

RHODES BUSINESS PARK

TECHNICAL NOTE

Flood Zone Analysis Modelling Results

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Introduction

As part of the Flood Risk Assessment and Drainage Strategy (40055 BGL-XX-XX-RP-D-0001-V2-Rhodes_BP-Flood Risk Assessment & Drainage Strategy) submission an independent flood modelling study was commissioned to supplement the FRA report as the proposed development site lies within a defended Flood Zone 3 along the northern bank of the River Irk.

JBA Consulting was commissioned to undertake the study on behalf of the client, Belshaw, to accurately represent the flood levels at the proposed development site. This includes flood levels, extents, velocities and depth of modelled flood scenarios.

The full JBA report, LGH-JBAU-XX-XX-RP-HM-S3-P01-Hydraulic_Model_Report, is included in the Appendix

Approach

The flood study covers the following storm events:

- 3.33% - 1 in 30 year,
- 1% - 1 in 100 year,
- 1% + 35% Climate Change factor - 1 in 100 year +35% CC uplift
- 0.1% - 1 in 1,000 year

The corresponding hydrographs were derived for each of the above storms to be incorporated in the modelling.

Topographical survey of the proposed development site was used, incorporating the top of the sheet-pile wall along the northern bank of the River Irk. This data, included with EA DEM elevation data for the surrounding land was used in the model.

Channel survey data was collected along the River Irk at key hydraulic structures, a total of 20 cross-sections were taken and used in the modelling analysis.

Results

The results of the modelling analysis show that the 3%, 1% return events do not flood the site. The 0.1% event the entire site floods:

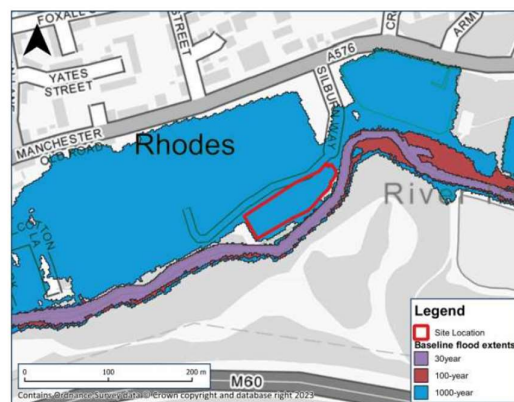


Figure 3-1: Baseline flood extents (30-year, 100-year, 1,000-year)

Although the 1% event f storm does not flood the site, the addition of the 35% Climate Change factor uplift shows the site at risk of flooding.

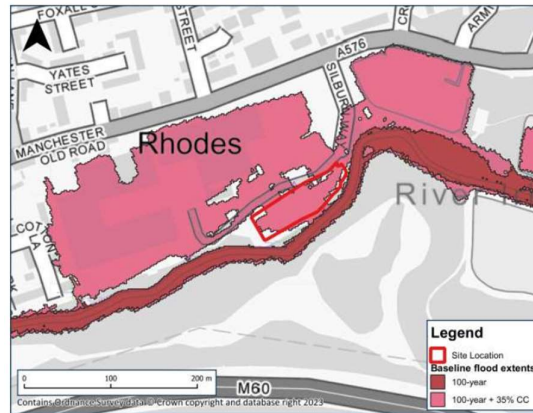


Figure 3-2: Baseline 100-year flood extent with climate change

Although the site is at risk of flooding for the 1% +CC event, the depths of flooding are generally below a depth of 100mm with slightly deeper flood depths in localised areas of depressions. The flooding generally occurs from the north of the site from Silburn Way and a small depression along the southern boundary of the proposed development site.

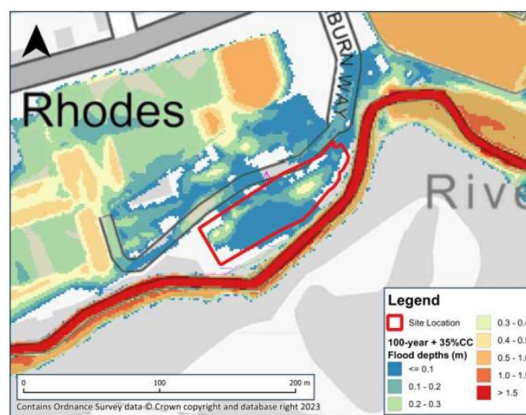


Figure 3-3: The 100-year plus 35% climate change flood depths

Conclusion

The results of the modelling analysis show that the 3% (1:30) and 1% (1:100) storm events do not flood the site, therefore the proposed development use is suitable for the site in question.

APPENDIX A

Hydraulic Modelling Study at Silburn Way, Middleton

Draft Report

S3-P01

November 2023

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This report describes work commissioned by Domenico Venuti on behalf of Belshaw by an instruction dated 17th August 2023. The Client's representative for the work was Domenico Venuti and Daniel Barnes of Burrows Graham. Hannah Evans of JBA Consulting carried out this work.

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Unless otherwise stated in this Report, the assessments made assume that the sites and facilities will continue to be used for their current purpose without significant changes.

Where field investigations are carried out, these have been restricted to a level of detail required to meet the stated objectives of the services. The results of any measurements taken may vary spatially or with time and further confirmatory measurements should be made after any significant delay in issuing this Report.

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Abbreviations

1D	One Dimensional
2D	Two Dimensional
AEP	Annual Exceedance Probability
CC	Climate Change
DTM	Digital Terrain Model
EA	Environment Agency
Flood Modeller	1D Hydraulic Modelling Software
FEH	Flood Estimation Handbook
FFL	Finished Floor Levels
Ha	Hectares
HQ	Head-Flow
JBA	Jeremy Benn Associates
LIDAR	Light Detection and Ranging
m AOD	Metres Above Ordnance Datum
NPPF	National Planning and Policy Framework
TUFLOW	2D Hydraulic Modelling Software

1 Introduction

1.1 Terms of Reference

JBA Consulting (JBA) were commissioned by Belshaw to undertake a hydraulic modelling study of the River Irk which flows along the southern boundary of the proposed development site located along Silburn Way, Middleton.

The purpose of this study is to increase the understanding of the fluvial flood risk to the site. To achieve this a 1D-2D ESTRY-TUFLOW hydraulic model was produced to allow accurate representation of flood levels, extents, velocities and hazards within the site boundary.

1.2 Site Description.

The 0.36ha site is located on land off Silburn Way in Middleton. The River Irk flows to the south of the site in a westerly direction.

Table 1-1: Summary of Site Details

Site address	Silburn Way, Middleton
Site area	0.36 hectares (ha)
Existing Land-use	Brownfield Site
OS NGR	SD 85481 05192
Country	England
County	Greater Manchester



1.3 Proposed development

The site is the subject of a proposal for a commercial scheme.

1.4 General approach

A 1D-2D hydraulic model of the River Irk and floodplain in the vicinity of the site was developed in ESTRY-TUFLOW to refine the understanding of flood risk at the site and within the surrounding area to improve upon the EA's Flood Map for Planning

The model incorporates site-specific topographic survey data, channel survey information and the latest publicly available Environment Agency LiDAR data.

Hydrographs were derived for 3.33% (1 in 30-year), 1% (1 in 100-year), 1% with 35% climate change uplift (1 in 100-year plus 35% climate change), and 0.1% (1 in 1,000- year) AEP fluvial events. These hydrographs were applied directly to the model to provide baseline model results.

The model's sensitivity to changes to downstream boundary, roughness and flow values were tested to improve the confidence in the model results within the site boundary and immediate surrounding area.

2 Methodology

2.1 Data availability

Grantham Coates Surveys Ltd (GCS) were commissioned to collect channel survey data from the River Irk in the vicinity of the site in September 2023. In total the survey consisted of 20 cross sections taken at regular intervals along the River Irk and at key hydraulic structures (Appendix B).

A topographic survey was provided by the client for use within the study in October 2023 (Appendix A). The topographic survey covered an area greater than the site as shown in

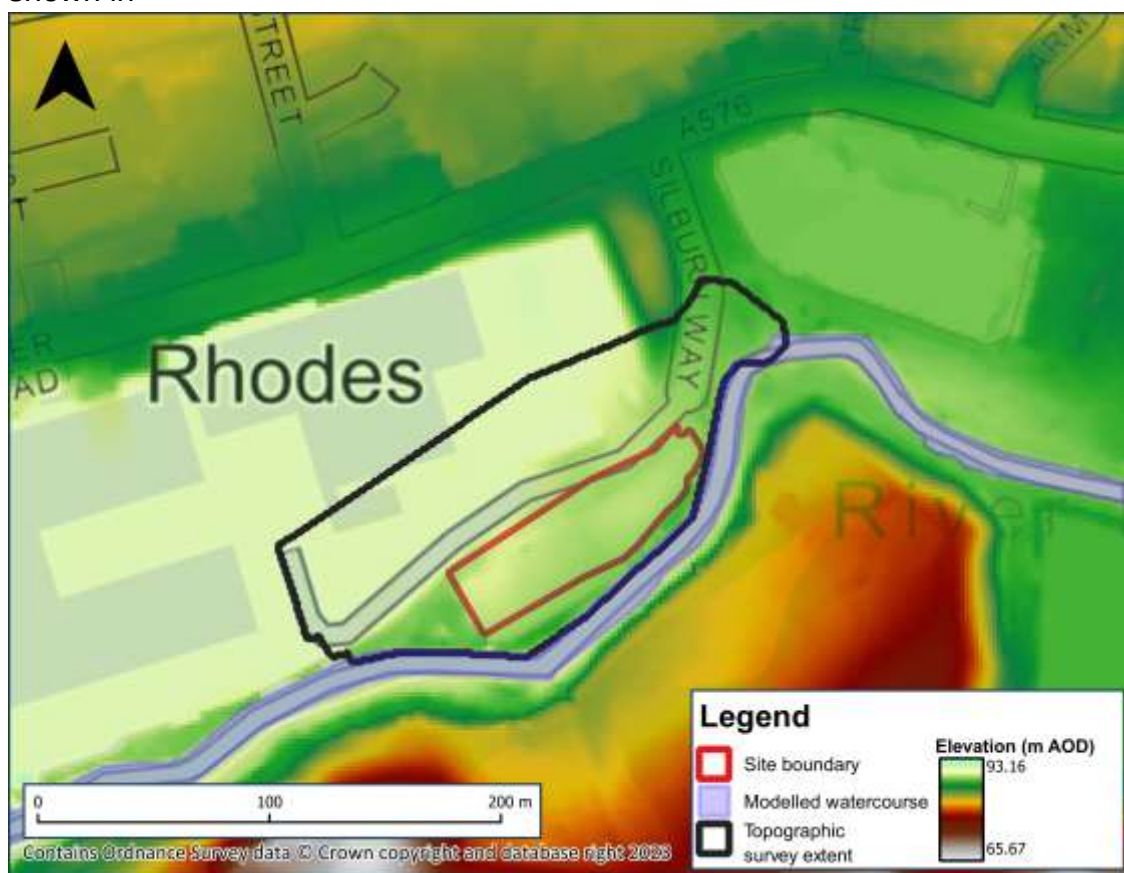


Figure 2-1. Environment Agency LiDAR was obtained from the Open Data website to represent ground levels within the wider floodplain. The latest available LiDAR has a grid resolution of 2m and was flown in 2020.

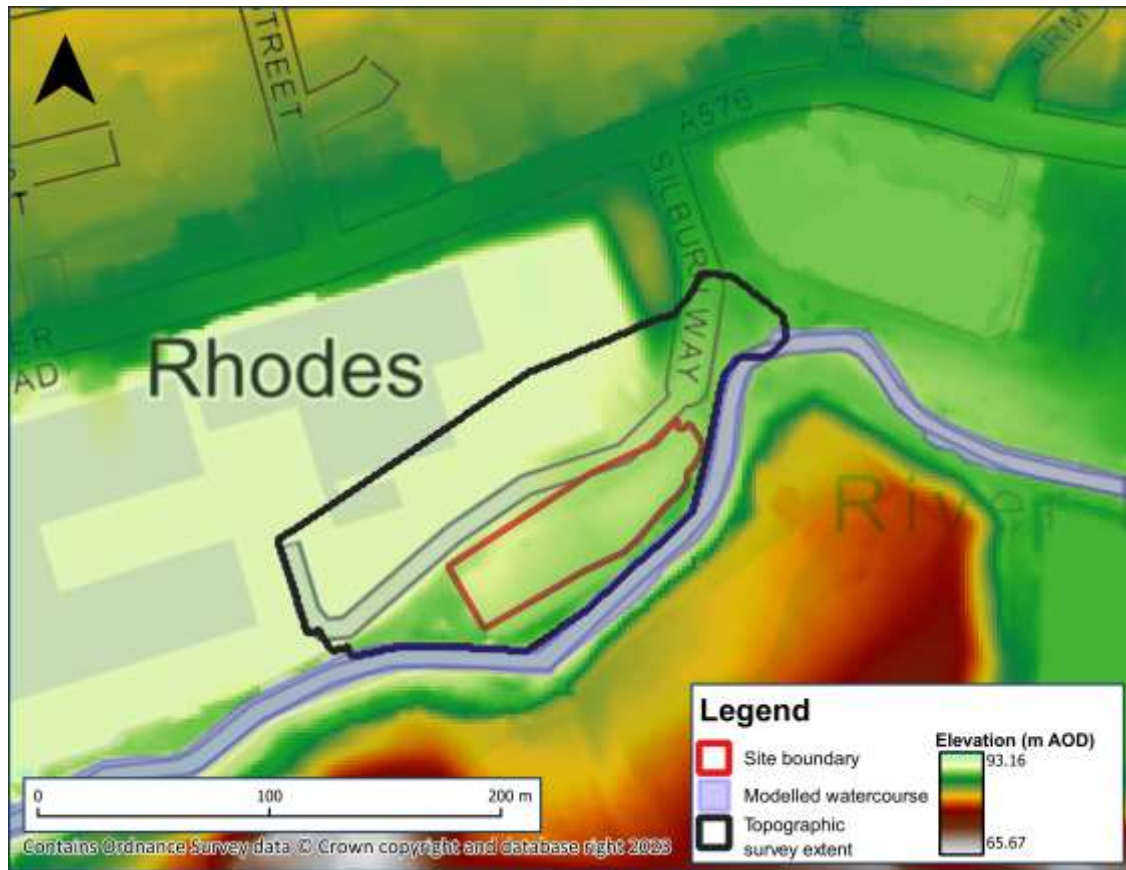


Figure 2-1: Topographic survey extent

2.2 Model extent and build

A 1D-2D ESTRY-TUFLOW model was built to represent the watercourse and floodplain in the vicinity of the proposed development site. The model was run using TUFLOW version 2023-03-AA-IDP-W64.

The River Irk channel was represented within the 1D domain using ESTRY. Model channel cross sections were constructed from channel survey collected by GCS in September 2023. The fluvial 1D ESTRY model, shown in

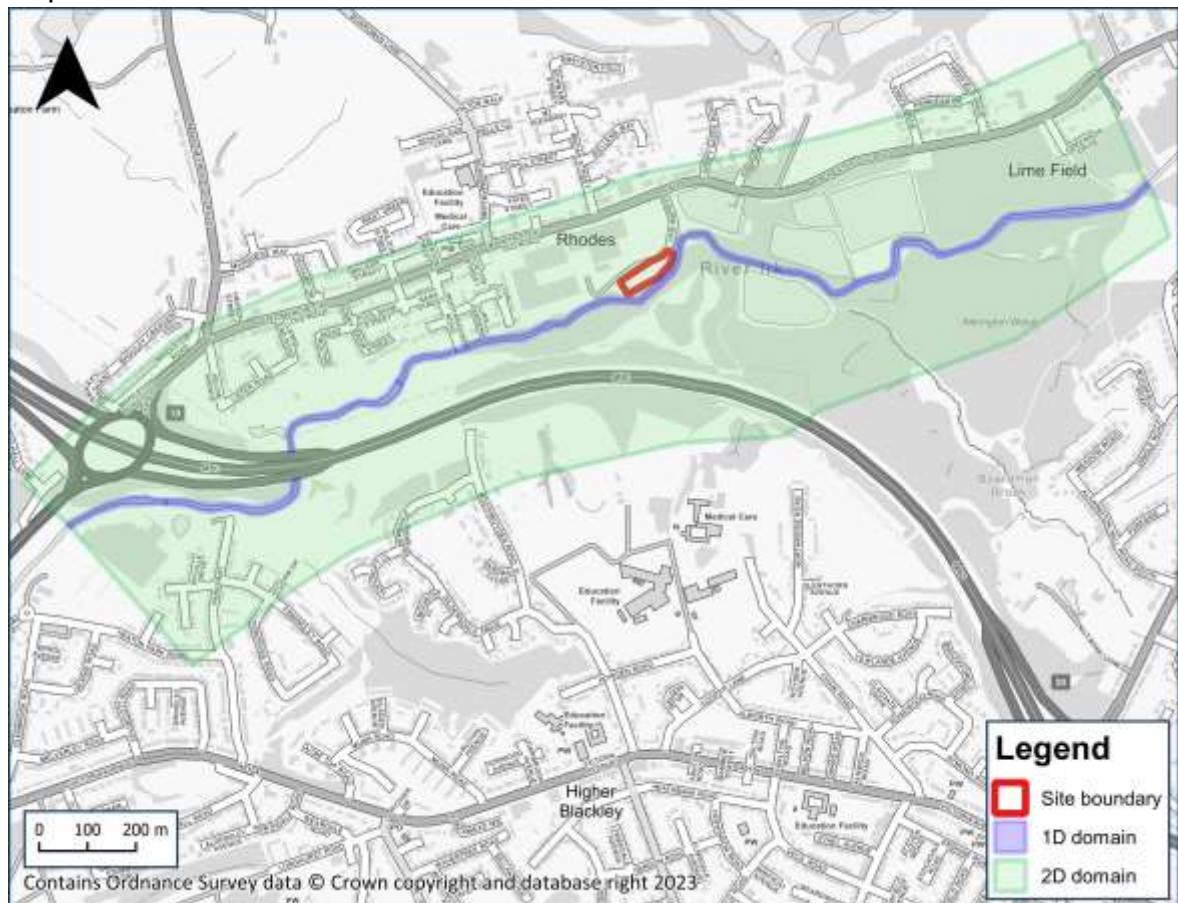


Figure 2-2 covers approximately 2.7km of watercourse within the vicinity of the site. Detailed information on the representation of hydraulic structures within the model are provided as part of Appendix C.

Channel cross sections were trimmed to the top of bank and linked to the 2D domain representing the floodplain.

The 2D TUFLOW model domain has an area of 124 hectares with a 3m grid resolution. Site-specific topographic survey data were used to represent ground levels in the site boundary and floodplain where available (Appendix A) and LiDAR data was used to inform the model topography across the wider floodplain. Bank levels were informed using survey bank levels from the channel survey, site specific topographic survey and LiDAR data.

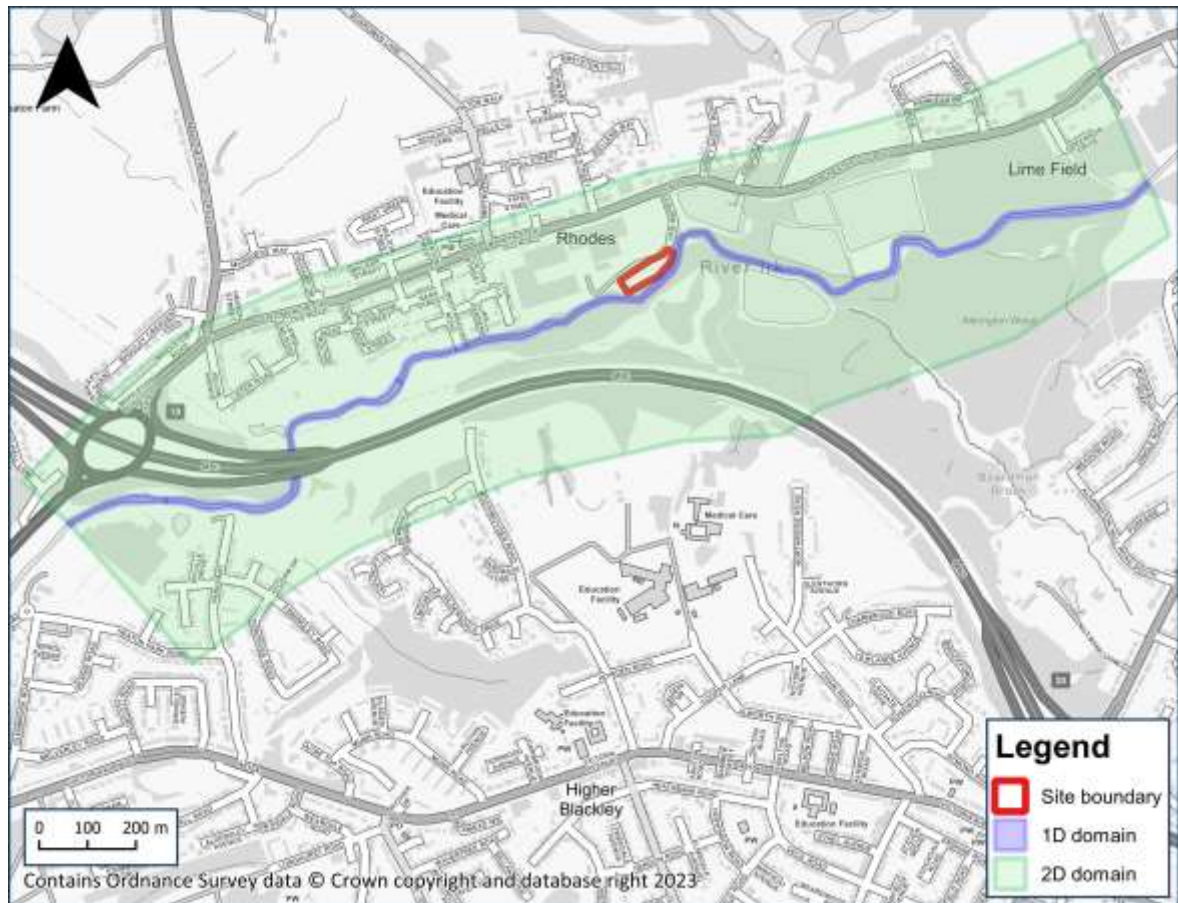


Figure 2-2: Fluvial hydraulic model 1D and 2D domain

2.3 Model roughness

Manning's 'n' values were used to represent the roughness for both the 1D channel and 2D floodplain. The values of the 1D roughness were based on photographs provided by GCS within the channel survey document.

Manning's 'n' values in the floodplain (2D) were set to represent different land uses within the model extent as shown in Table 2-1. Land uses were defined using satellite imagery and OS mapping.

Table 2-1: 2D Manning's 'n'; range within the hydraulic model

Features	Manning's 'n' value assigned
Buildings	0.3
Woodland	0.07
Road and Tracks	0.03
General surface	0.05
Channel roughness	0.04-0.05

2.4 Model boundary conditions

2.4.1 Fluvial model inflows

A hydrological assessment was carried out on the catchment in order to derive the peak flow estimates for the River Irk which flows in a westerly direction along the southern boundary of the site. The full hydrological assessment is included in Appendix D.

Flow-time hydrographs were estimated for the 1 in 30-year (3.3% AEP), 1 in 100-year (1% AEP), 1 in 100-year plus climate change and 1 in 1000-year (0.1% AEP) fluvial flood events. Climate change allowances were applied inline with the latest 2023 Environment Agency Guidance with the 1% AEP flows uplifted by 35% (ref: Central allowances for the 2080's epoch, Irwell Management Catchment).

2.4.2 Downstream boundary conditions

The downstream boundary in the 1D domain was generated using a flow estimator tool to generate a flow-stage rating curve based on the downstream cross section profile. A slope value of 0.001 was used based on the channel slope between the two downstream cross sections. A manning's value of 0.04 was chosen for the channel manning's n based on the channel survey photographs.

In the 2D domain, the downstream boundary is based on the average slope in the floodplain at the downstream extent of the model.

2.5 Model verification

There is no hydrometric information available for the watercourse. Therefore, no hydrometric data specific to the catchment was available to assist with the preparation of design hydrology or model verification/calibration.

The cumulative mass error % does not exceed the preferred +/-1% range and the dvol plot varies smoothly, this suggests that the model is stable. The model has also been validated with a comparison to EA flood maps for planning in Section 4 of this report.

2.6 Sensitivity Analysis

The model's sensitivity to changes in roughness, flow and downstream boundary was checked (see Appendix E).

Appendix E shows that within the site boundary the model results are insensitive to changes in the downstream boundary conditions. The model results are relatively sensitive to the modelled roughness parameters and flow values. However, there are no changes in peak flood extents predicted within the site boundary as a result of the sensitivity testing. The roughness and flow parameters used in the baseline modelling were derived following best practices and are considered to be appropriate.

2.7 Model runs

The following scenarios and events were simulated using the hydraulic model:

- [Baseline scenario] – 1 in 30-year (3.3% AEP) event- existing condition.
- [Baseline scenario] – 1 in 100-year (1% AEP) event- existing condition.
- [Baseline scenario] – 1 in 100-year plus 35% climate change event- existing condition.
- [Baseline scenario] – 1 in 1000-year (0.1% AEP) event- existing condition
- [Sensitivity Analysis] – 1 in 100-year flood event with [+20%] increase in roughness
- [Sensitivity Analysis] – 1 in 100-year flood event with [-20%] increase in roughness
- [Sensitivity Analysis] – 1 in 100-year flood event with [+250mm] increase in peak water level at the downstream model boundary.
- [Sensitivity Analysis] – 1 in 100-year flood event with [+20%] increase in flow.

3 Fluvial Hydraulic modelling Results

3.1 Peak modelled flood extents

The peak modelled flood extent for the 1 in 30-year, 1 in 100-year and 1 in 1000-year fluvial flood events are shown in Figure 3-1.

Figure 3-1 shows that the 30-year and 100-year flood extents do not encroach within the boundary of the site. During the 1,000-year flood event, the entire site is expected to flood.

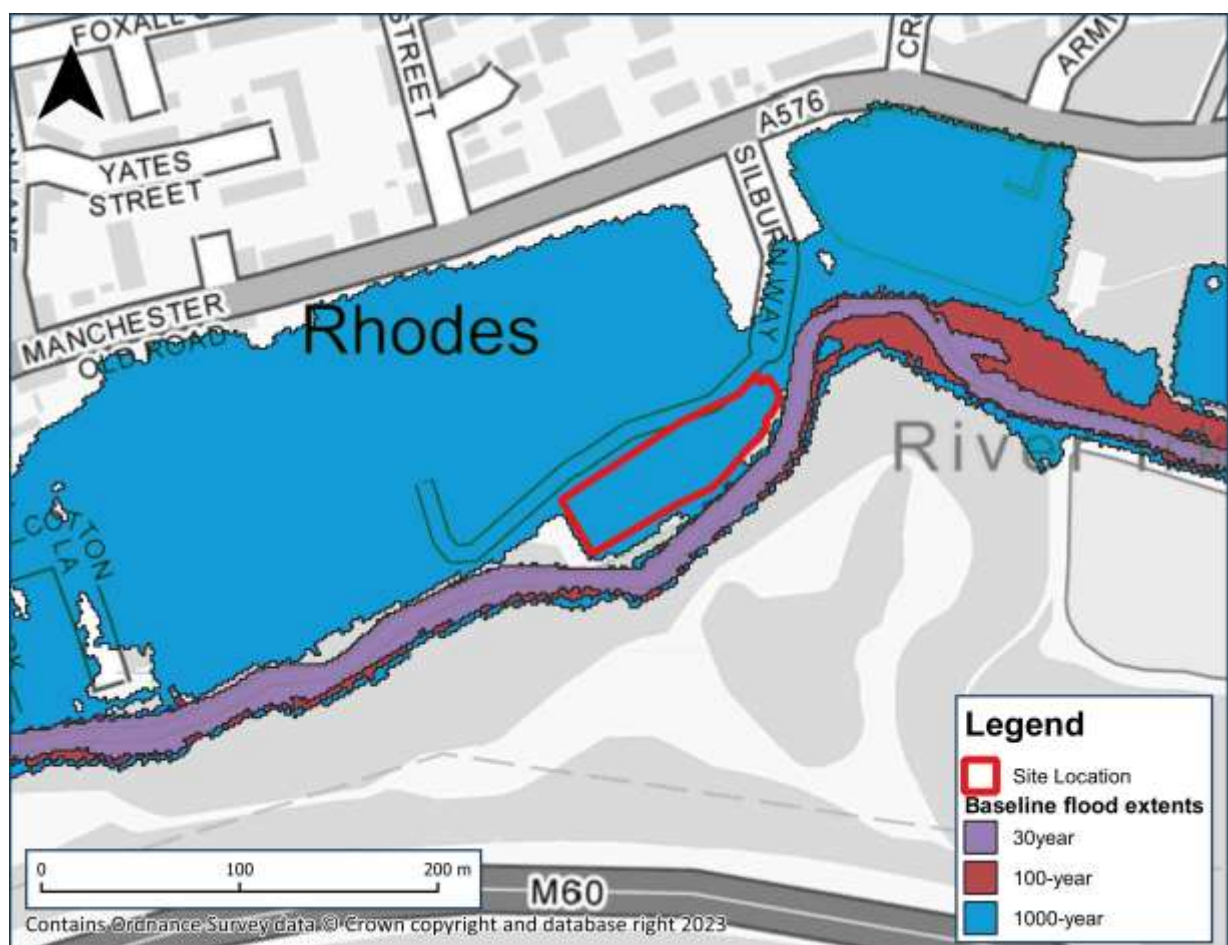


Figure 3-1: Baseline flood extents (30-year, 100-year, 1,000-year)

The 1 in 100-year and 1 in 100-year plus climate change (35%) peak modelled flood extents are shown in Figure 3-2.

Figure 3-2 shows the 100-year plus climate change (35%) flood extent flows into the site along the southern boundary. During the 100-year plus climate change event, the majority of the site is expected to flood.

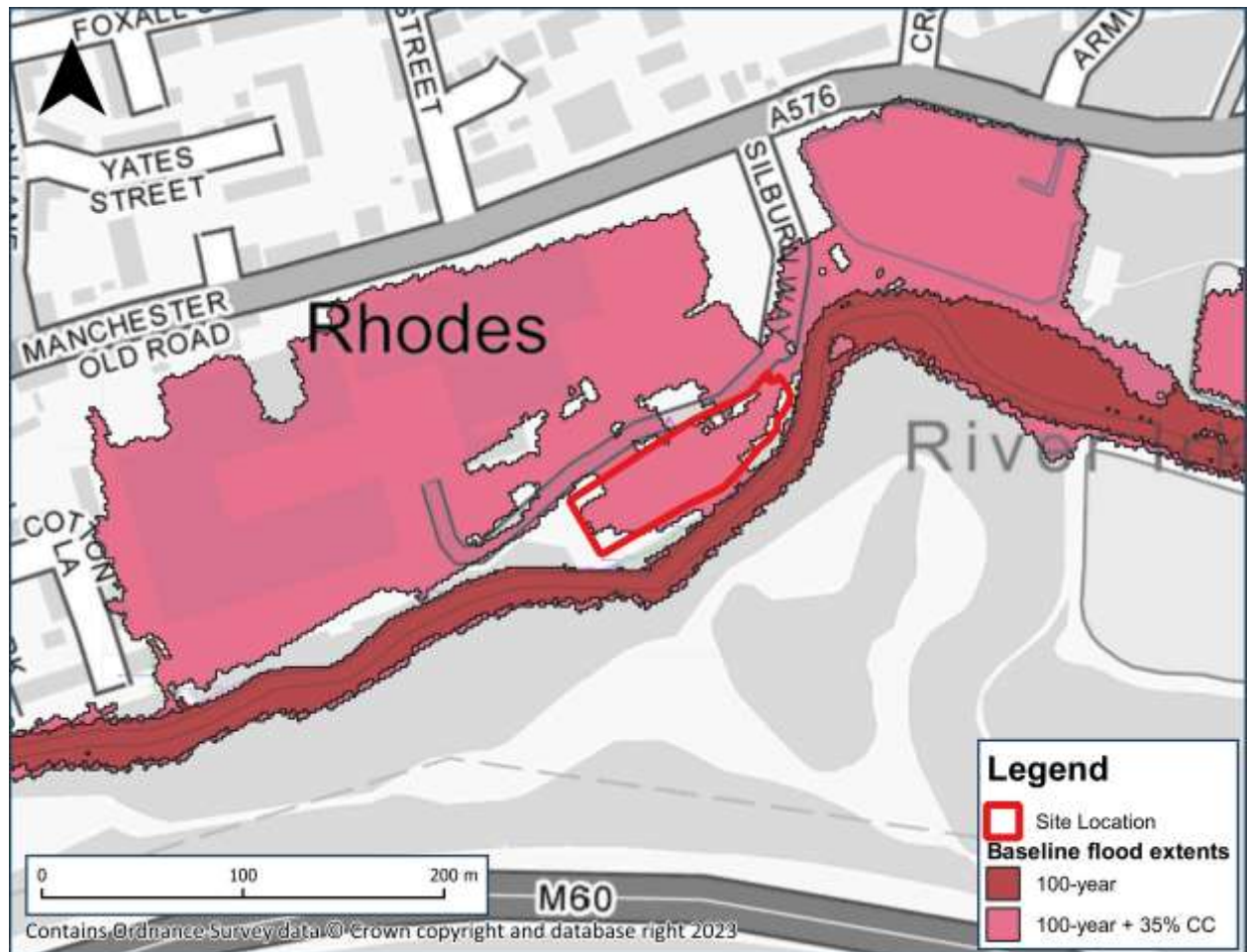


Figure 3-2: Baseline 100-year flood extent with climate change

3.2 Peak modelled flood depths

The peak modelled flood depths during the 100-year plus climate change flood event are shown in

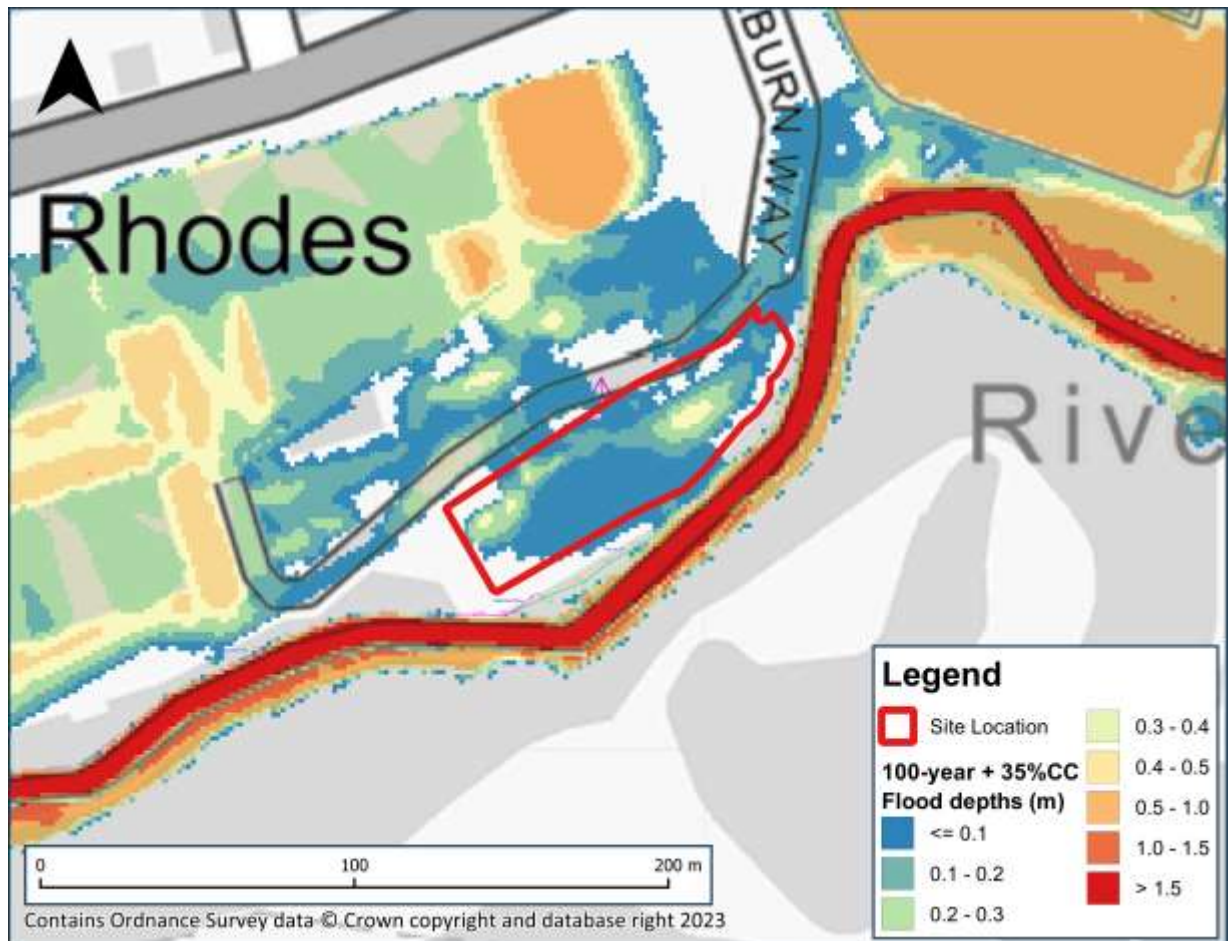


Figure 3-3. Flood depths during this event are typically less than 0.1m. However, peak modelled flood depths reach 0.37m in localised areas.

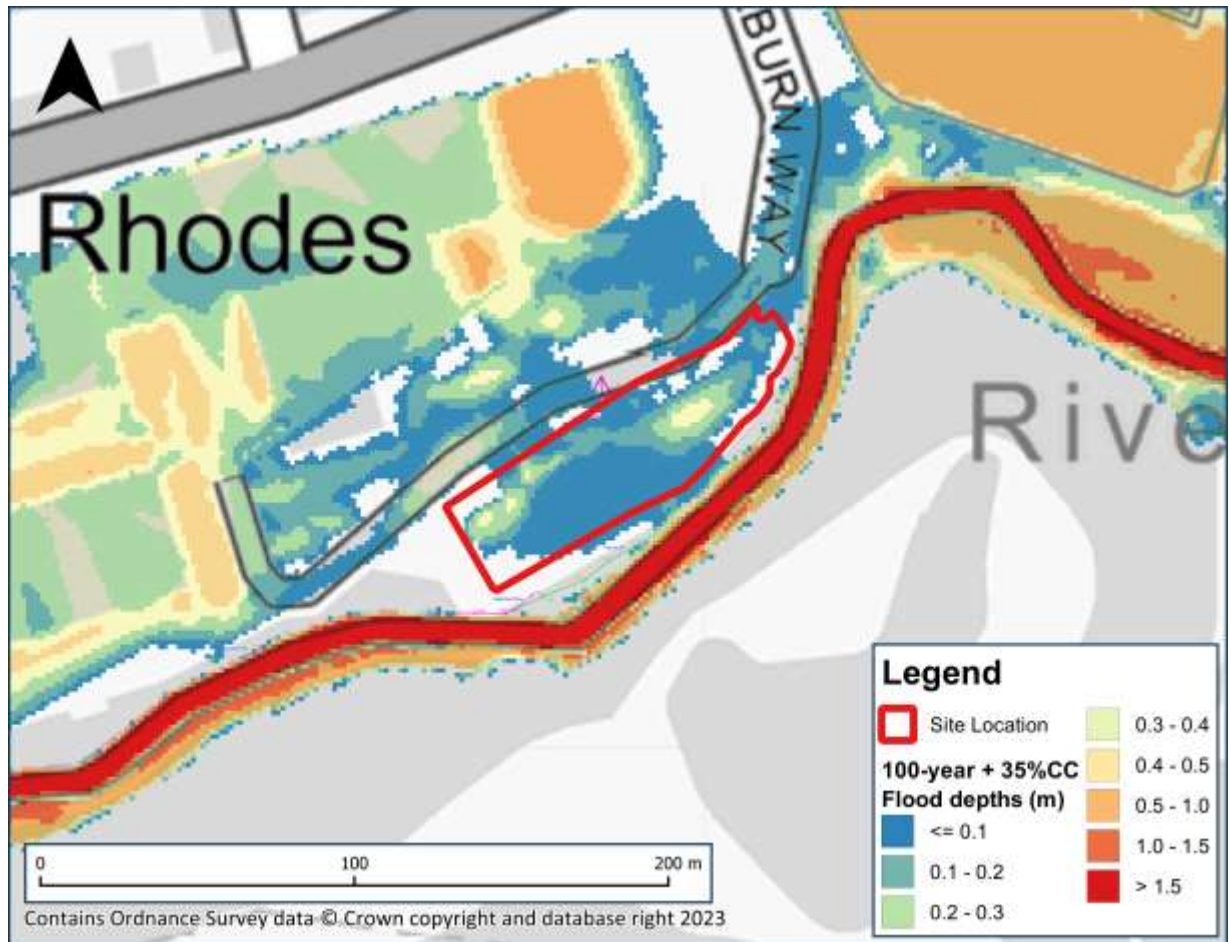


Figure 3-3: The 100-year plus 35% climate change flood depths

3.3 Peak modelled flood levels

The peak modelled flood levels during the 100-year plus climate change flood event are shown in Figure 3-4. Peak modelled flood levels of up to 70.44mAOD are predicted to occur within the site boundary during the 100-year plus 35% climate change fluvial flood event.

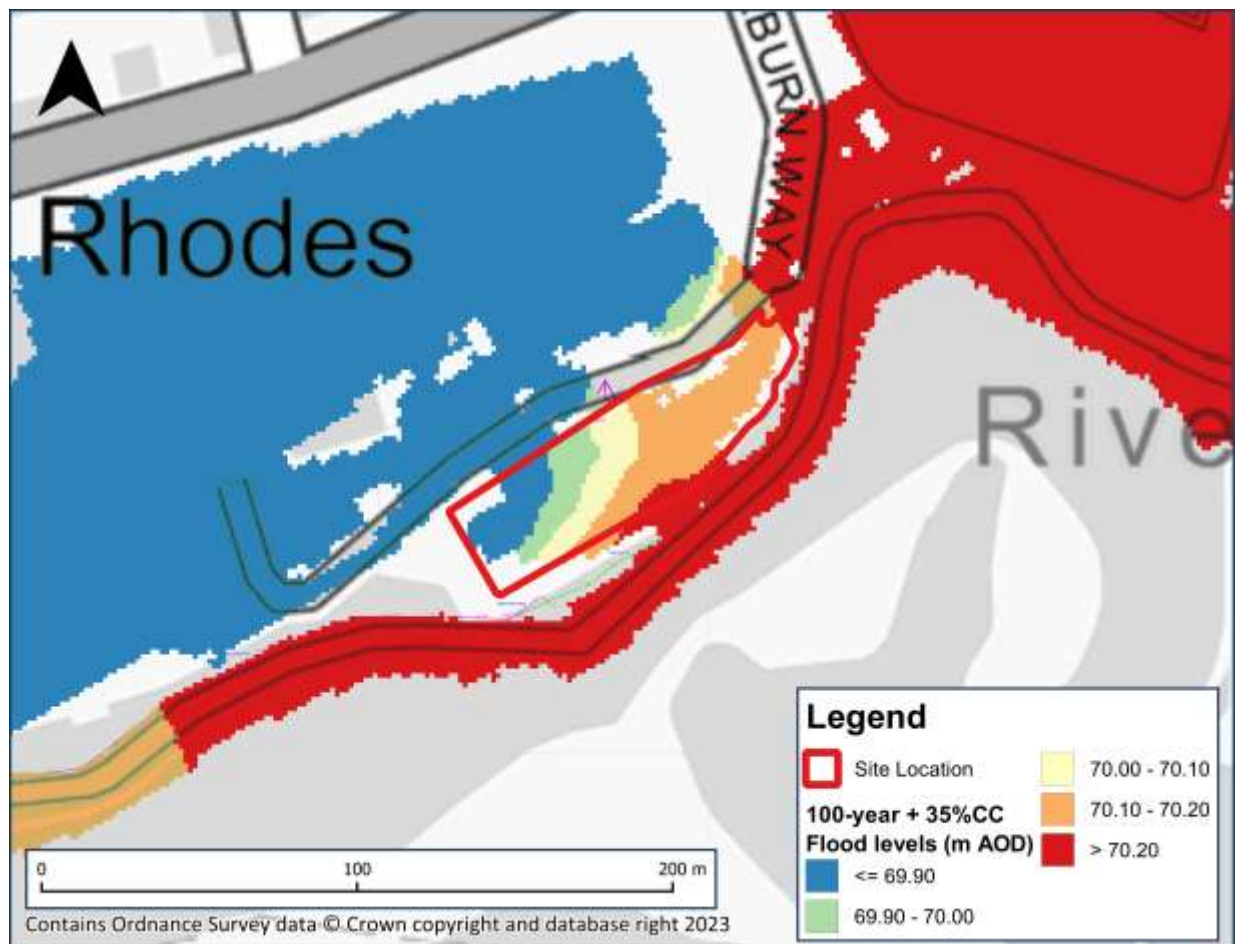


Figure 3-4: The 100-year plus 35% climate change flood levels

4 Model validation

4.1 Model Results and Flood Zone comparison

Figure 4-1 compares the Environment Agency's Flood Zone 2 and the 1000-year flood extent derived from the site specific hydraulic model. There is a good alignment between the 1000-year modelled extents and Flood Zone 2 which improves the confidence in the modelled data.

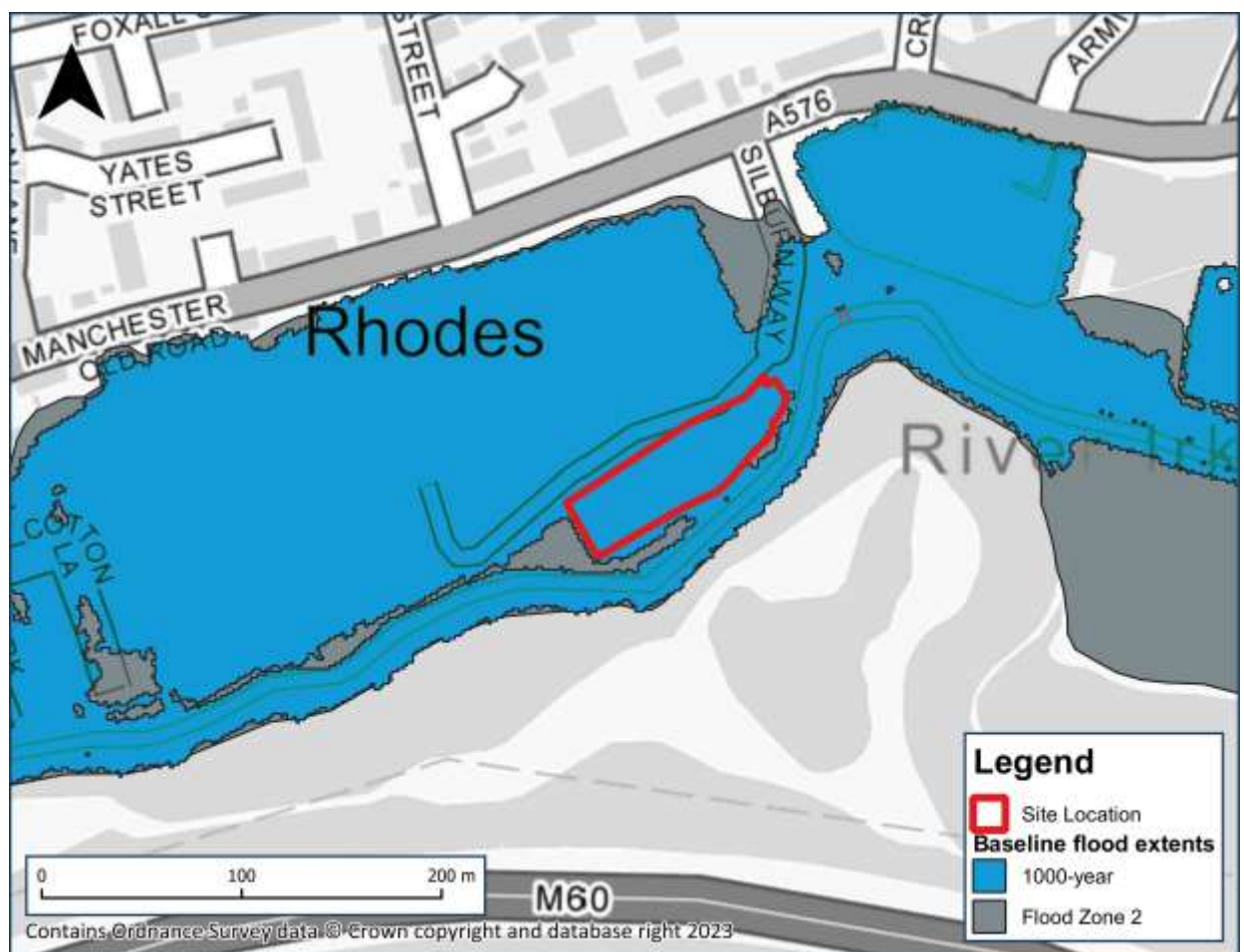


Figure 4-1: Flood Zone 2 and modelled 1000-year comparison

Figure 4-2 compares the Environment Agency's Flood Zone 3 and the 100-year flood extent derived from the site specific hydraulic model. Flood Zone 3 extends across the entire site. However, the modelled 100-year event remains in channel and does not encroach the site. This is due to the hydraulic modelling having a more refined representation of the channel and floodplain topography compared to the generalised modelling that informs the Flood Map for Planning.

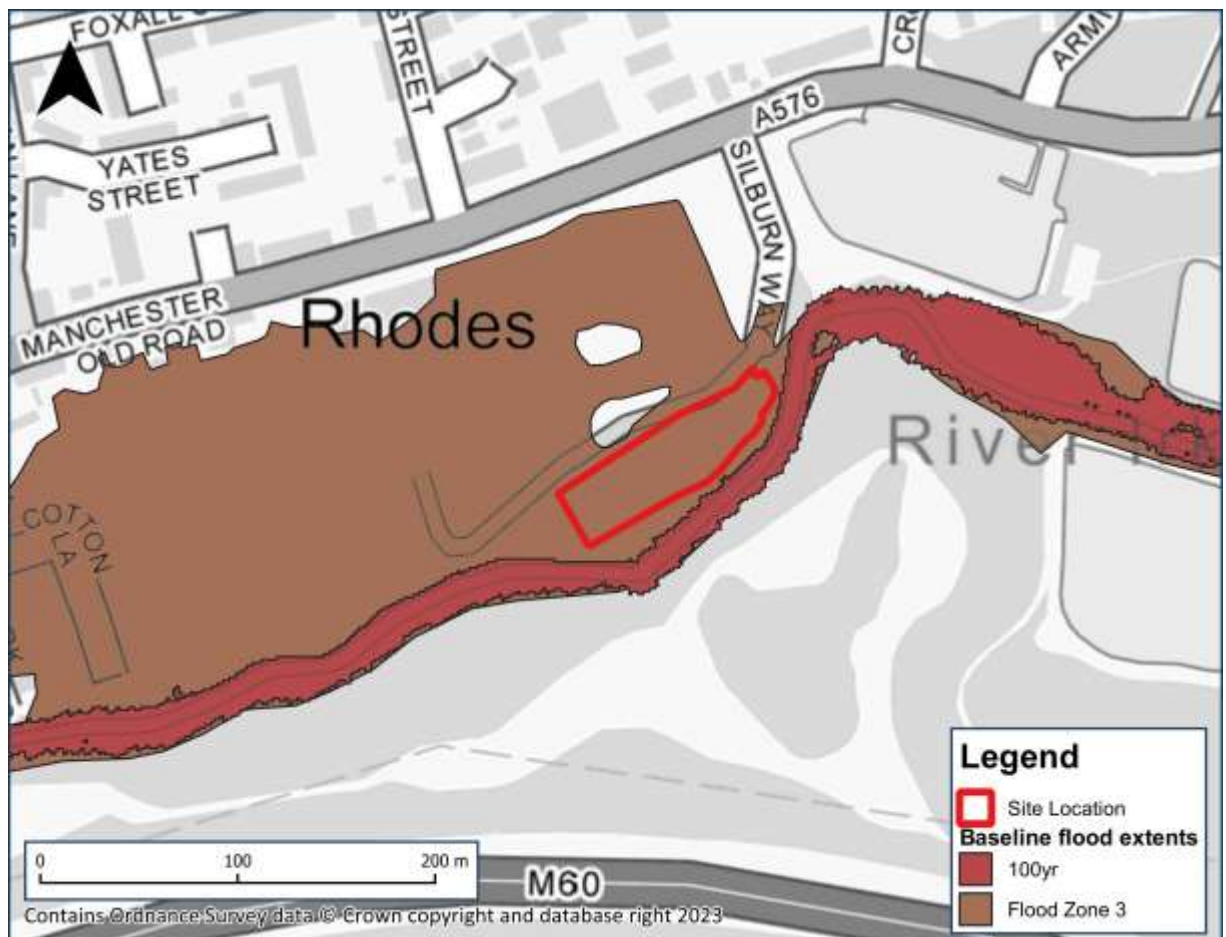


Figure 4-2: Flood Zone 3 and modelled 100-year comparison

5 Conclusion and recommendations

5.1 Conclusions

JBA Consulting was commissioned by Belshaw in August 2023 to undertake a hydraulic modelling study of the River Irk which flows along the southern boundary of the proposed development site located along Silburn Way, Middleton.

An ESTRY-TUFLOW hydraulic model was created to represent flood risk from the River Irk in the vicinity of the site. Channel survey data collected by Grantham Coates Surveys Ltd in September 2023 were used to represent the River Irk channel and structures. Site topographic surveys and LiDAR data flown in 2020 was used to represent ground levels within the floodplain.

Model results indicate that:

- The 30-year and 100-year flood extents do not encroach within the boundary of the site. During the 1,000-year flood event, peak flood extents are predicted to cover the majority of the site.
- The 100-year plus climate change (35%) flood extent flows into the site along the southern boundary. The peak modelled flood event covers the majority of the site during the 100-year plus climate change event.
- Typical peak flood depths of under 0.1m are predicted across the majority of the site during the 100-year plus climate change event. However, peak modelled flood depths reach 0.37m in localised areas within the site.
- Peak modelled flood levels of 68.9m AOD to 70.44mAOD are predicted to occur within the site during the 100-year plus 35% climate change fluvial flood event
- The model results are insensitive to changes in the downstream boundary conditions. The model results are relatively sensitive to the modelled roughness parameters and flow values. However, there are no changes in peak flood extents predicted within the site boundary as a result of the sensitivity testing.

5.2 Recommendations

It is recommended that the hydraulic model results are validated by the Environment Agency, ideally before developing a Masterplan or submitting a planning application.

As the site is predicted to flood during the 100-year plus climate change event, it is recommended that the hydraulic model is further used to assess post-developed flood risk, to ascertain whether there are any third-party flood risk impacts of the proposed development and to identify any requirements for mitigation.

6 Appendices

A Topographic Survey

B

Channel Survey



Whilst every effort has been made to identify all above ground details, it should be noted that some items may have been obscured at time of survey.

Below ground drainage information as been visually inspected from the surface and should therefore be treated as approximate only.

Where this survey has been carried out for the purpose of enabling trackside drainage design. The position of any running rail has been surveyed in line with a general topographic survey and should not be used for the purpose of track design.

All dimensions to be checked on site prior to design and construction.

Control Table				
Station	Description	Eastings	Northings	Height

Title: WATERCOURSE SURVEY AT
Silburn Way
(Key Plan)

 **Grantham Coates
Surveys Ltd**

2 Arden Court, Arden Road, Alcester
Warwickshire, B49 6HN

Drawing No: GCS/JBA/Silburn Way/1	Rev: -
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Date:	Notes:	Name:	Rev:

File Name: GCS-JBA-Silburn Way-1	Sheet size: A1	Sheet: 1 of 9
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ZERO CHAINAGE
TAKEN AS THE CONFLUENCE
WITH THE RIVER IRWELL

1	
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Whilst every effort has been made to identify all above ground details, it should be noted that some items may have been obscured at time of survey.

Below ground drainage information as been visually inspected from the surface and should therefore be treated as approximate only.

Where this survey has been carried out for the purpose of enabling trackside drainage design. The position of any running rail has been surveyed in line with a general topographic survey and should not be used for the purpose of track design.

All dimensions to be checked on site prior to design and construction.

Station	Description	Eastings	Northings	Height

Grid: *OS National Grid* **Datum:** *Ordnance Datum Newlyn*
Survey related to Ordnance Survey National Grid (OSGB36) via GPS and the OS Active Network.
A National Grid (OSGB36) coordinate has been established on site via Transformation OSTN15 and Geoid Model OSGM15, a further OS coordinate was used to orientate the survey to Ordnance Grid.
No scale factor has been applied to the survey

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E-Mail: info@gcsurveys.co.uk
Web Site: www.gcsurveys.co.uk



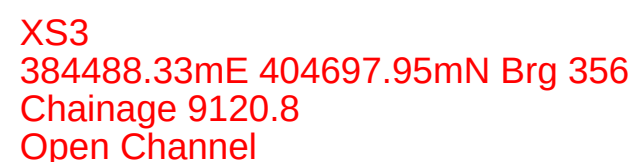
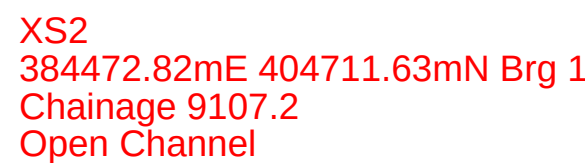
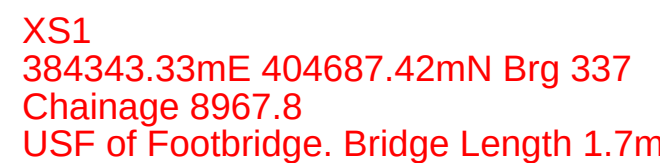
THE SURVEY
ASSOCIATION
FULL MEMBER



chartered
ICS

Drawing No: GCS/JBA/Silburn Way/1				Rev: -	
Date:	Notes:			Name:	Rev:
Drawn: MC	Checked: SC	Scale: 1:2500	Date: 29/09/23		
File Name: GCS-JBA-Silburn Way-1			Sheet size: A1	Sheet: 2 of 9	

ZERO CHAINAGE
TAKEN AS THE CONFLUENCE
WITH THE RIVER IRWELL



This survey should only be relied upon for its original purpose. Grantham Coates Surveys Limited accepts no responsibility for use of this plan outside of the original remit, or by use of any party other than the original client.

Whilst every effort has been made to identify all above ground details, it should be noted that some items may have been obscured at time of survey.

Below ground drainage information has been visually inspected from the surface and should therefore be treated as approximate only.

Where this survey has been carried out for the purpose of enabling trackside drainage design. The position of any running rail has been surveyed in line with a general topographic survey and should not be used for the purpose of track design.

All dimensions to be checked on site prior to design and construction.

Legend

AR VALVE	AV	WATER TAP	WP
SQUARE	AVL	TEMPERATURE BENCH MARK	TBP
BORE HOLE	BH	TELEPHONE CALL BOX	TCB
BY INSPECTION COVER	BI	TELEPHONE POST	TP
BT BTX CONNECTION	BTB	THRESHOLD LEVEL	TL
CABLE TV INSPECTION COVER	CTV	TRAFFIC LIGHT	TL
COVER LEVEL	CL	TOP OF CURB WALL	TCW
DOWN PIPE	DP	TELEGRAPH POLE	TP
DROPPED KERB	DK	UNABLE TO LIFT	UTL
ELECTRICITY CONTROL BOX	ECB	VENT PIPE	VP
GAZEBO HEIGHT	GB	RAIL WELD	WE
ELECTRICITY MANHOLE	EM	WASHOUT	WO
ELECTRICITY POLE	EP		
EARTH ROD	ER		
FINISHED FLOOR LEVEL	FFL		
FIRE HYDRANT	FIH		
FOUL WATER	FW		
GULLY	GW		
GATE POST	GP		
GAS VALVE	GV		
INSULATED BLOCK JOINT	IBJ		
INSPECTION COVER	IC		
INVERT LEVEL	IL		
KERB OUTLET	KO		
LAMPPOST	LP		
LITTER BIN	LB		
MARKER POST	MP		
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MOORING EYE	ME		
ROOOFING EYE	RE		
ROD HEIGHT	RH		
ROAD NAMEPLATE	RN		
ROAD SIGN	RS		
STOP SIGN	ST		
SOFTT LEVEL	SL		
SIGNAL POST	SP		
SIGNALS AND LEVELS BOX	SLB		
SIGNALS AND TELECOMS CAB	STC		
SIGNALS AND TELECOMS POST	STP		
SIGNALS	SN		
STOP TAP	STP		
STOP VALVE	SV		
STOP SIGN	ST		
STORM WATER	SW		

Diagram illustrating a survey station setup with a surveyor, tripod, and level staff.

Diagram illustrating a gate structure.

Diagram illustrating a security fence structure.

Diagram illustrating overhead cables and utility lines.

Diagram illustrating a height scale.

Diagram illustrating a tree structure.

Diagram illustrating a road sign.

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Control Table				
Station	Description	Eastings	Northings	Height

Grid and Datum

Grid: *OS National Grid* **Datum:** *Ordnance Datum Newlyn*
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No scale factor has been applied to the survey

Title

WATERCOURSE SURVEY AT
Silburn Way
(Cross Sections)

Client:

JBA CONSULTING
The Library
St. Philip's Courtyard
Coleshill
Warwickshire B46 3AD



Land - Engineering - Building Surveyors

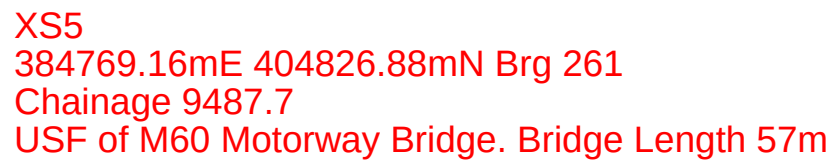
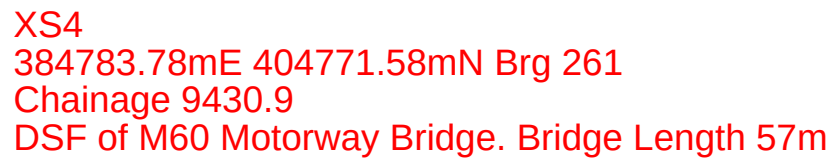
2 Arden Court, Arden Road, Alcester
Warwickshire, B49 6HN

Tel: 01789 764420

E-Mail: info@gcsurveys.co.uk
Web Site: www.gcsurveys.co.uk



Drawing No:			GCS/JBA/Silburn Way/1		Rev: -	
Date:		Notes:		Name:		Rev:
Drawn:		Checked:		Scale:		Date:
MC		SC		1:100		29/09/23
File Name: GCS-JBA-Silburn Way-1				Sheet size: A1		Sheet: 3 of 9



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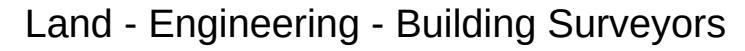
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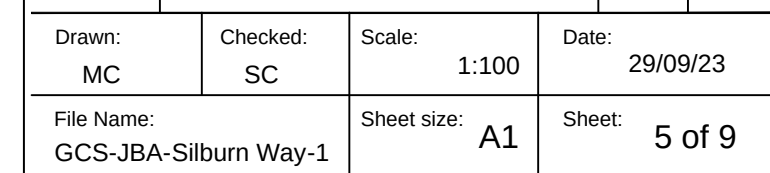
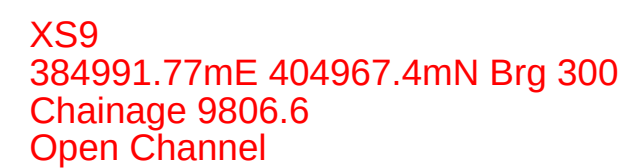
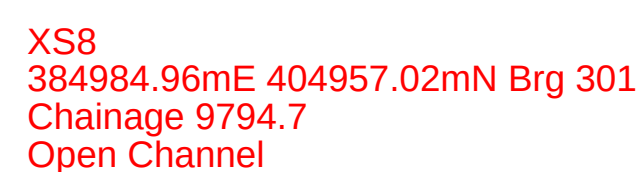
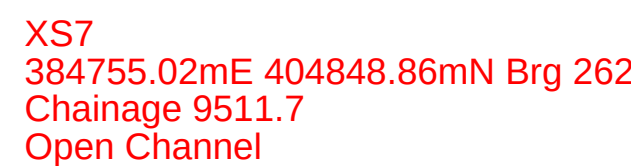
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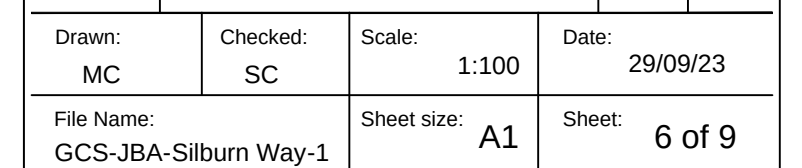
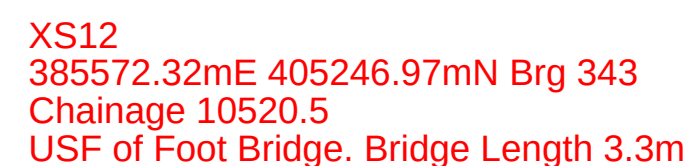
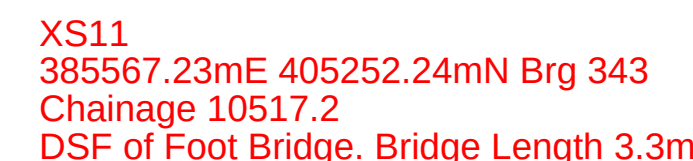
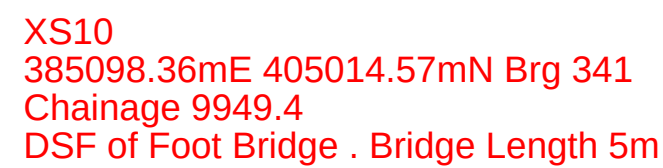
E-Mail: info@gcsurveys.co.uk
Web Site: www.gcsurveys.co.uk

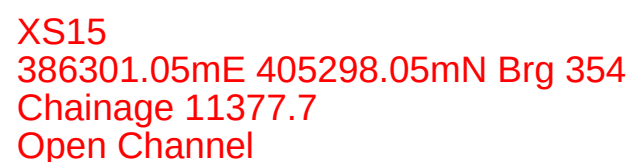
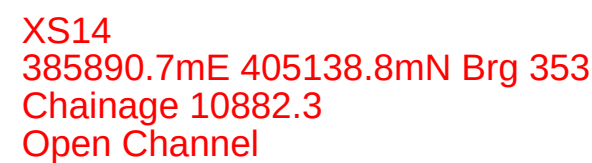
 THE SURVEY ASSOCIATION
FULL MEMBER

 chartered
ICS

Drawing No: GCS/JBA/Silburn Way/1				Rev: -	
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Drawn:	Checked:	Scale:	Date:		
MC	SC	1:100	29/09/23		
File Name:		Sheet size:	Sheet:		
GCS-JBA-Silburn Way-1		A1	4 of 9		







This survey should only be relied upon for its original purpose. Grantham Coates Surveys Limited accepts no responsibility for use of this plan outside of the original remit, or by use of any party other than the original client.

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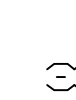
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Legend

AIR HOLE	AV	WATER TAP	TA
BOLLARD	BB	TEMPORARY BENCH MARK	TBM
BURIED	BHL	TELEPHONE CABLE BOX	TCP
BUS STOP	BS	TELEPHONE POLE	TP
BT INSPECTION COVER	BT	THRESHOLD LEVEL	TL
BT BOX	BTB	THREE LIGHT	TLH
CABLE TV INSPECTION COVER	CT	TOP-OF-CEILING	TC
COVER LEVEL	CL	UNLEIGH POLE	UP
DOWNPIPE	DP	UNABLE TO LIFT	UTL
DRAINAGE KERB	DK	VENT PIPE	VP
ELECTRICITY CONTROL BOX	ECB	WALL WELD	WW
EAVES HEIGHT	EH	WASHOUT	WO
ELECTRICITY MANHOLE	EM		
ELECTRICITY POLE	EP		
EARTH ROD	ER		
FINISHED FLOOR LEVEL	FFL		
FRESH IRRIGANT	FI		
FULL WATER	FW		
GULLY	GY		
GATE POST	GP		
GAS VALVE	GV		
INSULATED BLOCK JOINT	IBJ		
INSPECTION COVER	IC		
INVERT LEVEL	IL		
KERB GUT	KG		
LAMPPOST	LP		
LITTER BIN	LB		
MARKER POST	MP		
MALE POST	MK		
POST	PD		
RODDING EYE	RE		
RIDGE HEIGHT	RH		
ROUND NAMEPLATE	RN		
ROAD SIGN	RS		
STUMP	ST		
SOFIT LEVEL	SF		
SIGNAL POST	SIG		
RAIN/SLOPER LEVEL	SL		
SIGNALS AND TELECOMS BOX	STB		
SIGNALS AND TELECOMS CABLE	SC		
SIGNALS AND TELECOMS POST	STP		
SIGN	SN		
SOFT TAP	ST		
STORM WASTE	SW		
STAY	SV		
STORM WATER	SW		

SURVEY STATION



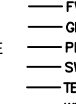
BUSHES



IC HEDGES



TREES



GATE



SECURITY FENCE



OVERHEAD CABLES



FOLI WASTE



GAS MAIN



UGC POWER LINE

UGC TELEPHONE

WATER MAIN

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GCS-JBA-Silburn Way-1				A1		7		of 9	



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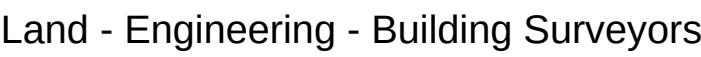
AR VALVE	AV	WATER TAP	TAP
BD	BD	SECONDARY BENCH MARK	TCH
BONE HOLE	BO	TELEPHONE LEX BOX	TOB
BS	BS	TELEPHONE POST	TEL
BU	BT	THRESHOLD LEVEL	TL
BUX STOP	BT	TRAFFIC LIGHT	TL
CV	CV	TOP OF WALL	TOP
COVER LEVEL	CL	TELEGRAPH POLE	TS
DOWN PIPE	DP	UNABLE TO LIFT	UNL
DOWN KERN	DK	VENT PIPE	VP
ELECTRICITY CONTROL BOX	ECB	RAIL WELD	WE
EAVES HEIGHT	EH	RAIL METER	WM
ELECTRICITY MANHOLE	EM	W/SCOUT	WS
ELECTRICITY POLE	EP		
EARTH ROD	ER		
FINISHED FLOOR LEVEL	FL		
FIRE HYDRANT	FD		
FOOT WATER	FW		
GULLY	GP		
GATE POST	GP	BUSHES	
GAZ VALVE	GV		
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INVERT LEVEL	IL		
KERN OUT	KO		
LAMPPOST	LO		
LITTER BIN	LB	TR TREES	
MARKER POST	MP		
MILE POST	MP		
POST	PO		
RODDING EYE	RE		
RIGHT HEIGHT	RH	GATE	
ROUND NAMEPLATE	RN		
ROAD SIGN	RS	SECURITY FENCE	
ROOF	RF	FENCE	
SOFFIT LEVEL	SL	OVERHEAD CABLES	
SIGNAL POST	SP	POOL WATER	
RAIL SIGN/LEVEL	SL	GAZ MAIN	
SIGNALS AND TELECOMS BOX	STB	UG POWER LINE	
SIGNALS AND TELECOMS CABLE	STC	UG WATER	
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STOP TAP	ST	WATER MAIN	
STOP VALVE	SV		
STAY	SY		
STORM WATER	SW		

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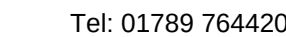
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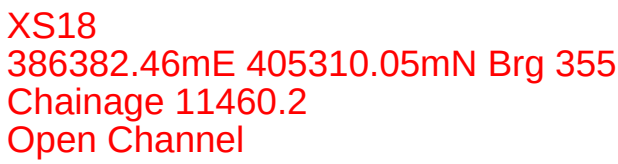
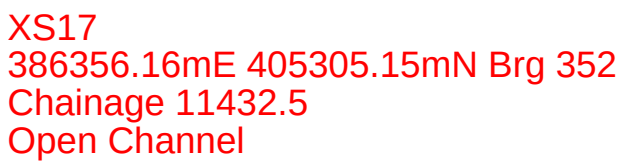
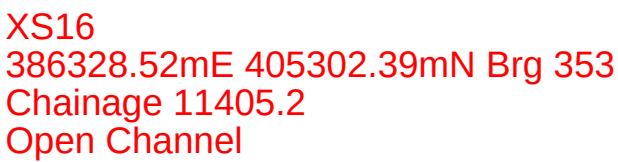


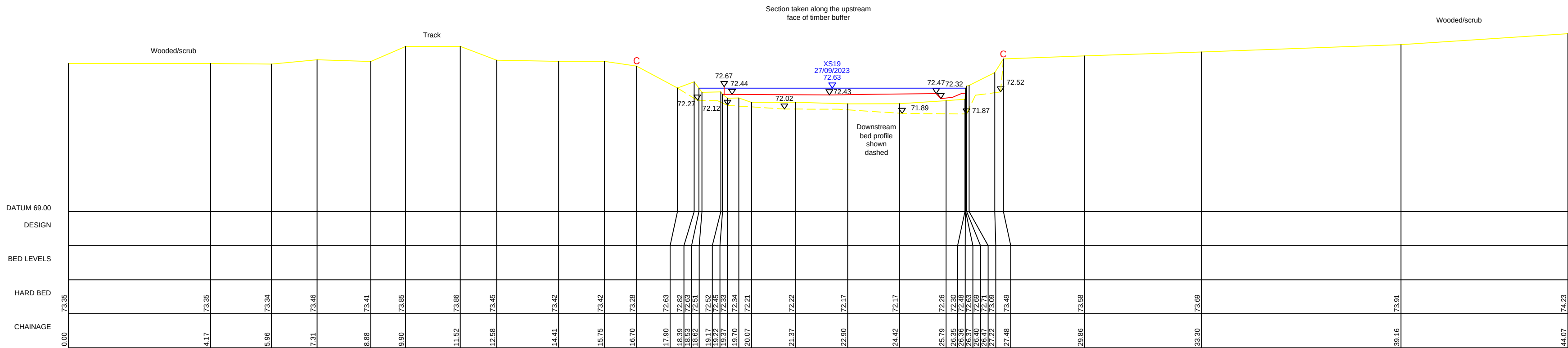
2 Arden Court, Arden Road, Alcester
Warwickshire, B49 6HN



Date:	Notes:	Name:	Rev:

Drawn: MC	Checked: SC	Scale: 1:100	Date: 29/09/23
File Name: GCS-JBA-Silburn Way-1		Sheet size: A1	Sheet: 8 of 9





C

Hydraulic Structures

Included in model? (state reason if not):	Yes																								
Model label:	IRK_11564us_BB																								
Type:	Bridge																								
How has structure been modelled?	The structure was modelled as a bridge unit using ESTRY. The following modelling parameters were used: <table border="1"> <thead> <tr> <th colspan="2">IRK_11564us_BB</th></tr> <tr> <th>H</th><th>W</th></tr> </thead> <tbody> <tr><td>71.256</td><td>0</td></tr> <tr><td>71.34</td><td>1.83</td></tr> <tr><td>71.39</td><td>2.35</td></tr> <tr><td>71.63</td><td>3.36</td></tr> <tr><td>71.79</td><td>4.99</td></tr> <tr><td>71.97</td><td>5.47</td></tr> <tr><td>71.98</td><td>5.54</td></tr> <tr><td>72.76</td><td>5.1</td></tr> <tr><td>73.57</td><td>4</td></tr> <tr><td>74.43</td><td>0</td></tr> </tbody> </table>	IRK_11564us_BB		H	W	71.256	0	71.34	1.83	71.39	2.35	71.63	3.36	71.79	4.99	71.97	5.47	71.98	5.54	72.76	5.1	73.57	4	74.43	0
IRK_11564us_BB																									
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72.76	5.1																								
73.57	4																								
74.43	0																								
Downstream Face, looking Upstream CS: Picture not available	Upstream Face, looking Downstream CS: 																								

Included in model? (state reason if not):	Yes																																								
Model label:	IRK_11487_WW																																								
Type:	Weir																																								
How has structure been modelled?	The structure was modelled as a weir unit using ESTRY. The following modelling parameters were used: <table border="1"> <thead> <tr> <th colspan="2">IRK_11487_WW</th> </tr> <tr> <th>X</th><th>Z</th></tr> </thead> <tbody> <tr><td>16.7</td><td>73.28</td></tr> <tr><td>17.9</td><td>72.63</td></tr> <tr><td>18.39</td><td>72.82</td></tr> <tr><td>18.53</td><td>72.63</td></tr> <tr><td>18.62</td><td>72.51</td></tr> <tr><td>19.17</td><td>72.52</td></tr> <tr><td>19.22</td><td>72.45</td></tr> <tr><td>22.4</td><td>72.43</td></tr> <tr><td>25.51</td><td>72.47</td></tr> <tr><td>25.64</td><td>72.32</td></tr> <tr><td>25.98</td><td>72.32</td></tr> <tr><td>26.26</td><td>72.48</td></tr> <tr><td>26.36</td><td>72.48</td></tr> <tr><td>26.37</td><td>72.63</td></tr> <tr><td>26.4</td><td>72.69</td></tr> <tr><td>26.47</td><td>72.71</td></tr> <tr><td>27.22</td><td>73.09</td></tr> <tr><td>27.48</td><td>73.49</td></tr> </tbody> </table>	IRK_11487_WW		X	Z	16.7	73.28	17.9	72.63	18.39	72.82	18.53	72.63	18.62	72.51	19.17	72.52	19.22	72.45	22.4	72.43	25.51	72.47	25.64	72.32	25.98	72.32	26.26	72.48	26.36	72.48	26.37	72.63	26.4	72.69	26.47	72.71	27.22	73.09	27.48	73.49
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Included in model? (state reason if not):	Yes																																												
Model label:	IRK_11460_WW																																												
Type:	Weir																																												
How has structure been modelled?	The structure was modelled as a weir unit using ESTRY. The following modelling parameters were used: <table border="1"> <thead> <tr> <th colspan="2">IRK_11460_WW</th> </tr> <tr> <th>X</th><th>Z</th></tr> </thead> <tbody> <tr><td>2.712</td><td>73.665</td></tr> <tr><td>3.898</td><td>73.093</td></tr> <tr><td>6.35</td><td>73.04</td></tr> <tr><td>7.07</td><td>72.79</td></tr> <tr><td>8.39</td><td>72.69</td></tr> <tr><td>8.6</td><td>72.67</td></tr> <tr><td>8.82</td><td>72.46</td></tr> <tr><td>8.87</td><td>72.37</td></tr> <tr><td>8.88</td><td>72.24</td></tr> <tr><td>8.9</td><td>72.16</td></tr> <tr><td>10.23</td><td>72.28</td></tr> <tr><td>10.75</td><td>71.99</td></tr> <tr><td>11.15</td><td>72.19</td></tr> <tr><td>14.42</td><td>72.24</td></tr> <tr><td>15.95</td><td>72.22</td></tr> <tr><td>15.98</td><td>72.37</td></tr> <tr><td>16.03</td><td>72.49</td></tr> <tr><td>17.02</td><td>72.88</td></tr> <tr><td>17.39</td><td>73.12</td></tr> <tr><td>18.791</td><td>73.49</td></tr> </tbody> </table>	IRK_11460_WW		X	Z	2.712	73.665	3.898	73.093	6.35	73.04	7.07	72.79	8.39	72.69	8.6	72.67	8.82	72.46	8.87	72.37	8.88	72.24	8.9	72.16	10.23	72.28	10.75	71.99	11.15	72.19	14.42	72.24	15.95	72.22	15.98	72.37	16.03	72.49	17.02	72.88	17.39	73.12	18.791	73.49
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Model label:	IRK_11433_WW																																																		
Type:	Weir																																																		
How has structure been modelled?	The structure was modelled as a weir unit using ESTRY. The following modelling parameters were used: <table> <tr> <th colspan="2">IRK_11433_WW</th></tr> <tr> <th>X</th><th>Z</th></tr> <tr><td>4.571</td><td>73.462</td></tr> <tr><td>5.727</td><td>73.093</td></tr> <tr><td>7.79</td><td>72.92</td></tr> <tr><td>8.97</td><td>72.66</td></tr> <tr><td>9.94</td><td>72.28</td></tr> <tr><td>10.42</td><td>72.07</td></tr> <tr><td>11.04</td><td>72.19</td></tr> <tr><td>11.05</td><td>72.12</td></tr> <tr><td>11.06</td><td>71.94</td></tr> <tr><td>13.76</td><td>71.94</td></tr> <tr><td>13.86</td><td>71.89</td></tr> <tr><td>14.26</td><td>71.83</td></tr> <tr><td>14.56</td><td>71.92</td></tr> <tr><td>16.56</td><td>71.97</td></tr> <tr><td>16.96</td><td>71.78</td></tr> <tr><td>17.06</td><td>71.97</td></tr> <tr><td>18.1</td><td>71.97</td></tr> <tr><td>18.1</td><td>72.12</td></tr> <tr><td>18.22</td><td>72.23</td></tr> <tr><td>18.78</td><td>72.44</td></tr> <tr><td>19.78</td><td>72.69</td></tr> <tr><td>20.44</td><td>73.14</td></tr> <tr><td>22.021</td><td>73.247</td></tr> </table>	IRK_11433_WW		X	Z	4.571	73.462	5.727	73.093	7.79	72.92	8.97	72.66	9.94	72.28	10.42	72.07	11.04	72.19	11.05	72.12	11.06	71.94	13.76	71.94	13.86	71.89	14.26	71.83	14.56	71.92	16.56	71.97	16.96	71.78	17.06	71.97	18.1	71.97	18.1	72.12	18.22	72.23	18.78	72.44	19.78	72.69	20.44	73.14	22.021	73.247
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Downstream Face, looking Upstream CS: 	Upstream Face, looking Downstream CS: 																																																		

Included in model? (state reason if not):	Yes																												
Model label:	IRK_11405_WW																												
Type:	Weir																												
How has structure been modelled?	The structure was modelled as a weirunit using ESTRY. The following modelling parameters were used: <table border="1"> <thead> <tr> <th colspan="2">IRK_11405_WW</th> </tr> <tr> <th>X</th><th>Z</th></tr> </thead> <tbody> <tr><td>5.424</td><td>72.983</td></tr> <tr><td>6.663</td><td>72.899</td></tr> <tr><td>9.18</td><td>72.14</td></tr> <tr><td>11.05</td><td>71.89</td></tr> <tr><td>11.08</td><td>71.84</td></tr> <tr><td>11.13</td><td>71.68</td></tr> <tr><td>18.04</td><td>71.68</td></tr> <tr><td>18.09</td><td>71.89</td></tr> <tr><td>18.32</td><td>72.01</td></tr> <tr><td>18.73</td><td>72.18</td></tr> <tr><td>19.59</td><td>72.88</td></tr> <tr><td>21.785</td><td>73.13</td></tr> </tbody> </table>	IRK_11405_WW		X	Z	5.424	72.983	6.663	72.899	9.18	72.14	11.05	71.89	11.08	71.84	11.13	71.68	18.04	71.68	18.09	71.89	18.32	72.01	18.73	72.18	19.59	72.88	21.785	73.13
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Downstream Face, looking Upstream CS:	Upstream Face, looking Downstream CS:  																												

Included in model? (state reason if not):	Yes																																				
Model label:	IRK_11378_WW																																				
Type:	Weir																																				
How has structure been modelled?	The structure was modelled as a weir unit using ESTRY. The following modelling parameters were used: <table> <tr> <th colspan="2">IRK_11378_WW</th></tr> <tr> <th>X</th><th>Z</th></tr> <tr><td>8.567</td><td>72.977</td></tr> <tr><td>9.33</td><td>72.92</td></tr> <tr><td>11.29</td><td>71.97</td></tr> <tr><td>11.53</td><td>71.7</td></tr> <tr><td>12.63</td><td>71.68</td></tr> <tr><td>12.66</td><td>71.6</td></tr> <tr><td>12.68</td><td>71.51</td></tr> <tr><td>12.73</td><td>71.43</td></tr> <tr><td>19.7</td><td>71.43</td></tr> <tr><td>19.75</td><td>71.6</td></tr> <tr><td>19.77</td><td>71.68</td></tr> <tr><td>20.24</td><td>71.66</td></tr> <tr><td>20.76</td><td>72.14</td></tr> <tr><td>21.37</td><td>72.25</td></tr> <tr><td>21.85</td><td>72.88</td></tr> <tr><td>22.52</td><td>73.07</td></tr> </table>	IRK_11378_WW		X	Z	8.567	72.977	9.33	72.92	11.29	71.97	11.53	71.7	12.63	71.68	12.66	71.6	12.68	71.51	12.73	71.43	19.7	71.43	19.75	71.6	19.77	71.68	20.24	71.66	20.76	72.14	21.37	72.25	21.85	72.88	22.52	73.07
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Downstream Face, looking Upstream CS: 	Upstream Face, looking Downstream CS: 																																				

Included in model? (state reason if not):	Yes																												
Model label:	IRK_10882_WW																												
Type:	Weir																												
How has structure been modelled?	The structure was modelled as a weir unit using ESTRY. The following modelling parameters were used: <table> <tr> <th colspan="2">IRK_10882_WW</th></tr> <tr> <th>X</th><th>Z</th></tr> <tr><td>11.247</td><td>71.522</td></tr> <tr><td>11.378</td><td>70.71</td></tr> <tr><td>11.393</td><td>70.557</td></tr> <tr><td>11.426</td><td>70.56</td></tr> <tr><td>13.284</td><td>70.56</td></tr> <tr><td>15.309</td><td>70.56</td></tr> <tr><td>17.101</td><td>70.545</td></tr> <tr><td>19.409</td><td>70.53</td></tr> <tr><td>21.079</td><td>70.53</td></tr> <tr><td>21.099</td><td>70.541</td></tr> <tr><td>21.115</td><td>70.71</td></tr> <tr><td>21.195</td><td>71.748</td></tr> </table>	IRK_10882_WW		X	Z	11.247	71.522	11.378	70.71	11.393	70.557	11.426	70.56	13.284	70.56	15.309	70.56	17.101	70.545	19.409	70.53	21.079	70.53	21.099	70.541	21.115	70.71	21.195	71.748
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Downstream Face, looking Upstream CS: 	Upstream Face, looking Downstream CS: 																												

Included in model? (state reason if not):	Yes																														
Model label:	IRK_10521_BB																														
Type:	Bridge																														
How has structure been modelled?	The structure was modelled as a bridge unit using ESTRY. The following modelling parameters were used: <table border="1"> <thead> <tr> <th colspan="2">IRK_10521_BB</th> </tr> <tr> <th>H</th><th>W</th></tr> </thead> <tbody> <tr><td>66.54</td><td>0</td></tr> <tr><td>66.55</td><td>1.37</td></tr> <tr><td>66.8</td><td>3.28</td></tr> <tr><td>66.87</td><td>3.53</td></tr> <tr><td>67.05</td><td>4.67</td></tr> <tr><td>67.25</td><td>5.05</td></tr> <tr><td>67.26</td><td>5.63</td></tr> <tr><td>68.07</td><td>5.65</td></tr> <tr><td>68.99</td><td>5.69</td></tr> <tr><td>69.22</td><td>5.28</td></tr> <tr><td>69.37</td><td>4.3</td></tr> <tr><td>69.5</td><td>3.2</td></tr> <tr><td>69.64</td><td>0</td></tr> </tbody> </table>	IRK_10521_BB		H	W	66.54	0	66.55	1.37	66.8	3.28	66.87	3.53	67.05	4.67	67.25	5.05	67.26	5.63	68.07	5.65	68.99	5.69	69.22	5.28	69.37	4.3	69.5	3.2	69.64	0
IRK_10521_BB																															
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Downstream Face, looking Upstream CS:	Upstream Face, looking Downstream CS:  																														

Included in model? (state reason if not):	Yes																										
Model label:	IRK_9499us_BB																										
Type:	Bridge																										
How has structure been modelled?	The structure was modelled as a bridge unit using ESTRY. The following modelling parameters were used: <table border="1"> <thead> <tr> <th colspan="2">IRK_9949us_BB</th> </tr> <tr> <th>X</th><th>Z</th></tr> </thead> <tbody> <tr><td>16.59</td><td>68.59</td></tr> <tr><td>16.653</td><td>66.469</td></tr> <tr><td>17.068</td><td>66.486</td></tr> <tr><td>18.166</td><td>66.412</td></tr> <tr><td>19.733</td><td>66.259</td></tr> <tr><td>21.102</td><td>66.19</td></tr> <tr><td>22.847</td><td>66.234</td></tr> <tr><td>23.694</td><td>66.365</td></tr> <tr><td>23.74</td><td>66.93</td></tr> <tr><td>23.871</td><td>68.588</td></tr> <tr><td>24.141</td><td>68.609</td></tr> </tbody> </table>	IRK_9949us_BB		X	Z	16.59	68.59	16.653	66.469	17.068	66.486	18.166	66.412	19.733	66.259	21.102	66.19	22.847	66.234	23.694	66.365	23.74	66.93	23.871	68.588	24.141	68.609
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Downstream Face, looking Upstream CS: 	Upstream Face, looking Downstream CS: Picture not available																										

Included in model? (state reason if not):	Yes																																		
Model label:	IRK_9807_WW																																		
Type:	Weir																																		
How has structure been modelled?	The structure was modelled as a weir unit using ESTRY. The following modelling parameters were used: <table border="1"> <thead> <tr> <th colspan="2">IRK_9807_WW</th> </tr> <tr> <th>X</th><th>Z</th></tr> </thead> <tbody> <tr><td>12.597</td><td>67.619</td></tr> <tr><td>12.821</td><td>67.54</td></tr> <tr><td>13.19</td><td>67.51</td></tr> <tr><td>13.259</td><td>66.688</td></tr> <tr><td>13.278</td><td>66.51</td></tr> <tr><td>13.343</td><td>66.51</td></tr> <tr><td>16.08</td><td>66.51</td></tr> <tr><td>17.359</td><td>66.525</td></tr> <tr><td>20.169</td><td>66.54</td></tr> <tr><td>22.484</td><td>66.55</td></tr> <tr><td>24.078</td><td>66.55</td></tr> <tr><td>24.14</td><td>66.55</td></tr> <tr><td>24.169</td><td>66.688</td></tr> <tr><td>24.338</td><td>67.467</td></tr> <tr><td>24.82</td><td>67.639</td></tr> </tbody> </table>	IRK_9807_WW		X	Z	12.597	67.619	12.821	67.54	13.19	67.51	13.259	66.688	13.278	66.51	13.343	66.51	16.08	66.51	17.359	66.525	20.169	66.54	22.484	66.55	24.078	66.55	24.14	66.55	24.169	66.688	24.338	67.467	24.82	67.639
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Downstream Face, looking Upstream CS:	Upstream Face, looking Downstream CS:  																																		

Included in model? (state reason if not):	Yes																										
Model label:	IRK_9512_WW																										
Type:	Weir																										
How has structure been modelled?	The structure was modelled as a weir unit using ESTRY. The following modelling parameters were used: <table border="1"> <thead> <tr> <th colspan="2">IRK_9512_WW</th></tr> <tr> <th>X</th><th>Z</th></tr> </thead> <tbody> <tr><td>8.012</td><td>65.429</td></tr> <tr><td>8.088</td><td>64.24</td></tr> <tr><td>8.095</td><td>64.05</td></tr> <tr><td>8.11</td><td>64.05</td></tr> <tr><td>10.246</td><td>64.05</td></tr> <tr><td>12.23</td><td>64.05</td></tr> <tr><td>14.759</td><td>64.05</td></tr> <tr><td>15.906</td><td>64.05</td></tr> <tr><td>15.907</td><td>64.05</td></tr> <tr><td>15.908</td><td>64.24</td></tr> <tr><td>15.91</td><td>65.412</td></tr> </tbody> </table>	IRK_9512_WW		X	Z	8.012	65.429	8.088	64.24	8.095	64.05	8.11	64.05	10.246	64.05	12.23	64.05	14.759	64.05	15.906	64.05	15.907	64.05	15.908	64.24	15.91	65.412
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Downstream Face, looking Upstream CS: 	Upstream Face, looking Downstream CS: Picture not available																										

Included in model? (state reason if not):	Yes																																																
Model label:	IRK_9488_I																																																
Type:	Culvert																																																
How has structure been modelled?	The structure was modelled as a culvert unit using ESTRY. The following modelling parameters were used: <table border="1"> <thead> <tr> <th colspan="2">IRK_9488_I</th> </tr> <tr> <th>X</th><th>Z</th></tr> </thead> <tbody> <tr><td>8.51</td><td>66.8</td></tr> <tr><td>8.52</td><td>65.14</td></tr> <tr><td>10.91</td><td>64.73</td></tr> <tr><td>13.54</td><td>64.17</td></tr> <tr><td>15.36</td><td>64.21</td></tr> <tr><td>17.91</td><td>63.9</td></tr> <tr><td>18.546</td><td>63.862</td></tr> <tr><td>18.622</td><td>63.04</td></tr> <tr><td>18.67</td><td>62.828</td></tr> <tr><td>20.344</td><td>62.912</td></tr> <tr><td>22.025</td><td>62.916</td></tr> <tr><td>23.787</td><td>62.804</td></tr> <tr><td>25.515</td><td>62.846</td></tr> <tr><td>26.509</td><td>62.787</td></tr> <tr><td>26.53</td><td>63.04</td></tr> <tr><td>26.596</td><td>63.869</td></tr> <tr><td>27.04</td><td>63.89</td></tr> <tr><td>27.73</td><td>64.06</td></tr> <tr><td>29.75</td><td>64.05</td></tr> <tr><td>32.08</td><td>65.11</td></tr> <tr><td>34.33</td><td>65.85</td></tr> <tr><td>34.34</td><td>66.51</td></tr> </tbody> </table>	IRK_9488_I		X	Z	8.51	66.8	8.52	65.14	10.91	64.73	13.54	64.17	15.36	64.21	17.91	63.9	18.546	63.862	18.622	63.04	18.67	62.828	20.344	62.912	22.025	62.916	23.787	62.804	25.515	62.846	26.509	62.787	26.53	63.04	26.596	63.869	27.04	63.89	27.73	64.06	29.75	64.05	32.08	65.11	34.33	65.85	34.34	66.51
IRK_9488_I																																																	
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Model label:	IRK_9121_WW																												
Type:	Weir																												
How has structure been modelled?	The structure was modelled as a weir unit using ESTRY. The following modelling parameters were used: <table border="1"> <thead> <tr> <th colspan="2">IRK_9121_WW</th> </tr> <tr> <th>X</th><th>Z</th></tr> </thead> <tbody> <tr><td>18.191</td><td>63.808</td></tr> <tr><td>18.229</td><td>62.47</td></tr> <tr><td>18.235</td><td>62.28</td></tr> <tr><td>18.243</td><td>62.28</td></tr> <tr><td>20.686</td><td>62.28</td></tr> <tr><td>20.788</td><td>62.28</td></tr> <tr><td>21.42</td><td>62.29</td></tr> <tr><td>24.287</td><td>62.3</td></tr> <tr><td>27.455</td><td>62.3</td></tr> <tr><td>27.469</td><td>62.3</td></tr> <tr><td>27.475</td><td>62.47</td></tr> <tr><td>27.525</td><td>63.856</td></tr> </tbody> </table>	IRK_9121_WW		X	Z	18.191	63.808	18.229	62.47	18.235	62.28	18.243	62.28	20.686	62.28	20.788	62.28	21.42	62.29	24.287	62.3	27.455	62.3	27.469	62.3	27.475	62.47	27.525	63.856
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18.235	62.28																												
18.243	62.28																												
20.686	62.28																												
20.788	62.28																												
21.42	62.29																												
24.287	62.3																												
27.455	62.3																												
27.469	62.3																												
27.475	62.47																												
27.525	63.856																												
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Included in model? (state reason if not):	Yes																																								
Model label:	IRK_8968_BB																																								
Type:	Bridge																																								
How has structure been modelled?	The structure was modelled as a bridge unit using ESTRY. The following modelling parameters were used: <table border="1"> <thead> <tr> <th colspan="2">IRK_8968_BB</th> </tr> <tr> <th>X</th><th>Z</th></tr> </thead> <tbody> <tr><td>8</td><td>63.07</td></tr> <tr><td>8.1</td><td>61.97</td></tr> <tr><td>8.97</td><td>61.5</td></tr> <tr><td>9.662</td><td>61.502</td></tr> <tr><td>10.308</td><td>60.274</td></tr> <tr><td>10.535</td><td>60.23</td></tr> <tr><td>10.871</td><td>60.095</td></tr> <tr><td>12.052</td><td>59.911</td></tr> <tr><td>13.463</td><td>59.881</td></tr> <tr><td>15.151</td><td>59.829</td></tr> <tr><td>16.665</td><td>59.981</td></tr> <tr><td>17.556</td><td>60.148</td></tr> <tr><td>17.789</td><td>60.23</td></tr> <tr><td>18.095</td><td>60.324</td></tr> <tr><td>18.164</td><td>61.505</td></tr> <tr><td>19.15</td><td>61.72</td></tr> <tr><td>19.74</td><td>61.97</td></tr> <tr><td>19.75</td><td>63.06</td></tr> </tbody> </table>	IRK_8968_BB		X	Z	8	63.07	8.1	61.97	8.97	61.5	9.662	61.502	10.308	60.274	10.535	60.23	10.871	60.095	12.052	59.911	13.463	59.881	15.151	59.829	16.665	59.981	17.556	60.148	17.789	60.23	18.095	60.324	18.164	61.505	19.15	61.72	19.74	61.97	19.75	63.06
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Hydrology Report

Flood estimation report: Silburn Way, Middleton

Introduction

This report template is based on a supporting document to the Environment Agency's flood estimation guidelines. It provides a record of the hydrological context, the method statement, the calculations and decisions made during flood estimation and the results.

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Approval

	Name and qualifications	Date
Method statement prepared by:	Sam Cogan BSc MSc	30/08/2023
Method statement reviewed by:	Eva Kordomenidi BSc MSc MCIWEM CWEM CSci	26/10/2023
Calculations prepared by:	Sam Cogan BSc MSc	31/08/2023
Calculations reviewed by:	Eva Kordomenidi BSc MSc MCIWEM CWEM CSci	26/10/2023

Revision History

Revision reference	Date issued	Amendments	Issued to

Abbreviations

AMAX.....	Annual Maximum
AREA	Catchment area (km ²)
BFI	Base Flow Index
BFIHOST	Base Flow Index derived using the HOST soil classification
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
NRFA	National River Flow Archive
POT	Peaks Over a Threshold
QMED	Median Annual Flood (with return period 2 years)
ReFH	Revitalised Flood Hydrograph method
SAAR.....	Standard Average Annual Rainfall (mm)
Tp(0).....	Time to peak of the instantaneous unit hydrograph
URBEXT1990	FEH index of fractional urban extent
URBEXT2000	Revised index of urban extent, measured differently from URBEXT1990
WINFAP-FEH.....	Windows Frequency Analysis Package – used for FEH statistical method

Note on flood probability

This document quotes the probability of a flood magnitude in terms of a return period based on analysis of annual maximum (AMAX) floods. The return period of a flood on the AMAX scale is the average interval between AMAX floods of that magnitude or greater. The inverse of the AMAX return period is the annual exceedance probability (AEP).

Return periods are output by the Flood Estimation Handbook (FEH) software and can be expressed more succinctly than AEP. AEP can be helpful when presenting results to non-specialists who may associate the concept of return period with a regular rather than an average interval.

Return period can also be measured on the peaks-over-threshold (POT) scale as the average interval between floods of that magnitude or greater. The difference between AMAX and POT return periods is only important for short return periods (under 10 years).

The table below is provided to enable quick conversion between these different measures.

AMAX return period (years)	n/a	2	5	10	20	30	50	75	100	200	1,000
AEP (%)	n/a	50	20	10	5	3.33	2	1.33	1	0.5	0.1
POT return period (years)	1	1.5	4.5	9.5	20	30	50	75	100	200	1,000

1 Method statement

1.1 Requirements for flood estimates

Overview

- Purpose of study
- Peak flows or hydrographs?
- Range of return periods and locations

The proposed development site is located adjacent to Silburn Way, Middleton (NGR: SD 85346 05209). Proposals for the site are for the redevelopment of an existing commercial site. The southern site boundary is located adjacent to the River Irk. This is a 'Main River' designated watercourse, falling within the remit of the Environment Agency. According to the Environment Agency's Flood Map for Planning, approximately 90% and 100% of the site is located within Flood Zones 3 and 2, respectively (Figure 1-1).

A detailed review of the Flood Map for Planning maps indicated a number of discrepancies with the topography of the valley. This indicates that the existing EA flood zone extents either originate from an older study and/or originate from broadscale modelling techniques

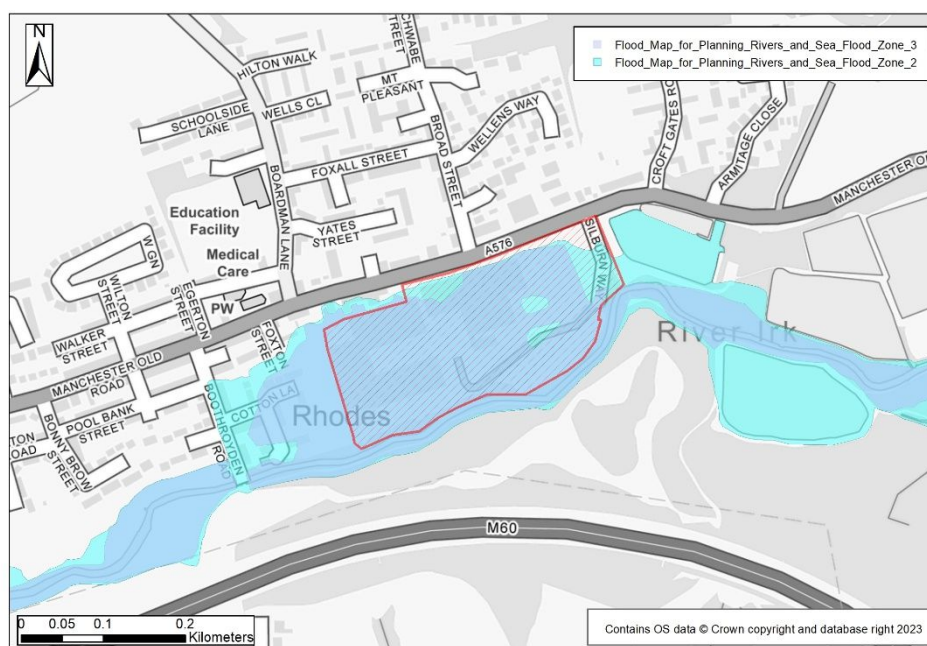


Figure 1.1 - Environment Agency's Flood Map for Planning

JBA Consulting was commissioned by Civils to assess the extent of Flood Zones 2 and 3, using up-to-date fluvial modelling results. Detailed modelling is required to accurately assess the risk of flooding from the River Irk, and evaluate development options for the site. As part of the scope of this project, hydrology estimates are therefore required for input to the hydraulic model of the River Irk. This document details the hydrological assessment undertaken to derive the hydraulic model inflows.

Peak flow estimates and hydrographs are required for three flow estimation points (FEP) for both the River Irk and Boardman Brook. Peak flow estimates and hydrographs have been derived for the following annual exceedance probabilities (AEP) events:

- 50%;
- 3.33%;

- 1%; and
- 0.1%.

Based on July 2021 Environment Agency climate change allowance guidance¹, the proposed development site is located within the Irwell Management Catchment. For the '2080' scenario, the Central allowance climate change uplift is 35%. This has been applied to the 1% AEP event peak flows. Peak flows for the Higher allowance (46% uplift) have also been calculated. Peak flow estimates and hydrographs derived from the hydrological analysis will be incorporated into a 1D-2D hydraulic model capable of simulating flood extents, levels and flows through time in relation to the development site.

1.2 The catchment

Map (Include river network, catchment boundary and gauging stations)

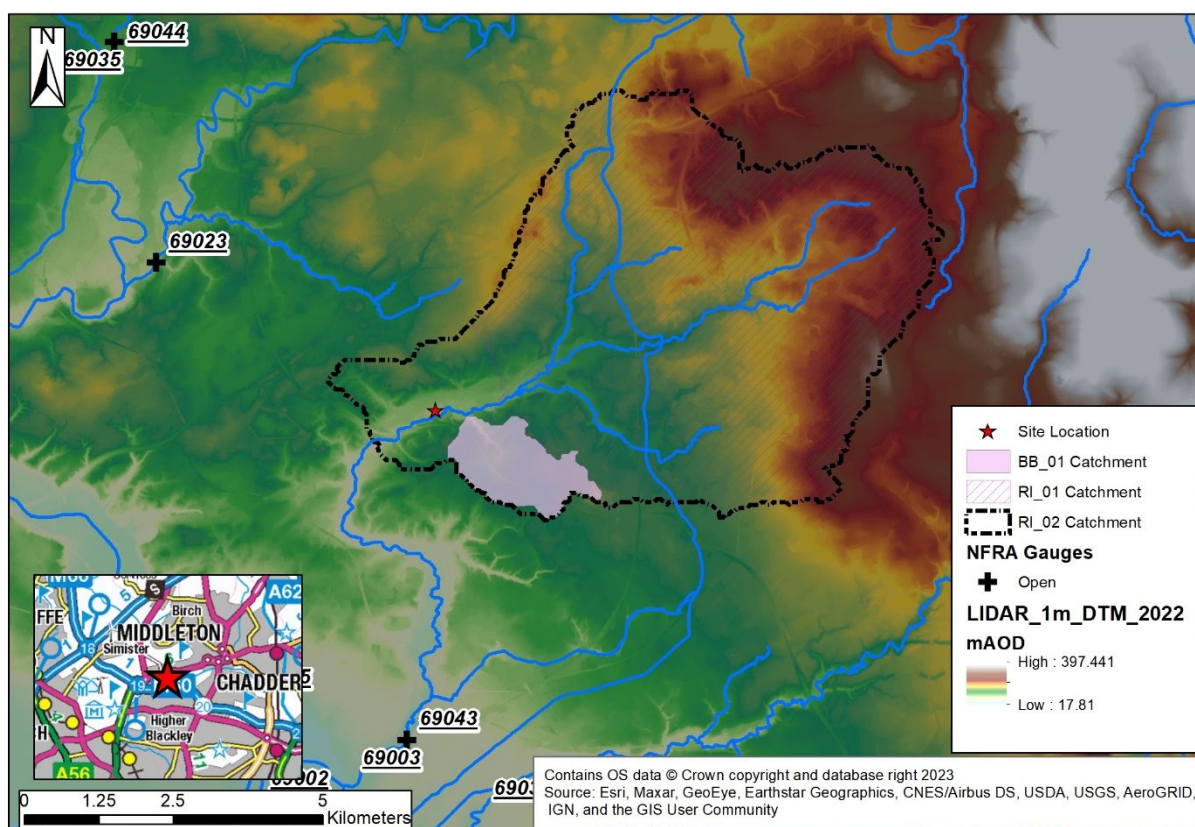


Figure 1.2 – Catchment extent

Description

Include topography, climate, geology, soils, land use and any unusual features that may affect the flood hydrology.

The River Irk, including contributing watercourses, drains an area of approximately 44.9km² to the downstream hydraulic model boundary and includes the contributing catchment of Broadman Brook. The general elevation trend of the larger study catchment is a decline from east to west as land falls from 215mAOd to 60mAOd.

Underlying bedrock geology of the wider River Irk catchment predominately consists of Pennine lower coal measures formation and

¹ Environment Agency (2023). Guidance: Flood risk assessments: climate change allowances. Accessed 30/08/2023. [Source: <https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances#Select-the-peak-river-flow-allowances-to-use-for-your-assessment>].

south wales lower coal measures formation (undifferentiated) - mudstone, siltstone, sandstone, coal, ironstone and ferricrete with bands of Triassic and Permian rocks (undifferentiated) to the very lower reaches of the catchment. Superficial deposits of the catchment consist of glacial sand and gravel and till.

Typical soils across the study catchment are variable however the catchment is predominately covered by freely draining slightly acid sandy soils with Slowly permeable seasonally wet acid loamy and clayey soils to the northern and southern edges of the catchment, which includes the catchment extent of Boardman Brook².

The underlying bedrock, superficial deposits and soil types would indicate that the fluvial response to rainfall based on soil properties would likely be slow due to the underlying freely draining soils. Generally, the catchment of the River Irk may be considered to be relatively permeable however the catchment of Boardman Brook may be considered to be relatively impermeable.

The catchment is located within the North West England's regional climate. The exposure of NW England to westerly maritime air masses and the presence of extensive areas of high ground mean that the region has some of the wettest places in the UK. The higher parts of the Lake District are particularly wet, with an average of over 3200mm of rain each year. In contrast, the reputedly wet city of Manchester averages only 830mm and the more sheltered areas of Cheshire and the Eden valley in Cumbria are even drier with less than 800mm per year. These areas benefit from the 'rain shadow' effect of the high ground of N Wales and the Lake District respectively³.

Based on the Environment Agency Asset Management website⁴, there are no structural flood defences along the bank of the River Irk, only high ground banks. The Asset ID (65334) has an actual condition of 'adequate' with an upstream crest level of 68.74m and a downstream crest level of 70.21m. The asset maintainer of the embankment is a Private individual, Company or Charity.

The wider catchment is generally comprised of grassland, agricultural land use and urban development associated with the outskirts of Manchester. The urban extent within the catchment may be a limitation to the methodologies applied within this study. In addition, there are a number of significant lakes / reservoirs within the study catchment, specifically within close proximity to the site, however these reservoirs will be included within the hydraulic model so they should not have any impact on the final methodology used within this study.

1.3 Source of flood peak data

Source	National River Flow Archive (NRFA) peak flows dataset, Version 11.1, released March 2023. This contains data up to water year 2020-21.
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² British Geological Survey (2021). UK Soil Observatory Map Viewer. Accessed: 30/08/2023. [Source: mapapps2.bgs.ac.uk/ukso/home.html].

³ https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/weather/learn-about/uk-past-events/regional-climates/north-west-england--isle-of-man_-climate---met-office.pdf

⁴ Environment Agency (2002) Asset Information and Maintenance Programme (data.gov.uk)

1.4 Gauging stations (flow or level)

(at or very near to the sites of flood estimates)

River Irk Gauges are all located downstream of the proposed model extent

Water-course	Station name	Gauging authority number	NRFA number	Catchment area (km ²)	Type (rated / ultrasonic / level...)	Start of record and end if station closed
River Irk	Irk @ Collyhurst Weir	-	69043	72.3	Broad-crested weir	01/1995 to present day
River Irk	Irk @ Scotland Weir	-	69003	72.5	Compound broad-crested weir	01/1949 to 01/2001

1.5 Data available at each flow gauging station in Table 1.4

Station name	Start and end of NRFA flood peak record	Update for this study?	OK for QMED?	OK for pooling?	Data quality check needed?	Other comments on station and flow data quality
Irk @ Collyhurst Weir	01/1995 to present day	N	Y	Y	N	NGR: SJ848996 Curved non-standard round nosed broad-crested weir to replace Scotland Weir (69003). Gauges a catchment with moorland headwaters but urbanised lower catchment. Water year 1994/1995 rejected as the AMAX is from the partial water year at the start of the record. Full period of record peak flow data reviewed and released in August 2021 (WINFAP Files v10).
Irk @ Scotland Weir	01/1949 to 01/2001	N	Y	Y	N	NGR: SJ841991 Non-standard weir affected by siltation, weed growth and debris. Due to siltation, weed growth and debris there is particular doubt on low-flow records before 1976, although data quality in general is not good. Weir damaged by a flood in December 1983. Station closed between February 1991 and October 1995.
Tabulate any updated or revised flood peak series in the Annex.						

Give link/reference to any further data quality checks carried out.

1.6 Rating equations

Station name	Type of rating e.g. theoretical, empirical; degree of extrapolation	Rating review needed?	Comments and link to any rating reviews
Irk @ Collyhurst Weir	Two peak flow ratings applied across period of record developed from current meter gaugings since 04/10/1995, with modelled top-end. Algal growth up to 5cm deep can occur on weir crest.	N	No rating updates are currently requested by the scope.
Irk @ Scotland Weir	Original rating based on physical model tests in 1936 and check gaugings at Redbank 1km upstream. Site was re-levelled in 1976 and new rating applied based on gaugings. Third rating, based on gaugings, applied after flood damage to weir crest in 1983. Flood Studies Report grade A1.	N	No rating updates are currently requested by the scope.

1.7 Other data available and how it has been obtained

Type of data	Data relevant to this study?	Data available ?	Source of data	Details
Check flow gaugings (if planned to review ratings)	N/A	N/A	-	No rating updates are currently requested by the scope.
Historic flood data Include chronology and interpretation of flood history in Annex or separate report.	Yes	Yes	Environment Agency WMS	No historic incidences of flooding recorded at the site or along the proposed model extent.
			BHS Chronology of British Hydrological Events	Based on historical records, approximately 5 flood events have occurred along the River Irk between 1662-1927 however none of these events make mention of Silburn Way but the 1927 event makes mention of Middleton.

			Faber Maunsell (2007) Irwell Areas Benefiting from Defences Study – Phases 2&3	A brief historic flood history for the River Irk was undertaken as part of the Faber Maunsell (2007) Irwell Areas Benefiting from Defences Study – Phases 2&3 study.
Flow or river level data for events	Yes	No	-	Ungauged watercourse
Rainfall data for events	No	No	-	Oldham raingauge is located within the study catchment. No flood event analysis is included within the scope
Potential evaporation data	No	No	-	No flood event analysis in scope.
Results from previous studies			Faber Maunsell (2007) Irwell Areas Benefiting from Defences Study – Phases 2&3	The South Area Northwest region of the Environment Agency appointed Faber Maunsell to undertake an 'Areas Benefiting from Defences' study for the Irwell catchment. The hydrology associated with the model made use of a 4.25hr storm duration for the upper Irk catchment based on a summer storm event profile. Time-to-peak was calculated based on the FEH equation. The final methodology used was FEH rainfall-runoff. A number of FEP's and their corresponding modelled levels and flows, which were centred around the site, was provided within the EA data request as well as 1% and 0.1% AEP level and flow results for a number of ISIS flow nodes along the River Irk.
Other data or information (e.g. groundwater, tides, channel widths, low flow statistics)	-	-	-	-

1.8 Hydrological understanding of catchment

Outline the conceptual model, addressing questions such as: - Where are the main sites of interest? - What is likely to cause flooding at those	The proposed development site is located adjacent to Silburn Way, Middleton (NGR: SD 85346 05209). The southern site boundary is located
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locations? (peak flows, flood volumes, backwater effects, combinations of peaks, groundwater, snowmelt, tides...) • Might those locations flood from runoff generated on part of the catchment only, e.g. downstream of a reservoir? • Is there a need to consider temporary debris dams or NFM features that could collapse?	adjacent to the River Irk. According to the Environment Agency's Flood Map for Planning, approximately 90% and 100% of the site is located within Flood Zones 3 and 2, respectively. The primary flood mechanism is likely to be channel capacity exceedance during times of sustained or heavy rainfall.
Any unusual catchment features to take into account? e.g. • highly permeable – avoid ReFH if BFIHOST>0.65, consider permeable catchment adjustment for statistical method if SPRHOST<20% • highly urbanised – seek local flow data; consider method that can account for differing sewer and topographic catchments • pumped watercourse – consider lowland catchment version of rainfall-runoff method • major reservoir influence (FARL<0.90) – consider flood routing, extensive floodplain storage – consider choice of method carefully	BFIHOST for the River Irk inflow catchment is around 0.65 due to its underlying freely draining soils and mudstone, siltstone, sandstone, coal, ironstone and ferricrete bedrock. Therefore, the catchment is considered highly permeable which may have an impact on derived flows. In addition, there is considered to be a moderate-high reservoir influence to the lower reaches of the catchment. However the reservoirs will be included within the hydraulic model, therefore the presence of reservoirs is not considered to be a major influence on the hydrological study. In addition, some of the study catchments are considered to be relatively urbanised.

1.9 Initial choice of approach

Is FEH appropriate? (it may not be for extremely heavily urbanised or complex catchments) If not, describe other methods to be used.	Yes. Catchment is somewhat permeable.
Initial choice of method(s) and reasons How will hydrograph shapes be derived if needed? Will the catchment be split into sub-catchments? If so, how?	<u>Peak flows</u> Peak flow estimates for inflow for the River Irk and Boardman Brook will be derived from application of FEH methods. Both FEH Statistical and ReH2 will be tested. <u>Hydrographs</u> Hydrographs for the model will be derived using the ReFH2 model. ReFH2 hydrographs will be scaled to the favoured peak flow estimates explored within this study.
Software to be used (with version numbers)	FEH Web Service⁵ / WINFAP v5⁶ / ReFH2.3 calibrated to FEH22

⁵ CEH 2015. The Flood Estimation Handbook (FEH) Online Service, Centre for Ecology & Hydrology, Wallingford, Oxon, UK.

⁶ WINFAP-FEH v4 © Wallingford HydroSolutions Limited 2016.

2 Locations where flood estimates required

The table below lists the locations of subject sites. The site codes listed below are used in all subsequent tables to save space.

2.1 Summary of subject sites

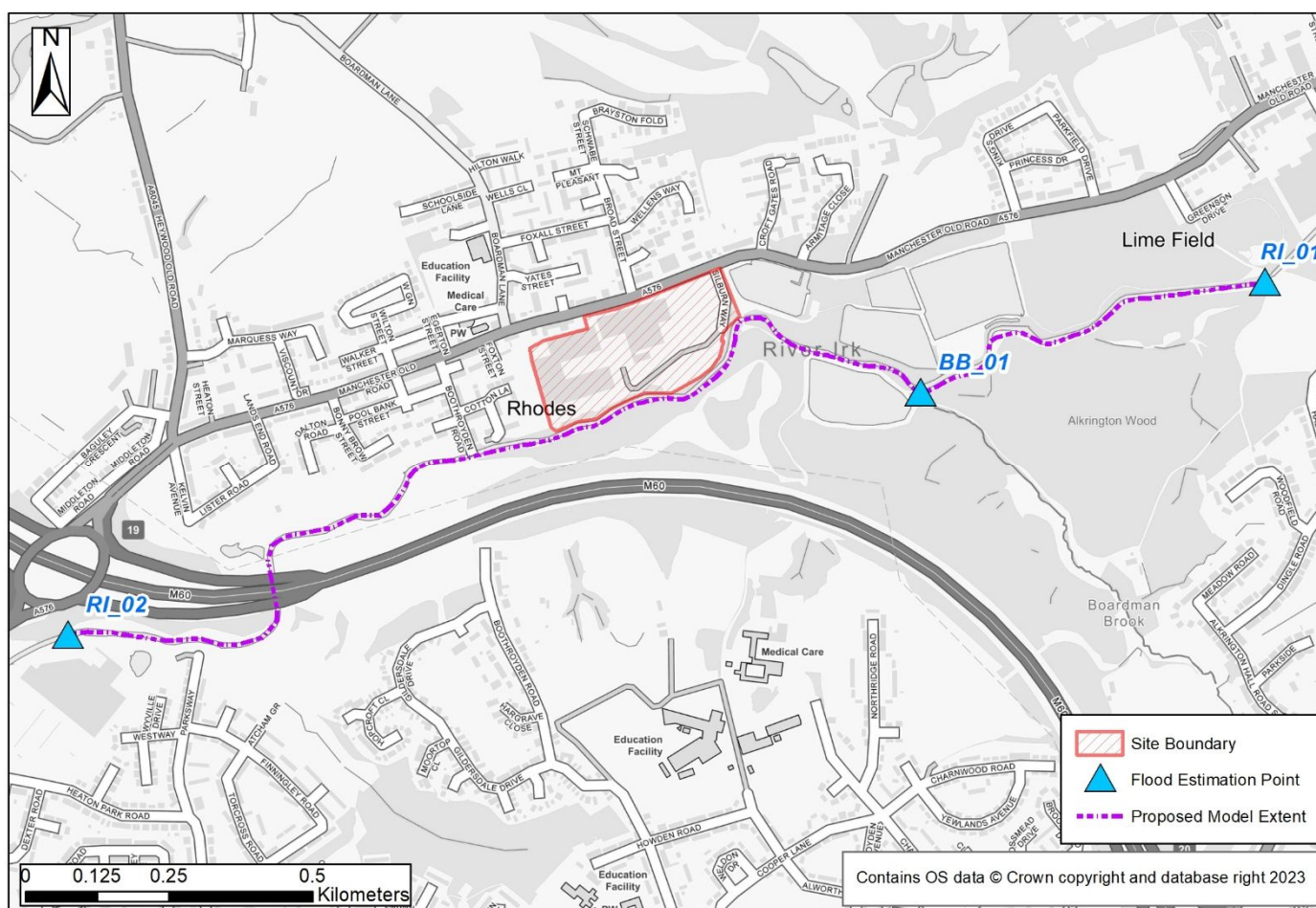


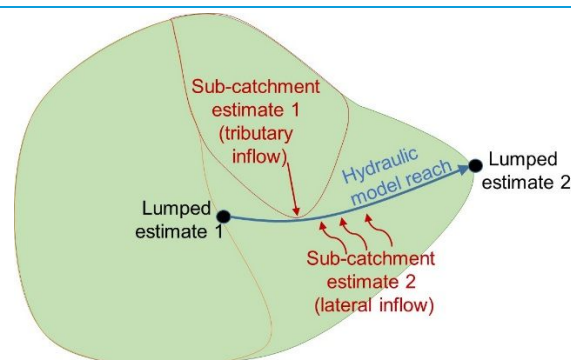
Figure 2.1 – Flood Estimation Point Location

Site code	Type of estimate L: lumped catchment S: Sub-catchment	Watercourse	Name or description of site	Easting	Northing	AREA on FEH CD-ROM (km ²)	Revised AREA if altered
RI_01	L	River Irk	River Irk - Model inflow location	386473	405337	38.1	38.3
BB_01	L	Boardman Brook	Boardman Brook - Model inflow location	385874	405144	2.7	2.5
RI_02	L	River Irk	River Irk - Model downstream boundary	384390.5	404721.5	44.9	-

Note: Lumped catchments (L) are complete catchments draining to points at which design flows are required.

Sub-catchments (S) are catchments or intervening areas that are being used as inputs to a semi-distributed model of the river system. There is no need to report any design flows for sub-catchments, as they are not relevant: the relevant result is the hydrograph that the sub-catchment is expected to contribute to a design flood event at a point further downstream in the river system. This will be recorded within the hydraulic model output files. However, catchment descriptors and ReFH model parameters should be recorded for sub-catchments so that the results can be reproduced.

The schematic diagram illustrates the distinction between lumped and sub-catchment estimates.



2.2 Important catchment descriptors at each subject site (incorporating any changes made)

Site code	FARL	PROPWET	BFIHOST 19	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	URBEXT 2000 ⁷	FPEXT
RI_01	0.977	0.57	0.683	7.37	49.9	1072	0.401	0.093
BB_01	0.994	0.57	0.333	1.94	27.4	999	0.377	0.140
RI_02	1.00	0.57	0.644	7.31	50.1	1062	0.380	0.096

2.3 Checking catchment descriptors

Record how catchment boundary was checked and describe any changes (add maps if needed)	The catchment boundaries have been reviewed against Ordnance Survey mapping and 50m contours. 1m LiDAR data and 50m terrain LiDAR data were consulted. Modifications to the natural catchment boundaries were considered necessary to all of the study catchments of the exported catchments to reflect natural topographic elevations.
Record how other catchment descriptors were checked and describe any changes. Include before/after table if necessary.	A qualitative sense check was carried out for BFIHOST and FARL. For RI_02, as the reservoirs within the catchment are to be included within the model, FARL was set to 1.00 to ensure there was no double counting of losses due to reservoir influence. For RI_01 DPLBAR value was modified using the standard modification equation ($\text{Area}^{0.548}$). For BB_01, due to the size of the study catchments the DPLBAR value was modified on an area ratio basis as the standard modification equation is known to produce suspect values for smaller catchments. Catchment descriptors checked against Cranfield University (2021). Cranfield Soil and Agrifood Institute: Soilscales and British Geological Society (2021). Geology of Britain viewer. Underlying bedrock geology of the catchment is generally composed of mudstone, siltstone, sandstone, coal, ironstone and ferricrete. Typical soils across the study catchment are predominately freely draining slightly acid sandy soils⁸. The variable BFIHOST values are considered representative of the variable nature of the catchment.
Version of URBEXT	URBEXT1990 / URBEXT2000
Method for updating of URBEXT	CPRE formula from 2006 CEH report on URBEXT2000

⁷ Updated to current year

⁸ British Geological Society (2021). UK Soil Observatory Map Viewer. Accessed: 16/11/2022. [Source: mapapps2.bgs.ac.uk/ukso/home.html].

Source of BFIHOST	BFIHOST19 was used in the ReFH2 calculations, since the current release (ReFH2.3) was calibrated using BFIHOST19, and also in the FEH Statistical method, since this has been found to improve the results ⁹ .
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⁹ Griffin, A., Young, A. and Stewart, E. (2019). Revising the BFIHOST catchment descriptor to improve UK flood frequency estimates. Hydrology Research.

3 Statistical method

3.1 Overview of estimation of QMED at each subject site

Site code	Initial QMED rural (m ³ /s) (from catchment descriptors)	Final method	Data transfer					Urban adjust-ment factor (UAF)	Final QMED estimate (m ³ /s)
			NRFA numbers for donor sites used (see 3.3)	Distance between centroids d _{ij} (km)	Moderated QMED adjustment factor, (A/B) ^a	If more than one donor			
						Weight	Weighted ave. adjustment		
RI_01	7.1	DT	69043	2.462	1.091	-	-	1.850	14.3
BB_01	1.9	DT	69020	5.855	0.845	-	-	1.365	2.2
RI_02	10.1	DT	69043	1.845	1.101	-	-	1.712	19.1
Are the values of QMED spatially consistent?					Yes, QMED increases sensibly moving downstream.				
Method used for urban adjustment for subject and donor sites					WINFAP v4 ¹⁰				
Parameters used for WINFAP v4 urban adjustment if applicable									
Impervious fraction for built-up areas, IF			Percentage runoff for impervious surfaces, PR _{imp}		Method for calculating fractional urban cover, URBAN				
0.3			70%		From updated URBEXT2000				
Notes									
Methods: AM – Annual maxima; POT – Peaks over threshold; DT – Data transfer (with urban adjustment); CD – Catchment descriptors alone (with urban adjustment); BCW – Catchment descriptors and bankfull channel width (add details); LF – Low flow statistics (add details).									
The QMED adjustment factor A/B for each donor site is given in Table 3.2. This is moderated using the power term, a, which is a function of the distance between the centroids of the subject catchment and the donor catchment. The final estimate of QMED is: (A/B) ^a x QMED _{initial} x UAF									
Important note on urban adjustment									
The method used to adjust QMED for urbanisation published in Kjeldsen (2010) ¹¹ in which PRUAF is calculated from BFIHOST is not correctly applied in WINFAP-FEH v3.0.003. Significant differences occur only on urban catchments that are highly permeable.									

¹⁰ Wallingford HydroSolutions (2016). WINFAP 4 Urban adjustment procedures.

¹¹ Kjeldsen, T. R. (2010). Modelling the impact of urbanization on flood frequency relationships in the UK. Hydrol. Res. **41**. 391-405.

3.2 Search for donor sites for QMED (if applicable)

Comment on potential donor sites Include a map if necessary. Note that donor catchments should usually be rural.	A number of potential donor catchments for this study were identified using the NFRA website and the 'Estimating QMED by data transfer' tool which is available in WINFAP-FEH3 as there are no donor catchments available within the study catchments. (There is a gauge located a while downstream on the Irk catchment, which is considered as a donor here). Two were taken forward for further consideration as a potential donor catchment: 69043 - Irk @ Collyhurst Weir 69020 - Medlock @ London Road Both donors were identified by NFRA as potentially suitable due to a mixture of proximity and on catchment descriptors. As the River Irk is gauged downstream of the study catchments (69043 - Irk @ Collyhurst Weir) and considered to be the best donor catchment for the River Irk inflow and downstream checkpoint based on catchment descriptors and on proximity so was used within this study. For BB_01, 69020 - Medlock @ London Road was considered to be the best donor catchment for the site based on catchment descriptors and on proximity so was also used within this study.
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3.3 Donor sites chosen and QMED adjustment factors

NRFA no.	Reasons for choosing	Method (AM or POT)	Adjustment for climatic variation ?	QMED from flow data (A)	QMED from catchment descriptors (B)	Adjustment ratio (A/B) *
69043	Closest hydroclimatological similarities to subject site (RI_01 and RI_02)	AM	No	28.3	15.23	1.154
69020	Closest hydroclimatological similarities to subject site (BB_01)	AM	No	23.3	24.29	0.684
* After application of separate 'de-urbanisation' factors to the observed QMED values.						

3.4 Derivation of pooling groups

Several subject sites may use the same pooling group.

Name of group	Site code from whose descriptors group was derived	Subject site treated as gauged? (enhanced single site analysis)	Changes made to default pooling group, with reasons	Weighted average L-moments, L-CV and L-skew, (before urban adjustment)
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BB_01 'Small Catchment' Pooling ¹²	BB_01	No	Removed: 27073 (Brompton Beck @ Snainton Ings) and 49005 (Bolingey Stream @ Bolingey Cocks Bridge): L-moment outliers Included: 73015 (Keer @ High Keer Weir)	L-CV: 0.252, L-SKEW: 0.263.
RI_02 Pooling	RI_02	No 69043 is located significantly downstream of the subject site.	Removed: 47023 (Tamar @ Tamarstone Bridge): Insufficient number of years Included: -	L-CV: 0.233, L-SKEW: 0.198.

Note: Pooling groups were derived using the procedures from Science Report SC050050 (2008).

3.5 Derivation of flood growth curves at subject sites

Site code	Method (SS, P, ESS, J)	If P, ESS or J, name of pooling group (Error! Reference source not found.)	Distribution used and reason for choice	Note any urban adjustment or permeable adjustment	Parameters of distribution (location, scale and shape after adjustments)	Growth factor for 100-year return period
RI_01	P	RI_02 Pooling	GEV Acceptable fit in WINFAP v5 software	WINFAP-FEHV4 urban adjustment	Location: 1.000 Scale: 0.241 Shape: -0.149	2.54
BB_01	P	BB_01 'Small Catchment' Pooling	GEV Acceptable fit in WINFAP v5 software	WINFAP-FEHV4 urban adjustment	Location: 1.000 Scale: 0.248 Shape: -0.240	2.99
RI_02	P	RI_02 Pooling	GEV Acceptable fit in WINFAP v5 software	WINFAP-FEHV4 urban adjustment	Location: 1.000 Scale: 0.252 Shape: -0.144	2.55

eNotes

Methods: SS – Single site; P – Pooled; ESS – Enhanced single site; J – Joint analysis

A pooling group (or ESS analysis) derived at one gauge can be applied to estimate growth curves at a number of ungauged sites. Each site may have a different urban adjustment, and therefore different growth curve parameters.

Urban adjustments are all carried out using the method of Kjeldsen (2010).

Growth curves were derived using the procedures from Science Report SC050050 (2008).

¹² Small Catchment pooling method applied via WINFAP v5

3.6 Flood estimates from the statistical method

Site code	Flood peak (m ³ /s) for the following AEP (%) events					
	50	3.3	1	1 + 35% climate change allowance (Central)	1 + 46% climate change allowance (Higher)	0.1
RI_01	14.3	28.5	36.3	49.0	53.0	55.6
BB_01	2.2	4.9	6.7	9.0	9.8	11.9
RI_02	19.1	38.2	48.6	65.6	70.9	74.0

4 Revitalised flood hydrograph 2 (ReFH2) method

4.1 Parameters for ReFH2 model

In accordance with research findings, all catchments with an URBEXT2000 up to 0.30 should be modelled as if they were rural. Research on flood estimation in small catchments¹³ found that flood frequency estimates on such catchments were more accurate if the catchment was treated as rural. However the study catchments all have an updated URBEXT2000 value over 0.3.

EA Flood Estimation Guidelines LIT 11832 (2022) that the FEH Statistical method or ReFH2 methods can be applied to urbanised catchments with an URBEXT2000 value up to 0.6¹⁴. A winter storm rainfall depth, Cini and initial baseflow values and storm profile should be used for all catchments, unless:

- URBEXT2000 $\geq$ 0.30;
- or URBEXT2000 $\geq$ 0.15 and BFIHOST19 $\geq$ 0.65

Therefore a Summer, Urban Profile was used.

All catchments					Only extremely heavily urbanised catchments
Site code	Method	C _{max} (mm)	T _p _{rural} (hours)	BL (hours)	Area of catchment modelled as urban (km ²)
RI_01	CD	589.25	3.3	49.26	-
BB_01	CD	237.39	1.86	23.82	-
RI_02	CD	532.48	3.28	47.45	-
Link to details of any lag or flood event analysis		Not within scope			
Version of the ReFH2 model applied		ReFH2.3 using the water balance option. This treats BR (baseflow recharge) as a state variable rather than a parameter, setting it automatically in order to conserve volume. The values of BR vary with return period and so are not reported here.			
Parameters for urban runoff model		The impervious fraction of urban areas, IF, was kept at its default of 0.4. The impervious runoff factor, IRF, (which can also be interpreted as the fraction of the impervious surface that is positively drained) was kept at its default of 0.7. The depression storage was kept at its default of 0.5mm. Tp for runoff from areas modelled as positively drained was calculated as 0.75 times Tp _{rural} .			
Methods: OPT: Optimisation from fitting to observed flow data, BR: Baseflow recession fitting, CD: Catchment descriptors, DT: Data transfer (give details)					

4.2 Design events for ReFH2 method: Lumped catchments

Site code	Season of design event	Storm duration (hours)	Storm area for ARF (if not catchment area)
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¹³ Stewart, Lisa, Duncan Faulkner, Giuseppe Formetta, Adam Griffin, Tracey Haxton, Ilaria Prosdoci, Gianni Vesuviano and Andy Young (2021). Estimating flood peaks and hydrographs for small catchments (Phase 2). Report – SC090031/R0, Environment Agency.

¹⁴ Environment Agency (2012) Estimating flood peaks and hydrographs for small catchments: Phase 1 and Phase 2. LGH_JBAU_XX_00_RP_HO_0001_S1_P1_FEH calculation record

RI_01	Urban, Summer	10:15:00	-
BB_01	Urban, Summer	05:15:00	-
RI_02	Urban, Summer	10:15:00	-
Are the storm durations likely to be changed in the next stage of the study, e.g. by optimisation within a hydraulic model?			Storm Duration stated in the table is the Critical Storm Duration for each individual Flood Estimation Point, determined through sensitivity testing of a range of durations within ReFH2 to determine the duration that produced the highest flow. The storm duration is used here to undertake 'worst case' scenario flow comparisons between ReFH2 and FEH Statistical for each individual flow point. Due to the permeability of the catchment, the preferred methodology for this study will be FEH Statistical. For modelling purposes, design ReFH2 hydrographs to a critical storm duration of 10:15:00 (CSD of RI_02) will be taken forward

4.3 Flood estimates from the ReFH2 method

Note: This table is for recording results for lumped catchments. There is no need to record peak flows from sub-catchments or intervening areas that are being used as inputs to a semi-distributed model of the river system.

Peak Flows

Site code	Flood peak (m ³ /s) for the following AEP (%) events					
	50	3.3	1	1 + 35% climate change allowance (Central)	1 + 46% climate change allowance (Higher)	0.1
RI_01	12.9	26.5	34.7	46.9	50.7	55.9
BB_01	2.5	5.3	6.8	9.2	10.0	11.1
RI_02	15.4	31.7	41.6	56.1	60.7	67.5

Model design duration (10:15:00hr)

Site code	Flood peak (m ³ /s) for the following AEP (%) events					
	50	3.3	1	1 + 35% climate change allowance (Central)	1 + 46% climate change allowance (Higher)	0.1
RI_01	12.9	26.5	34.7	46.9	50.7	55.9
BB_01	2.4	4.9	6.5	8.7	9.4	10.6
RI_02	15.4	31.7	41.6	56.1	60.7	67.5

5 Discussion and summary of results

5.1 Comparison of results from different methods

This table compares peak flows from various methods with those from the FEH Statistical method at example sites for two key return periods. Blank cells indicate that results for a particular site were not calculated using that method.

Site code	Ratio of peak flow to FEH Statistical peak	
	Return period 2 years	Return period 100 years
	ReFH2	ReFH2
RI_01	0.91	0.96
IB_01	1.11	1.02
RI_02	0.81	0.86

5.2 Final choice of method

Choice of method and reasons Include reference to type of study, nature of catchment and type of data available.	Flows derived through the application of the ReFH2 model were compared with those derived from the FEH statistical method. Flows derived from the ReFH2 methodology are shown to be up to 11% greater than flows derived from FEH statistical methodology for BB_01. For RI_01 and RI_02 flows derived from the FEH Statistical methodology are shown to be up to 19% greater than flows derived from ReFH2 methodology up to the 0.1% AEP event, where ReFH2 flows are greater at RI_01. LIT 11832 Flood Estimation Guidelines (2023) states that the statistical method is based on a much larger dataset of flood events and has been more directly calibrated to reproduce flood frequency on UK catchments, therefore it is often preferable over design event (rainfall-runoff) approaches. In addition, the EA OI_197_08-Flood Estimation Guidelines, recommends in preference use of FEH Statistical over ReFH2 method for permeable catchments. Therefore the preferred methodology for this study will be FEH Statistical. The Statistical method is valid for up to a 100-year AEP approximately and less certain for rarer events. Therefore, peak flows derived using the FEH Statistical method for the 1000-year event has been adjusted to apply the growth factor derived from ReFH2 methodology (often referred to as the "Hybrid" approach).
How will the flows be applied to a hydraulic model? If relevant. Will model inflows be adjusted to achieve a match with lumped flow estimates, or will the model be allowed to route inflows?	Catchment flows will be distributed along the study reach at locations where flow points have been identified within Figure 2.1. For modelling purposes, hydrographs were obtained using the ReFH2 method to storm duration of 10:15:00hr (CSD for RI_01 and RI_02). During the modelling phase of this study, if it is found that a lateral inflow is required, flows for the lateral area (c. 4km²) will be derived by using an area ratio method from the flows derived for RI_02. The hydrograph adopted for the lateral areas will be the design hydrograph for RI_02.

5.3 Assumptions, limitations and uncertainty

List the main assumptions made (specific to this study)	The main assumptions are: -The data used for the derivation of local design flow estimates are accurate. -The design peak flows derived are representative of those that would be observed during flood events; -The catchment boundaries and descriptors have been assumed to be representative; -The pooling group used to derive peak flow estimates is representative of the subject catchment; -Design hydrographs generated using the ReFH2 model are representative of those that would be observed during typical flood events. - Peak flows, rather than hydrograph volumes, are assumed to be the main control on flood risk at the site. - Use of GEV distribution in pooling group assessment is assumed to be preferable to the other distributions identified by WINFAP 5 due to its z-value. - There are no significant sewers draining in or out of the catchment. It is not within the scope of this study to define sewer boundaries.
Discuss any particular limitations, e.g. applying methods outside the range of catchment types or return periods for which they were developed.	Limitations are generic to the methods used. The main limitation for this study is the absence of flow gauge data for the River Irk within the study catchments which could be used to improve peak flow estimates. As flood generation on urban catchments is sensitive to local circumstances it is not possible to obtain a reliable estimate of the flood frequency curve using generalised methods. There is no substitute for obtaining local data. The scope of the study is also a limitation as it was not possible to assess the surface water sewer network for the purposes of sub-catchment definition or to undertake lag analysis to improve the ReFH2 Tp model parameter. One of the catchments is considered to be small relative to the overall database of gauging station data used for calibration, the use of FEH / ReFH is considered to be a primary limitation of the study. Urbanisation of the catchments is also a limitation. A simplification is also applied with a consistent AEP applied to all inflows, for a given design even model run. A joint probability analysis could be undertaken for the catchment upstream inflows, but applying a constant AEP for the purposes of a Flood Risk assessment gives a conservative result. It is recommended to review the modelling results once the flows are applied to the model. If these are found to over-estimate local flood risk, additional work could be undertaken with a joint probability analysis of the model inflows. However a joint probability analysis is outwith the scope of this project.
Give what information you can on uncertainty in the results, e.g. confidence limits from Kjeldsen (2014).	No published methods of calculating confidence intervals exist for ReFH hydrological models; therefore, the uncertainty for each of these watercourses is difficult to

	quantify. The uncertainty will depend on many factors, for example, how unusual the study catchment is relative to the pooling group and donor catchment, and the uncertainty in flow measurement at other gauges. The Environment Agency Flood Estimation Guidelines present confidence limits for Statistical method design flows at ungauged sites. There are confidence intervals for rural catchments ($URBEXT2000 < 0.03$) and moderately urbanised catchments ($0.03 \leq URBEXT2000 < 0.15$). The 95% confidence limits for a 1% AEP flood estimate without donor adjustment of QMED are: - Rural catchments: 0.45 – 2.23 times the best estimate - Moderately urbanised catchments: 0.33 – 3.01 times the best estimate Confidence intervals for heavily urbanised catchments ($URBEXT2000 > 0.15$) are not provided because there are not enough suitable catchments with flood peak data to provide reliable statistics. It may be assumed that the confidence intervals will be somewhat wider than those for moderately urbanised catchments.
Comment on the suitability of the results for future studies, e.g. at nearby locations or for different purposes.	These flow estimates were derived specifically for this study. They should not be used elsewhere without at least being reviewed for suitability.
Give any other comments on the study, e.g. suggestions for additional work.	Confidence could be improved through installation of hydrometric monitoring and event hydrometric data.

5.4 Checks

Are the results consistent, for example at confluences?	Yes, results are considered sensible in that they increase with downstream distance where applicable.
What do the results imply regarding the return periods of floods during the period of record?	No data is available in regards to flood events applicable to the site. No flow gauges are available within the study catchment, therefore no comparison with previous events can be undertaken at this stage.
What is the range of 100-year growth factors? Is this realistic?	The 1% AEP growth factor for each of the methods are: - FEH Statistical: 2.54-2.99 - ReFH2: 2.68-2.73 The typical range is 2.1 to 4.0 (based on FSR regional growth curves) therefore the 1% AEP growth factor for all FEP's are inside the typical range for both flow estimation methodologies.
If 1000-year flows have been derived, what is the range of ratios for 1000-year flow over 100-year flow?	The 0.1%/ 1% AEP event growth factor for each of the methods are: - FEH Statistical: 1.52-1.77 - ReFH2: 1.61-1.62
How do the results compare with those of other studies? Explain any differences and conclude which results should be preferred.	Flows have been provided within the Faber Maunsell (2007) Irwell Areas Benefiting from Defences Study – Phases 2&3. The report provided as part of the EA data request makes reference to the Final Hydrology Report, however this report was not supplied. A number of flows

for a number of node points are included within the provided report however it is difficult to ascertain exact node locations. None of the design peak flows within the report relates to the FEP's within this study, however there are some nodes where flows and levels from the model have been extracted which have been used for comparison. Flows derived within the 2007 study are significantly greater than the flows derived within this study.

Site code	Flood peak (m ³ /s)	
	100	1000
2023: RI_02 FEH	48.6	78.9
2023: RI_02 ReFH2	41.6	67.5
2007: IRKR02_5773B (without defences)	54.9	101.7

Difference in flows between this study and the 2007 study is likely due to updates in methodologies, software and updates to catchment descriptors. The Revitalised Flood Hydrograph (ReFH1 and ReFH2) method has replaced the original 1999 FEH rainfall-runoff method for most applications. As this study utilises 2023 methodologies and more up to date data, flows derived within this study are the preferred flows.

Are the results compatible with the longer-term flood history?	This will be determined at the modelling stage.
Describe any other checks on the results	-

5.5 Final results

Site code	Flood peak (m ³ /s) for the following AEP (%) events					
	50	3.3	1	1 + 19% climate change allowance (Central)	1 + 30% climate change allowance (Higher)	0.1
RI_01	14.3	28.5	36.3	49.0	53.0	58.4*
BB_01	2.2	4.9	6.7	9.0	9.8	10.9*
RI_02	19.1	38.2	48.6	65.6	70.9	78.9*
* growth factor derived from ReFH2 methodology applied						

If flood hydrographs are needed for the next stage of the study, where are they provided? (e.g. give filename of spreadsheet, hydraulic model, or reference to table below)	Annex B
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6 Annex A – Pooling Groups

UK Design Flood Estimation

Summary of ESS/Pooled Estimation Analysis using the Flood Estimation Handbook Statistical Method

Date of creation: 30-08-2023 11:53:46
Software: WINFAP Version: 5.0.8181 (30330)
Peak Flow dataset: Peak Flow Dataset 11.1.1
Supplementary data used: No

Site details

Site number: 427445649
Site name: BB_01
Site location: SD 85900 05100
Easting: 385900
Northing: 405100
Catchment area: 2.51 km²
SAAR: 999 mm
BFIHOST19: 0.333
FPEXT: 0.140
FARL: 0.994
URBEXT2000: 0.3770

Analysis settings

At-site data

At-site data present: No

Urbanisation settings

User defined: No
Urban area: 1.48 km²
PRimp: 70.00%
Impervious Factor: 0.300
UAF: 1.36508

Growth curve settings

Distance Measure Method: Small catchment
Pooling group URBEXT2000 Threshold: 0.030
Deurbanise Pooling Group L-moments: Yes

QMED settings

Use at-site data: No
Method: Donor Station(s)

Growth curve data and results

Pooling Group

Station	Distance	Years of data	QMED AM	L-CV Observed	L-CV Deurbanised	L-SKEW Observed	L-SKEW Deurbanised	Discordancy
76011 (Coal Burn @ Coalburn)	0.433	44	1.840	0.168	0.168	0.302	0.302	0.878
45816 (Haddeo @ Upton)	0.962	28	3.352	0.293	0.294	0.424	0.423	1.018
27051 (Crimple @ Burn Bridge)	1.035	49	4.564	0.217	0.218	0.143	0.142	0.584
28033 (Dove @ Hollinsclough)	1.247	46	4.138	0.223	0.223	0.379	0.379	0.974
25019 (Leven @ Easby)	1.515	43	5.677	0.334	0.335	0.373	0.372	0.865
27010 (Hodge Beck @ Bransdale Weir)	1.594	41	9.420	0.224	0.224	0.293	0.293	0.205
47022 (Tory Brook @ Newnham Park)	1.646	26	6.649	0.250	0.252	0.149	0.146	1.173
44008 (South Winterbourne @ Winterbourne Steepleton)	1.650	30	0.496	0.421	0.422	0.289	0.289	2.393
26016 (Gypsy Race @ Kirby Grindalythe)	1.661	24	0.103	0.304	0.304	0.240	0.240	1.072
25011 (Langdon Beck @ Langdon)	1.689	35	15.647	0.226	0.226	0.324	0.324	2.264
72014 (Conder @ Galgate)	1.995	53	16.912	0.231	0.232	0.145	0.144	0.560
18014 (Bannock Burn @ Bannockburn)	2.008	29	16.634	0.224	0.225	0.162	0.160	0.403
73015 (Keer @ High Keer Weir)	2.009	31	12.421	0.208	0.209	0.195	0.195	0.612
Total		479						
Short records	Discordant	No Pooling	No Pooling, no QMED					

Pooling Group Rejected Stations

Station	Distance	Years of data	QMED AM	L-CV Observed	L-CV Deurbanised	L-SKEW Observed	L-SKEW Deurbanised
27073 (Brompton Beck @ Snainton Ings)	1.313	41	0.820	0.212	0.213	0.006	0.005
49005 (Bolingey Stream @ Bolingey Cocks Bridge)	1.475	11	5.777	0.262	0.263	0.207	0.206

Growth curve L-moments

Rural L-CV:	0.252	Urban L-CV:	0.202
Rural L-Skewness:	0.263	Urban L-Skewness:	0.333

Rural fitted parameters

Distribution	Location	Scale	Shape	H	Bound
GL	1.000	0.251	-0.263		0.046
GEV	0.867	0.354	-0.140		-1.666
KAP3	0.932	0.297	-0.208	-0.400	-0.494

Urban fitted parameters

Distribution	Location	Scale	Shape	H	Bound
GL	1.000	0.187	-0.333		0.440
GEV	0.905	0.249	-0.239		-0.134
KAP3	0.950	0.214	-0.292	-0.400	0.218

Goodness of fit

GL: 1.2017 *
GEV: -0.1624 *
P3: -2.1971
GP: -3.6108
KAP3: 0.7506 *

* Distribution gives an acceptable fit (absolute Z value < 1.645)

Heterogeneity

Standardised test value H2: 1.7536

The pooling group is possibly heterogeneous and a review of the pooling group is optional.

Standardised growth curves

Rural

Return period	GL	GEV	KAP3
2	1.000	1.000	1.000
5	1.420	1.458	1.436
10	1.747	1.804	1.773
20	2.116	2.172	2.145
25	2.248	2.297	2.275
30	2.360	2.401	2.385
50	2.703	2.707	2.714
75	3.007	2.964	2.999
100	3.243	3.155	3.217
200	3.887	3.648	3.795
500	4.938	4.377	4.698
1000	5.919	4.993	5.504

Urban

Return period	GL	GEV	KAP3
2	1.000	1.000	1.000
5	1.329	1.354	1.338
10	1.605	1.646	1.623
20	1.934	1.981	1.957
25	2.056	2.100	2.078
30	2.161	2.202	2.183
50	2.490	2.510	2.505
75	2.792	2.782	2.796
100	3.031	2.991	3.024
200	3.710	3.558	3.658
500	4.883	4.465	4.717
1000	6.040	5.296	5.728

QMED data and results

Donor selection criteria

Only sites suitable for QMED: Yes
URBEXT2000: <0.030
Donor adjusted FSE: 1.399
No. of donors: 1

Donor stations

Station	Distance	URBEXT	Use QMED obs deurbanised	QMED obs	QMED deurbanised	QMED CDs urban	QMED CDs rural	Centroid X	Centroid Y	Area	SAAR
*BB_01 @ SD 85900 05100)		0.377						386937	404182	2.510	999
69048 (Tame @ Uppermill)	13.52	0.023	Yes	21.885	21.422	22.430	22.430	399678	408701	40.602	1359

Unused Donor stations

Station	Distance	URBEXT	Use QMED obs deurbanised	QMED obs	QMED deurbanised	QMED CDs urban	QMED CDs rural	Centroid X	Centroid Y	Area	SAAR
69046 (Bradshaw Brook @ Bradshaw Tennis Club)	19.36	0.023	Yes	22.598	22.105	12.256	12.256	372843	417450	36.865	1.0
27088 (Calder @ Mytholmroyd)	25.04	0.023	Yes	82.325	80.632	81.846	81.846	395015	427885	146.868	1.0
69017 (Goyt @ Marple Bridge)	26.72	0.025	Yes	61.047	59.443	53.096	53.096	402591	382528	184.232	1.0
68007 (Wincham Brook @ Lostock Gralam)	30.05	0.020	Yes	20.402	19.888	19.576	19.576	375825	376264	148.340	8.0
68011 (Arley Brook @ Gore Farm)	30.39	0.021	Yes	6.093	5.972	11.089	11.089	366592	381601	33.760	8.0
28043 (Derwent @ Chatsworth)	38.01	0.006	Yes	88.165	87.610	96.834	96.834	418886	383583	344.337	1.0
28023 (Wye @ Ashford)	38.32	0.023	Yes	16.685	16.089	30.120	30.120	411221	374539	152.280	1.0
68044 (Dane @ Hug Bridge)	38.72	0.001	Yes	43.990	43.947	43.891	43.891	398635	367269	72.558	1.0
68018 (Dane @ Congleton Park)	39.43	0.023	Yes	41.750	40.836	52.357	52.357	394496	365488	142.565	1.0

QMED

Rural: 1.909 m³/s
Urban: 2.606 m³/s

Flood Frequency Curve

Rural Flood Frequency Curve

Return period	GL (m³/s)	GEV (m³/s)	KAP3 (m³/s)
2	1.909	1.909	1.909
5	2.711	2.784	2.741
10	3.335	3.444	3.384
20	4.040	4.146	4.095
25	4.291	4.384	4.342
30	4.505	4.583	4.552
50	5.159	5.167	5.180
75	5.740	5.658	5.726
100	6.190	6.024	6.140
200	7.420	6.965	7.245
500	9.427	8.355	8.968
1000	11.298	9.531	10.507

Urban Flood Frequency Curve

Return period	GL (m³/s)	GEV (m³/s)	KAP3 (m³/s)
2	2.606	2.606	2.606
5	3.463	3.527	3.487
10	4.182	4.290	4.228
20	5.041	5.163	5.099
25	5.356	5.473	5.415
30	5.631	5.738	5.687
50	6.487	6.541	6.528
75	7.274	7.250	7.287
100	7.899	7.795	7.881
200	9.668	9.271	9.532
500	12.724	11.636	12.291
1000	15.739	13.802	14.925

UK Design Flood Estimation

Summary of ESS/Pooled Estimation Analysis using the Flood Estimation Handbook Statistical Method

Date of creation: 31-08-2023 09:37:30
Software: WINFAP Version: 5.0.8181 (30330)
Peak Flow dataset: Peak Flow Dataset 11.1.1
Supplementary data used: No

Site details

Site number: 4071048075
Site name: RI_02
Site location: SD 84400 04700
Easting: 384400
Northing: 404700
Catchment area: 44.91 km²
SAAR: 1062 mm
BFIHOST19: 0.644
FPEXT: 0.096
FARL: 1.000
URBEXT2000: 0.3800

Analysis settings

At-site data

At-site data present: No

Urbanisation settings

User defined: No
Urban area: 26.74 km²
PRimp: 70.00%
Impervious Factor: 0.300
UAF: 1.71138

Growth curve settings

Distance Measure Method: Standard
Pooling group URBEXT2000 Threshold: 0.030
Deurbanise Pooling Group L-moments: No

QMED settings

Use at-site data: No
Method: User Defined

Growth curve data and results

Pooling Group

Station	Distance	Years of data	QMED AM	L-CV Observed	L-CV Deurbanised	L-SKEW Observed	L-SKEW Deurbanised	Discordancy
76019 (Roe Beck @ Stockdalewath)	0.529	22	42.495	0.218	0.218	0.311	0.311	1.110
41020 (Bevern Stream @ Clappers Bridge)	0.529	52	13.780	0.201	0.203	0.166	0.164	0.662
73015 (Keer @ High Keer Weir)	0.650	31	12.421	0.208	0.209	0.195	0.195	0.237
48012 (Fal @ Trenowth)	0.676	23	10.210	0.146	0.148	0.279	0.275	2.201
41022 (Lod @ Halfway Bridge)	0.678	51	15.900	0.295	0.297	0.183	0.181	0.599
72014 (Conder @ Galgate)	0.681	53	16.912	0.231	0.232	0.145	0.144	0.266
43029 (Wyllye @ Brixton Deverill)	0.700	38	1.668	0.374	0.375	0.254	0.253	2.803
53017 (Boyd @ Bitton)	0.735	48	13.908	0.240	0.242	0.081	0.079	1.195
76023 (Dacre Beck @ Dacre Bridge)	0.735	21	35.854	0.189	0.189	0.213	0.213	0.834
28041 (Hamps @ Waterhouses)	0.754	36	26.582	0.218	0.218	0.272	0.272	1.645
49002 (Hayle @ St Erth)	0.793	64	4.785	0.240	0.241	0.201	0.199	0.145
49004 (Gannel @ Gwills)	0.798	52	14.510	0.257	0.259	0.114	0.113	0.979
72007 (Brock @ upstream of A6)	0.836	43	29.917	0.195	0.195	0.208	0.208	0.324
Total		534						
Short records	Discordant	No Pooling	No Pooling, no QMED					

Pooling Group Rejected Stations

Station	Distance	Years of data	QMED AM	L-CV Observed	L-CV Deurbanised	L-SKEW Observed	L-SKEW Deurbanised
47023 (Tamar @ Tamarstone Bridge)	0.774	6	18.596	0.154	0.154	0.690	0.690

Growth curve L-moments

Rural L-CV:	0.233	Urban L-CV:	0.186
Rural L-Skewness:	0.198	Urban L-Skewness:	0.265

Rural fitted parameters

Distribution	Location	Scale	Shape	H	Bound
GL	1.000	0.235	-0.198		-0.192
GEV	0.870	0.351	-0.042		-7.384
KAP3	0.935	0.286	-0.127	-0.400	-1.312

Urban fitted parameters

Distribution	Location	Scale	Shape	H	Bound
GL	1.000	0.179	-0.265		0.323
GEV	0.905	0.252	-0.142		-0.867
KAP3	0.951	0.211	-0.210	-0.400	-0.056

Goodness of fit

GL: 3.2886
GEV: 0.9934 *
P3: -0.3868 *
GP: -4.1544
KAP3: 2.4547

* Distribution gives an acceptable fit (absolute Z value < 1.645)

Heterogeneity

Standardised test value H2: 0.4137

The pooling group is acceptably homogeneous and a review of the pooling group is not required.

Standardised growth curves

Rural

Return period	GL	GEV	KAP3
2	1.000	1.000	1.000
5	1.376	1.414	1.392
10	1.648	1.699	1.672
20	1.940	1.981	1.963
25	2.041	2.072	2.061
30	2.126	2.147	2.142
50	2.379	2.359	2.378
75	2.597	2.529	2.576
100	2.763	2.652	2.723
200	3.199	2.953	3.097
500	3.875	3.364	3.644
1000	4.472	3.686	4.101

Urban

Return period	GL	GEV	KAP3
2	1.000	1.000	1.000
5	1.300	1.327	1.311
10	1.534	1.574	1.552
20	1.799	1.837	1.819
25	1.894	1.927	1.912
30	1.974	2.001	1.991
50	2.220	2.221	2.227
75	2.439	2.406	2.432
100	2.609	2.543	2.588
200	3.073	2.898	3.005
500	3.830	3.423	3.656
1000	4.538	3.868	4.238

QMED data and results

QMED

Rural: 18.900 m³/s
Urban: 32.345 m³/s

Flood Frequency Curve

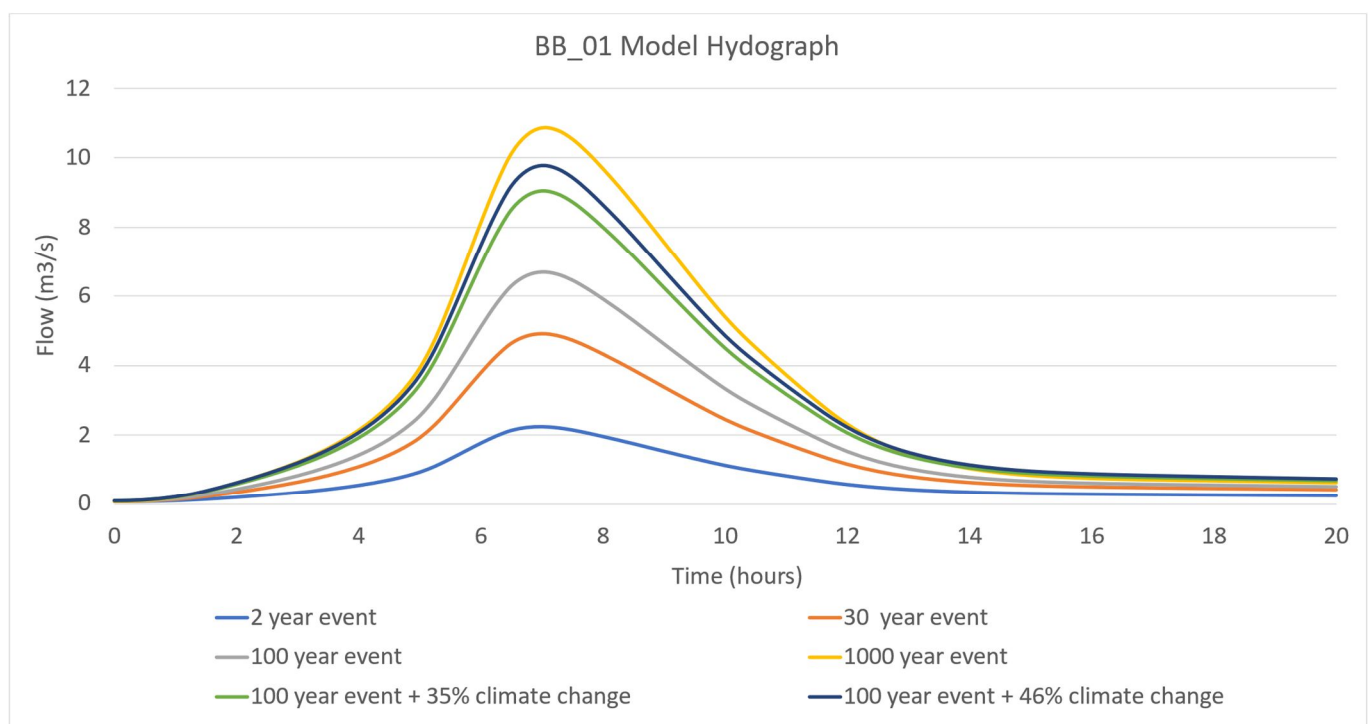
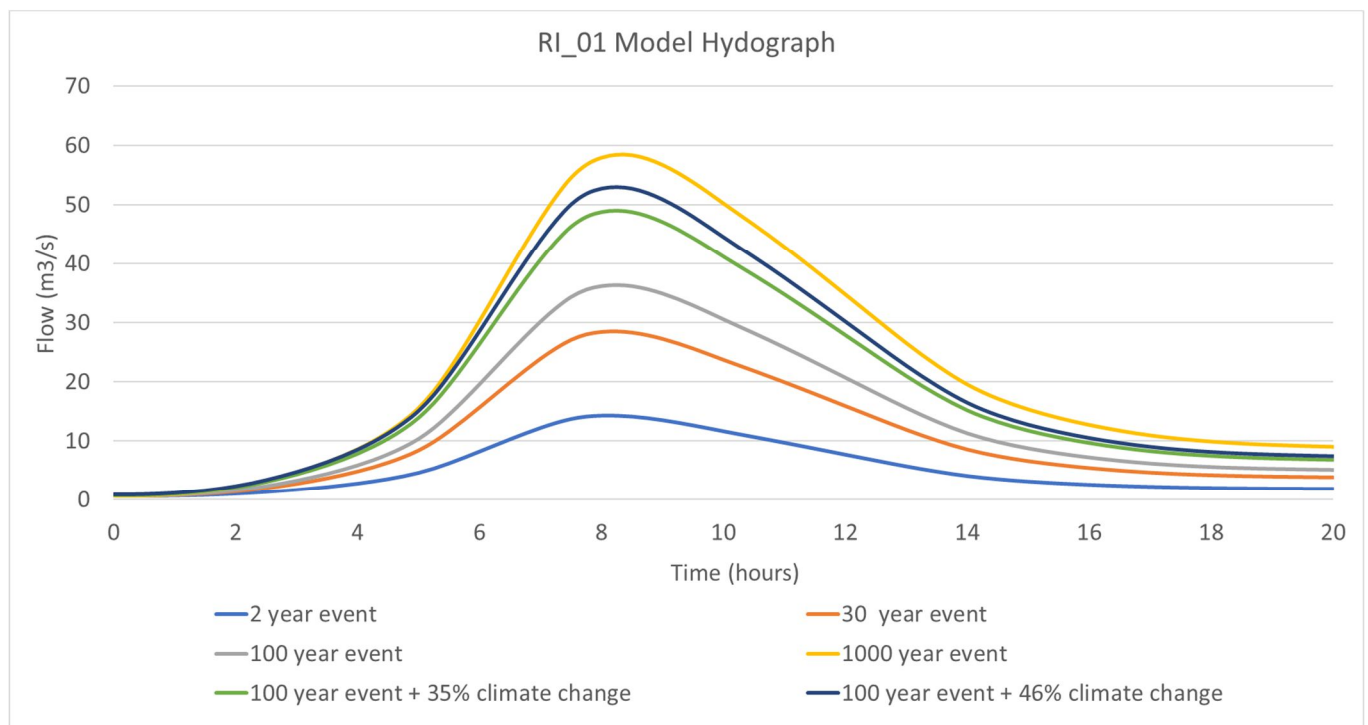
Rural Flood Frequency Curve

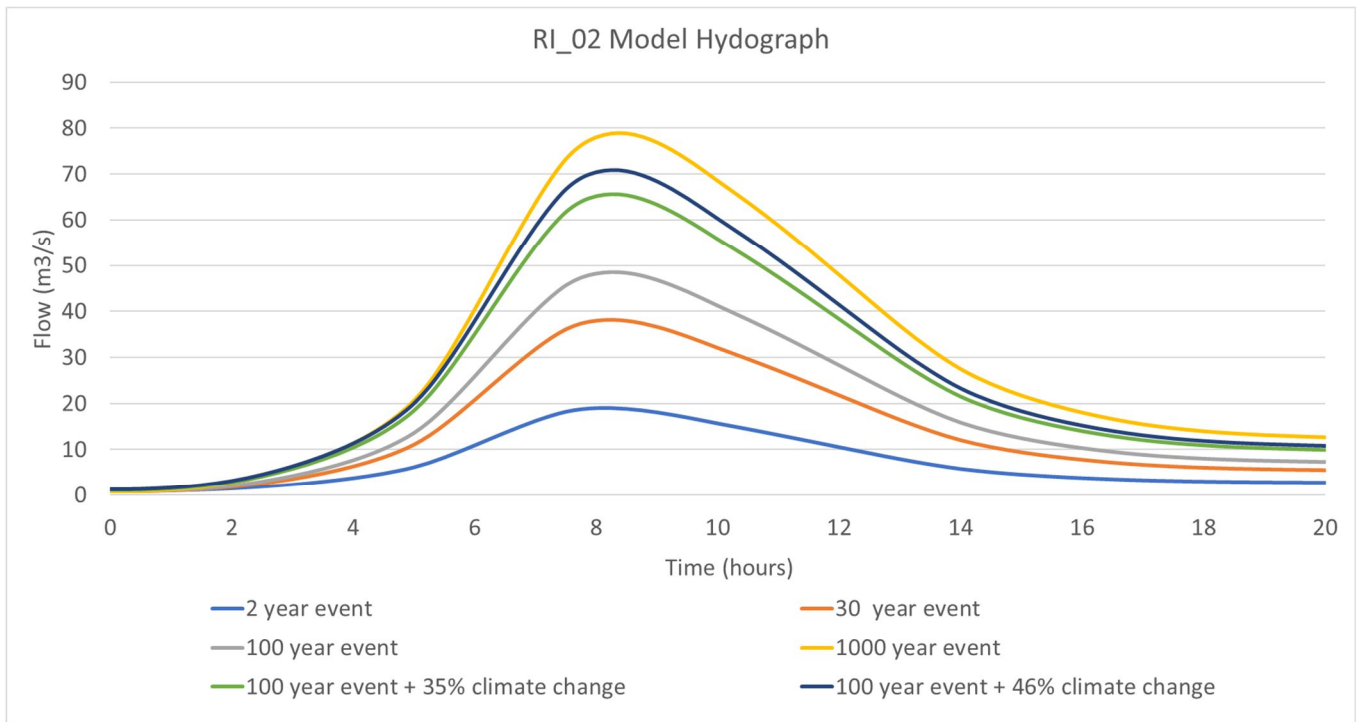
Return period	GL (m³/s)	GEV (m³/s)	KAP3 (m³/s)
2	18.900	18.900	18.900
5	25.997	26.717	26.309
10	31.144	32.103	31.603
20	36.675	37.433	37.102
25	38.578	39.159	38.944
30	40.186	40.575	40.481
50	44.969	44.580	44.953
75	49.092	47.806	48.692
100	52.212	50.123	51.456
200	60.470	55.813	58.529
500	73.233	63.581	68.864
1000	84.529	69.656	77.515

Urban Flood Frequency Curve

Return period	GL (m³/s)	GEV (m³/s)	KAP3 (m³/s)
2	32.345	32.345	32.345
5	42.058	42.914	42.408
10	49.630	50.910	50.210
20	58.202	59.425	58.833
25	61.249	62.314	61.838
30	63.860	64.734	64.389
50	71.817	71.826	72.030
75	78.894	77.809	78.669
100	84.377	82.258	83.722
200	99.387	93.736	97.191
500	123.895	110.726	118.242
1000	146.781	125.123	137.066

7 Annex C – Design Hydrographs





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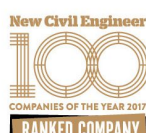
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E

Sensitivity Analysis

E.1

Sensitivity to roughness

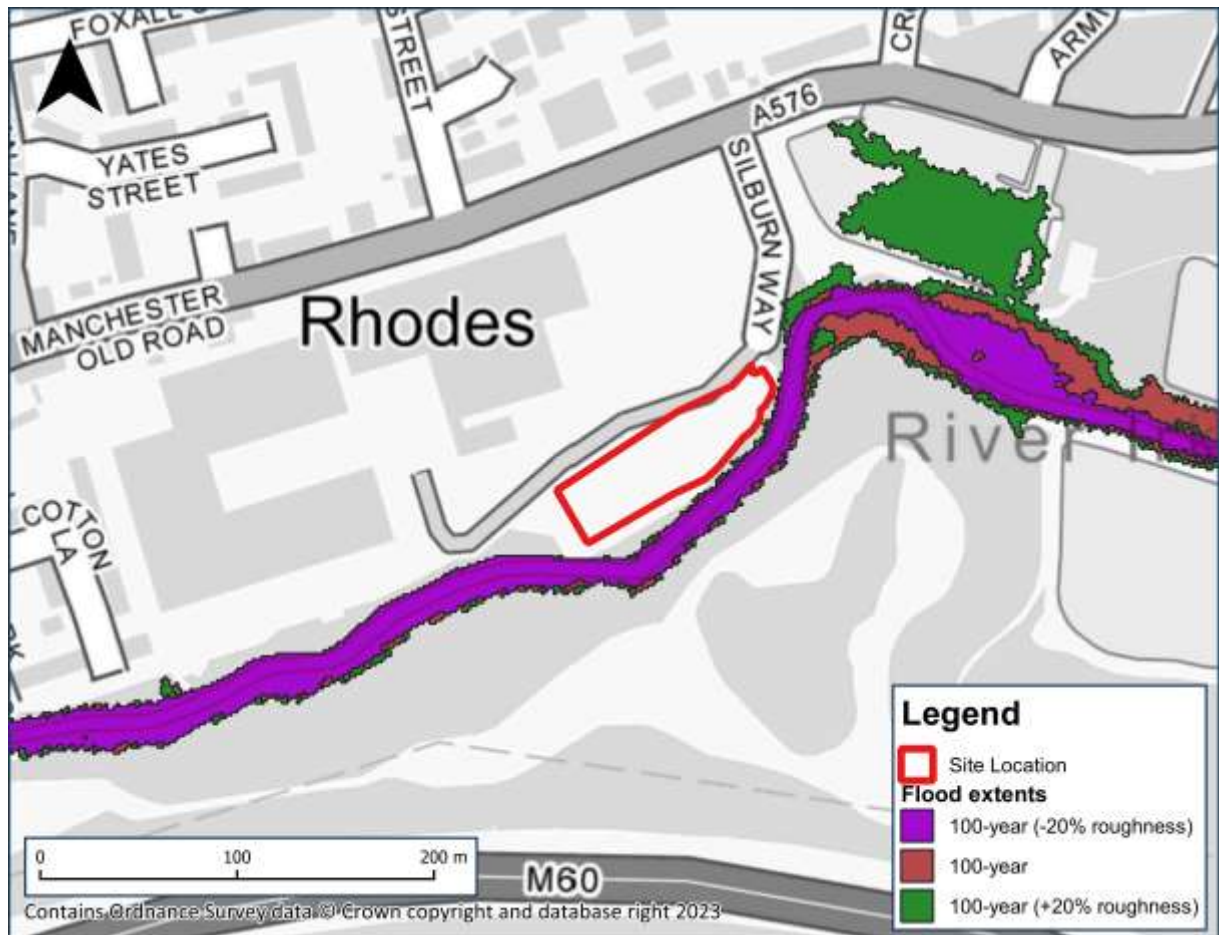


Figure 6-1 shows the changes in peak flood extent compared to the baseline 100-year event when the 1D and 2D roughness is adjusted by +/- 20%.

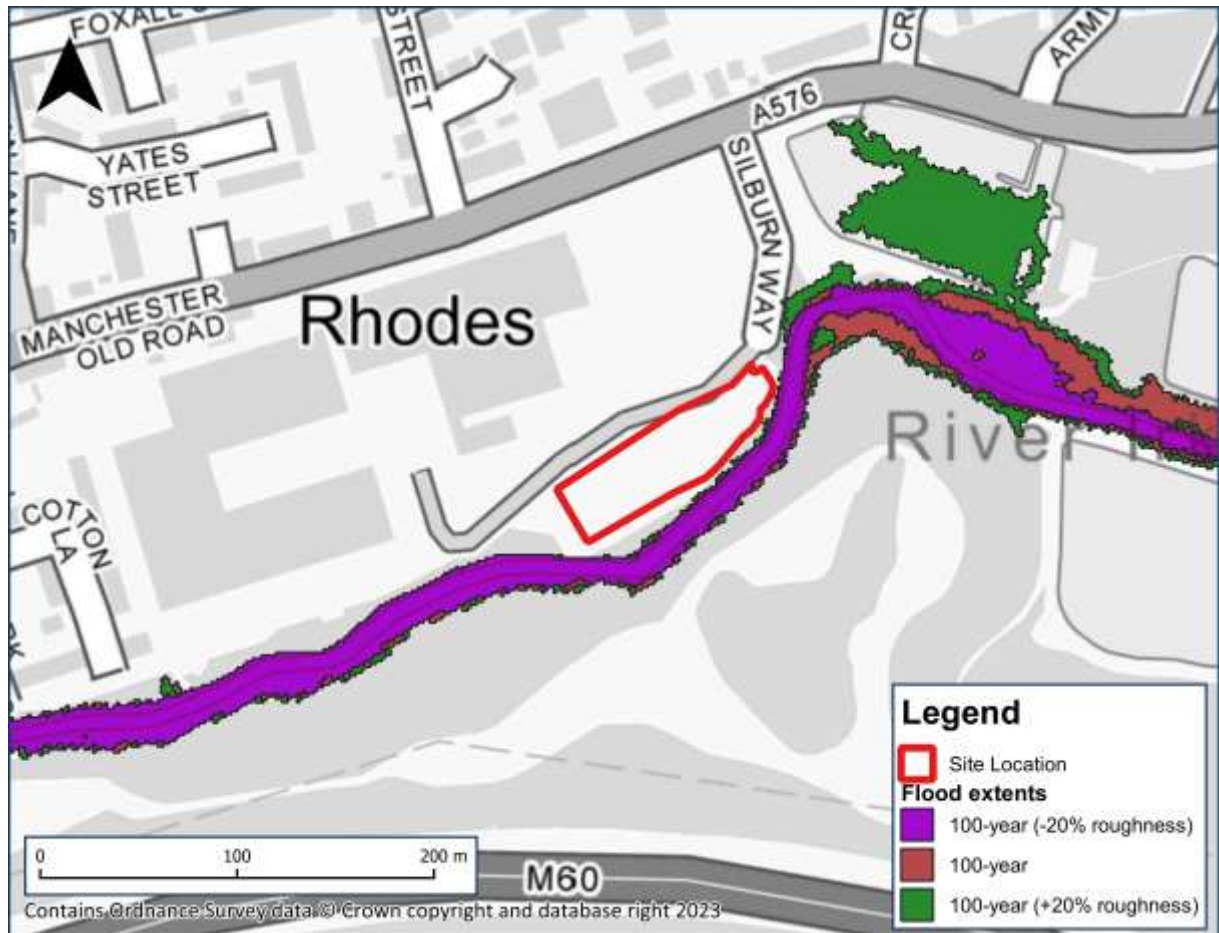


Figure 6-1: Sensitivity analysis +/- 20% roughness

The sensitivity analysis shows that the model is relatively sensitive to the roughness applied to the 1D and 2D domains. However, there are no changes in peak flood extents within the site boundary when roughness is adjusted by +/-20%.

E.2

Sensitivity to downstream boundary

Figure 6-2 shows the changes in peak flood extents compared to the baseline 100-year event when a 250mm increase in gradient to the 1D and 2D downstream boundary.

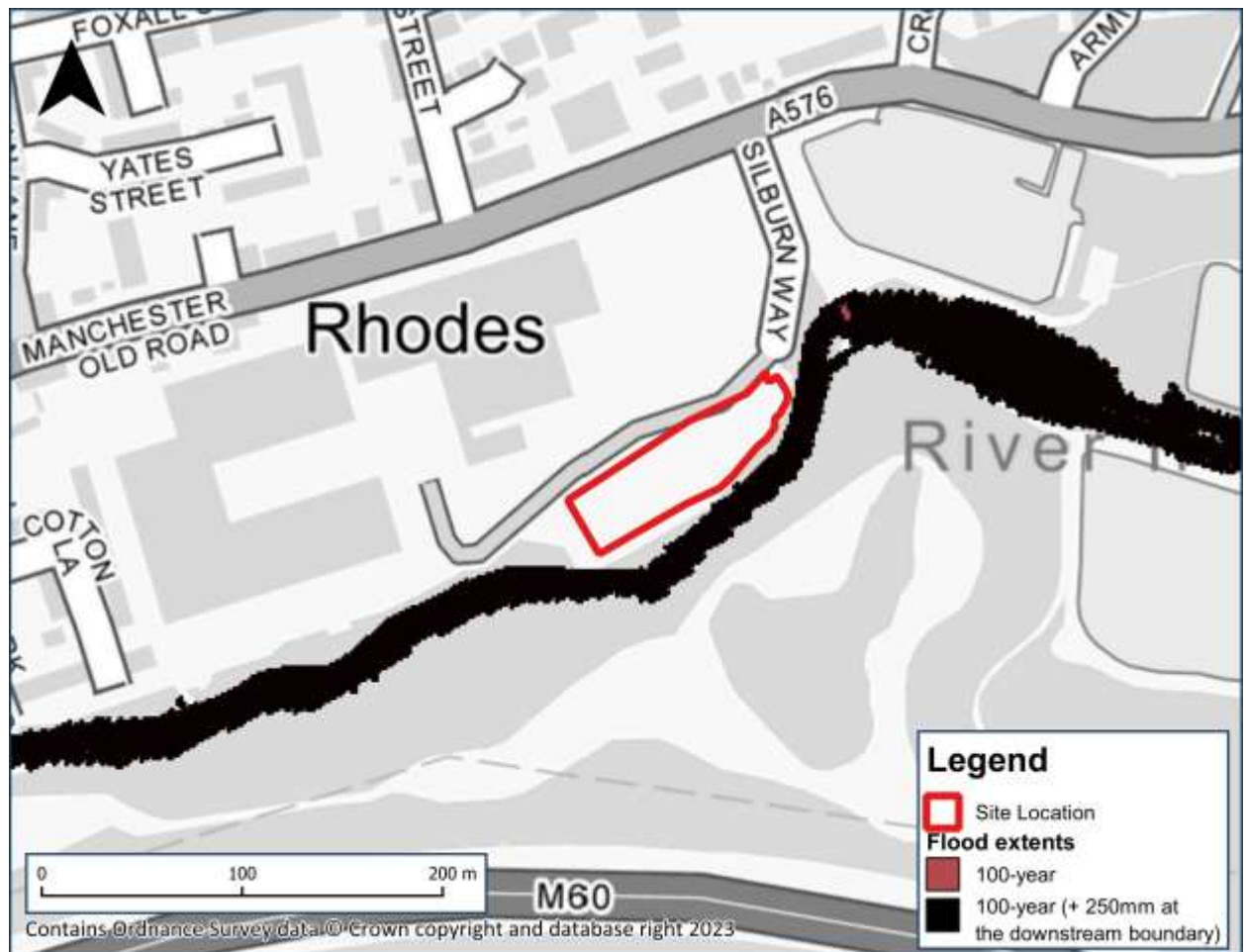


Figure 6-2 Sensitivity analysis for +250mm in gradient at the downstream boundary

Figure 6-2 model results show there is negligible impact on peak flood events within the site boundary when an increase in the downstream boundary is applied, with the downstream boundary far enough downstream of the site to not have a notable impact on the model results within the vicinity of the site.

E.3

Sensitivity to flow

Figure 6-3 shows the changes in peak flood extent compared to the baseline 100-year event when the 1D flow is adjusted by 20%.

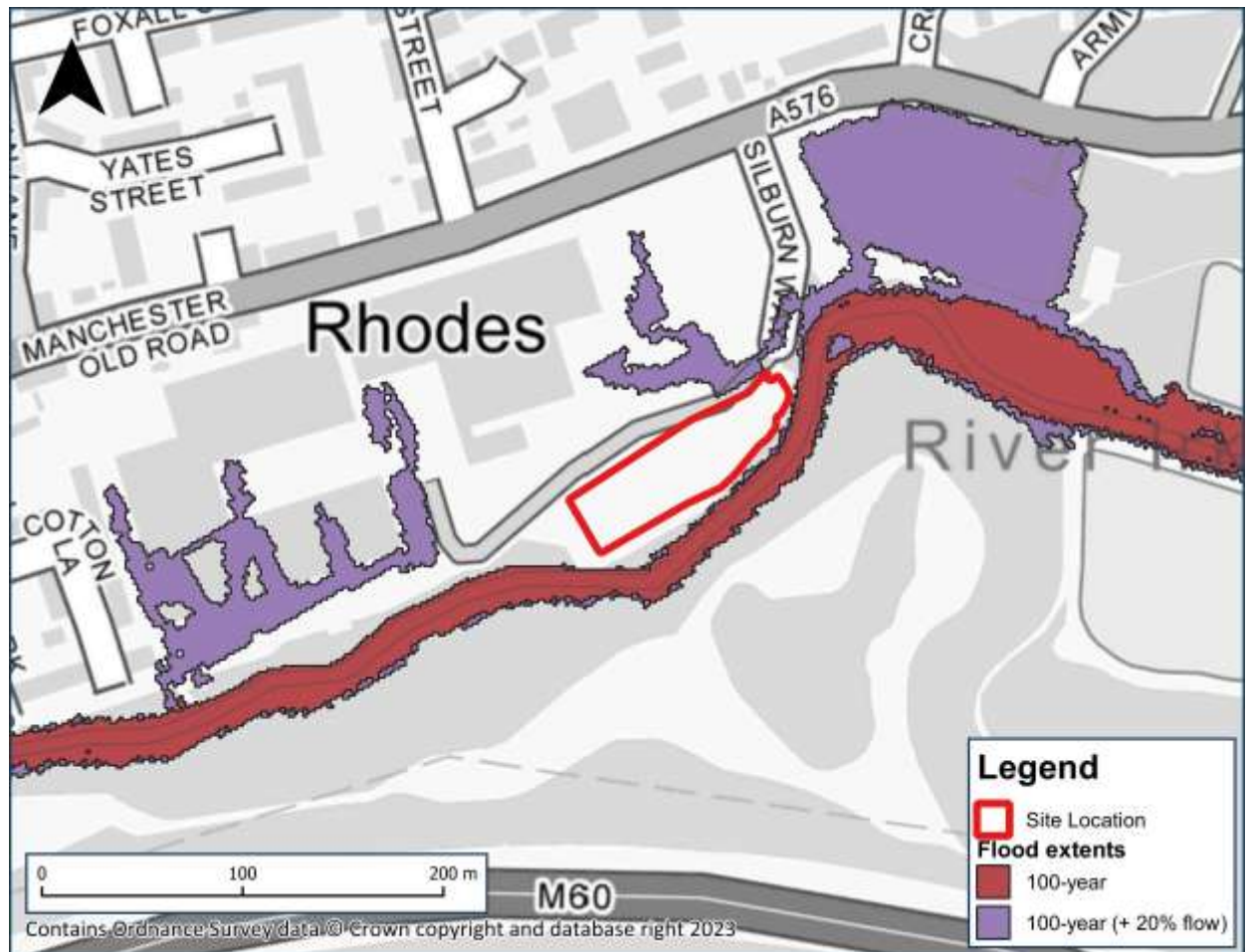


Figure 6-3: Sensitivity analysis for +20% flow

The sensitivity analysis shows that the model is relatively sensitive to flow values. However, there are no changes in peak flood extents within the site boundary when flow is adjusted by +20%.

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