA guidance³. In the current study the 2080s higher estimate has also been considered as a sensitivity test.

³ [Flood Risk Assessments: climate change allowances](#)

The climate change flow uplifts were applied to the 1% AEP event, following EA guidance. The impact of this flow scaling is shown in Figure 3-3.

Table 3-2: River Flow Climate Change allowances for the River Irwell catchment

Epoch	Central	Higher	Upper
2020s	12	15	24
2050s	19	26	43
2080s	35	46	75

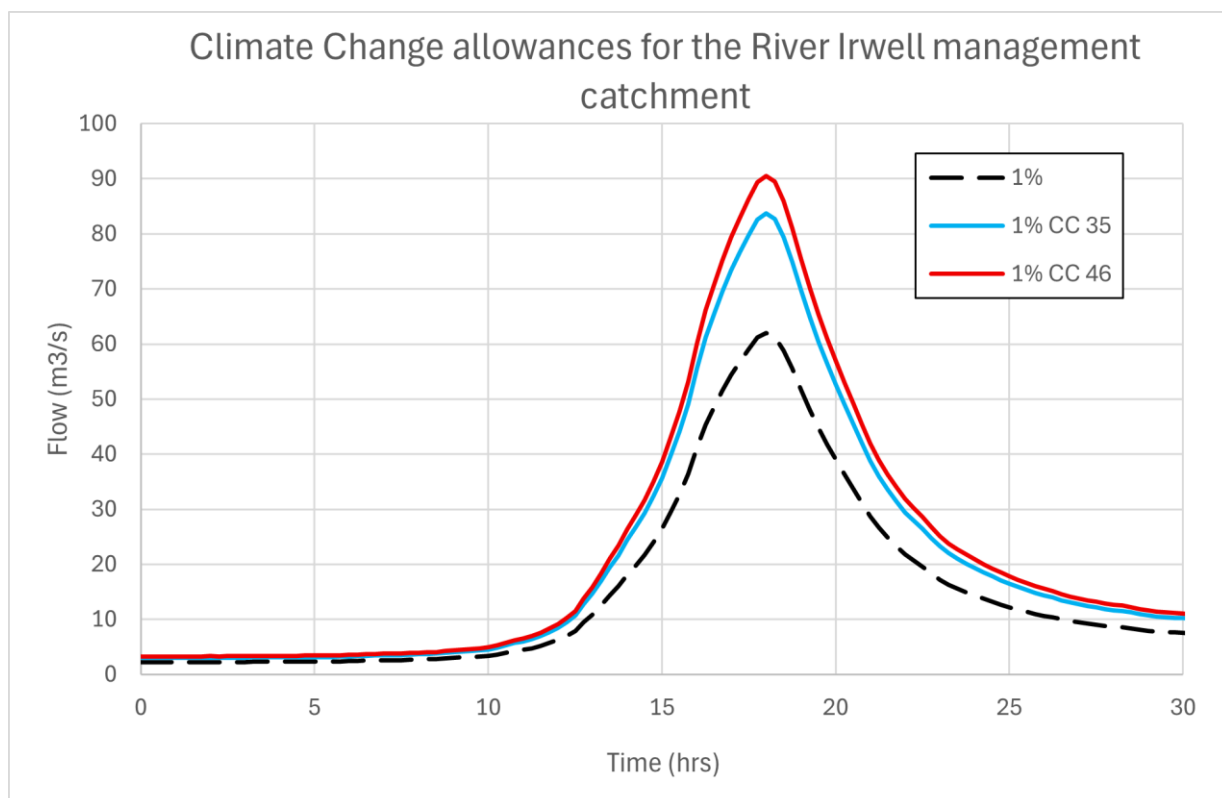


Figure 3-3: Uplifted climate change hydrographs.

3.6 Combined Sewer Overflows (CSOs)

The EA Medlock model included a series of point inflows which represent flow inputs from Combined Sewer Overflows (CSOs), which were originally calculated in a United Utilities drainage model. What is not clear is whether these flows were used to represent the lateral inflow between two lumped estimates or whether these were in addition, potentially representing flow transfers from outside the catchment. Consideration was given to removing these inflows (or using these locations to apply new lateral inflows) in the current study as new flow estimates have been produced. However, it was decided to retain these inflows, following the precautionary principle, to provide a worst-case scenario.

In situations where these CSO flows were unavailable, such as the 3.3% AEP event, the 1% CSO flows was used a proxy. For climate change scenarios these inflows were also scaled by the same flow uplifts, again adopting a worst-case approach.

4 Fluvial Modelling

4.1 Baseline Updates

4.1.1 Model Domain

The previous model domain extended from Upstream of Alan Turing Way (386915, 399089) in the east to the Bridgwater Canal in the west (382582, 397279) north of Hulme Hall Road. During the model review a decision was made to reduce the upstream extents of the model to the South of Fairfield Street along the railway line leading into Manchester Picadilly (385265, 397565). This location is also in proximity to the upstream flow estimate at the London Road gauge. The model was not truncated to the gauge site as there is culvert immediately downstream. In an extreme flood the culvert may not have sufficient capacity to convey the design flood which would result in out of bank flow and the culvert overtopping. To capture this potential flooding mechanism the upstream boundary is a short distance upstream. The changes in model domain are visible in Figure 4-1.

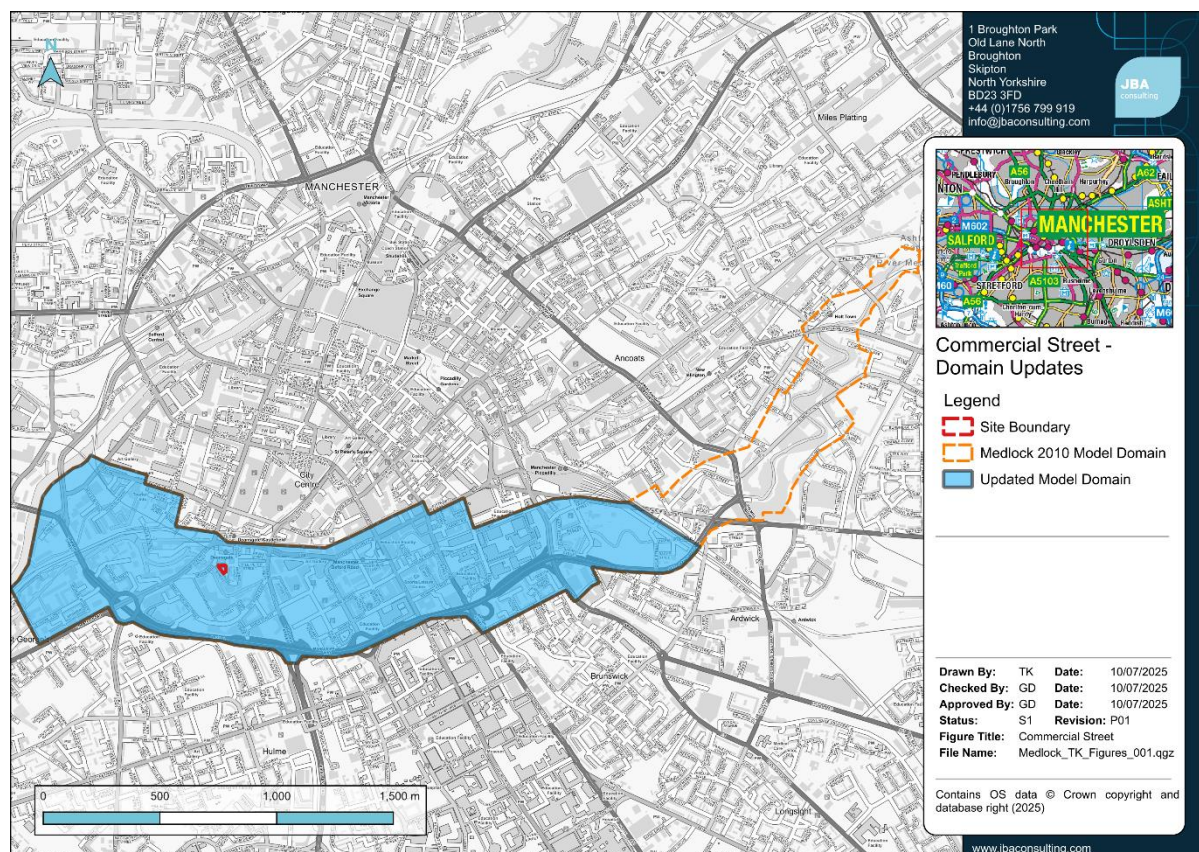


Figure 4-1: Comparison between the previous and updated 2D model domain.

4.1.2 Ground Model

A Digital Terrain Model (DTM) was used in the TUFLOW domain to represent overland flow routes across the floodplain. The DTM was obtained from the EA under the Open

Government Licence and was available in several spatial grid resolutions. The most detailed available DTM comprised LIDAR data at a 1m resolution and was flown in 2020. The floodplain was modelled within the TUFLOW model at a 4m grid resolution, retaining the original grid resolution and orientation.

4.1.3 Building representation

The methodology around the building representation was maintained as discussed within Section 2.4. However, the underlying LIDAR in which set the 'base' level for the buildings were updated using the latest LIDAR. This involved sampling the average LIDAR elevation for each building and stamping this into the TUFLOW domain via a shapefile. An additional shapefile is then overlayed, adding 300mm to the base to represent the thresholds of the buildings. This technique is consistent with the previous modelling and sensitivity of its application for this site-specific study has been considered in Section 6.5.

As the buildings layer used in the original study is likely based on data in 2010, this was assessed for its suitability. Whilst Manchester City Centre has undergone changes in development footprint since that time, a site-specific update was completed to represent present-day site topography. This involved the removal of three buildings on. The buildings are believed to have been removed between 2008 and 2012 and therefore the LIDAR is the most accurate representation of site conditions in these areas. Comparison of the topographic layout of the site from the previous and updated model is visible in Figure 4-2.

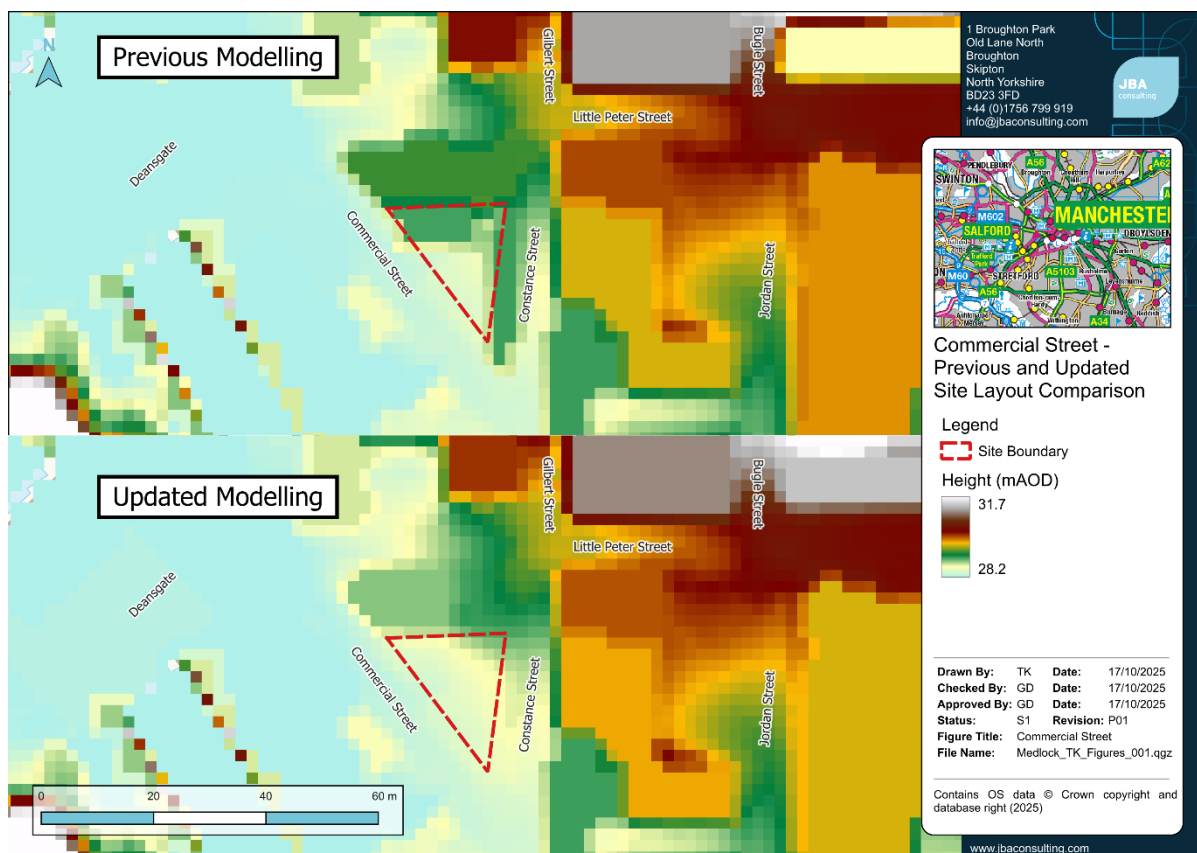


Figure 4-2: Comparison of the site layout between the previous and updated model set up.

4.2 Proposed Development

For information on the proposed development, please see the associated Flood Risk Assessment.

5 Modelling Results

5.1 Overview

Based on the simulations completed in this assessment results are available for the 3.3 AEP, 1 AEP and 0.1 AEP present-day events and the 1% AEP + CC35% and 1% AEP + CC46% climate change events.

5.2 Flow reconciliation

Flow reconciliation was completed at both London Road Gauge (Medlock US) and adjacent to the site (Medlock DS) to confirm that the flow application was appropriate for a site-specific assessment of flood risk. The results of the flow reconciliation are shown in Table 5-1 below.

Table 5-1: Flow reconciliation results.

AEP (%)	Medlock US (node: MEDL01_2099F)			Medlock DS (node: MEDL01_0058)		
	ESS peak flow (m ³ /s)	Modelled flow (m ³ /s)	Ratio (%)	ESS peak flow (m ³ /s)	Modelled flow (m ³ /s)	Ratio
3.3	49	48.89	99.78	55	56.56	102.84
1	62	61.64	99.41	70	70.58	100.83
0.1	95	84.45	88.90	107	101.03	94.42

Typically, a successful flow reconciliation would place modelled flows within $\pm 10\%$ of the flow estimates. Overall, the modelled flows show a good correlation with all lumped estimates across all simulated events. Whilst the Medlock US value for the 0.1% AEP falls out of this range, this is due to the total flow not being captured due to out of bank flooding. The downstream reconciliation adjacent to the site is within the expected range.

5.3 Outputs

5.3.1 Updated Outputs

Figure 5-1 below shows a comparison between the EA FMfP 3.3% AEP extent to the 3.3% AEP extent which has been generated by this site-specific fluvial modelling study. The updated extents from this study show a significant reduction in flooding despite flows increasing. This reduction is primarily a result of the floodplain being formally represented in the current study as opposed to no floodplain in the model used to produce the existing Flood Zones.

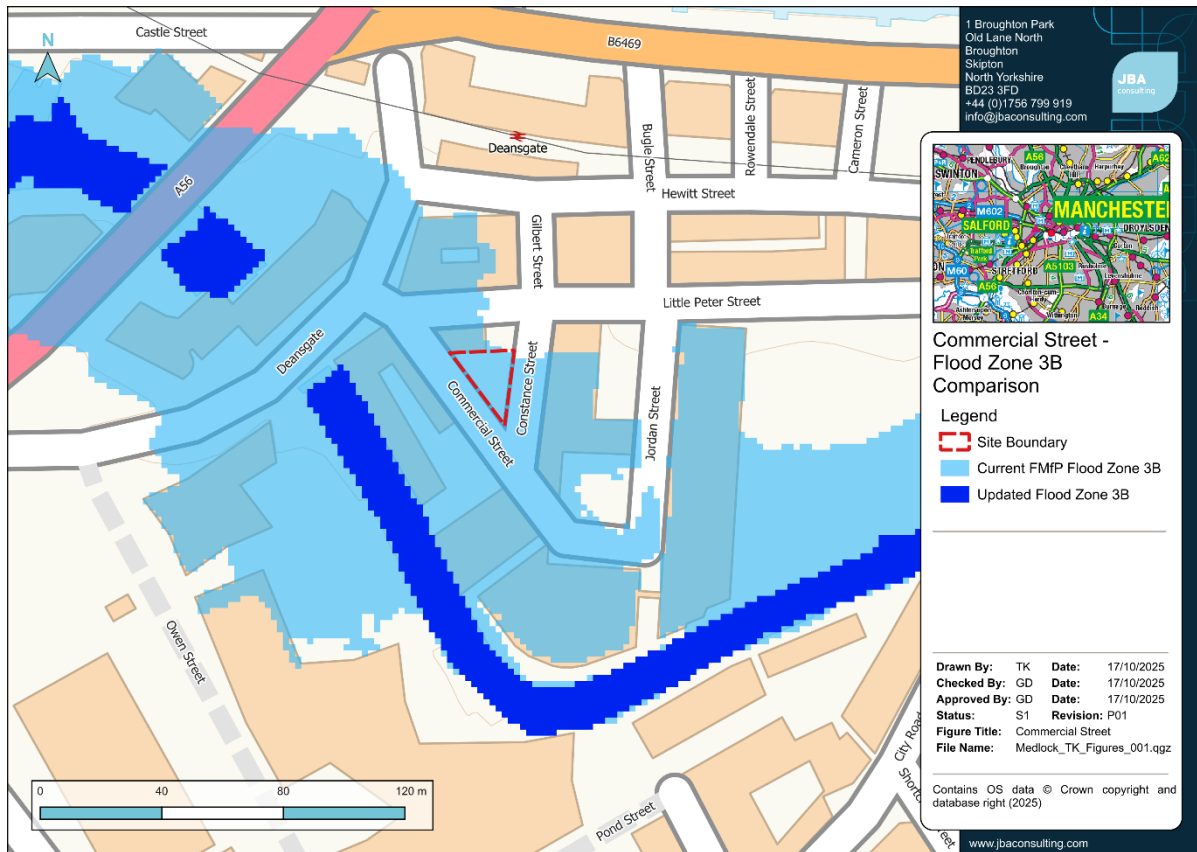


Figure 5-1: Comparison between the FMfP Flood Zone 3B and the one produced from the updated modelling.

5.3.2 Updated Flood Zones

Figure 5-2 below shows the updated 3.3% AEP, 1% AEP and 0.1% AEP extents which have been generated in the current study. Out of the design event simulations completed in this study, only the 0.1% AEP encroaches onto the site. Adjacent to the site the River Medlock is in bank for both the 3.3% AEP and the 1% AEP events.

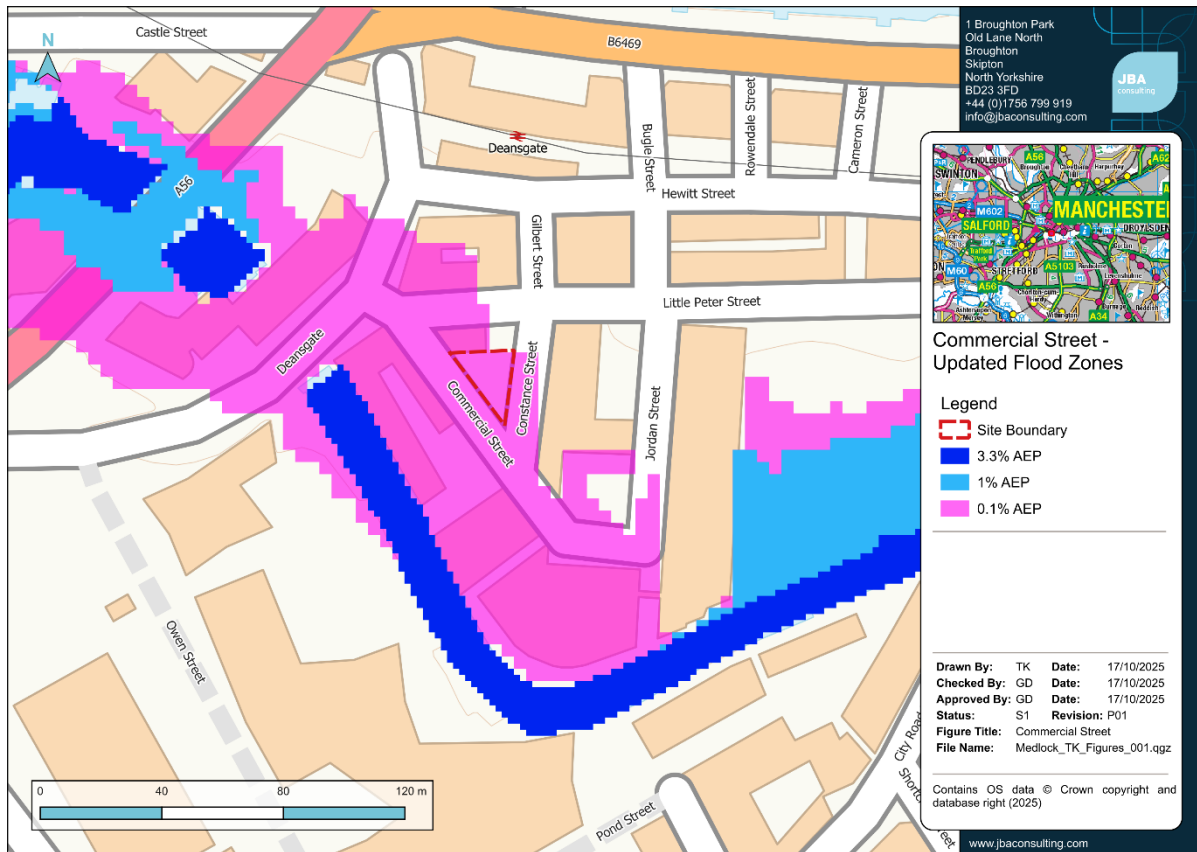


Figure 5-2: Updated model outputs for the 3.3%, 1% and 0.1% AEP events.

5.3.3 Climate Change Outputs

The modelled 1% AEP with climate change outlines are shown in Figure 5-3. The indication is that flood risk within the study area will increase in the future as flows increase with climate change. Both the climate change scenarios encroach slightly onto the site via Commercial Street. For this site-specific assessment the 1% AEP + CC 35% should be initially considered when estimating the design flood level for use in site design.

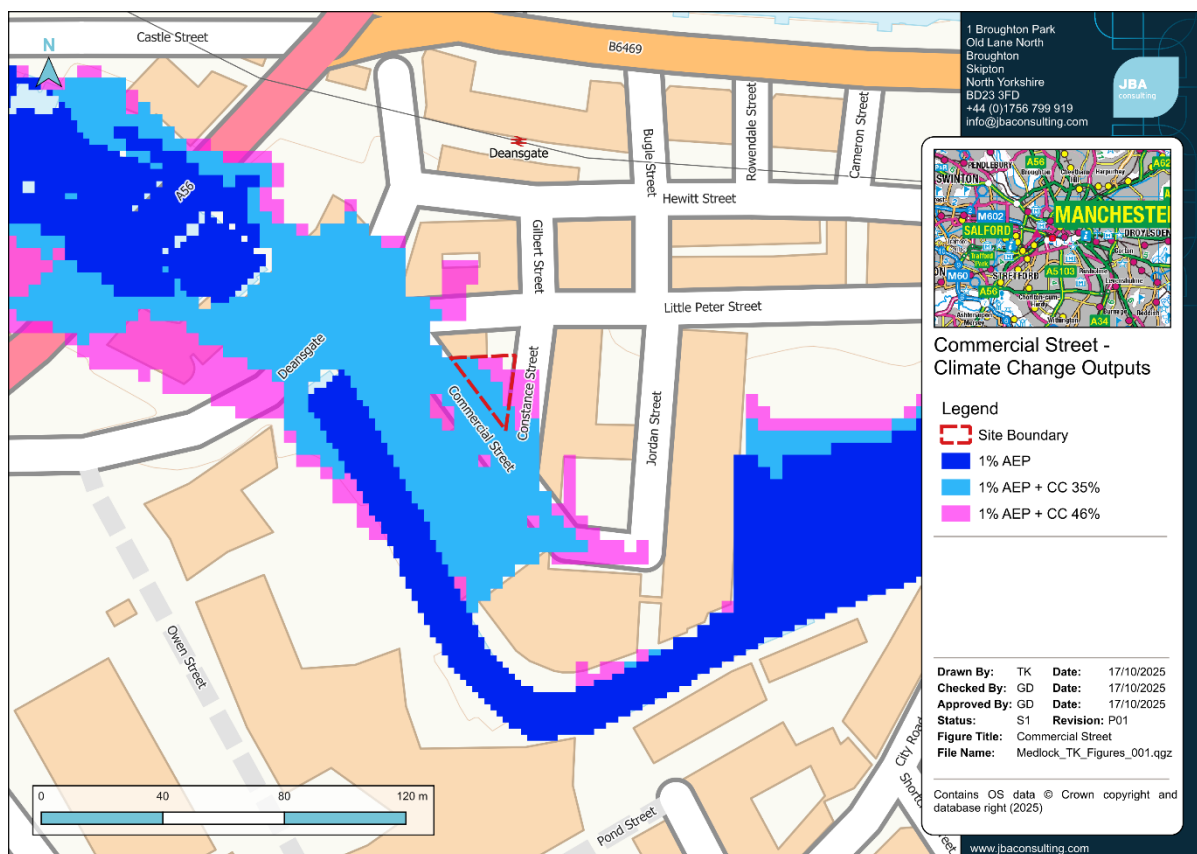


Figure 5-3: The 1% AEP and climate change extents produced by this study.

5.4 Flood Levels

Maximum flood levels for the 1% AEP + CC 35%, 1% AEP + CC 46%, and the 0.1% AEP are available in Table 5-2 below. For all other events simulated as part of this site-specific study, no encroachment onto the site and have therefore not been included within the table.

Table 5-2: Flood levels on site for the 1% AEP + CC 46% and 0.1% events.

Return Period (AEP%)	Onsite Flood Level (mAOD)
1% AEP + CC 35%	28.62
1% AEP + CC 46%	28.86
0.1%	29.01

6 Sensitivity Testing

6.1 Overview

In hydraulic modelling, the aim of sensitivity analysis is to establish the hydraulic response of a given system to changes in its defining parameters, the objective being to establish the likely effect of these on model behaviour and predictions. Sensitivity analysis can often enhance model calibration/verification quite significantly and tends to play an even greater role where there are no field observations / measurements, in which case it is used together with published data from the literature and 'modelling judgement' to refine the applicable range of parameter values.

There are a multitude of factors that can affect hydraulic behaviour, but experience indicates that the critically important ones (and those for which sensitivity can be readily demonstrated) are downstream boundary conditions and hydraulic roughness. These are the variables around which the sensitivity testing of the hydraulic model was focussed. Unless stated, the 1% AEP event was used in all sensitivity tests. A $\pm 20\%$ flow sensitivity was also completed for the 1% AEP event as this is typically requested by EA review teams. In addition, sensitivity to building representation and model schematisation directly adjacent was also considered due to the urban nature of the watercourse.

6.2 Sensitivity to Roughness

The impact of floodplain and in-channel hydraulic roughness coefficients was tested to understand how modelled flows and water levels would be affected. In this test a $\pm 20\%$ variation in roughness was considered. As seen in Figure 6-1, the adjustments to the Mannings n values both in and out of channel do not increase risk to the site in a 1% AEP event. During this event, flows do not exceed channel capacity adjacent to the site.

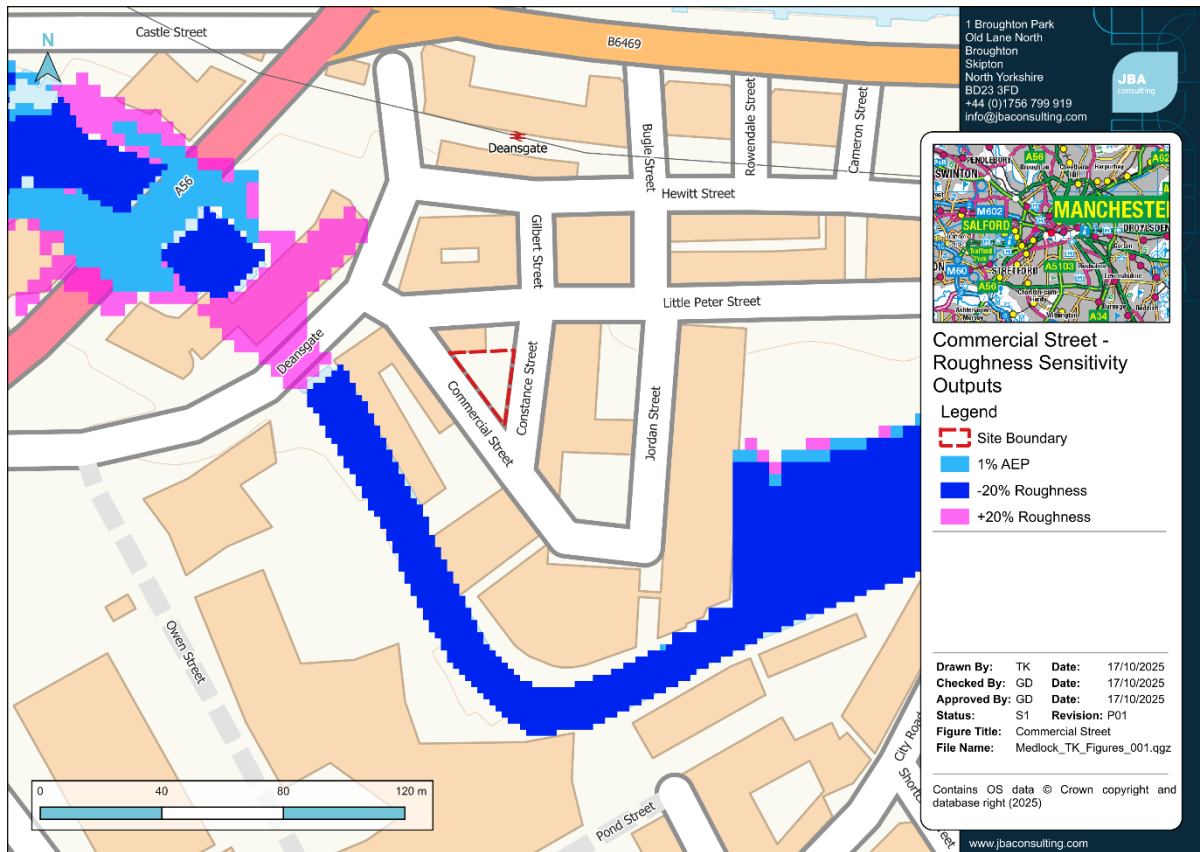


Figure 6-1: Extents for the roughness sensitivity test during a 1% AEP event.

6.3 Sensitivity to Flow

The impact of flow sensitivity was tested to understand how modelled flows and water levels would be affected. In this test a $\pm 20\%$ variation in flow was considered and tested on the 1% AEP event. As seen in Figure 6-2, the adjustments to the flow values increases risk in the vicinity of the site in a 1% AEP event. During this event, flows exceed the channel capacity immediately adjacent to the site which flows overland and encroaches onto the site.

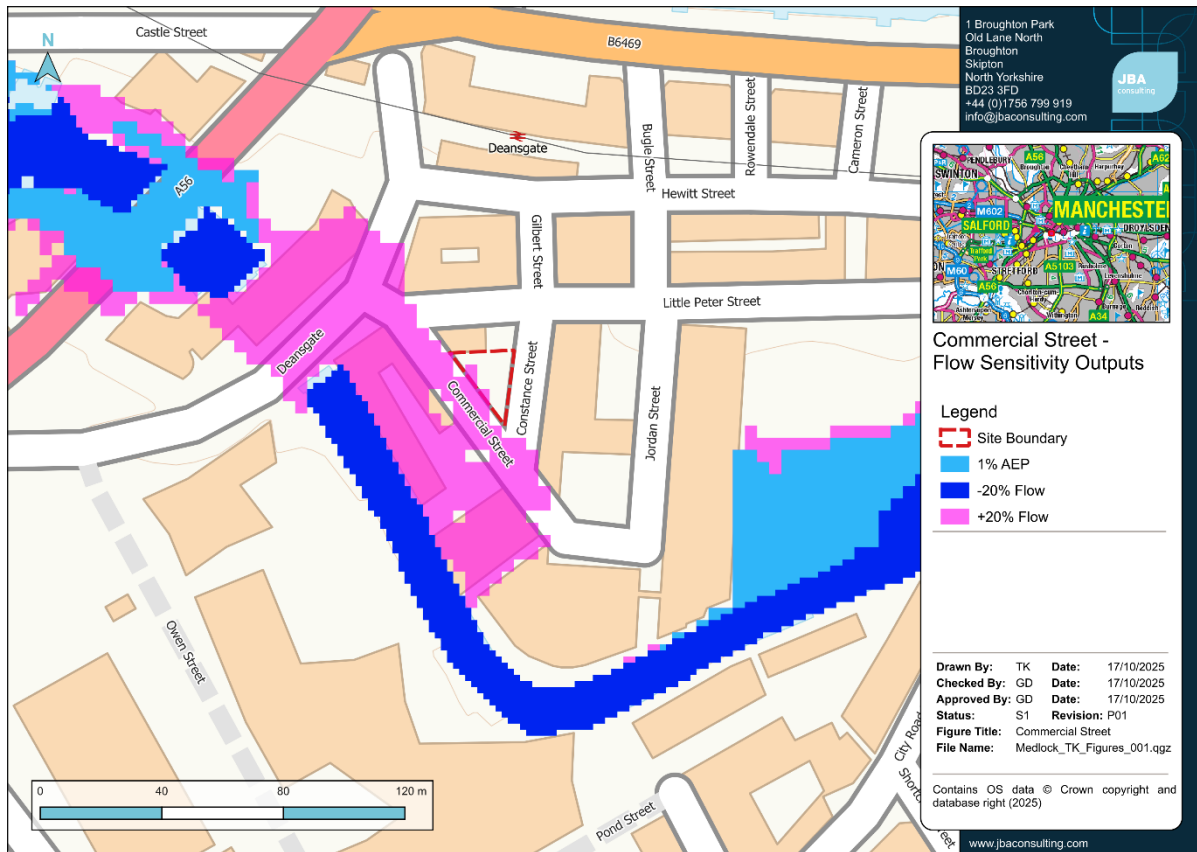


Figure 6-2: Extents for the flow sensitivity test during a 1% AEP event.

6.4 Sensitivity to Downstream Boundary

The impact of the model's downstream boundary was tested in order to understand whether its parameterisation impacts the predicted water level on site. For this test the level component of the downstream boundary was increased by $\pm 0.5\text{m}$. This was applied on both the Bridgewater canal and the downstream boundary for the Medlock. As seen in Figure 6-2, the adjustments to the downstream boundary do not increase risk to the site in a 1% AEP event. During this event, flows do not exceed channel capacity adjacent to the site but some extent increases are visible downstream.

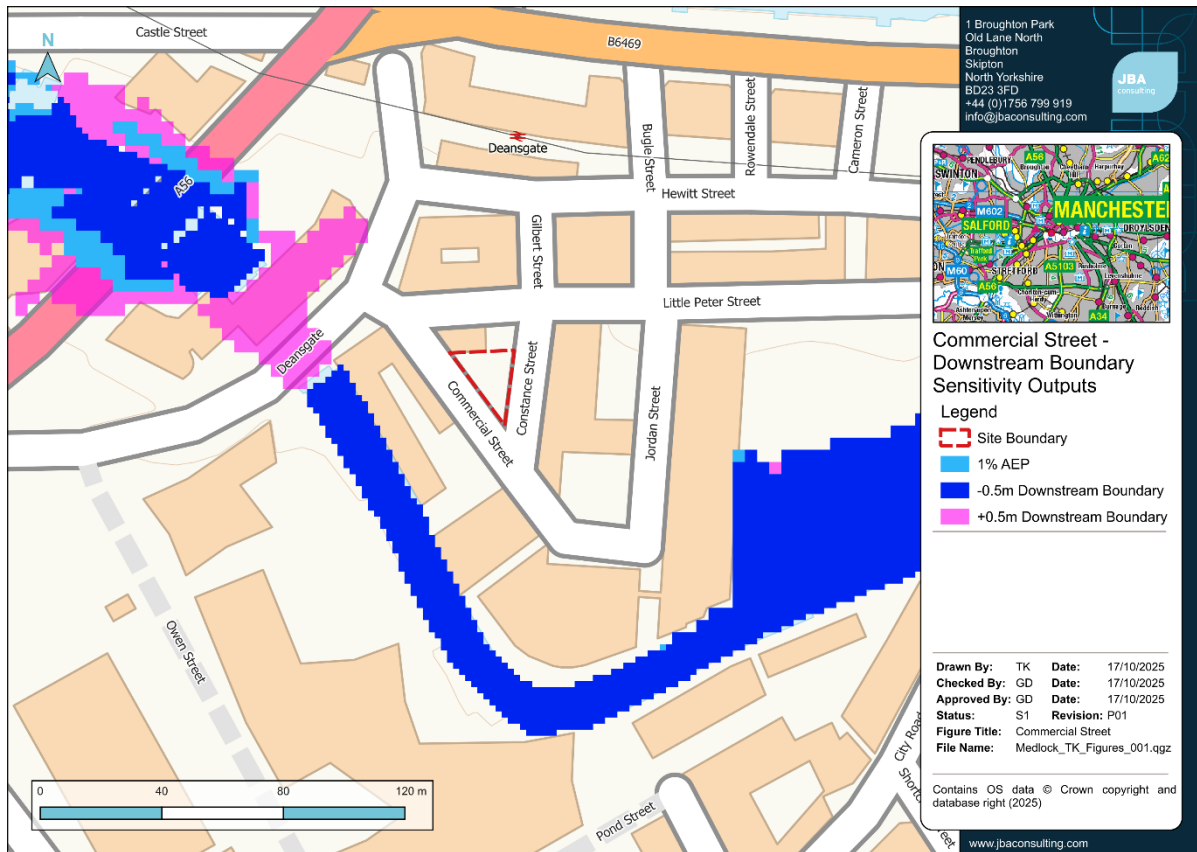


Figure 6-3: Extents for the downstream boundary sensitivity test during a 1% AEP event.

6.5 Sensitivity to Building Representation

As there are a number of technically acceptable approaches to represent buildings in a floodplain, alternative approaches have been considered as a sensitivity test. One potential criticism of the stubby building approach is that flow routes could be closed off resulting in flood risk on site being underpredicted. In this test the representation of the buildings was reverted to a roughness only approach, i.e. no ground level adjustments were made. This was assessed for the 1% AEP +CC46% as the 1% AEP remains in bank.

As seen in Figure 6-4 below, A greater proportion of the site is flooded during the building representation sensitivity test in comparison to the baseline. The removal of the building uplift allows for water stored within Little Peter Street carpark to move westwards through the site.

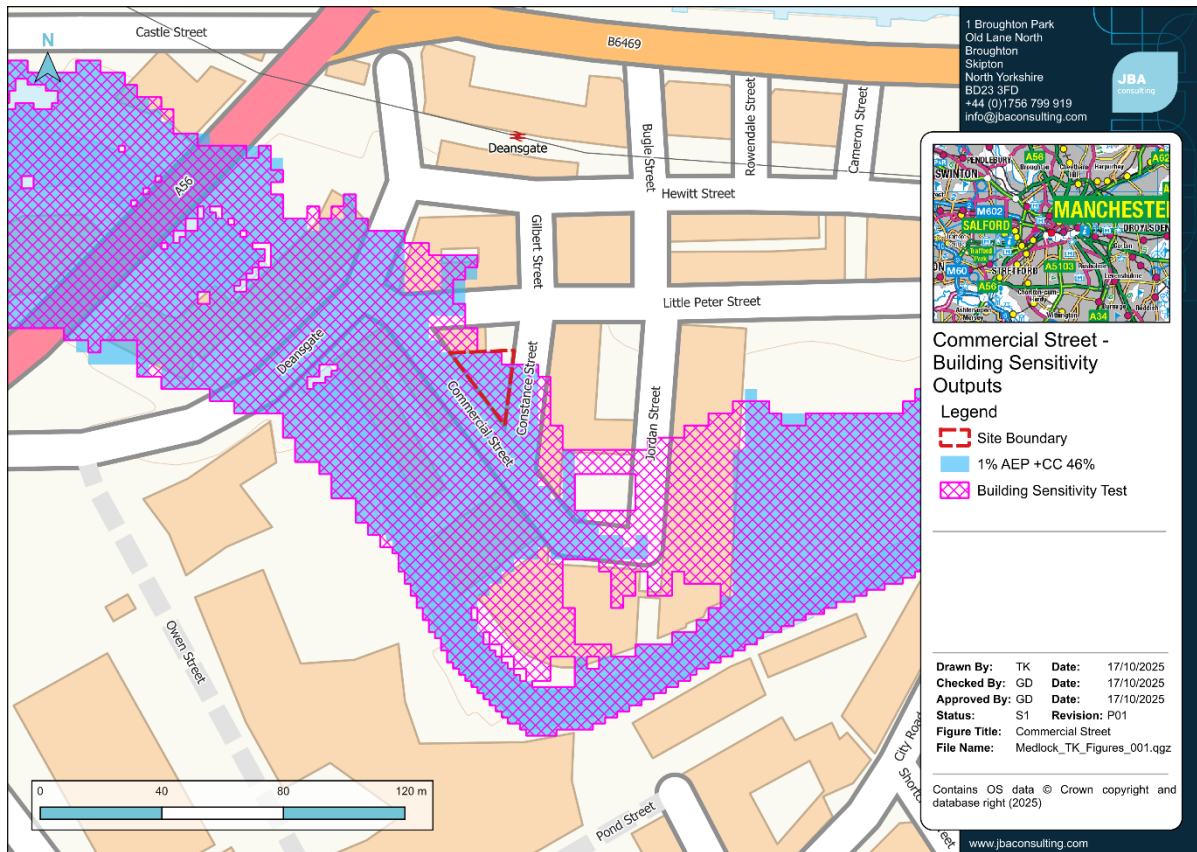


Figure 6-4: Results of the building representation sensitivity test for the 1% AEP +CC46% event.

6.6 Representation of Overtopping Spills

During the model review it was noted that there was no overtopping spill to allow water directly onto Deansgate. Whilst there are walls there currently there are gates that provide access to the river. Typically walls and gates are not formally represented in hydraulic model unless they are designated as flood defence assets as they may collapse in a flood event or allow water to leak through. In the initial model setup (as reported) the as supplied configuration (no overtopping allowed) was retained as it was felt this would provide a more conservative representation of flood risk on site.

As a sensitivity test the HX lines were wrapped around the deck of the bridge (therefore allowing flow directly onto Deansgate should water levels reach the level of the road). Ground levels were set to 28.26mAOD on the upstream face of bridge, this was taken from as built drawings available from the Manchester City Council Planning Portal (Doc Ref: CDN_18_0903-CON_36_-_RIVER_EDGE_ELEVATION-1050993). Comparison were also made to LIDAR levels on Deansgate (28.18mAOD) which confirms a suitable match.

As flooding in the urban environment is complex this is only currently considered as a sensitivity test, again the 1% AEP + CC46% event was simulated. As seen in Figure 6-5, it is evident that this update reduces water levels upstream as there is a slight reduction in flood extents. This is to be expected as the model now allows water to move more freely

downstream. As a result the site remains free from flood water during a 1% AEP + CC 46% event.

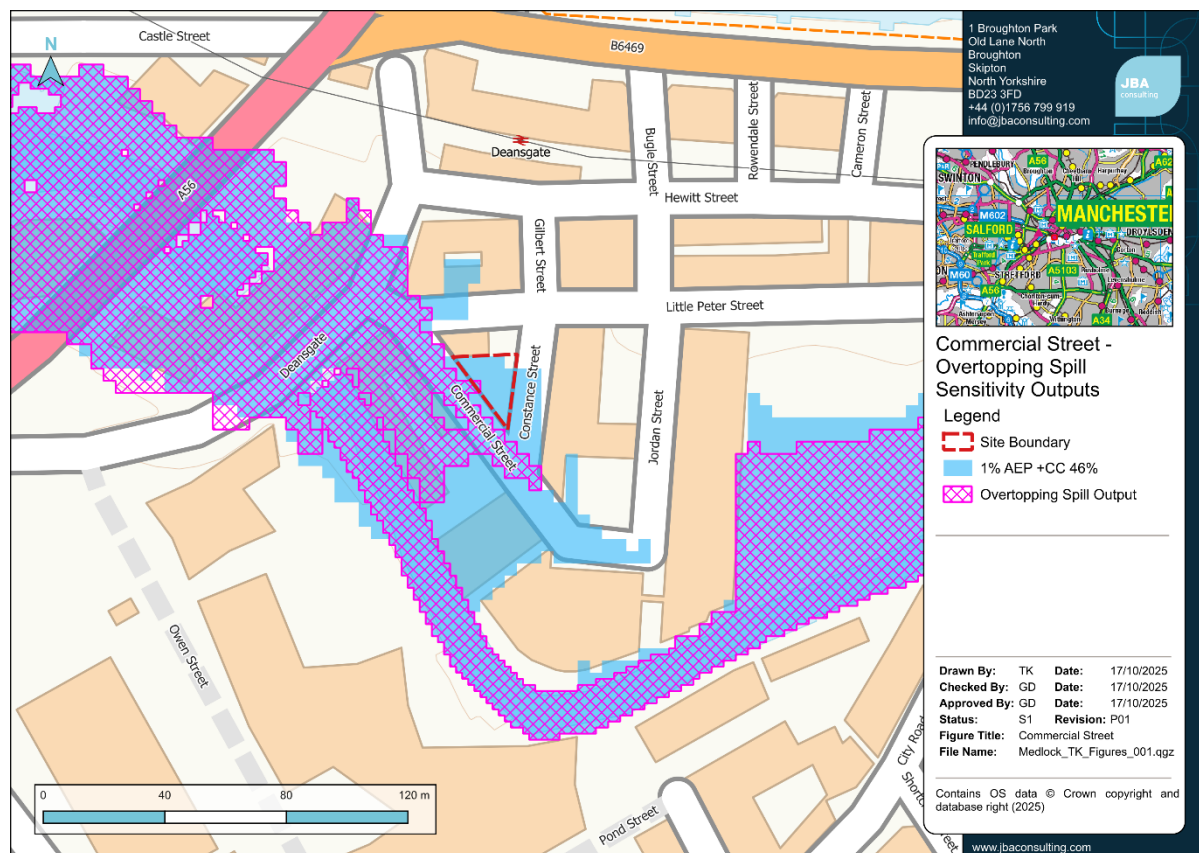


Figure 6-5: Results of the spill representation sensitivity test for the 1% AEP +CC46% event.

7 Conclusions

JBA Consulting (JBA) was commissioned by Meadway Developments in May 2025 to produce a flood risk summary for a site on Commercial Street, Manchester. It is understood that the site is to be redeveloped for residential use which would cover all of the site. As part of this study the existing Environment Agency (EA) flood product data has been reviewed and updated to provide a site-specific assessment of flood risk for the site. As part of this assessment the following conclusions can be made:

- The current FMFP significantly over-estimates the flood risk at the site. The existing EA data suggest the site has a very high risk of flooding. The site-specific hydraulic modelling suggests the site is at low risk of flooding. This is in line with historic estimates of risk completed in support of earlier planning applications.
- Out of the design simulations completed in this study, only the 0.1% AEP encroaches onto the site. In terms of the stretch of Medlock adjacent to the site, both the 3.3% AEP and the 1% AEP remain in bank.
- In the climate change scenarios assessed, both encroach onto the site via Commercial Street. Maximum water levels for the 1% AEP + CC 35% should be initially used as a design flood level, this has been estimated as 28.62 mAOD. This does not include any allowance for freeboard.
- In the sensitivity tests, the site is not shown to be sensitive to changes in roughness or downstream boundary. However increasing the flow by 20% allows for flood water to encroach onto the site via Commercial Street. This is not surprising given the general increase in flooding observed during the climate change simulations.
- A general increase in flood extents, when compared to the baseline equivalent, is observed for the building representation sensitivity. The removal of the building uplift allows for water stored within Little Peter Street carpark to move westwards towards the site.
- When assessing the sensitivity of the overtopping spill onto Deansgate, it is evident that flood risk on site reduces. The site remains free from flood water during a 1% AEP + CC 46% event.

A FEH Calculation record

Flood Estimation Report

**2025s0757 Commercial Street,
Manchester**

Final

17/10/2025

www.jbaconsulting.com

Description

This report template is based on a supporting document to the Environment Agency's Flood Estimation Guidelines (LIT 11832). It provides a record of the hydrological context, the method statement, the calculations, the decisions made, and the results of flood estimation.

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Approval

Revision stage	Analyst	Approved by	Amendments	Date
Method statement	Anthony Hammond	Kirstie Murphy	NA	28/05/2025
Calculations - Revision 1	Anthony Hammond	Kirsty Murphy	NA	28/05/2025
Calculations - Revision 2				

Revision history

Revision reference	Date issued	Amendments	Issued to
1.0	23/05/2025	NA	Steven Carnes
Final	17/10/2025	Final Reporting	Steven Carnes

Abbreviations

AEP	annual exceedance probability
AMAX	annual maximum
AREA	catchment area (km ²)
ARF	areal reduction factor
BFI	baseflow index
BFIHOST19	baseflow index derived using the HOST soil classification, revised in 2019
CPRE	Council for the Protection of Rural England
FARL	FEH index of flood attenuation due to reservoirs and lakes
FEH	Flood Estimation Handbook
HOST	Hydrology of Soil Types
NGR	national grid reference
NRFA	National River Flow Archive
OS	Ordnance Survey
POT	peaks over a threshold
QMED	median annual flood (with return period 2 years)
ReFH2	Revitalised Flood Hydrograph 2 method
SAAR	standard average annual rainfall (mm)

Tp	time to peak of the instantaneous unit hydrograph
UKFE	United Kingdom Flood Estimation (R package for implementing flood hydrology methods)
URBAN	Flood Studies Report index of fractional urban extent
URBEXT2000	revised index of urban extent
WINFAP	Windows Frequency Analysis Package (software that can be used for FEH Statistical method)

1 Summary of assessment

1.1 Summary

Catchment location:

The site of interest is a triangular area of approximately 430m² in Manchester, less than 100m south of Deansgate train station. The central grid reference is 383430, 397430. The site is accessed via Commercial Street, which also forms the sites southern and western boundary. Constance Street forms the sites eastern boundary and Little Peter Street is a short distance to the north. The site is currently a carpark. At the closest point, the river Medlock is approximately 30 metres from the site, to the southwest. The River Medlock is the source of possible flooding that is considered in this report.

Purpose of study and complexity:

Flood modelling is required to support a flood risk assessment (FRA) of the site for the purposes of potential redevelopment. The site is at potential risk of flooding from the River Medlock. Hydrological assessment is required to develop inputs for the hydraulic model. The study is not complex in the sense that there are two flood estimation points, one at a gauge and one less than 2km downstream from there.

Key catchment features:

The catchment is heavily urbanised. Flows on the River Medlock are also artificially influenced due to effluent releases, in addition to culverting downstream of the London Road gauge, with a resulting backwater effect.

Flooding mechanisms:

Potential flooding at the site from the Medlock would likely be caused by the river discharge exceeding the channel capacity and flowing northeast toward commercial street between the buildings.

Gauged / ungauged:

There is a hydrometric gauge on the river Medlock (NRFA reference 69020), less than 3km upstream. The gauge is located where the London Road bridges the Medlock. The gauge is categorised as suitable for both pooling and QMED and has over 50 years of digital flow record.

Final choice of method:

- ReFH2.3 analysis using the London Road gauging station is the final method applied.

Key limitations / uncertainties in results:

- The catchment is heavily urbanised, with changes to the urban extent and channel potentially having occurred during the gauged record – although the AMAX sample at London Road appears to be stationary. The catchment boundary, as defined by topography, may not represent the system inputs and outputs because of CSO influence, effluent release, and urban drainage outside of the topographical catchment. However, a good quality flow gauge in close proximity to the site of interest overcomes many of these issues.

1.2 Flood frequencies

- The frequency of a flood can be quoted in terms of a return period, which is defined as the average time between years with at least one larger flood, or as an annual exceedance probability (AEP), which is the inverse of the return period.
- Return periods are output by the Flood Estimation Handbook (FEH) software and can be expressed more succinctly than AEP. However, AEP can be helpful when presenting results to members of the public who may associate the concept of return period with a regular occurrence rather than an average recurrence interval.
- Results tables in this document use AEP; if required, this can be changed to return period.
- The table below is provided to enable quick conversion between return periods and annual exceedance probabilities.

AEP (%)	50	20	10	5	3.33	2	1.33	1	0.5	0.1
AEP	0.5	0.2	0.1	0.05	0.033	0.02	0.013	0.01	0.005	0.001
Return period (yrs)	2	5	10	20	30	50	75	100	200	1,000

2 Method statement

2.1 Requirements for flood estimates

2.1.1 Overview

JBA Consulting (JBA) have been commissioned to undertake a Flood Risk Assessment (FRA) for a site off Commercial Street, Manchester. The site of interest is a triangular area of approximately 430m² in Manchester, less than 100m south of Deansgate train station (see Figure 2.1). The central grid reference is 383430, 397430. The site is accessed via Commercial Street, which also forms the sites southern and western boundary. Constance Street forms the sites eastern boundary and Little Peter Street is a short distance to the north. The site is currently a carpark. At the closest point, the river Medlock is approximately 30 metres from the site, to the southwest. The River Medlock is the source of possible flooding that is considered in this report.

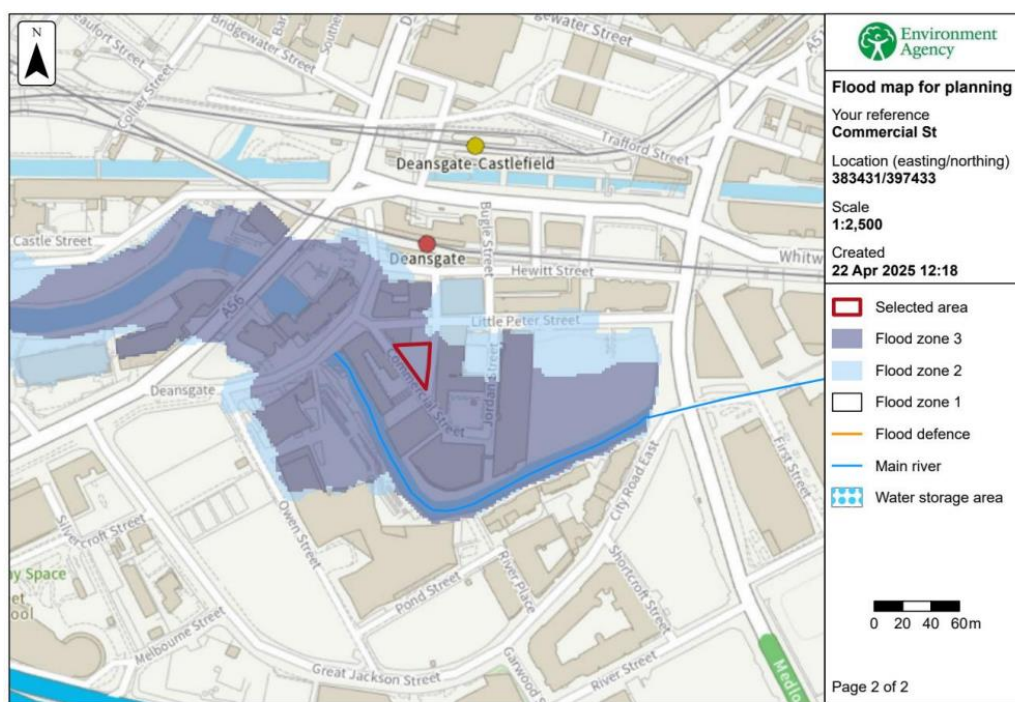


Figure 2.1: Environment Agency map of site location

The reach of model that will be hydraulically modelled is between an upstream gauge at London Road (see 2.3.1) and the site of interest (see Figure 2.2).

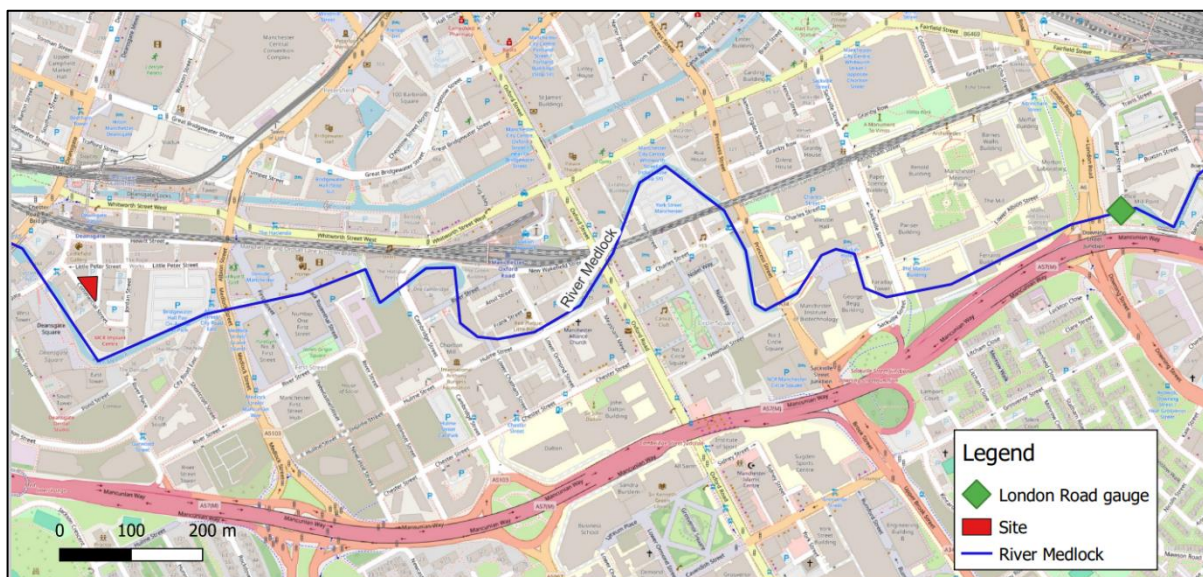


Figure 2.2: Model reach. Map data © OpenStreetMap contributors and Ordnance Survey. Contains OS data © Crown copyright and database right [2025]

2.2 The catchment

Catchment description:

The site is 30m from the River Medlock, which is a tributary to the River Irwell (Figure 2.3). The catchment of the Medlock in proximity to the site is well represented by the flow gauge which is less than 3km upstream. The associated catchment area is 57km² (adjacent to the site the catchment area is 64km²) and is predominantly urban land in its downstream reaches and a combination of urban and improved grassland cover upstream¹. This is consistent with the high URBEXT2000 value of 0.37, which is likely to influence flood generating mechanisms.

The catchment average annual rainfall (1991-2020) was 1083mm and the potential evapotranspiration (PET) over the same period was 592mm. Typically, assuming a correctly specified catchment area, this should result in a mean flow of approximately 1m³/s at the gauge. In a water balance sense and assuming storage to even out over the long term, the minimum possible daily mean flow is 0.89m³/s (rainfall minus PET) at the gauge. Over that period the NRFA recorded mean flow is 0.79m³/s and Q25 is 0.88m³/s. This suggests either an error in the catchment boundary (it would have to be an error in the order of 20 to 30%) and/or flow being transferred prior to reaching the gauge. Given the geology it cannot be attributed to aquifer recharge (due to a lack of aquifer).

¹ UKSO (undated) UKSO Map Viewer. Available at: <https://mapapps2.bgs.ac.uk/ukso/home.html>

The catchment is underlain by a variety of bedrock geology, with large areas of Pennine Upper Coal Measures Formation and sandstones of the Bardsley Rock and Collyhurst Sandstone Formations² (Figure 2.4). Superficial geology is dominated by Devensian Till (Figure 2.5). Catchment elevation ranges from almost 350 mAOD in the upper reaches near the town of Moorside in northeast Manchester to 35mAOD at the downstream extent in central Manchester¹ (Figure 2.3).

² British Geological Survey (undated) BGS Geology Viewer. Available at: <https://www.bgs.ac.uk/map-viewers/bgs-geology-viewer/>

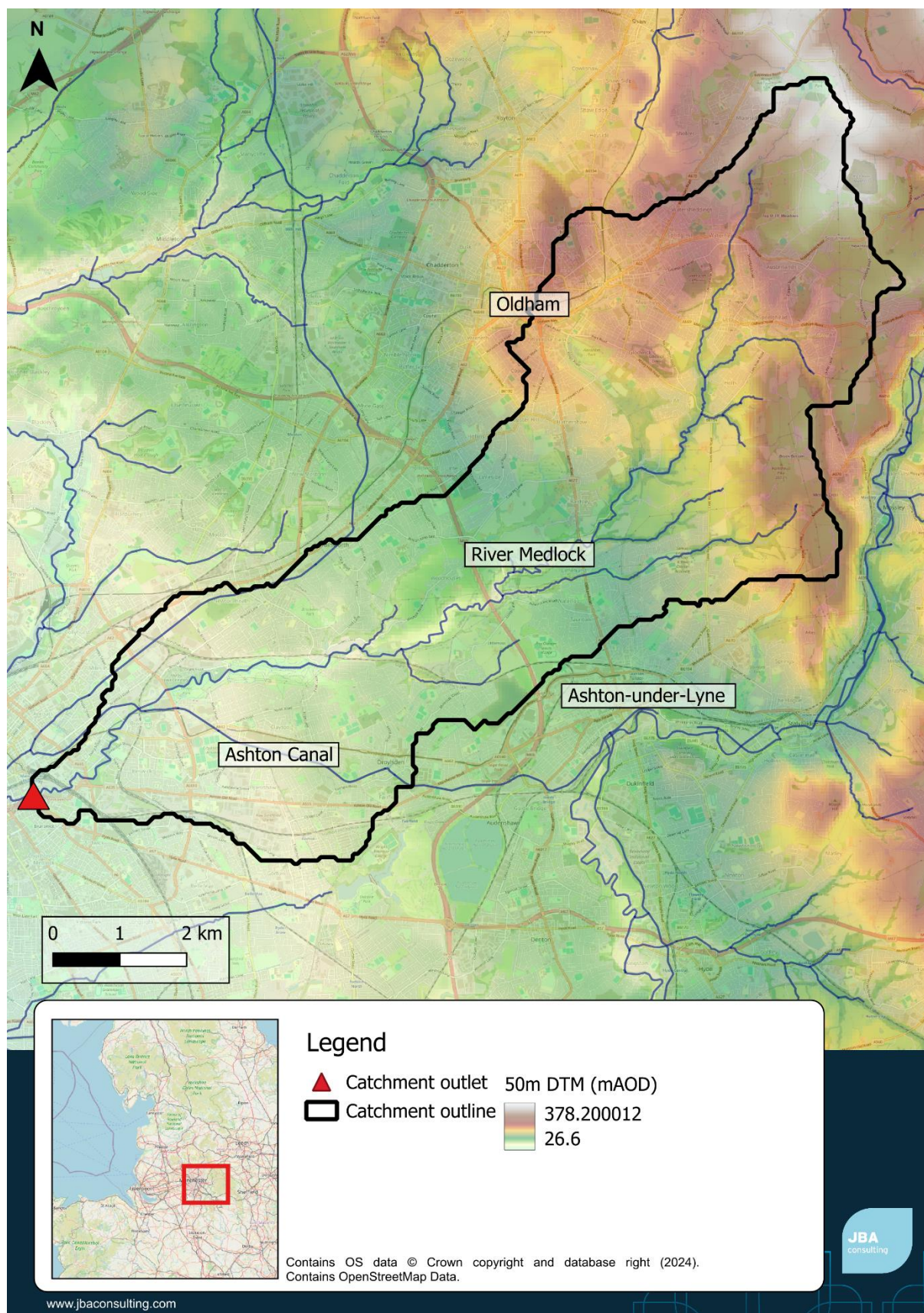


Figure 2.3: Catchment overview of the River Medlock catchment.

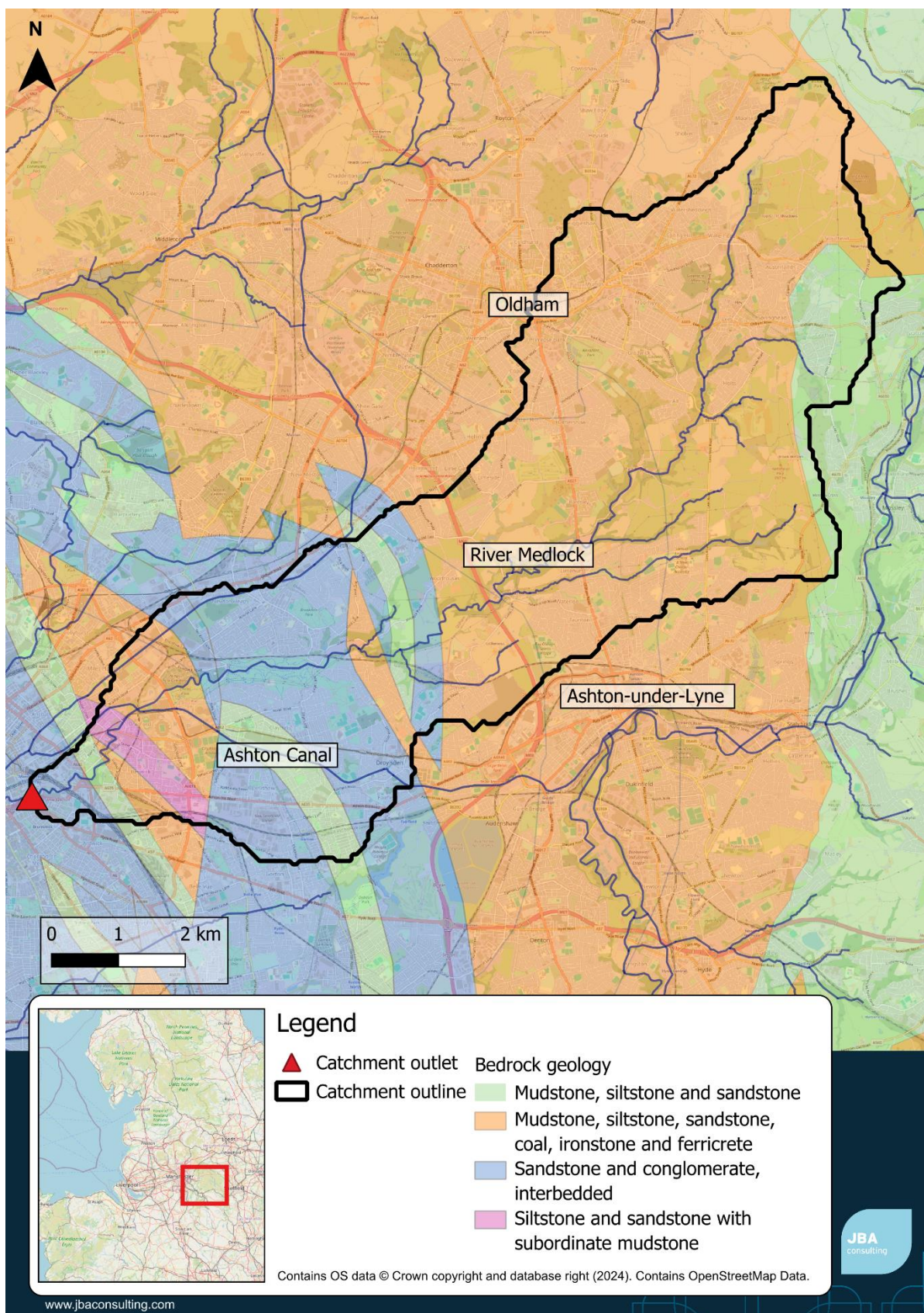


Figure 2.4: Bedrock geology of the River Medlock catchment.

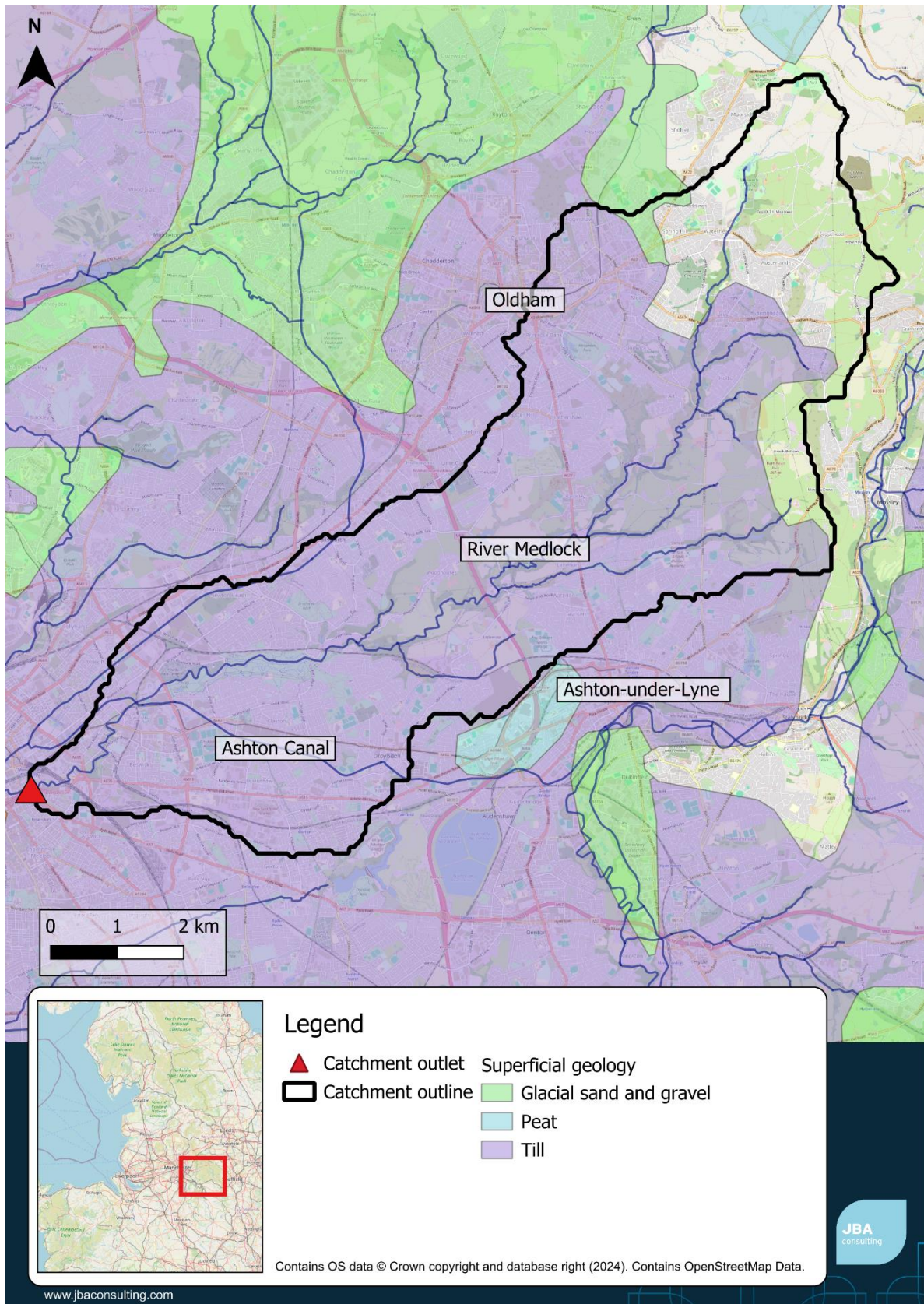


Figure 2.5: Superficial geology of the River Medlock catchment.

2.3 Data review

This section provides a summary of the data available for the study, initial discussion of data quality, and identifies potential uses of the data for the hydrological assessment. Where relevant an indication is provided regarding other potential uses of the data, for example, hydraulic model calibration. Where applicable, the data is examined in more detail in Section 2.4.

2.3.1 River flow

Gauging station details

Watercourse	Station name	Grid reference	Gauging authority number	NRFA number	Catchment area (km ²)
River Medlock	London Road	SJ848975	69	69020	57

Data available

Station name	Type	Start and end dates of supplied data and source of data	Start and end of NRFA flood peak record	Data resolution
London Road	Miscellaneous.	02/04/1969 – present. NRFA.	02/04/1969 – present.	15-minute.

Data quality

Station name	OK for QMED?	OK for pooling?	Other comments on station and flow data quality
London Road	Yes	Yes	Runoff may be from artificial surfaces. Flow is greatly affected by effluent discharges. Weir located in a rectangular concrete channel with vertical walls, upstream of a large culvert. See below for quality flag breakdown

Flag	Percentage	First	Last
Estimated	1.6	31/05/2011	24/09/2024
Good	70	01/03/1975	20/03/2025
Missing	0.065	10/08/1992	10/02/2023

Flag	Percentage	First	Last
Suspect	5.7	31/01/1990	11/12/2020
Unchecked	23	18/03/1975	09/05/2025

Ratings

Station name	Type of rating	Rating review needed?
London Road	Power law, extrapolated above LMED.	Not for this project.

Uses of the data for this study:

Data from the London Road gauging station (69020) will be used as the inflow boundary for the model on the River Medlock.

2.3.2 Rainfall

Using Veronoi polygons, four gauges were identified as applicable for catchment average rainfall for the catchment area in question (Figure 2.6). The gauge details are provided below.

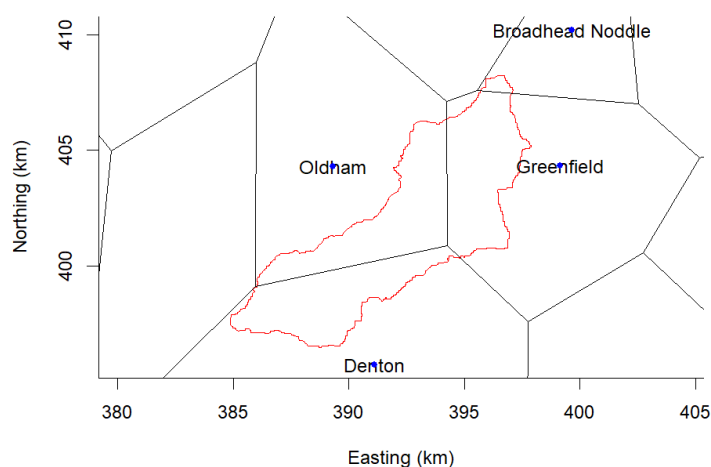


Figure 2.6: Rainfall gauge Voronoi polygons for the Medlock catchment (in red) at London Road

Gauging station details

Station	WISKI ID	Easting	Northing	Date Start	Voronoi weight
Oldham	563170	389331	404290	2020-01-01	0.35
Denton	559970	391123	395737	1998-04-30	0.32
Greenfield	559586	399157	404322	1990-12-01	0.32
Broadhead Noddle	559484	399644	410200	1990-11-11	0.01

Oldham starts in 2020 and catchment average monthly rainfall since then was extracted using the HADUK Met Office data³. Double mass plots for each of the four gauges are shown in Figure 2.7. They compare the cumulative sum of monthly rainfall with the HADUK monthly data since the beginning of 2020 to the end of 2023 (the end of the available data). The red line is a linear relationship based on the first third of the concurrent data. Divergence from this linear relationship suggests a possible change over time in the relationship between the two plotted rainfall samples. Denton appears to be diverging over the last year of data.

³ <https://data.ceda.ac.uk/badc/ukmo-hadobs/data/insitu/MOHC/HadOBS/HadUK-Grid/v1.3.0.ceda/1km/rainfall/mon/v20240514>

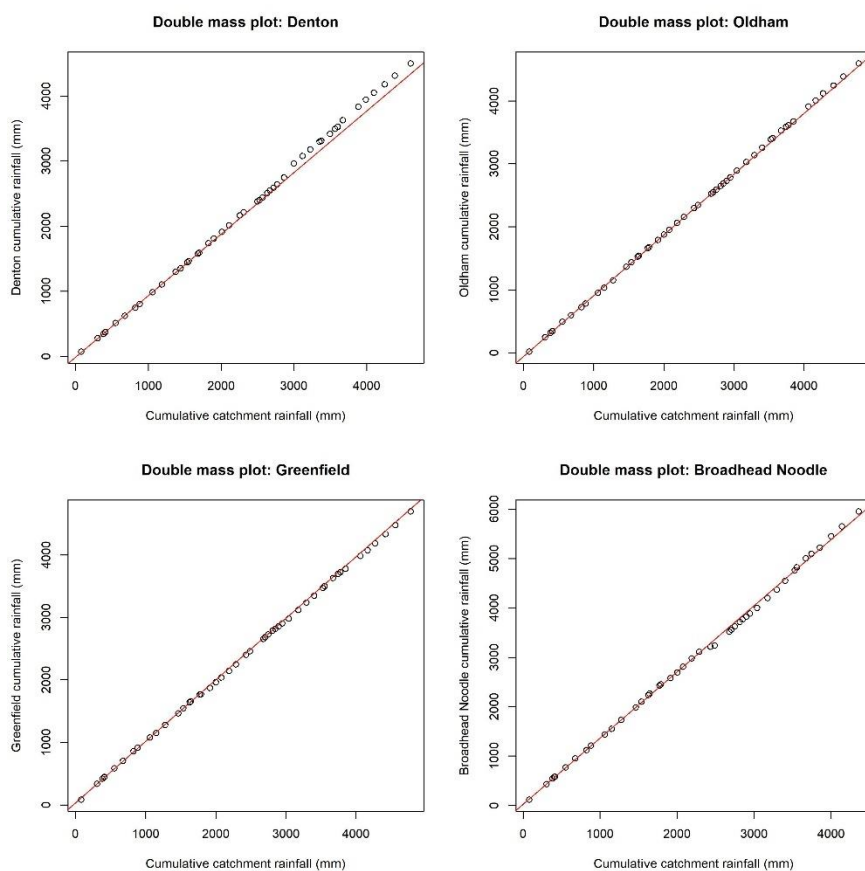


Figure 2.7: Double mass rainfall plots

Uses of the data for this study:

Despite the possible divergence at Denton, all four rainfall gauges will be used to derive catchment average event data from 2020 onwards. This will be used to assess the catchment response to rainfall.

2.3.3 Flood history

There is no flood information specific to the site in question or the roads surrounding it. Furthermore, there is no recorded river level above bank level at the London Road gauge. However, flood events have been recorded for the River Medlock (See Appendix), including along Downing Street (1856) which is near the gauge, and London Road (1866). See the Appendix for a table of anecdotal flood history for the river Medlock.

Uses of the data for this study:

The Appendix provides a summary of flood events identified from a range of sources. Four large flood events are noted since 1799, however there is limited flood history identified after 1900. This data provides useful qualitative understanding of the magnitude and frequency of flood events within the catchment before the period of gauging began, therefore may support validation of flood estimates or may be incorporated formally into the calculations. However, there has been significant change in this area of Manchester since the recorded flooding in proximity to the gauge (over 150 years ago).

2.3.4 Conclusions of data review:

Data type	Suitability for flood estimation calculations	Suitability for hydraulic modelling	Any further comments
River flow	Yes, good quality AMAX.	Yes, model calibration/validation.	
Rainfall	Yes	NA	Useful for catchment event rainfall.
Flood history	Not suitable.	Not suitable.	The only flood history is greater than 100 years ago in a catchment with significant change in urbanisation over that time.

2.4 Hydrological understanding of the catchment

The mean flow of the catchment, as gauged at London Road, is a little under $1\text{m}^3/\text{s}$. The monthly mean flows can be seen in Figure 2.8. The flow was converted to mm/day, and the monthly rainfall and flow were extracted for comparison in Figure 2.9. The runoff ratio is 0.46 (1974 – 2018), suggesting that 54% of rainfall is lost to evapotranspiration, extraction, transfer, etc.

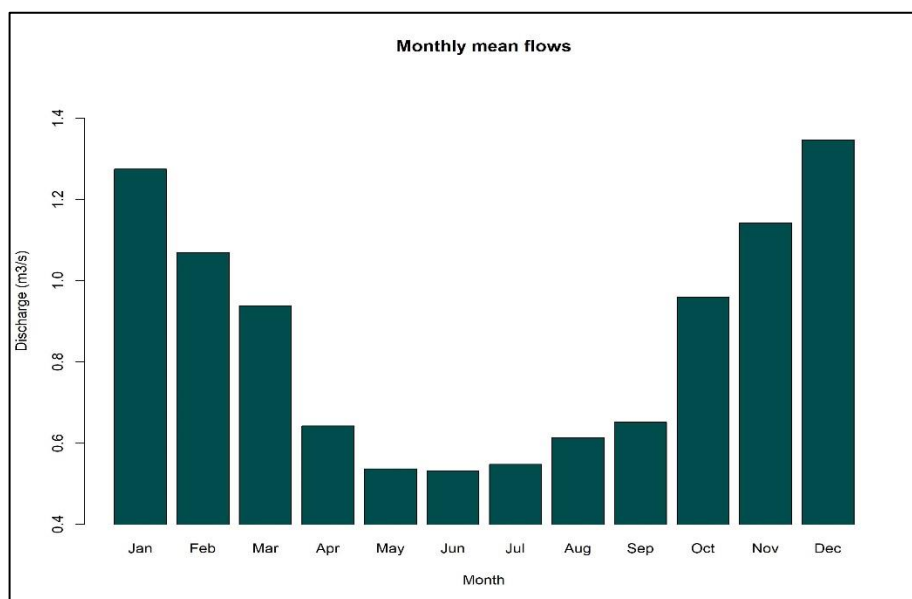


Figure 2.8: Monthly mean flows at London Road

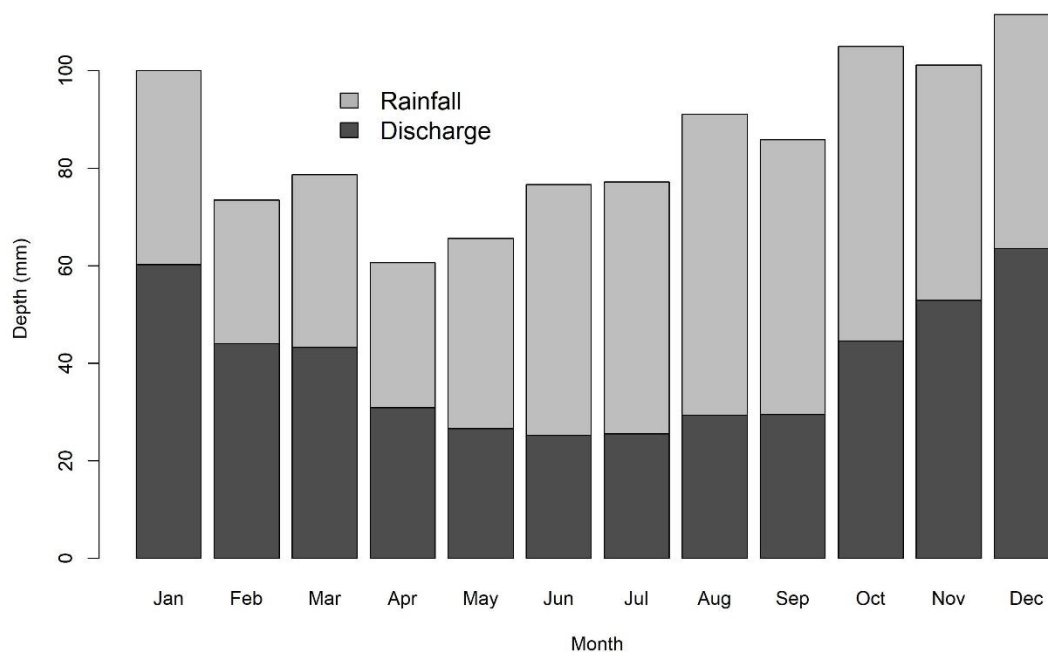


Figure 2.9: Catchment rainfall and discharge

The catchment is relatively flashy with a steep flow duration curve (see Figure 2.10). The Richard-Baker flashiness index⁴ is 0.45, which is higher than 72% of catchments categorised as suitable for pooling.

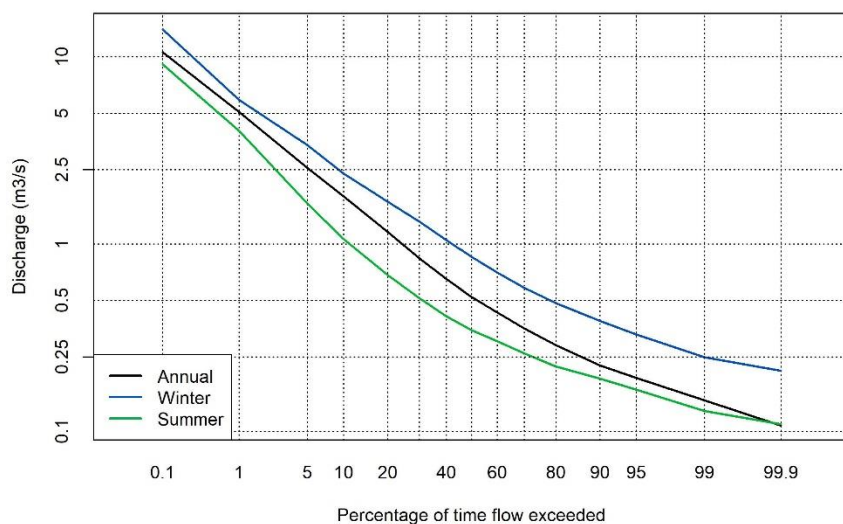


Figure 2.10: Flow duration curve, Medlock at London Road

This flashiness suggests that it may be susceptible to summer downpours. The seasonality plot (Figure 2.11), which is based on POT data from the NRFA, highlights that flood peaks are not particularly seasonal and occur throughout the year.

⁴ <https://onlinelibrary.wiley.com/doi/10.1111/j.1752-1688.2004.tb01046.x>

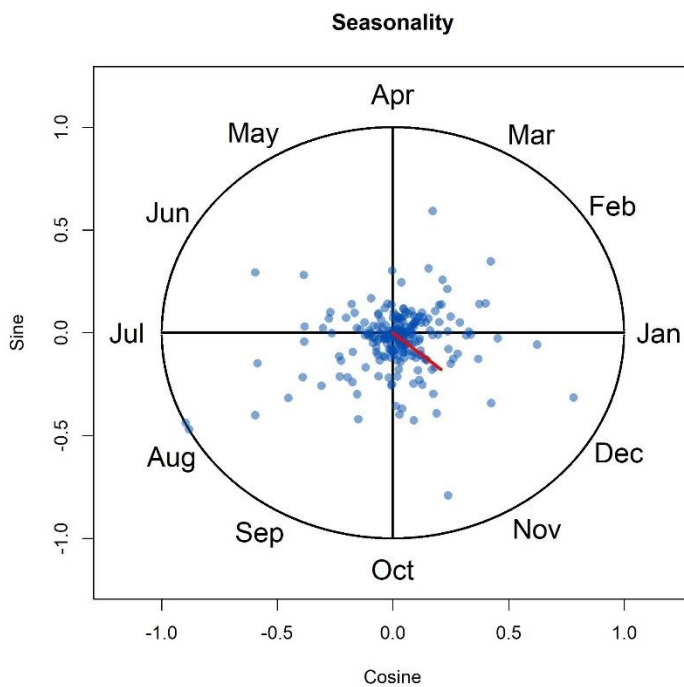


Figure 2.11: Seasonality of POT data at London Road

The highest peak recorded was in 2025 (not included in the seasonality plot) and is shown in Figure 2.12 with the associated catchment rainfall. The next two highest peaks occurred in August. The lag time tends to be 3 to 5 hours which is relatively short for a catchment of 57km² and can be attributed to urbanisation quickening the response to rainfall.

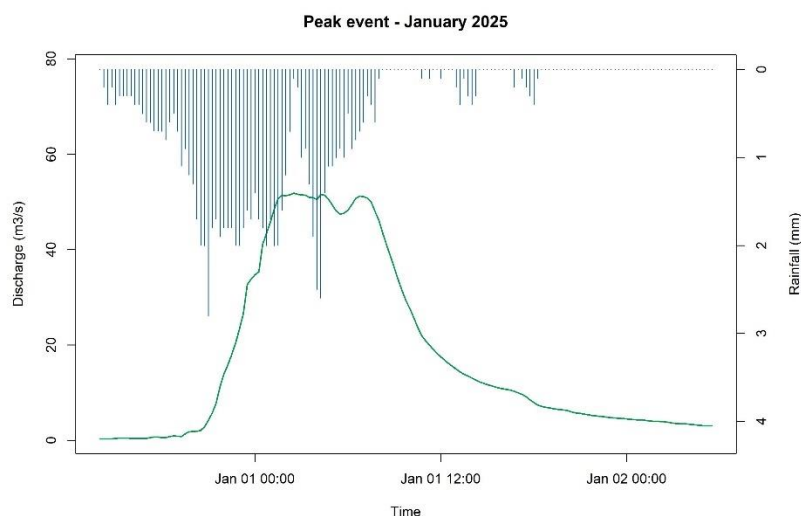


Figure 2.12: Highest recorded peak event (15-minute resolution)

There are few single peaked hydrographs and Figure 2.13 shows the derivation of an average hydrograph shape from six events (shown in Table 2.1). The average hydrograph time of rise is approximately 10 hours, and it recedes over the next 30 hours.

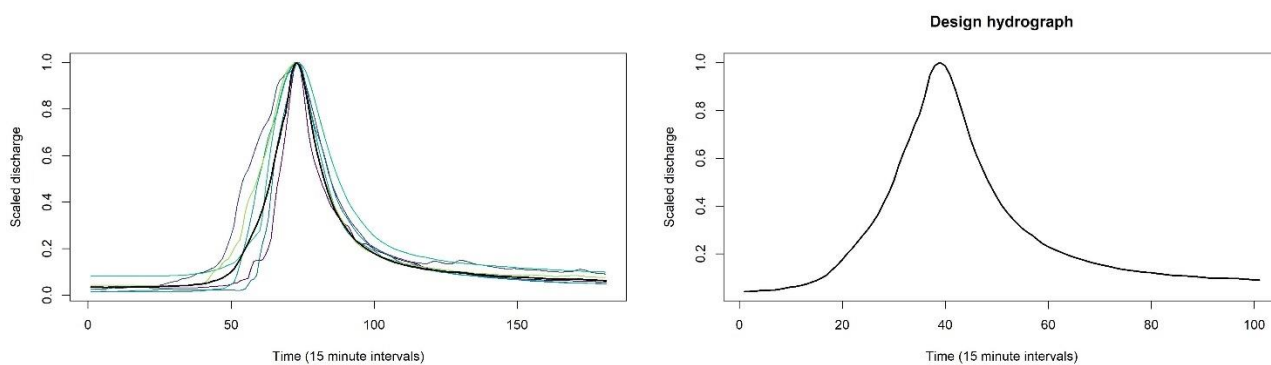


Figure 2.13: Average hydrograph shape

Table 2.1: Design hydrograph events

Date-Time	Peak (m ³ /s)
21/11/2016 20:15	31.9
26/10/2008 07:00	27.8
12/10/2012 02:00	27.8

Date-Time	Peak (m ³ /s)
05/10/2017 04:00	26.4
11/11/1991 04:30	26.3
12/12/2015 18:45	26.1

2.4.1 Flood statistics

Figure 2.14 shows the annual maximum (AMAX) flow for the River Medlock at the London Road gauge. The three years between 1989 to 1992 are noted as being excluded from the data set due to construction works taking place, with direct effect on flow through the gauging station. There does not appear to be any further outliers, step changes or trends observable within the AMAX series. A Mann Kendal trend test results in a tau of 0.118 and a p-value of 0.21 (two sided).

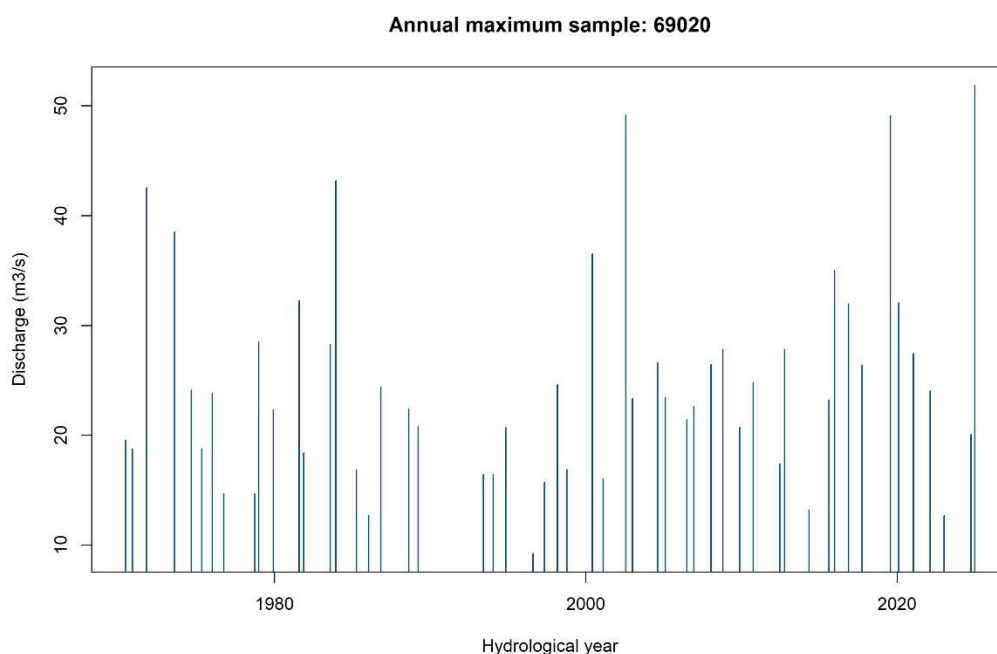


Figure 2.14: Annual maximum sample at London Road

2.4.2 Flood response

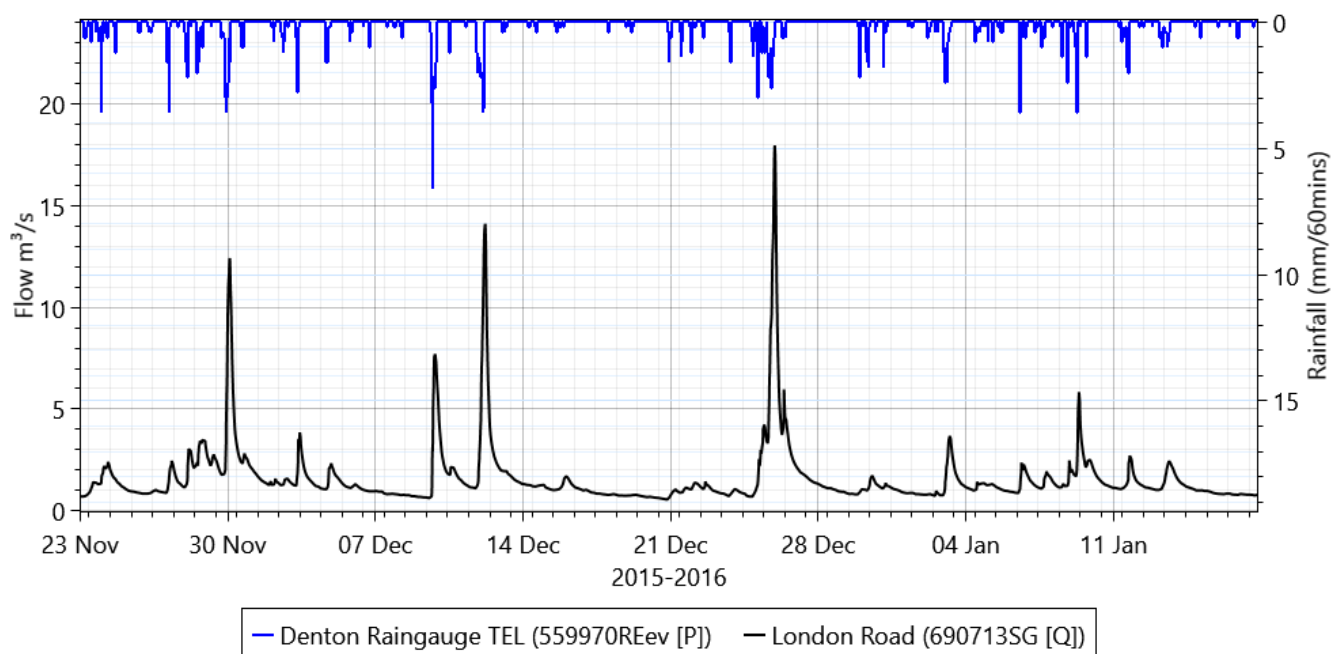


Figure 2.15. Flow (m³/s) at London Road gauge on the River Medlock between November 2015 - January 2016.

Figure 2.15 presents flow (m³/s) at the London Road gauge. Several high flow events are identified which exceed the peaks over threshold (POT) of 11.4m³/s (ref). A rapid rising limb is identified during all events, indicating rapid response to rainfall inputs to the catchment. Smaller events during this period, such as on 09/01/16 present a similar response, therefore suggesting consistency within flood generation between varying event magnitudes.

2.4.3 Conceptual model

The main site and upstream gauge are within a heavily urbanised catchment, which produces a rapid/flashy runoff response to rainfall. Lower flows are affected by urban drainage and sewer systems, but these are unlikely to have a significant impact on peak flows. Storms of between seven and fifteen hours tend to cause the observed high flows with an associated peak response approximately three to five hours after the centroid of rainfall. The loss associated with storm events vary from 50% to 90% - see below with two examples having 56% and 78% loss respectively (flow separation done with the Flow Split function in UKFE). The falling limb tends to return to near pre-storm conditions within 24 to 48 hours (assuming no further rainfall).

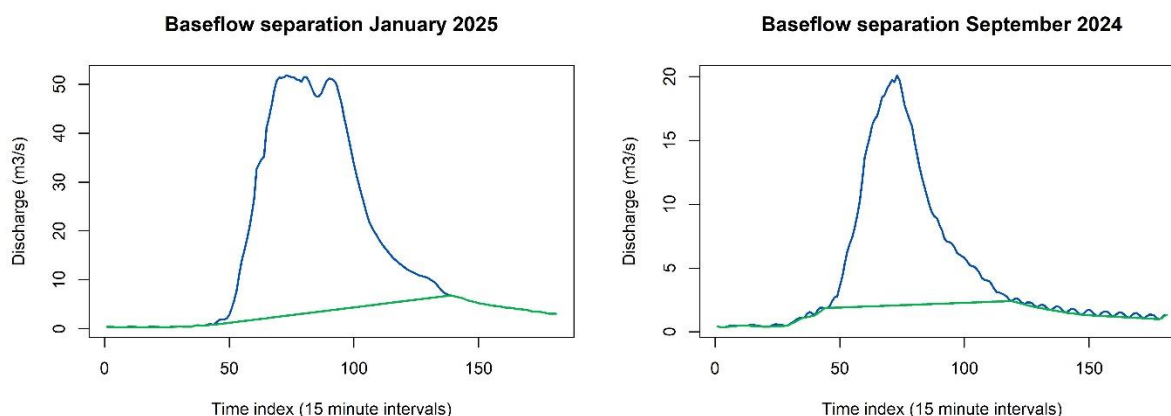


Figure 2.16: Flow separation for two observed events

With this in mind, we can conceptualise the catchment response to a 10-hour event, with the most intense part of the rainfall event at approximately the fourth to fifth hour and the hydrograph peaking three to four hours after. The peak flow is then during the 8th hour, and the flow begins to recede dropping off to the baseflow over the next 24 hours or so.

2.4.4 Unusual catchment features

The catchment is heavily urbanised, particularly at the downstream end, which is likely to influence flood generation. Runoff is also affected by effluent discharges⁵. Whilst there are additional watercourses in the catchment, including the Ashton Canal, this has no interaction with the River Medlock.

2.5 Initial choice of approach

Are FEH methods appropriate: Yes

Initial choice of method(s) and reasons:

The catchment is gauged, with a record length of over 50 years, including peak flow data and QMED suitability. This favours use of the FEH-Statistical method. The gauged record can also be used to derive a hydrograph shape.

⁵ NRFA (undated). 69020 – Medlock at London Road. Available at: <https://nrfa.ceh.ac.uk/data/station/info/69020>

How will hydrograph shapes be derived, if needed:

Hydrograph shapes will be derived using the gauged flow record.

Will the catchment be split into sub-catchments? If so, how:

Due to the proximity of the gauge to the subject site, a single inflow point is considered suitable for the hydraulic model boundary condition. Lateral inflows will be applied to the model by scaling the peak flows between the upstream gauged point and the Medlock in proximity to the site of interest.

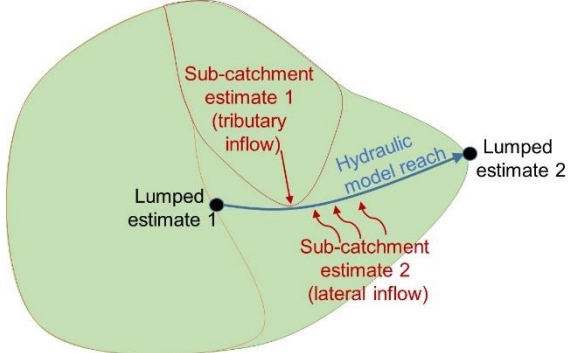
Source of flood peak data & software to be used:

- NRFA peak flow dataset, v13.1 (September 2024)
- FEH Web Service⁶
- R package UKFE v0.4.0
- ReFH 2.3-FEH22 Calibrated

2.6 Selection of flood estimation locations

Site code	Type of estimate:	Watercourse	Site name / description	Easting	Northing
MedlockU S	L	River Medlock	Upstream model extent on the River Medlock and the location of the London road gauge	384840	397530
MedlockD S	L	River Medlock	Downstream location on the River Medlock.	383450	397330

⁶ CEH 2015. The Flood Estimation Handbook (FEH) Online Service, Centre for Ecology & Hydrology, Wallingford, UK.

Site code	Type of estimate:	Watercourse	Site name / description	Easting	Northing
					

L = lumped catchment; S = sub-catchment

3 Locations where flood estimates are required

3.1 Catchment boundary checks and revisions

The FEH Webservice catchment boundary was checked against 50m DTM data. No amendments were made to the catchment boundary. Other catchment descriptor checks and revisions:

URBEXT:

URBEXT2000 is 0.37 for the catchment at the downstream estimation point which is consistent with the high urban land cover. URBEXT2000 was updated using the Urban Expansion Factor for 2025.

BFIHOST:

BFIHOST19 is 0.38 for the catchment at the gauge estimation point, which is a little lower than the observed baseflow index of 0.47.

FARL:

There are several small reservoirs or storage areas in the upper catchment. However, these are all below 0.012km², and the FARL of 0.97 remains high, therefore suggesting these have limited impact on flood generation.

Version of URBEXT: URBEXT2000

Version of BFIHOST: BFIHOST19

3.2 Catchment descriptors

Final catchment descriptors at each subject site:

Site code	AREA on FEH Web Service (km ²)	Revised AREA (km ²)	BFIHOST19	DPLBAR (km)	DPSBAR (m/km)	FARL	FPEXT	PROPWET	SAAR (mm)	URBEXT 2000
MedlockUS	57	NA	0.381	12.76	58.5	0.97	0.11	0.55	1025	0.335*
MedlockDS	64	NA	0.377	13.45	53.6	0.98	0.13	0.54	1010	0.418*
*Denotes values that were manually adjusted from their default value.										

4 Stationary statistical methods

4.1 Estimating QMED

4.1.1 QMED at gauged subject sites

Site code	Method	Initial QMED (m ³ /s)	Water years used	Number of water years used	Adjustment for climatic variation?	Final QMED (m ³ /s)
MedlockUS	AM	23	1969 – 2024 (the final one being a partial year but including the highest peak on record)	53 (two years missing)	N	23

QMED estimation methods: **AM** – Annual maxima

4.1.2 QMED at ungauged subject sites

Site code	Method	Initial QMED (rural) from CDs (m ³ /s)	Donors used (NRFA numbers)	Donor distance from subject centroid (km)	Moderation term (α) value	Final donor adjustment factor	Urban adjustment factor	Final QMED (m ³ /s)
MedlockDS	DT	27	69020	0.8	1	0.96	1.45	26

QMED estimation methods: **DT** - catchment descriptors with donor transfer

Donor distance weighting method:

Moderation term not applied (full donor adjustment).

Multiple donors:

Only one donor was used.

Parameters used for WINFAP v4 urban adjustment:

No urban adjustment applied.

4.1.3 Search for donor sites

Discussion of selected donor sites / rejected donor sites:

The London Road (69020) gauging station on the River Medlock is less than 3km upstream of the site of interest and the associated flow estimation point. The catchments are very similar, and the centroids are less than a km apart. Due to the proximity and similarity, the gauge is identified to be a suitable donor for the downstream site.

Donor sites chosen and QMED adjustment factors:

NRFA no.	Method	Adjustment for climatic variation?	QMED from flow data (m ³ /s)	Urban adjustment factor	Urbanised QMED from catchment descriptors (m ³ /s) (A)	QMED from catchment descriptors (m ³ /s) (B)	Adjustment ratio (A/B)
69020	AM	N	23	1.375	34	24	0.71

Methods: **AM** – Annual maxima

4.2 Estimating growth curves

4.2.1 Derivation of pooling groups

Name of group	Small catchment pooling procedure applied?	Site code from whose descriptors group was derived	Subject site treated as gauged? (ESS)	URBEXT2000 threshold applied to pooling group selection	L-moments deurbanised (including subject site for ESS)
PoolUS	No	MedlockUS	Y	<0.03	L-CV: 0.23 L-SKEW: 0.146

Methods: Unless otherwise stated, pooling groups were derived using the procedures from Science Report SC050050 (2008). The small catchment pooling procedure is given in the report on Phase 2 of project SC090031 (2021) and implemented in WINFAP v5 / UKFE.

4.2.2 Pooling group composition

Name of group	Changes made to default pooling group	Weighted average L-moments	Weighted average L-moments with non-flood year adjustment
PoolUS	None	L-CV: 0.254 L-SKEW: 0.146	N/A (no records with greater than 15% non-flood)

4.2.3 Derivation of growth curves at subject sites

Site code	Method	If P or ESS, name of pooling group	Distribution used and reason for choice	Any urban or non-flood years adjustments	Parameters of distribution (location, scale and shape)	Growth factor for 1% AEP
MedlockUS	ESS	PM_DS	Gen. Logistic had the closest absolute z-score to 0.	Urban adjustment applied.	1, 0.261, -0.146	2.7
MedlockUS	SS – L-moments				1.00, 0.209, -0.222	2.7
MedlockUS	SS, MLE				1.00, 0.209, -0.255	2.8

Methods: **SS** - Single Site; **P** - Pooled; **ESS** - Enhanced Single Site; **H** - Historical.

Pooled and ESS growth curves were derived using the procedures from Science Report SC050050 (2008). Urban adjustments are carried out using the method of Kjeldsen (2010) which is used within the WINFAP v4 urban adjustment procedures using URBAN rather than URBEXT2000.

4.2.4 Flood frequency curve plots

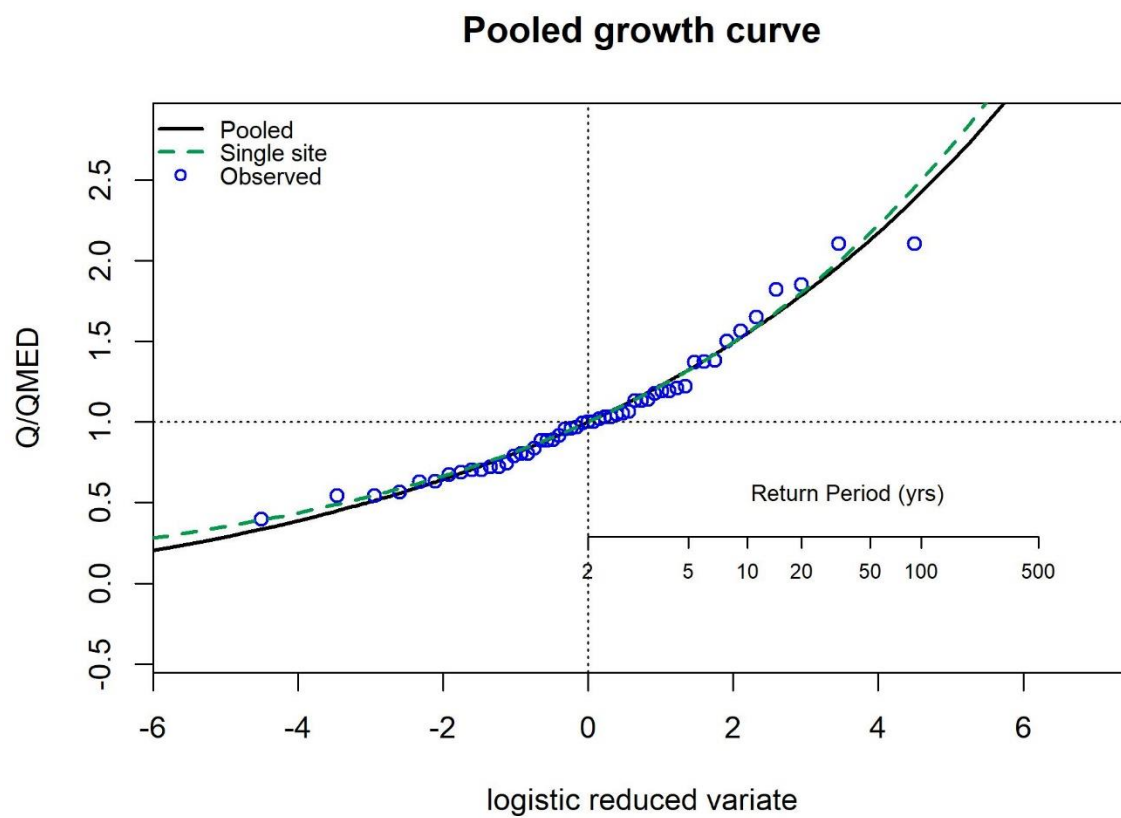


Figure 4.1: Single site and ESS growth curve (GLO)

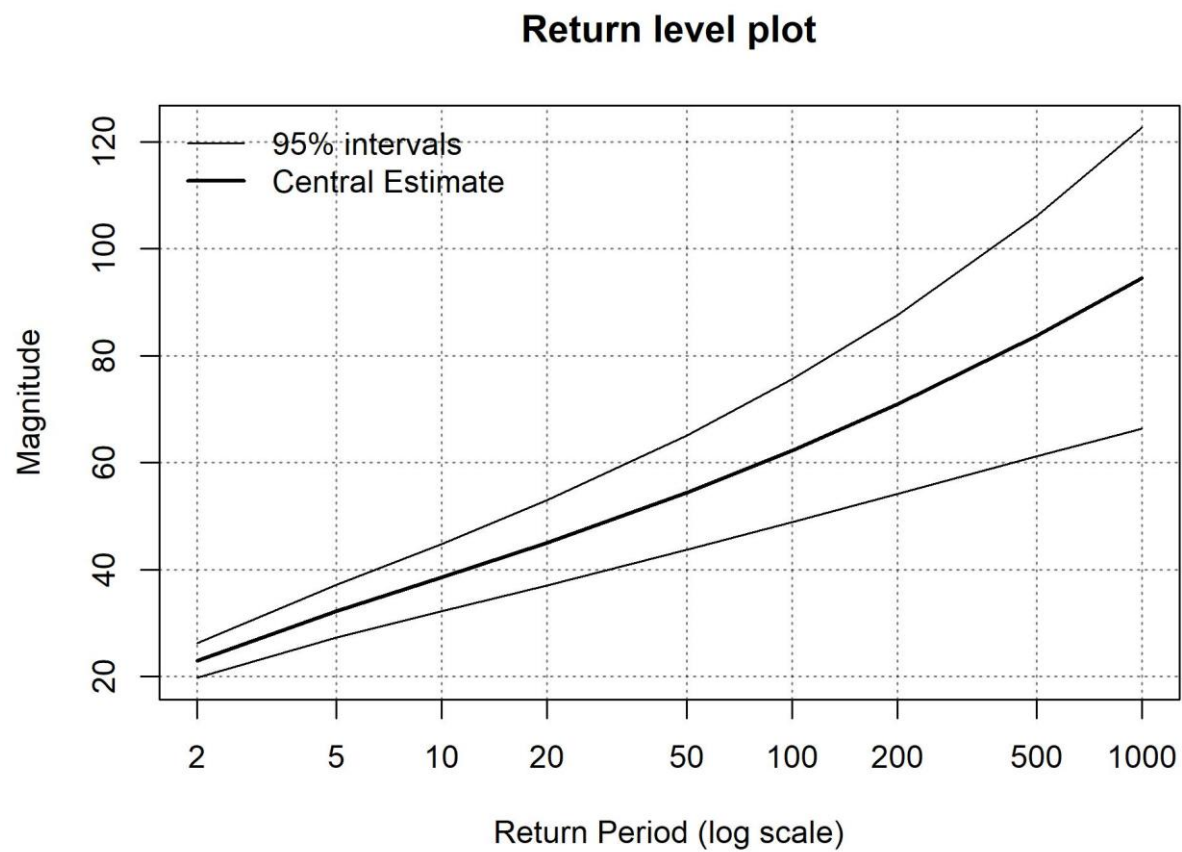


Figure 4.2: Return level plot with uncertainty for the ESS GLO analysis

4.3 Final choice of QMED and growth curves

Site code	Final choice of QMED and reasons	Final choice of flood growth curve method and reasons
MedlockUS	The final choice of method was the Enhanced Single Site analysis based on the London Road Gauge.	The gauge is less than 3km upstream from the subject site, it has more than 50-years of AMAX and is classified as suitable for pooling. On further inspection there seemed little reason to doubt this categorisation. The rating fits well to the spot gauging's and the flow has been constrained to the channel throughout the record length. The ReFH2.3 model was also applied with default settings for comparison.

4.4 Final flood estimates from stationary statistical methods

Site code	50%	20%	10%	5%	3.3%	2%	1.3%	1%	0.5%	0.1%
MedlockUS	23	32	39	45	49	54	59	62	71	95
MedlockDS	26	36	44	51	55	61	67	70	80	107

Flood peak in m³/s for the AEP (%) events

5 Revitalised Flood Hydrograph 2 (ReFH2) method

5.1 Model parameters

5.1.1 Summary of rural model parameters:

Site code	Method	Tp (hours) rural	Cmax (mm)	BL (hours)
MedlockUS	CD	4.47	270.94	39.62

Methods: **CD**: Catchment descriptors

5.1.2 Summary of urban model parameters:

Site code	Area modelled as urban (km ²)	TP urban scaling factor	IF	IRF	DS
MedlockUS	32.87	0.75	0.4	0.7	0.5

5.2 Comparison with observed events

The ReFH2.3 model was applied, with the above stated parameters and observed rainfall to compare against observed flows. Firstly, a single peaked event was chosen for which 15-minute resolution catchment average rainfall was available (derived as per section 2.3.2). As can be seen from Figure 5.1 to Figure 5.3, the fit is reasonable. No parameters were changed and only the initial conditions Cini (set at 15mm) and Bfini (set as observed) needed to be adjusted (BR was 1.08). The resulting ReFH2.3 modelled loss for the observed event is 73% which, based on analysis of other observed events, is typical of the catchment. It is also very similar to the loss calculated using the baseflow separation method which was 78% (see Figure 2.16). Secondly, the rainfall for the largest event (January 2025 – see Figure 2.12) was run through the model in the same way. In this case, the fit was reasonable when adjusting the Cini to 55, which provided a loss of 54%. This, again, is similar to the loss calculated via baseflow separation which was 56% (see Figure 2.16).

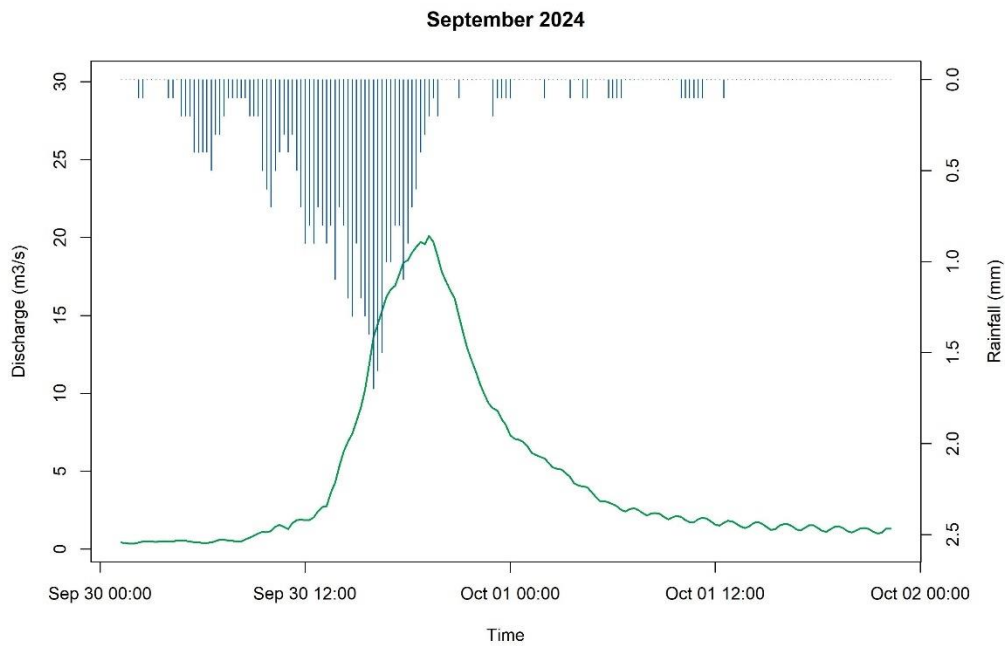


Figure 5.1: Observed catchment rainfall and flow (London Road)

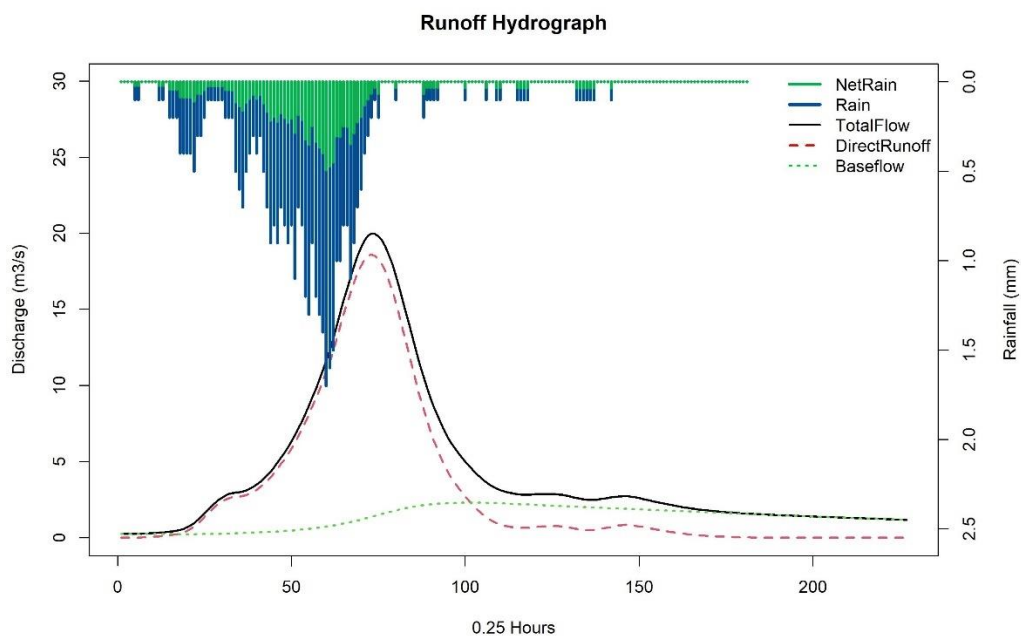


Figure 5.2: Modelled flow from observed rainfall (September 2024)

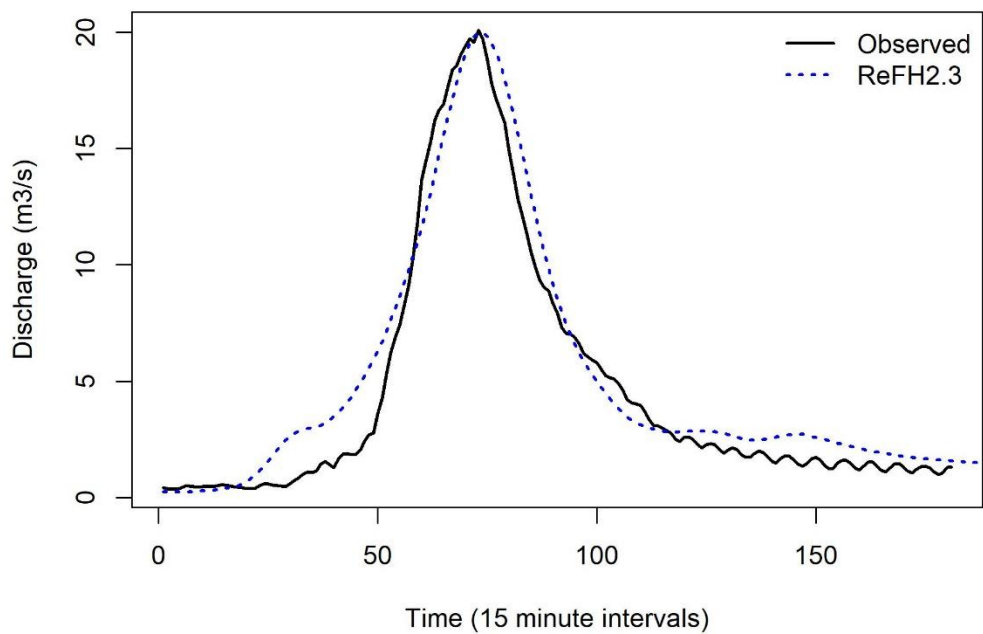


Figure 5.3: Modelled versus observed flow event (September 2024)

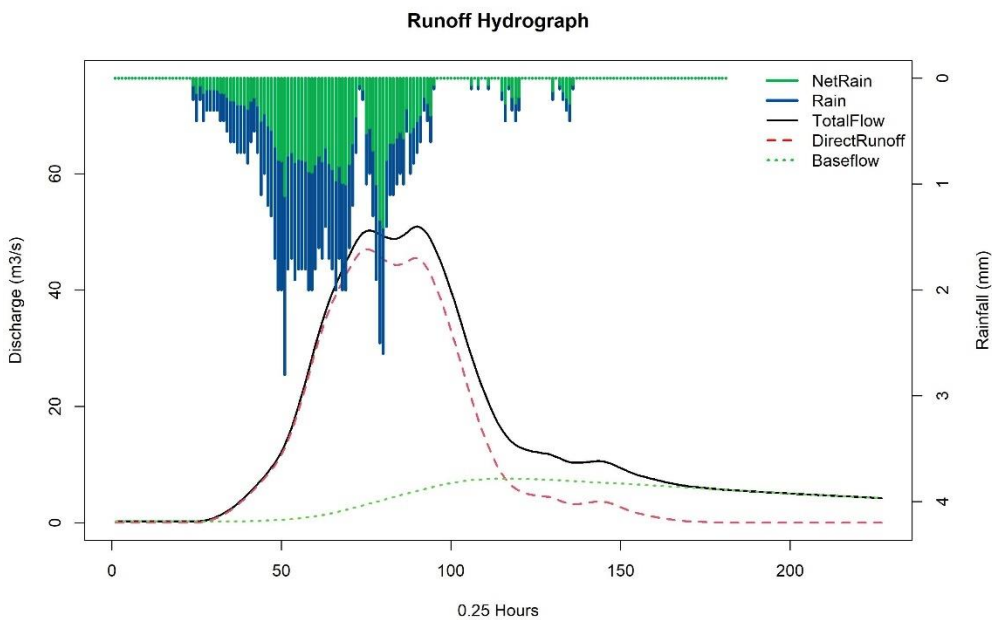


Figure 5.4: Figure 5.2: Modelled flow from observed rainfall (January 2025)

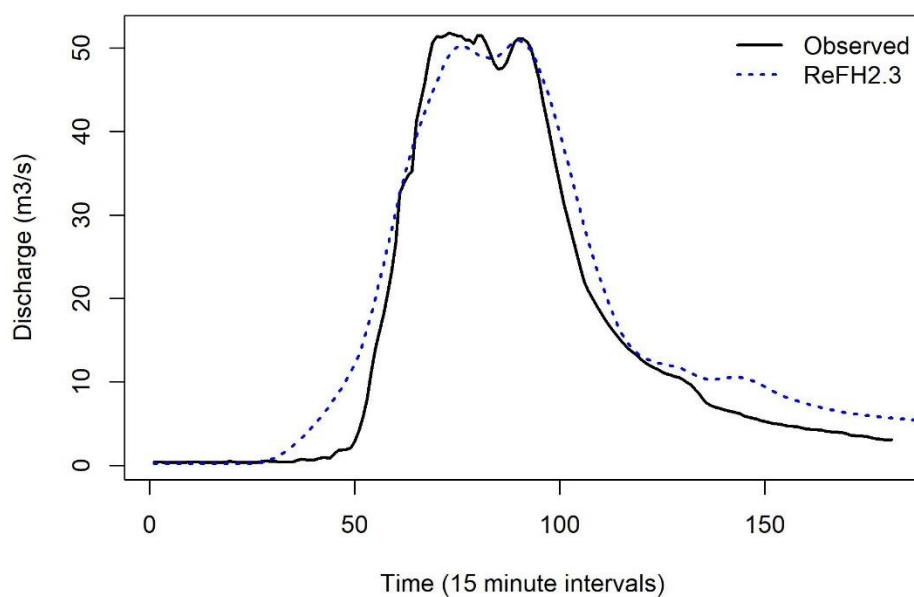


Figure 5.5: Figure 5.3: Modelled versus observed flow event (January 2025)

5.3 Model inputs for design events

Design events for lumped catchments:

Site code	Default season of design event	Storm duration (hrs)	Initial soil moisture, Cini	Initial baseflow, BF0
MedlockUS	Summer	9.5	86.55	1.86

Note: Design storm(s) to be applied to a hydraulic model are detailed in Section 6.3.

Rainfall depths (after ARF and SCF) and associated BR values (duration 9.5 hours):

AEP%	Depth (mm)	BR
50	26	1.72
20	35	1.60
10	41	1.53
5	48	1.45
2	58	1.34

AEP%	Depth (mm)	BR
1	67	1.26
0.5	75	1.18
0.1	100	0.98

Is the catchment groundwater-dominated:

No

Which rainfall DDF model has been used:

FEH22

Given the reliable fit to observed events the ReFH2.3 model appears to be a reasonable choice for estimating the growth curve. To consider the range of possible initial conditions, inputs and uncertainty in the rainfall extremes, a Monte Carlo simulation approach was applied, using the ReFH2.3 model (coded in R). The model was run 100 times, each having the parameters as above but randomly sampling from a plausible range of initial conditions and the sampling distribution of the rainfall depth. Each time the model was run in this way a random rainfall profile for the duration of interest was selected. This was done for five durations (8 to 12 hours) for a total of 500 runs. Furthermore, it was done for the 50%, 2%, 1%, and 0.1% AEP depths for those durations (see Table 5.1). Although the flow data shows weak seasonality (events can occur throughout the year), the summer seasonal correction factor (SCF) was applied for the purposes of precaution (the winter SCF reduces the depths more).

The sampling of the baseflow and Cini was uniform with a range for the baseflow between the lowest mean flows across the months ($0.5\text{m}^3/\text{s}$) (see Figure 2.8) and $2\text{m}^3/\text{s}$ (the highest monthly mean flow is $1.35\text{m}^3/\text{s}$ and the default CDs estimate is $1.86\text{m}^3/\text{s}$). The range for Cini was set from 10mm to 100mm. This was chosen because 15mm was necessary for the fit to the 2024 event, 55mm was necessary for the 2025 event and the CDs estimate is 86.55mm.

The rainfall was sampled from the assumed sampling distribution assuming a factorial standard error of 1.02, 1.06, 1.08, and 1.12 for the 50%, 2%, 1%, and 0.15%AEP depths, respectively. The sampling was undertaken using Equation 1, where N denotes the normal distribution, P_s is the sampling distribution for the rainfall estimate, P_c is the central estimate and P_{FSE} is the factorial standard error. The central estimate for the sampling was

Equation 1

$$P_s = \exp[N(\ln(P_c), \ln(P_{FSE}))]$$

The rainfall simulation, for each timestep, was generated randomly using an exponential distribution, but was set to generate front, uniform, middle, and back loaded profiles at random. These were scaled to sum to unity and multiplied by the selected depth from Equation 1. An example of each rainfall profile type, for 12 timesteps, is provided in Figure 5.6.

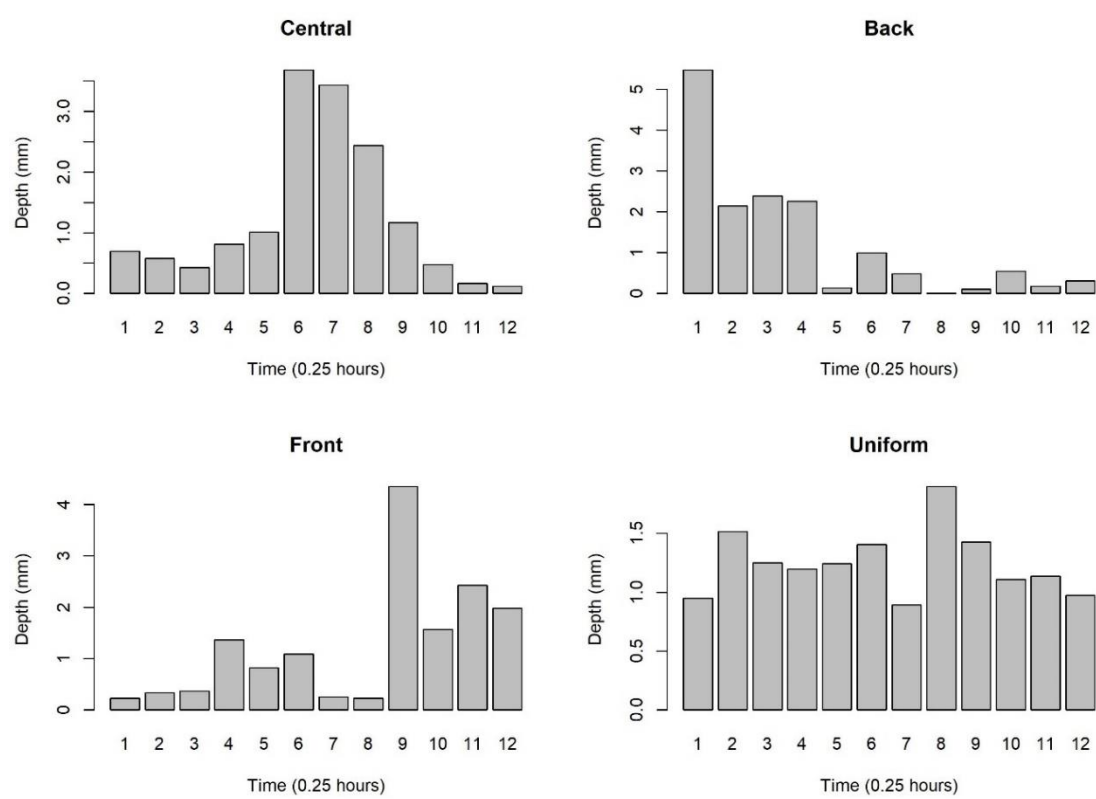


Figure 5.6: Examples of randomly simulated rainfall profiles

Table 5.1: Central estimate of rainfall depths (mm) for the range of durations

Duration (hrs)	50%AEP	2%AEP	1%AEP	0.10%AEP
8	25	54	61	93
9	26	57	64	98
10	27	59	67	102
11	28	61	70	106
12	29	63	73	110

The distributions of peak flows from the Monte Carlo analysis can be seen in Figure 5.7. The mean of these distributions and the associated factorial standard errors (FSE) can be seen in Table 5.2. The FSEs were calculated using Equation 2, where $\bar{q}$ is the mean of the distribution and q_i is a single peak from the distribution.

Equation 2

$$FSE = \exp \left[\sqrt{\frac{1}{n} \sum_i^n \{\ln(\bar{q}) - \ln(q_i)\}^2} \right]$$

However, there is greater certainty for the QMED estimate than the Equation 2 would suggest when only considering the outputs of the Monte Carlo analysis. Therefore, they have been adjusted so that the 50%AEP is the same as the FSE for the observed QMED. The FSE values for the less frequent events were divided by this reduced QMED FSE to derive the final FSE values in Table 5.2.

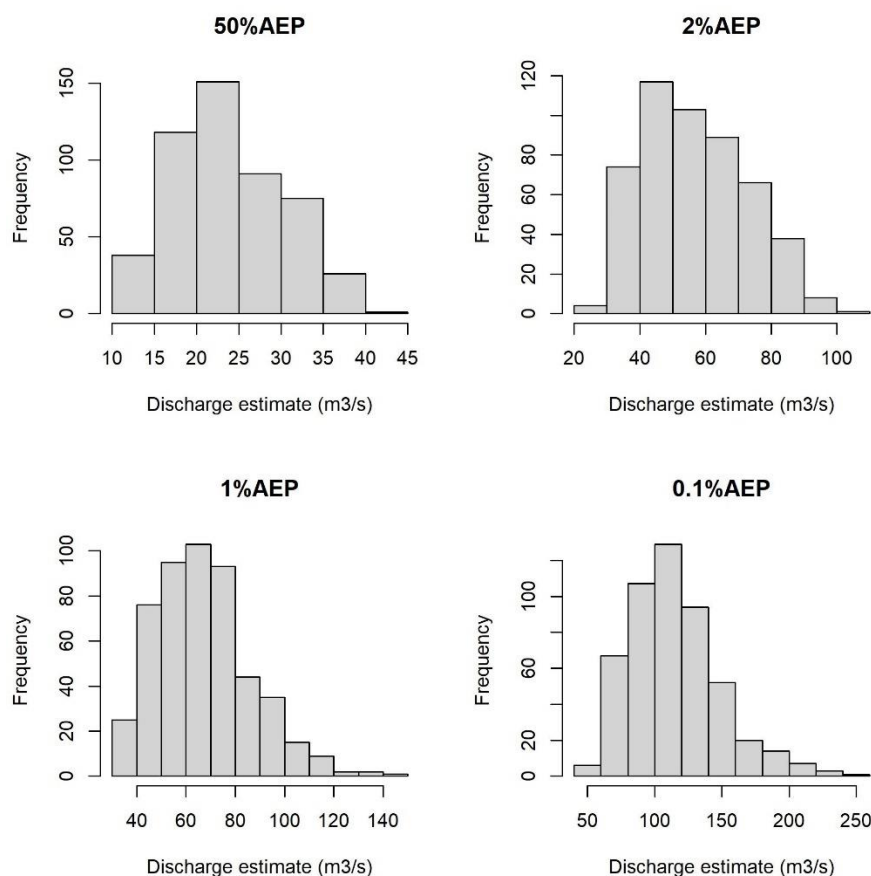


Figure 5.7: Peak flow results from the Monte Carlo analysis

Table 5.2: Mean results and FSEs for the Monte Carlo derived estimates

AEP%	Q (m3/s)	FSE
50	23.2	1.06
2	55	1.18
1	65	1.2
0.1	111	1.29

To interpolate between design events the GLO distribution was optimised on the results of Table 5.2, providing parameters of 23.2, 5.15, and -0.23, for the location, scale, and shape, respectively.

5.4 Final choice of ReFH2 flow estimates

Method choice and reasons:

Site code	Final choice of design inputs and model parameters
MedlockUS	ReFH2.3 method with Monte Carlo mean estimates. The parameters were seen to fit observed events well. The baseflow and Cini parameters were considered based on observed events and the Monte Carlo approach facilitates the quantification of uncertainty in the estimates. As the FEH states, catchment descriptors alone should be a last resort.
MedlockDS	Same growth curve as derived for MedlockUS is assumed and the QMED is the observed QMED at MedlockUS multiplied by the DS and US ReFH2.3 peak flow for the 50%AEP. i.e. $23 * (30/29) = 25\text{m}^3/\text{s}$.

Details for distributed modelling using a hydraulic model are provided in Section 6.3.

Estimates from ReFH2.3 method:

Site code	50%	20%	10%	5%	3.3%	2%	1.3%	1%	0.5%	0.1%
MedlockUS default deterministic Approach	28	38	45	53	58	66	72	77	91	126
MedlockUS Monte Carlo mean results	23.2	32	38	45	50	56	61	65	76	110
MedlockDS default deterministic Approach	30	41	49	57	63	71	78	83	98	137
MedlockDS Monte Carlo growth curve	25	35	41	48	54	61	65	70	82	118

Flood peak in m³/s for AEP (%) event

The final ReFH2.3 results taken forward are the results from the Monte Carlo analysis (second row in the table above). Note that the QMED estimate is the same as that observed at the gauge. The choice of result downstream is the fourth row in the table which applies the same growth curve as defined by the Monte Carlo 'mean estimate' at the upstream gauged site. The 50% AEP flow for the MedlockDS (for multiplying by the aforementioned growth curve) is

the observed QMED at the gauge (23m³/s) multiplied by the ratio of the ReFH2.3 deterministic MedlockDS QMED to the ReFH2.3 deterministic MedlockUS QMED. i.e. $23 * (30/29) = 25\text{m}^3/\text{s}$.

An associated return level plot with uncertainty bounds is shown in Figure 5.8. Note that the uncertainty bounds are wider than those for the statistical ESS method (Figure 4.2). However, the ReFH2.3 return level plot encompasses both sampling uncertainty (for the estimates of rainfall) and components of epistemic uncertainty associated with the rainfall inputs and the initial conditions. The ESS uncertainty only includes the sampling uncertainty (aleatoric uncertainty) assuming a particular distribution fit (it does not include uncertainty due to user choices).

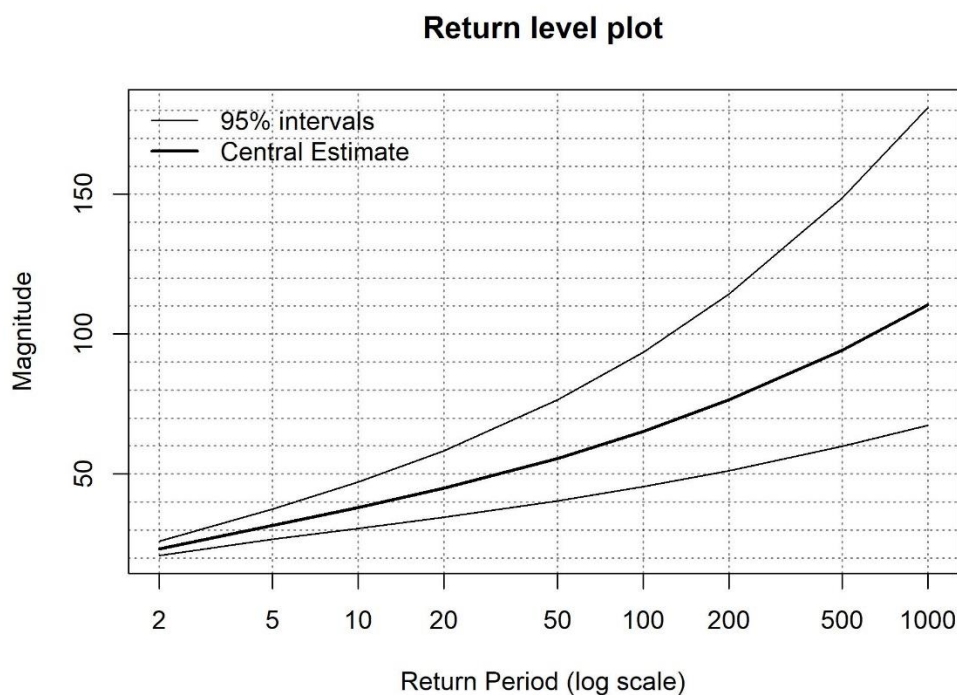


Figure 5.8: Return level plot for ReFH2.3 Monte Carlo results

6 Discussion and summary of results

6.1 Comparison of results from different methods

Site code	ReFH2 peak flow (m ³ /s), 50% AEP	Statistical peak flow (m ³ /s), 50% AEP	ReFH2 peak flow (m ³ /s), 1% AEP	Statistical peak flow (m ³ /s), 1% AEP
MedlockUS	23.2	23.3	65	62
MedlockDS	25	26 (donor adjusted)	70	70

Site code	Ratio (ReFH2 / Stat), 50% AEP	Ratio (ReFH2 / Stat), 1% AEP
MedlockUS	1	1.05
MedlockDS	1.04	1

6.2 Final choice of method

Choice of method and reasons:

The ReFH model was seen to fit well to observed events and Monte Carlo analysis facilitated the quantification of uncertainty associated with both rainfall extremes and initial conditions. The process-based modelling of the ReFH2.3 model provides a constraint on the peak flow estimates providing confidence over a purely empirical probability model-based approach. It is clear that the Monte Carlo approach and the ESS approach are preferable to the default ReFH2.3 results because they are based on the gauged data. The choice between these is perhaps a moot point given their similarity. However, the Monte Carlo approach is not commonly applied, and therefore ESS is the final choice of method for the purposes of an expedient review process.

6.3 Application of inflows to a hydraulic model

How will the flows be applied to a hydraulic model?

Intervening area flows are to be apportioned within the hydraulic model at known CSO inflow locations. The design hydrograph derived in 2.4 will be used for the upstream boundary and will be scaled to the necessary peaks.

6.4 Checks

Growth factor checks:

Site code	1% AEP growth factor	0.1% AEP / 1% AEP ratio	Comments
MedlockUS	2.82	1.69	Within the inter quartile range of growth factors and growth factor ratios for 543 sites considered suitable for pooling (assuming a GLO).

Specific discharge:

Site code	50%	1%	Comments
MedlockUS	0.56	1.14	Within the 68% intervals of specific discharge for 543 sites considered suitable for pooling (assuming a GLO for the 1%)

Site code	50%	1%	Comments
MedlockDS	0.41	1.14	Within the inter quartile range of specific discharge for 543 sites considered suitable for pooling (assuming a GLO for the 1%)

Flood peak in $\text{m}^3/\text{s}/\text{km}^2$ for the AEP (%) events.

Spatial consistency of results:

Yes, flows increase moving downstream.

Frequency of notable historical floods:

There is no record of flooding at the site of interest.

Compatibility with longer-term flood history:

The discharge has not come out of bank at London Road for the duration of the record (50+ years). It is therefore not possible to compare observed floods with modelled flow frequency at the associated bank exceedance.

Comparisons with previous studies:

Previous flow estimates undertaken were for an ICM model which applied different methods so there is no direct comparison of results. However, a more recent flood estimation record completed by JBA consulting was undertaken in October 2024. Due to the presence of a good quality flow gauge the results are similar to the final results in this study. The 50%, 1%, and 0.1%AEP peak flows estimated were 23.3, 58, and 92 m^3/s , respectively.

6.5 Assumptions, limitations, and uncertainty

Assumptions:

- The FSEs for rainfall used in the Monte Carlo analysis are the same as an average FSEs calculated on daily catchment rainfall for the Thames at Kingston and the Tay at Ballathie (catchment rainfall from the NRFA).
- For the statistical method it is assumed that the AMAX distribution is of the Generalised logistic form, that all AMAX (at site and within the pooling group) are independent and identically distributed, that all AMAX in the pooling group are identically distributed except for a scaling factor, and that the AMAX samples between sites are not correlated.

- The ReFH2.3 model was shown to provide good results up to the highest peak flow on record (52m³/s). It is assumed that the model can reasonably extrapolate to greater than double the observed rainfall and peak flows.

Limitations:

- The catchment is heavily urbanised, with changes to the urban extent and channel potentially having occurred during the gauged record.
- There is only one flow gauge in proximity to the site of interest, and it has 53 years of annual maxima.
- There is no record of recent flooding and flooding noted in proximity to the locations of interest occurred over 100-years ago. It is assumed that much has changed within the catchment over that time.
- The concurrently available sub-daily rainfall for the rain gauges with weighting (Voronoi polygons), is only from 2020 onwards.
- There is no information about the uncertainty in rainfall estimates. The associated FSE are based on daily catchment rainfall extremes for sites with + 50 years of data.
- Catchment boundary in the urban area may be uncertain due to known CSO influence. Effluent release from CSO may impact flows.

Uncertainty:

- The aleatoric and components of epistemic uncertainty were quantified using a Monte Carlo simulation approach and the resulting FSEs and intervals can be seen in Table 5.2 and Figure 5.8.
- Uncertainty at the gauged downstream estimation point relates to data uncertainty of the modelled flows, choice of estimation method and parameter uncertainty.

6.6 Final results

Final method applied:

- For the upstream estimation point, the ESS method at the London Road gauging station is the final method applied.
- For the downstream estimation point, the same growth curve is assumed, and the index flood (QMED) is derived by donor transfer.

Site code	50%	20%	10%	5%	3.3%	2%	1.3%	1%	0.5%	0.1%
MedlockUS	23	32	39	45	49	54	59	62	71	95
MedlockDS	26	36	44	51	55	61	67	70	80	107

Flood peak in m³/s for the AEP (%) events.

Uncertainty:

Site code	50% AEP Lower 95%	50% AEP Upper 95%	5% AEP Lower 95%	5% AEP Upper 95%	1% AEP Lower 95%	1% AEP Upper 95%
MedlockUS	20	26	35	58	45	93
MedlockDS	23	29	39	65	51	104

Upper and lower 95% confidence bounds for the flood peak in m³/s for the AEP (%) events.

Climate change estimates:

Climate change estimates are as above but increased by a percentage according to the Environment Agency's climate change allowance for the River Irwell management catchment. These percentages can be seen in the table below.

Epoch	Central	Higher	Upper
2020s	12	15	24
2050s	19	26	43
2080s	35	46	75

Suitability of results for future studies:

The work undertaken herein and the associated results are for the purposes detailed in this report. The suitability of these results for future use is dependent on the purpose of the study for which they are used, and any justification for their use is the responsibility of those using them

Recommendations for future work:

'Spot gauging's' are recommended at London Road above LMED to provide further confidence in the observed peak flows.

Quantification of uncertainty of the design rainfall estimates would provide useful information for inputs to design rainfall runoff modelling.

7 Appendix

7.1 Other supporting information

Flood History:

Data available

Table 7.1. Summary of historic flood events in the River Medlock catchment.

Event date	Details	Source
Aug 1799	On the Medlock Irk and Tame many bridges have been washed down.	BCFF
Jul 1829	Manchester: People were struck and injured by lightning The river Medlock never rose so high in living memory	BCFF
1833	1833 River Medlock "credited by J.F. Bateman [Proc I.C.E. Vol 67] with 107 cusec/sq. mile"	CBHE
Sep 1847	Manchester had 3.13 inches during the week. The Rivers Irwell Medlock and Irk were in high flow and caused problems with mills due to the amount of sediment.	BCFF British Newspaper Archive
Feb 1852	Lower Broughton Road, Great Clowes Street, Hough Lane, and other streets in the neighbourhood were flooded, and their inhabitants on returning from work had to be taken home by boat. The lower part of Peel Park was covered with water to a depth of four feet. The Medlock, Irk, Mersey, Goyt, and Black Brook, also overflowed and did considerable damage'.	CBHE
Aug 1856	The rivers Irk Medlock Irwell and Tib rose to a height not known for many years. The River Medlock rose 15 feet above ordinary level and flooded a vast number of warehouses storehouses and cellars, mainly in Downing St and Buxton St off London Road.	BCFF
Aug 1857	Along the Medlock the water rose 3 to 5 feet higher than last August; many properties were flooded this time which escaped in the 1856 flood, including Chorlton Mills. An engineer's premises at Great Marlborough St were flooded to 8 feet. Mills in Zara Street and Temple Street on the other side of the Medlock were also flooded; chemical works in Jackson St were flooded as was the Hanover Mill in Buxton Street.	BCFF British Newspaper Archive
Dec 1860	1860 December 6 'In consequence of the heavy rains, the river Medlock overflowed its banks, causing much inconvenience and loss to property owners'.	CBHE
Jun 1863	The heavy rains during the last week caused serious floods in Manchester and its neighbourhood. The three streams which run through Manchester-the Irk, the Irwell, and-the Medlock rose considerably, and much damage and obstruction ...	British Newspaper Archive
Nov 1866	Along the course of the River Medlock the following places were flooded, a coachbuilder near Ardwick bridge, houses in Tipping St, Tennant's Chemical Works, a spinning mill at Jackson Street and an iron works, a dyeing company at Brook Street and scores of other places along the river. Inhabitants left their houses in Broughton and Strangeways where buildings had become unstable.	BCFF

Event date	Details	Source
Jul 1867	Manchester: the River Medlock had risen 7 or 8 feet overnight and rose with unexampled suddenness. The body of a woman was found in the river next morning. Phillips Park cemetery was flooded to 4 or 5 feet and coffins were floating about. The inquest concluded she had been washed out of a grave.	BCFF

Event date	Details	Source
July 1872	<u>Internet search</u> "...It was about half past twelve when the floods came ... the banks of the Medlock were overflowed to such an alarming extent and the first intimation of the flood was the sweeping away of a footbridge near to Philips Park.....The flood increased in depth and power, and at a length swept in a fierce torrent over a large portion of ground apportioned to the Roman Catholics at the Bradford Cemetery carrying away not only tombstones but actually washing out of their graves, a large number of dead bodies. 'Indeed, from the first indication of danger, so far as works on the banks of the Medlock were concerned, dead bodies were observed floating down the river, and those watching could easily see that the bodies had been disinterred out of the Bradford cemetery. It is impossible to calculate how many had been swept out of their final resting place, but the number is not short of fifty.' Afterwards there were rumours that as many as five hundred bodies had been swept away, with large numbers lost at sea. " <u>BCFF</u> Manchester: the River Medlock overflowed its banks to an extent which eclipsed all former floods including the one in 1866. The districts bordering the Medlock, which flows through Manchester from Phillips Park to Knott Mill, has been quite laid under water and affected some of the most populous parts of the city. The districts affected include Bradford, Beswick, Ancoats, Fairfield Street, London road, Brook Street, Charles Street, Oxford Road and on through Gaythorn. The Medlock at its peak was 21 feet above its normal level. Many streets were impassable for six hours including the London road which is the main artery with depths from 2 to 5 feet. Hundreds of houses were flooded with water rising in some to the bedrooms. At 12.00 the Medlock was only 3 or 4 feet above its normal level but by 3.30 it was 20 feet above its ordinary level at London Road bridge. The cemetery at Phillips park was flooded and bodies washed out of graves.	https://confidentials.com/manchester/strange-city-4-the-great-flood-the-floating-dead BCFF British Newspaper archive (multiple references)

Event date	Details	Source
Jul 1877	However there were reports of flooding on the Irwell and Medlock, the Croal at Bolton, the Douglas at Wigan, the Irk and Mersey..... The Medlock was swollen to a considerable extent. An engineer noted that if a sewer scheme under construction had been completed the flooding would not have occurred in Lower Broughton.	BCFF
Nov 1890	A very large district in the neighbourhood of Manchester has been flooded by the overflowing of the Rivers Irwell, Medlock, and Mersey. The water stretches over the low-lying lands for miles. The Manchester ...	British Newspaper Archive
Jun 1900	A boy was drowned in the River Medlock. He was playing in the bed of the river near Palmerstone Street, Beswick with the stream in a comparatively shallow state when the water suddenly came down in a flood. Three boys managed to escape with no more than a wetting, a fourth clung to a river wall until he was rescued, the other was carried downstream where the river wall was 30 feet high and attempts to rescue him failed. River Medlock at Palmerston Bridge SJ859981	BCFF
Aug 1915	... Place, Chorlton-on-Medlock, it will remembered, were swept off their feet the sudden flooding of the sewer in which they were working under York-street, Hulme, and carried down the stream towards the outfall into the River Medlock. The dead body of Williams ...	British Newspaper Archive

7.1.1 Pooling group:

Pooling group:

NRFA ID	Names	ARE A	SAA R	FA RL	FPE XT	BFIHOS T19	QM ED	Lcv	LSk ew	N	SD M	Discordancy	Discordant.
69020	Medlock at London Road	57	1025	0.973	0.1094	0.381	23.3	0.262	0.145	51	0.000	0.297	FALSE
76019	Roe Beck at Stockdalewath	63	983	1	0.0796	0.45	42.5	0.215	0.312	24	0.406	0.667	FALSE
205005	Ravernet at Ravernet	74	946	0.934	0.1065	0.366	14.5	0.206	0.302	51	0.459	1.533	FALSE
48012	Fal at Trenowth	65	1248	0.979	0.0712	0.462	9.97	0.156	0.249	25	0.598	1.051	FALSE
41022	Lod at Halfway Bridge	52	857	0.951	0.0612	0.428	16.6	0.290	0.168	53	0.665	0.735	FALSE
52004	Isle at Ashford Mill	87	891	0.979	0.0837	0.455	35.4	0.207	0.046	58	0.711	0.337	FALSE
205008	Lagan at Drumiller	85	1016	0.992	0.0694	0.326	27.2	0.139	-0.065	49	0.721	2.008	FALSE
26003	Foston Beck at Foston Mill	60	698	0.987	0.1062	0.894	1.78	0.249	0.010	62	0.743	0.828	FALSE
53023	Sherston Avon at Fosseway	78	835	0.999	0.07	0.724	7.39	0.232	0.145	47	0.746	0.181	FALSE
33032	Heacham at Heacham	56	688	0.983	0.116	0.932	0.434	0.299	0.141	55	0.769	1.021	FALSE
26015	Driffield Canal at Wansford Bridge	49	699	0.998	0.0968	0.879	2.49	0.170	0.092	13	0.789	2.048	FALSE
26013	Driffield Trout Stream at Driffield	53	690	0.997	0.0934	0.837	2.7	0.269	0.281	13	0.798	1.294	FALSE

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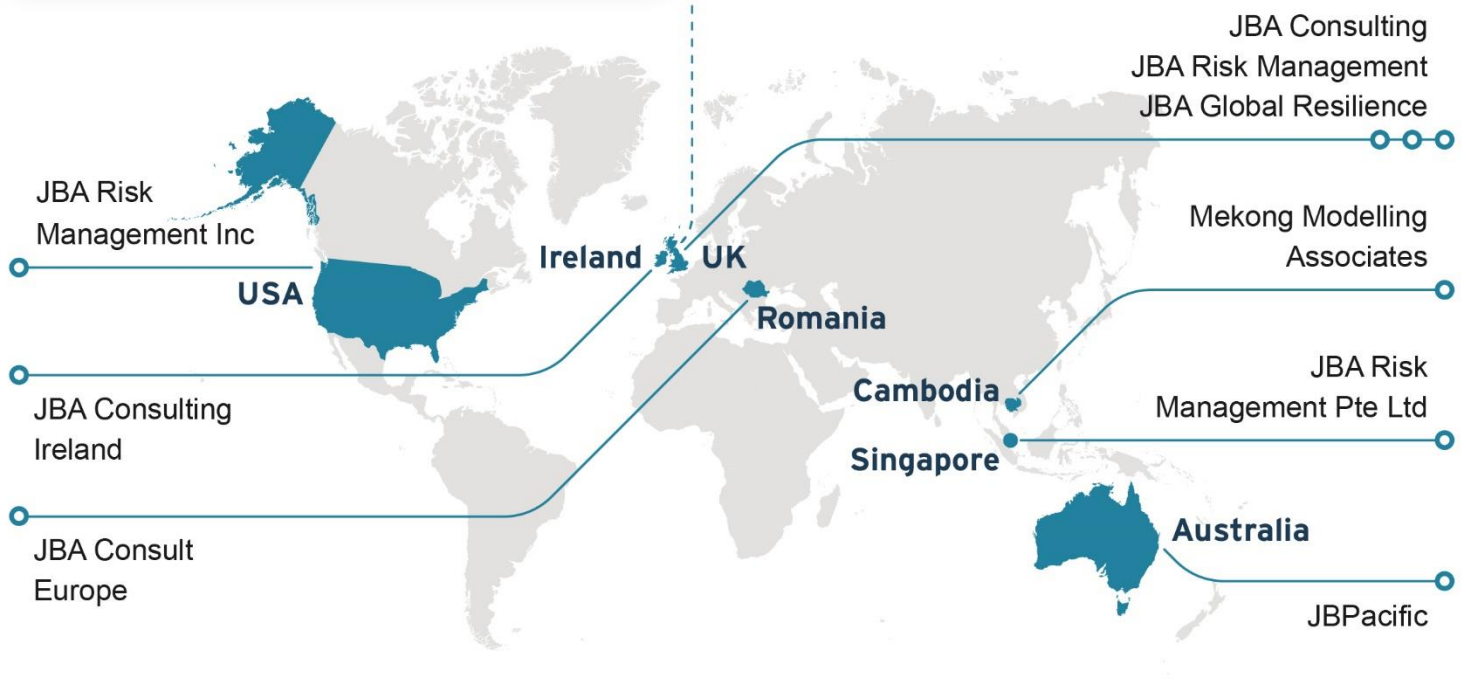
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