

Upstream face, looking downstream



Downstream face, looking upstream.



C.7 Farm Access Culvert

Included in model?
(state reason if not):
Model label:
Type:
How has structure been modelled?

Yes

UNN_541

Two circular culverts.

The culverts were modelled as an two separate conduit units using Flood Modeller.
Overtopping of the bridge was represented within the 1D domain using a spill unit.

	UNN_541	RIVER	SECTION			
	UNN_541	JUNCTION	OPEN	UNN_541CU1i	UNN_541CU2i	UNN_541Su
	UNN_541CU1i	CULVERT	INLET	UNN_541CU1u	UNN_541	
	UNN_541CU1u	CONDUIT	CIRCULAR			
	UNN_541CU1d	CONDUIT	CIRCULAR			
	UNN_541CU1d	CULVERT	OUTLET	UNN_541CU1o		UNN_536
	UNN_541CU2i	CULVERT	INLET	UNN_541CU2u	UNN_541	
	UNN_541CU2u	CONDUIT	CIRCULAR			
	UNN_541CU2d	CONDUIT	CIRCULAR			
	UNN_541CU2d	CULVERT	OUTLET	UNN_541CU2o		UNN_536
	UNN_541Su	SPILL		UNN_541Sd		
	UNN_541CU1o	JUNCTION	OPEN	UNN_541CU2o	UNN_536	UNN_541Sd
	UNN_536	RIVER	SECTION			

Upstream face, looking downstream.



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C.8 Farm Access Culvert

Included in model?
(state reason if not):
Model label:
Type:
How has structure been modelled?

Yes

UNN_488

Circular culvert.

The pipe was modelled as a circular culvert using Flood Modeller.
Overtopping of the bridge was represented within the 1D domain using a spill unit.

	UNN_488	RIVER	SECTION			
	UNN_488	JUNCTION	OPEN	UNN_482Cui	UNN_482Su	
	UNN_482Cui	CULVERT	INLET	UNN_482CUu	UNN_488	
	UNN_482CUu	CONDUIT	CIRCULAR			
	UNN_482CUd	CONDUIT	CIRCULAR			
	UNN_482CUd	CULVERT	OUTLET	UNN_482CUo		UNN_482
	UNN_482Su	SPILL		UNN_482Sd		
	UNN_482CUo	JUNCTION	OPEN	UNN_482	UNN_482Sd	
	UNN_482	RIVER	SECTION			

Downstream face, looking upstream.



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C.9 Farm Access Culvert

Included in model?
(state reason if not):
Model label:
Type:
How has structure been modelled?

Yes

UNN_384

Circular culvert.

The pipe was modelled as a circular culvert using Flood Modeller.
Overtopping of the bridge was represented within the 1D domain using a spill unit.

	UNN_384	RIVER	SECTION			
	UNN_384	JUNCTION	OPEN	UNN_384Cui	UNN_384Su	
	UNN_384Cui	CULVERT	INLET	UNN_384CUu	UNN_384	
	UNN_384CUu	CONDUIT	CIRCULAR			
	UNN_384CUd	CONDUIT	CIRCULAR			
	UNN_384CUd	CULVERT	OUTLET	UNN_384CUo		UNN_380
	UNN_384Su	SPILL		UNN_384Sd		
	UNN_384CUo	JUNCTION	OPEN	UNN_380	UNN_384Sd	
	UNN_380	RIVER	SECTION			

Upstream face, looking downstream.



D Hydrological Assessment

Flood estimation report: 2020s1151 - Rodgers Leask - Hydraulic Modelling at Burbage

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.

Contents

1	Method statement	2
2	Locations where flood estimates required	8
3	Statistical method	10
5	Revitalised flood hydrograph 2 (ReFH2) method	13
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Approval

	Name and qualifications	Date
Method statement prepared by:	Rozy Shepherd BSc	09/09/2020
Method statement reviewed by:	Eva Kordomenidi	02/10/2020
Calculations prepared by:	Rozy Shepherd BSc	09/09/2020
Calculations reviewed by:	Eva Kordomenidi	02/10/2020

Revision History

Revision reference	Date issued	Amendments	Issued to
P01	October 2020	Draft	Nick Fenton, Rodgers Leask

Abbreviations

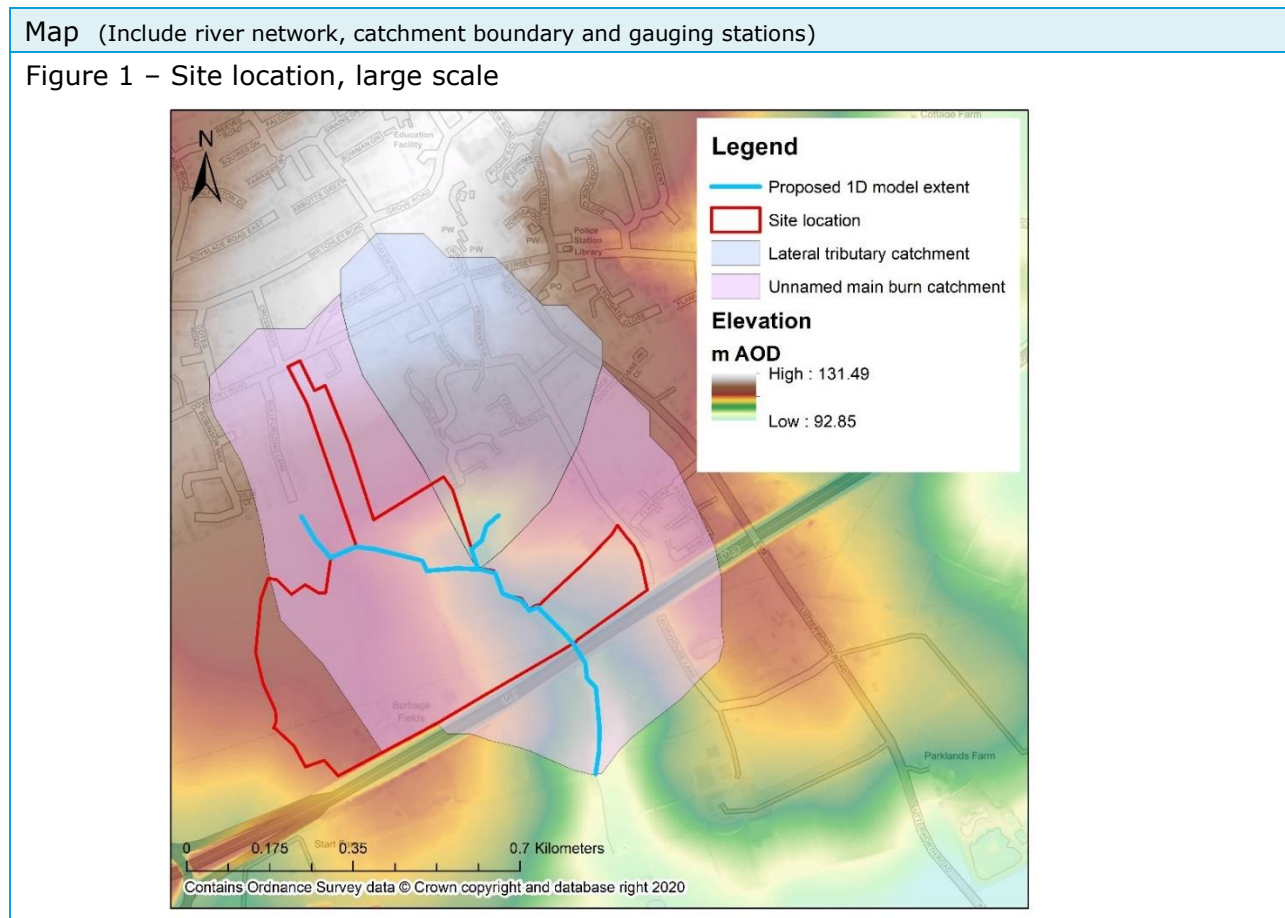
AM.....	Annual Maximum
AREA	Catchment area (km ²)
BFI	Base Flow Index
BFIHOST	Base Flow Index derived using the HOST soil classification
CFMP	Catchment Flood Management Plan
CPRE	Council for the Protection of Rural England
FARL.....	FEH index of flood attenuation due to reservoirs and lakes
FEH	Flood Estimation Handbook
FSR	Flood Studies Report
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)
SPR	Standard percentage runoff
SPRHOST	Standard percentage runoff derived using the HOST soil classification
Tp(0)	Time to peak of the instantaneous unit hydrograph
URBAN	Flood Studies Report index of fractional urban extent
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

1 Method statement

1.1 Requirements for flood estimates

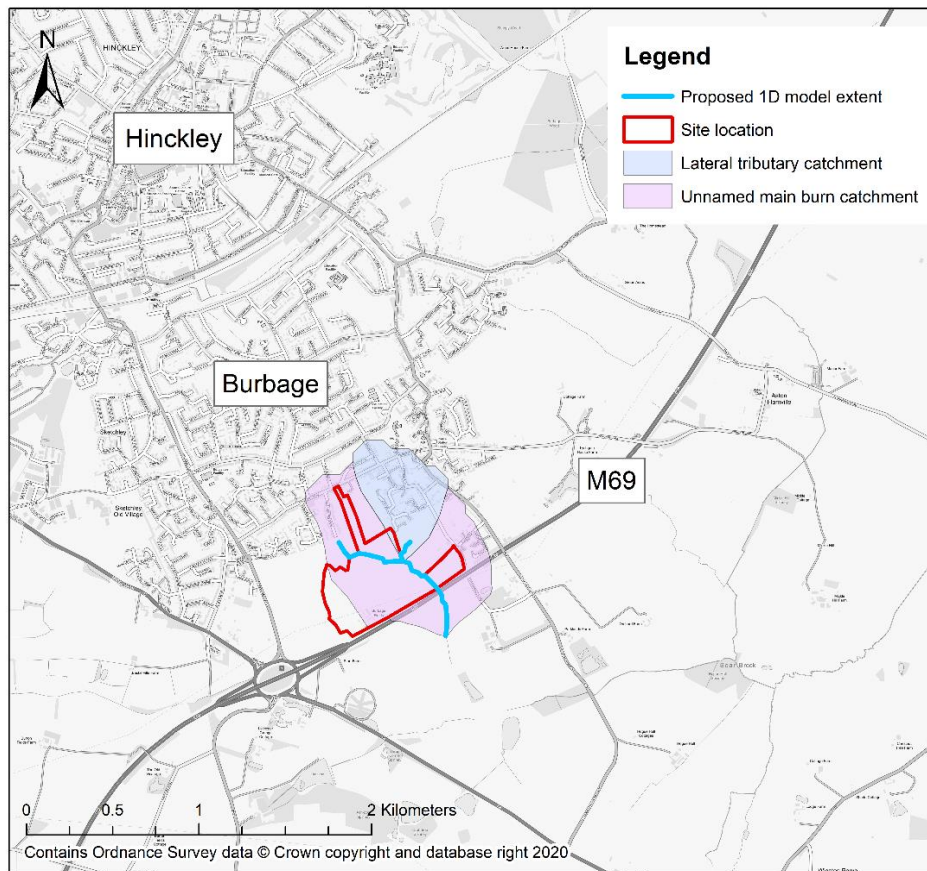
Overview - Purpose of study - Peak flows or hydrographs? - Range of return periods and locations	This calculation record documents the approach used for obtaining peak flows and design hydrographs for use in a fluvial hydraulic model of a small, unnamed burn near Burbage, Leicestershire. This unnamed burn is a small tributary of the River Soar. The aim of the hydraulic model is to investigate flood risk to a proposed housing development (across one parcel of land) at Burbage fields, between Burbage and the M69. The return periods of interest are the 20-year, 100-year and 1000-year events, as well as the 100 year event with a 30% and 50% allowance for climate change¹.
Project scope - Rating reviews? - Flood history? - ReFH parameter estimation? - Joint probability?	The hydraulic model study is being carried out for the client, Rodgers Leask, for their use in their FRA at the site. The catchment is ungauged, and as such no rating reviews are required. The site is inland, and therefore joint probability will also not be required. The sewer and surface water asset maps for the catchment were purchased from Severn Trent. These were reviewed to understand their impact on the hydrology and potential flood risk in the catchment, in particular at the site.

1.2 The catchment



¹ Environment Agency – Flood Risk Assessments, climate change allowances. February 2016. Upper end allowances for the Humber River Basin District, for the ‘2050s’ and ‘2080s’ as outlined in Table 1 (<https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances>).

Figure 2 – site location, small scale



Description

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

The catchment is small, ungauged, mixed urban / rural and gently slopes to the southern boundary. With reference to Environment Agency open source LiDAR data, the topology of the catchment ranges from elevations of circa. 130 mAOD in the northern area of the catchment, to circa. 100 mAOD in the southern section of the catchment (downstream extent of the hydraulic model). The proposed parcel of land considered for housing development is in the middle to south-western section of the catchment and is situated at circa. 105 mAOD to 127 mAOD (with reference to available LiDAR data). There is a road bridge (M69) over the unnamed burn, just downstream of the site boundary.

There are two inflows in to the hydraulic model – one at the upstream extent of the model (western inflow – unnamed main burn) and the other at a smaller tributary, which joins about half way down the model's reach.

The unnamed burn flows in a south-easterly direction and has a total catchment area of 0.72 km² at the downstream extent of the model (grid reference 444500 291300, as downloaded from the UK CEH FEH web service). The catchment area for the small tributary to this burn (which flows in a south-westerly direction) is encompassed within the overall catchment area of the unnamed burn. The location used to calculate peak flows for the small tributary was also taken from the downstream extent of the model, as the drainage network on the FEH web service did not go upstream of this location (i.e. it did not cover the location of the confluence between the main burn and the tributary).

The catchment area for the small tributary was adjusted to not include the catchment area already accounted for the inflow to the main burn.

The land use in the catchment is mainly agricultural with the southern outskirts of Burbage being urbanised areas within the catchment (URBEXT2000: 0.018).

The underlying geology includes a sedimentary bedrock completely overlain by superficial deposits of diamicton, sand and gravel².

The unnamed burn joins the Soar Brook at a confluence about 500 m to the south of the catchment, which in itself is a tributary of the River Soar. The unnamed burn's catchment is within NRFA hydrometric region 28 - Trent.

Review of Severn Trent asset data (last revision August 2020)

The sewer and surface water asset maps for the catchment were purchased from Severn Trent. These show that there are three surface water drains within the urbanised area adjacently to the north of the site:

1. One drain covers the small residential area of Robinsons way, to the south of Coventry road. This area is to the north of the site, and adjacent to the north-western boundary of the catchment area, as used for the fluvial modelling. This surface water drain is discharged at the upstream extent of the unnamed main burn.
2. A second drain also runs down Bullfurlong lane, starting to the south of Coventry road. This lane is within the catchment boundary, to the north of the site. The surface water drain also discharges to the upstream extent of the unnamed main burn.
3. A third drain runs down a short section of Britannia road, within the catchment area for the small tributary. Discharge is at a manhole near Frezenberg close, also within the catchment. As with the other surface water drains above, this drain is outwith the site boundary.

Given that the drain outlined in point 1 is a small network and mostly within the catchment area, and also drains directly to the unnamed main burn, then this network is anticipated to have negligible affect on the hydrology of the catchment. The catchment area of the drain outlined in point 2 and 3 above are completely within the catchment area. All drains are anticipated to be low risk with regard to flooding on site.

All combined and foul drains route and discharge to the west or east of the catchment and site boundary area, either along Coventry road and Canberra way (to the west) or Britannia road and Lutterworth road to the east, and the risk of flooding from these drainage networks are therefore considered to be low. There are no drainage networks that currently route through the site's boundary. The asset maps are included in the appendix.

² BGS open geoscience. 2020. <http://mapapps.bgs.ac.uk/geologyofbritain/home.html>
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1.3 Source of flood peak data

Source	NRFA peak flows dataset, Version 8, released September 2019. This contains data up to water year 2017-18.
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1.4 Gauging stations (flow or level)

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

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
N/A – no NRFA river gauges in the vicinity of the catchment						

1.5 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 - ungauged	No		
Historic flood data Include chronology and interpretation of flood history in Annex or separate report.	No historic flood review undertaken			
Flow or river level data for events	N/A - ungauged	No		
Rainfall data for events	N/A			
Potential evaporation data	N/A			
Results from previous studies	None undertaken in area			
Other data or information (e.g. groundwater, tides, channel widths, low flow statistics)	Severn Trent asset maps	Yes – purchased from Severn Trent		Sewer and surface water asset maps for the catchment were reviewed.

1.6 Hydrological understanding of catchment

Hydrological interpretation Catchment processes, response time, propagation of flood, contributions from tributaries	Flood water has been known to collect at the upstream face of the M69 road bridge. This area is within the site boundary. It is hoped that this study will inform of the extents, depths and levels of flooding in this area.
Plots of flood peak	N/A

data i.e. AMAX or POT series	
Hydrological interpretation Discuss outliers, non-stationarity.	N/A

Outline the conceptual model, addressing questions such as: - Where are the main sites of interest? - What is likely to cause flooding at those locations? (peak flows, flood volumes, 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 that could collapse?	The main area of interest is the lowest topographic area within the site's boundary, which is at the upstream face of the M69 road bridge, over the unnamed burn (flood water has been known to collect here during storm events, potentially due to restriction of the road bridge on the watercourse at this location).
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	Key catchment descriptors indicate that the catchment has fairly low rainfall (over 644 mm per year) and fairly high runoff (SPRHOST values of over 46.23%) with moderate/high permeability (BFIHOST19 value of 0.47). The land use in the catchment is a mix of urban and rural (URBEXT2000: 0.018). The catchment has a high FARL value (1), suggesting it is not affected by attenuation effects of reservoir storage.

1.7 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
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?	Initial method: ReFH2.3 Reason: Small, semi-urban catchments are generally more suited to having peak flows calculated by a rainfall-run-off method, and the ReFH2 method (using FEH13 rainfall) is considered an accepted rainfall-runoff method by the EA. In addition, ReFH2.3 (an updated version of ReFH2) incorporates the BFIHOST19 catchment descriptor values as downloaded from the UK CEH FEH web service. In addition, there are no gauges at or near the catchment which could be used for single site or enhanced single site statistical method. However, the FEH Statistical method (with pooling group) has been undertaken for comparison purposes. The catchment has been split in to two sub

	catchments, as there are two inflows required for the hydraulic model. This is described in section 1.2.
Software to be used (with version numbers)	FEH Web Service ³ / WINFAP-FEH v3.0.003 ⁴ / ReFH2.3

³ CEH 2015. The Flood Estimation Handbook (FEH) Online Service, Centre for Ecology & Hydrology, Wallingford, Oxon, UK.

⁴ WINFAP-FEH v3 © Wallingford HydroSolutions Limited and NERC (CEH) 2009.
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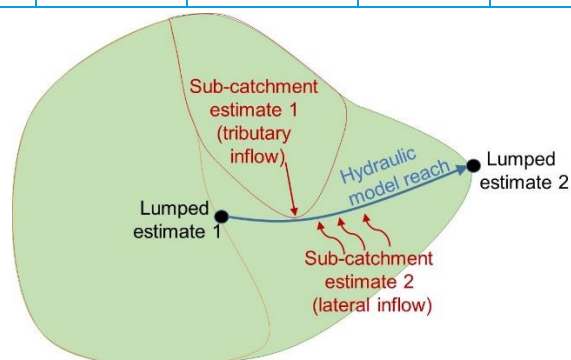
2 Locations where flood estimates required

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

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
Ungauged_01	flow	Unnamed main burn	Downstream extent of hydraulic model (downstream of M69 road bridge)	444500	291300	0.72	0.59 (inflow for 'unnamed main burn')
Ungauged_02	flow	Small tributary	Downstream extent of hydraulic model (downstream of M69 road bridge)	444500	291300	0.72	0.23 (inflow for 'lateral tributary')

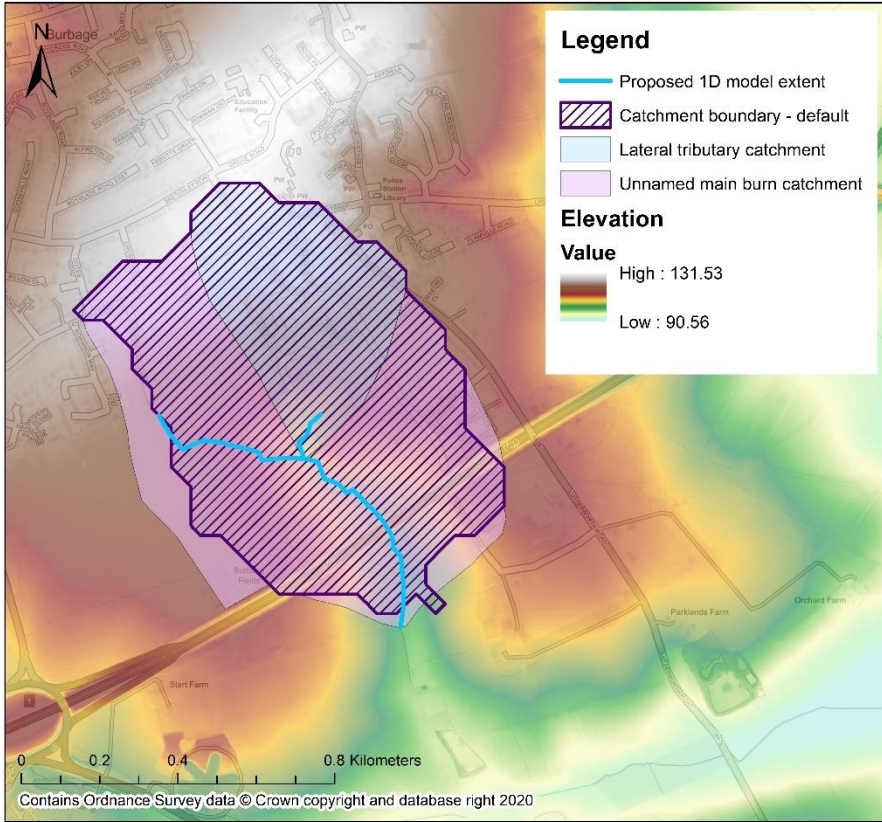
Note: Lumped catchments (L) are complete catchments draining to points at which design flows are required. Sub-catchments (S) are catchments or intervening areas that are being used as inputs to a semi-distributed model of the river system. There is no need to report any design flows for sub-catchments, 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	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	URBEXT 2000	FPEXT
Ungauged_01	1	0.3	0.491 (BFIHOST 19 = 0.47)	0.75	24.1	664	0.18	0.049
Ungauged_02	1	0.3	0.491 (BFIHOST 19 = 0.47)	0.75	24.1	664	0.18	0.049

2.3 Checking catchment descriptors

Record how catchment boundary was checked and describe any changes (add maps if needed)	The catchment boundaries were checked against Ordnance Survey (OS) mapped information and LiDAR data (open source, available from the Environment Agency) and slight adjustments were made with reference to this. The catchment boundary was taken from the downstream extent for both inflows, and adjusted for both inflows so that the catchment areas used for each inflow do not overlap. Consideration to the topography of the small tributary catchment has been considered when adjusting the catchment, to try and consider the area of the small tributary as realistically as possible. Figure 3 - Default catchment boundary 
Record how other catchment descriptors were checked and describe any changes. Include before/after table if necessary.	DPLBAR recalculated with regard to FEH equation $DPLBAR = AREA \wedge 0.548^5$. All other catchment descriptors were obtained from the UK CEH FEH Web Service and are deemed appropriate.
Source of URBEXT	URBEXT2000
Method for updating of URBEXT	CPRE formula from 2006 CEH report on URBEXT2000

⁵ CEH. (1999). Flood Estimation Handbook Volume 5: Catchment Descriptors.
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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		
Unguag ed_01	0.15	CDs	-	-	-	-	-	1.254	0.18
Unguag ed_02	0.07	CDs	-	-	-	-	-	1.254	0.08
Are the values of QMED spatially consistent?					N/A – only downloaded at one location				
Method used for urban adjustment for subject and donor sites					Kjeldsen (2010) ⁶				
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			
N/A			N/A			N/A			
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) ⁷ 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.									

⁶ Kjeldsen, T. R. (2010). Modelling the impact of urbanization on flood frequency relationships in the UK. Hydrol. Res. **41**. 391-405.

⁷ 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.	The suggested donors from WinFAP v3 did not appear to be suitable, mainly due to the very small size of the catchment and the fact that there are no known river gauges in close proximity to the site (the closest is Soar at Littlethorpe, NRFA number 28082, about 12 km to the east of the catchment). It was decided that using CDs to calculate QMED would give less uncertainty in the peak flow estimates.
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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)
No donor sites chosen for QMED donor transfer						

3.4 Derivation of pooling groups

Several subject sites may use the same pooling group.

Name of group	Site code from whose descriptor s 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)
FinalPoolingGroup_Burba geFields	Ungauged_01 (and Ungauged_02)	No	See appendix.	L-CV: 0.256 L-skew: 0.280

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
Ungauged_01	P	FinalPoolingGroup_Burba geFields	GL (marked as appropriate to use in Winfap)	Urban adjustment - Kjeldsen (2010).	Location: 1.000 Scale: 0.218 Shape: -0.315	3.25

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
Unga uged_02	P	FinalPooli ngGroup_ BurbageFi elds	GL (marked as appropriate to use in Winfap)	Urban adjustment - Kjeldsen (2010).	Location: 1.000 Scale: 0.218 Shape: -0.315	3.25

Notes

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).

3.6 Flood estimates from the statistical method

Site code	Flood peak (m ³ /s) for the following return periods (in years)										
	50	20	10	5	3.3	2	1.3	1	0.5	0.2	0.1
Unga uged_01	0.18	0.25	0.31	0.38	0.42	0.49	0.55	0.60	0.73	0.96	1.18
Unga uged_02	0.08	0.11	0.14	0.17	0.19	0.22	0.25	0.27	0.33	0.43	0.53

5 Revitalised flood hydrograph 2 (ReFH2) method

5.1 Parameters for ReFH2 model

Site code	Method	T _p rural (hours)	C _{max} (mm)	PR _{imp} % runoff for impermeable surfaces	BL (hours)	BR
Ungauged_01	CD	2.33	387.95	0.7	31.94	2.34
Ungauged_02	CD	1.74	387.95	0.7	28.57	2.52
Brief description of any flood event analysis carried out (further details should be given in the annex)				N/A		
Methods: OPT: Optimisation, BR: Baseflow recession fitting, CD: Catchment descriptors, DT: Data transfer (give details)						

5.2 Design events for ReFH2 method: Lumped catchments

Site code	Urban or rural	Season of design event (summer or winter)	Storm duration (hours)
Ungauged_01	urban	Winter	3.5 h
Ungauged_02	urban	Winter	2.75 h (adjusted to 3.5 h)

5.3 Design events for ReFH2 method: Sub-catchments and intervening areas

Site code	Season of design event	Storm duration (hours)	Storm area for ARF (if not catchment area)
No sub catchments or intervening areas.			
Are the storm durations likely to be changed in the next stage of the study, e.g. by optimisation within a hydraulic model?			No

5.4 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.

Site code	Flood peak (m ³ /s) for the following return periods (in years)										
	50	20	10	5	3.3	2	1.3	1	0.5	0.2	0.1
Ungauged_01	0.19	0.27	0.32	0.38	0.42	0.47	0.52	0.56	0.68	0.87	1.03
Ungauged_02	0.09	0.13	0.15	0.18	0.20	0.23	0.25	0.27	0.33	0.42	0.50

6 Discussion and summary of results

6.1 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		
	ReFH	ReFH2	Other method	ReFH	ReFH2	Other method
Ungauged_01		1.06			0.93	
Ungauged_02		1.12			1.0	

6.2 Final choice of method

Choice of method and reasons Include reference to type of study, nature of catchment and type of data available.	Final method: ReFH2.3 Reason: There is appreciable uncertainty associated with both methods. Small, semi-urban catchments are generally more suited to having peak flows calculated by a rainfall-run-off method, and ReFH2 (using FEH13 rainfall) is a recommended method by Environment Agency. ReFH2.3 (an updated version of ReFH2) was used, which incorporates the BFIHOST19 catchment descriptor values as downloaded from the UK CEH FEH web service. On comparison with the statistical method, the ReFH2.3 peak flows were generally slightly higher for the lower return periods, but lower than the statistical method for the higher return periods. However, the statistical method has a relatively high 100-year growth curve factor, that is just outside of the range recommended from the Environment Agency (section 6.4). Hence, the ReFH2.3 method was deemed more appropriate to use.
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?	Unnamed main burn – peak flows derived from the DS model extent, with the adjusted catchment area, will be applied as the inflow. The default storm duration of 3.5 hours with timestep of 0.5 hours will be used, and ReFH2.3 urban hydrographs will be used in the hydraulic model (if the model is 1D unsteady). Small tributary – peak flows derived from DS model extent, with the catchment area adjusted to include that of the tributary but not include that already accounted for at the US model extent. The storm duration was adjusted to that derived for the upstream model extent. This gave slightly more conservative peak flows for the small tributaries catchment. ReFH2.3 urban hydrographs will also be used in the hydraulic model (if the model is 1D unsteady).

6.3 Assumptions, limitations and uncertainty

List the main assumptions made (specific to this study)	The pooling group used in the statistical method for Ungauged_01 and Ungauged_02 is representative of the catchment as a whole.
Discuss any particular	The small tributary is not included in the drainage network

limitations, e.g. applying methods outside the range of catchment types or return periods for which they were developed.	on the UK CEH FEH webservice, so the exact catchment descriptors for this catchment area could not be downloaded from the website. The catchment descriptors used for the small tributaries catchment were therefore downloaded from the DS extent of the model, and the catchment area adjusted. The catchment is ungauged and so there is no flow data for the catchments that could be used for peak flow estimation.
Give what information you can on uncertainty in the results, e.g. confidence limits from Kjeldsen (2014).	For the FEH Statistical method, the uncertainty will depend on a variety of factors, for example, how unusual the catchment is relative to the pooling group, and the uncertainty in flow measurement at these gauges. Recent guidance on the reliability of design flood estimates in the UK (Kjeldsen, 2014) quotes average UK measures of uncertainty. The 95% confidence limits for a 1% AEP event flood estimate are: - Without donor adjustment of QMED (CDs): 0.42 - 2.37 times the best estimate. - With donor adjustment of QMED (DT): 0.45 - 2.25 times the best estimate.
Comment on the suitability of the results for future studies, e.g. at nearby locations or for different purposes.	The results should be refined before being used for any other purpose or at any other location within the catchment.
Give any other comments on the study, e.g. suggestions for additional work.	The sewer and surface water asset maps for the catchment have been purchased from Severn Trent (DigDat website), and have been reviewed to understand their impact on hydrology and potential flood risk in the catchment, in particular at the site.

6.4 Checks

Are the results consistent, for example at confluences?	N/A
What do the results imply regarding the return periods of floods during the period of record?	N/A – ungauged catchment
What is the range of 100-year growth factors? Is this realistic?	Ungauged_01 – US model extent (FEH Stat method) = 3.25 Ungauged_02 – small tributary (FEH Stat method) = 3.25 These are both slightly outside of the Environment Agency's recommended range of 1.8 to 3.0
If 1000-year flows have been derived, what is the range of ratios for 1000-year flow over 100-year flow?	Ungauged_01 – US model extent (Refh2.3) = 1.82 Ungauged_02 – small tributary (Refh2.3) = 1.85
How do the results compare with those of other studies? Explain any differences and conclude which results should be preferred.	No other studies were known to have been undertaken in the area.
Are the results compatible with the longer-term flood history?	History of flood events in the area not known. However, flood water has been seen to collect at the upstream face of

	the M69 road bridge, although it is uncertain how often this occurs, and the extent of flooding in this area.
Describe any other checks on the results	The statistical method and ReFH2.3 method both gave very similar peak flows at each return period.

6.5 Final results

Site code	Flood peak (m ³ /s) for the following return periods (in years)										
	50	20	10	5	3.3	2	1.3	1	0.5	0.2	0.1
Ungauged_01	0.19	0.27	0.32	0.38	0.42	0.47	0.52	0.56	0.68	0.87	1.03
Ungauged_02	0.09	0.13	0.15	0.18	0.20	0.23	0.25	0.27	0.33	0.42	0.50

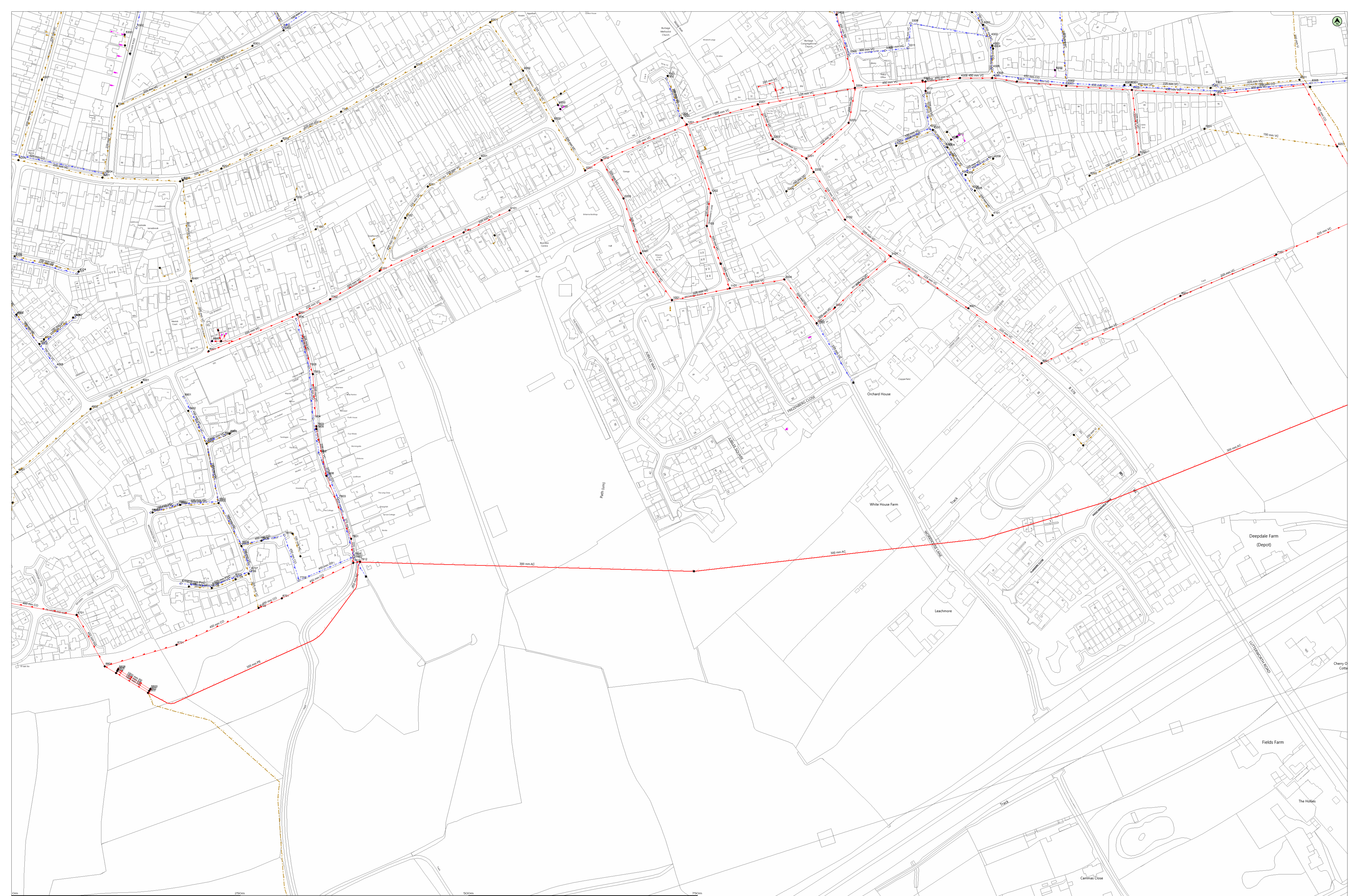
If flood hydrographs are needed for the next stage of the study, where are they provided? (e.g. give filename of spreadsheet, hydraulic model, or reference to table below)	Saved at this location: N:\2020\Projects\2020s1151 - Rodgers Leask - HYdraulic Modelling at Burbage\1_WIP\HO\Non_Graphical Spreadsheet titled 'EDS-JBAU-XX-XX-CA-HO-0002-Hydrology_Summary.xlsx'
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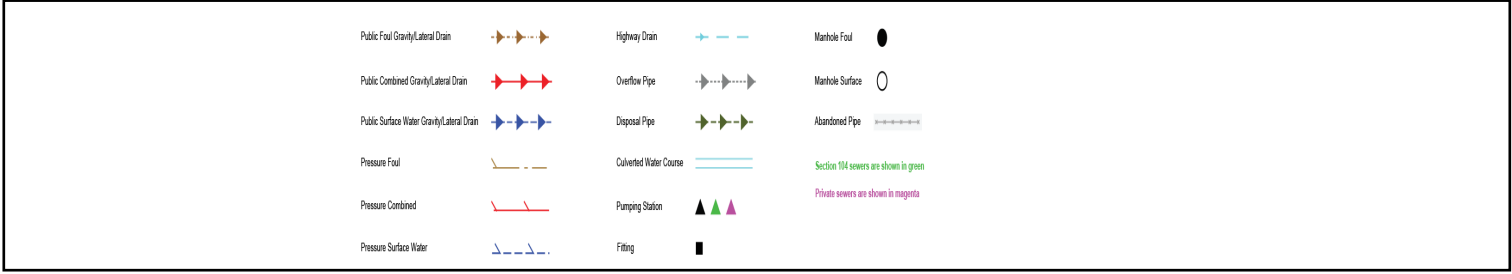
A Annex

A.1 Changes made to default pooling group – FEH statistical method

Adjustment/ Changes made to Default Pooling Group. Also note sites that were investigated but retained in the group (i.e. for discordancy)			
Station number	Name	Addition/ Deletion/ Move/ Investigate	Reason
27073	Brompton Beck @ Snainton Ings	Deletion	High FPEXT of 0.237
91802	Allt Leachdach @ Intake	Deletion	High SAAR of 2555 and High PROPWET of 0.83
49006	Camel @ Camelford	Deletion	marked as discordant (value 3.072)
54022	Severn @ Plynlimon Flume	Deletion	High SAAR of 2483 and High PROPWET of 0.66
206006	Annalong @ Recorder	Deletion	High SAAR of 1720 and High PROPWET of 0.59
203046	Rathmore Burn @ Rathmore Bridge	Addition	increase record length
51002	Horner Water @ West Luccombe	Addition	increase record length
27032	Hebden Beck @ Hebden	Addition	increase record length
49003	de Lank @ de Lank	Addition	increase record length

A.2 Severn Trent Asset maps (last revised August 2020)





GENERAL CONDITIONS AND PRECAUTIONS TO BE TAKEN WHEN CARRYING OUT WORK ADJACENT TO SEVERN TRENT WATER'S APPARATUS

Please ensure that a copy of these conditions is passed to your representative and/or your contractor on site. If any damage is caused to Severn Trent Water Limited (STW) apparatus (defined below), the person, contractor or subcontractor responsible must inform STW immediately on: 0800 753 4444 (24 hours)

- a) These general conditions and precautions apply to the public sewerage, water distribution and cables in ducts including (but not limited to) sewers which are the subject of an Agreement under Section 104 of the Water Industry Act 1991(a legal agreement between a developer and STW, where a developer agrees to build sewers to an agreed standard, which STW will then adopt), mains installed in accordance with an agreement for the self-construction of water mains entered into with STW and the assets described at condition b) of these general conditions and precautions. Such apparatus is referred to as "STW Apparatus" in these general conditions and precautions.
- b) Please be aware that due to The Private Sewers Transfer Regulations June 2011, the number of public sewers has increased, but many of these are not shown on the public sewer record. However, some idea of their positions may be obtained from the position of inspection covers and their existence must be anticipated.
- c) On request, STW will issue a copy of the plan showing the approximate locations of STW Apparatus although in certain instances a charge will be made. The position of private drains, private sewers and water service pipes to properties are not normally shown but their presence must be anticipated. This plan and the information supplied with it is furnished as a general guide only and STW does not guarantee its accuracy.
- d) STW does not update these plans on a regular basis. Therefore the position and depth of STW Apparatus may change and this plan is issued subject to any such change. Before any works are carried out, you should confirm whether any changes to the plan have been made since it was issued.
- e) The plan must not be relied upon in the event of excavations or other works in the vicinity of STW Apparatus. It is your responsibility to ascertain the precise location of any STW Apparatus prior to undertaking any development or other works (including but not limited to excavations).
- f) No person or company shall be relieved from liability for loss and/or damage caused to STW Apparatus by reason of the actual position and/or depths of STW Apparatus being different from those shown on the plan.

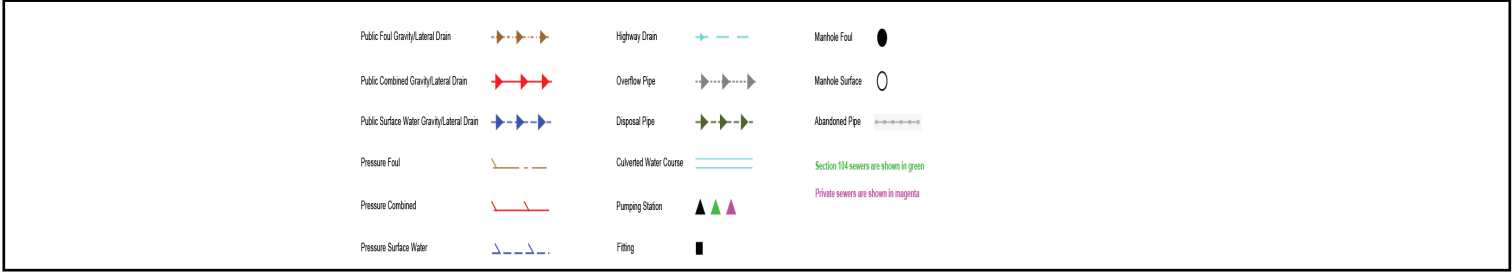
In order to achieve safe working conditions adjacent to any STW Apparatus the following should be observed:

1. All STW Apparatus should be located by hand digging prior to the use of mechanical excavators.
2. All information set out in any plans received from us, or given by our staff at the site of the works, about the position and depth of the mains, is approximate. Every possible precaution should be taken to avoid damage to STW Apparatus. You or your contractor must ensure the safety of STW Apparatus and will be responsible for the cost of repairing any loss and/or damage caused (including without limitation replacement parts).
3. Water mains are normally laid at a depth of 900mm. No records are kept of customer service pipes which are normally laid at a depth of 750mm; but some idea of their positions may be obtained from the position of stop tap covers and their existence must be anticipated.
4. During construction work, where heavy plant will cross the line of STW Apparatus, specific crossing points must be agreed with STW and suitably reinforced where required. These crossing points should be clearly marked and crossing of the line of STW Apparatus at other locations must be prevented.
5. Where it is proposed to carry out piling or boring within 20 metres of any STW Apparatus, STW should be consulted to enable any affected STW Apparatus to be surveyed prior to the works commencing.
6. Where excavation of trenches adjacent to any STW Apparatus affects its support, the STW Apparatus must be supported to the satisfaction of STW. Water mains and some sewers are pressurised and can fail if excavation removes support to thrust blocks to bends and other fittings.
7. Where a trench is excavated crossing or parallel to the line of any STW Apparatus, the backfill should be adequately compacted to prevent any settlement which could subsequently cause damage to the STW Apparatus. In special cases, it may be necessary to provide permanent support to STW Apparatus which has been exposed over a length of the excavation before backfilling and reinstatement is carried out. There should be no concrete backfill in contact with the STW Apparatus.
8. No other apparatus should be laid along the line of STW Apparatus irrespective of clearance. Above ground apparatus must not be located within a minimum of 3 metres either side of the centre line of STW Apparatus for smaller sized pipes and 6 metres either side for larger sized pipes without prior approval. No manhole or chamber shall be built over or around any STW Apparatus.
9. A minimum radial clearance of 300 millimetres should be allowed between any plant or equipment being installed and existing STW Apparatus. We reserve the right to increase this distance where strategic assets are affected.
10. Where any STW Apparatus coated with a special wrapping is damaged, even to a minor extent, STW must be notified and the trench left open until the damage has been inspected and the necessary repairs have been carried out. In the case of any material damage to any STW Apparatus causing leakage, weakening of the mechanical strength of the pipe or corrosion-protection damage, the necessary remedial work will be recharged to you.
11. It may be necessary to adjust the finished level of any surface boxes which may fall within your proposed construction. Please ensure that these are not damaged, buried or otherwise rendered inaccessible as a result of the works and that all stop taps, valves, hydrants, etc. remain accessible and operable. Minor reduction in existing levels may result in conflict with STW Apparatus such as valve spindles or tops of hydrants housed under the surface boxes. Checks should be made during site investigations to ascertain the level of such STW Apparatus in order to determine any necessary alterations in advance of the works.
12. With regard to any proposed resurfacing works, you are required to contact STW on the number given above to arrange a site inspection to establish the condition of any STW Apparatus in the nature of surface boxes or manhole covers and frames affected by the works. STW will then advise on any measures to be taken, in the event of this a proportionate charge will be made.
13. You are advised that STW will not agree to either the erection of posts, directly over or within 1.0 metre of valves and hydrants,
14. No explosives are to be used in the vicinity of any STW Apparatus without prior consultation with STW.

TREE PLANTING RESTRICTIONS

There are many problems with the location of trees adjacent to sewers, water mains and other STW Apparatus and these can lead to the loss of trees and hence amenity to the area which many people may have become used to. It is best if the problem is not created in the first place. Set out below are the recommendations for tree planting in close proximity to public sewers, water mains and other STW Apparatus.

15. Please ensure that, in relation to STW Apparatus, the mature root systems and canopies of any tree planted do not and will not encroach within the recommended distances specified in the notes below.
16. Both Poplar and Willow trees have extensive root systems and should not be planted within 12 metres of a sewer, water main or other STW Apparatus.
17. The following trees and those of similar size, be they deciduous or evergreen, should not be planted within 6 metres of a sewer, water main or other STW Apparatus. E.g. Ash, Beech, Birch, most Conifers, Elm, Horse Chestnut, Lime, Oak, Sycamore, Apple and Pear. Asset Protection Statements Updated May 2014
18. STW personnel require a clear path to conduct surveys etc. No shrubs or bushes should be planted within 2 metre of the centre line of a sewer, water main or other STW Apparatus.
19. In certain circumstances, both STW and landowners may wish to plant shrubs/bushes in close proximity to a sewer, water main of other STW Apparatus for screening purposes. The following are shallow rooting and are suitable for this purpose: Blackthorn, Broom, Cotoneaster, Elder, Hazel, Laurel, Privet, Quickthorn, Snowberry, and most ornamental flowering shrubs.



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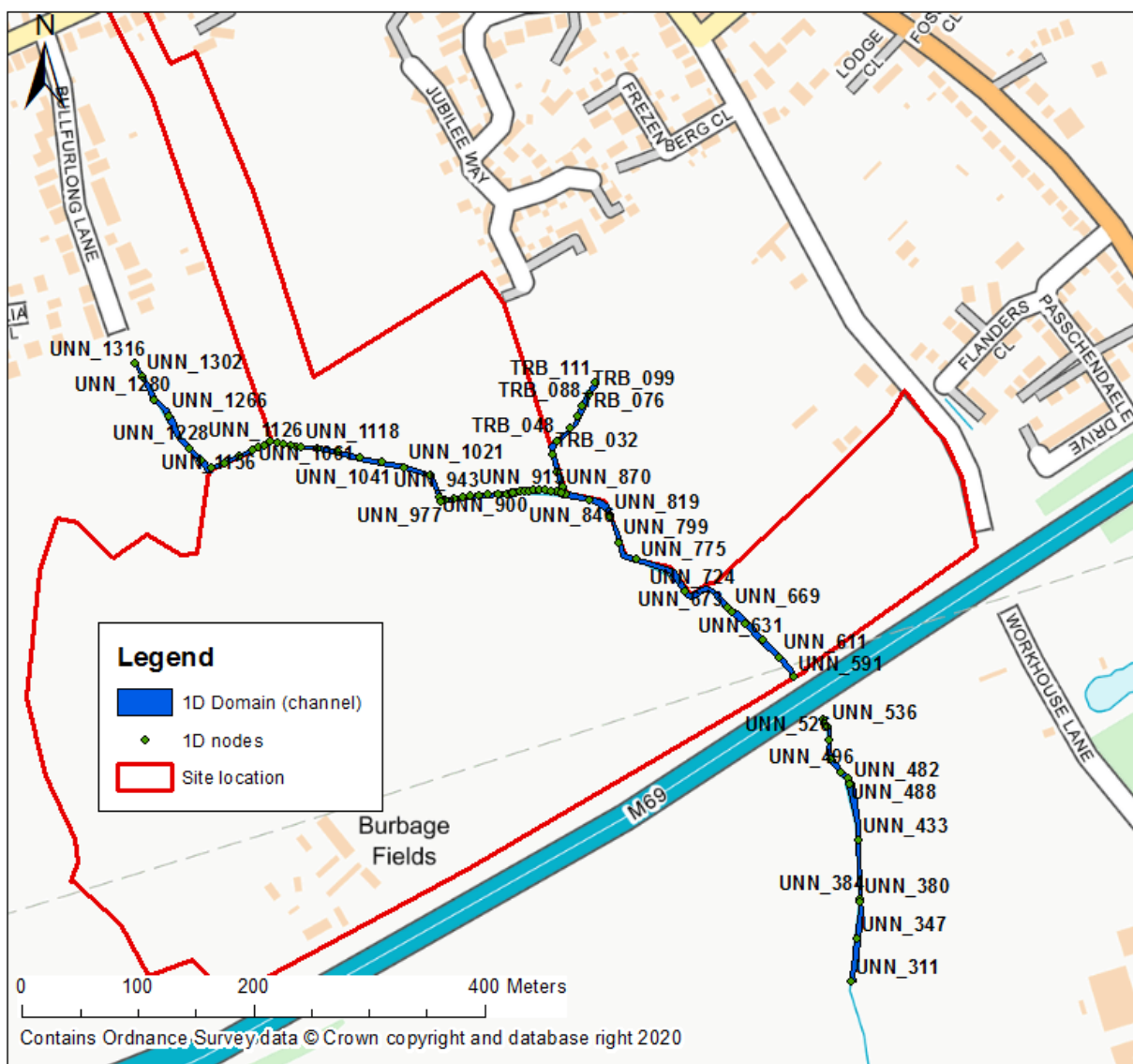
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E Modelled water levels

E.1 Node location

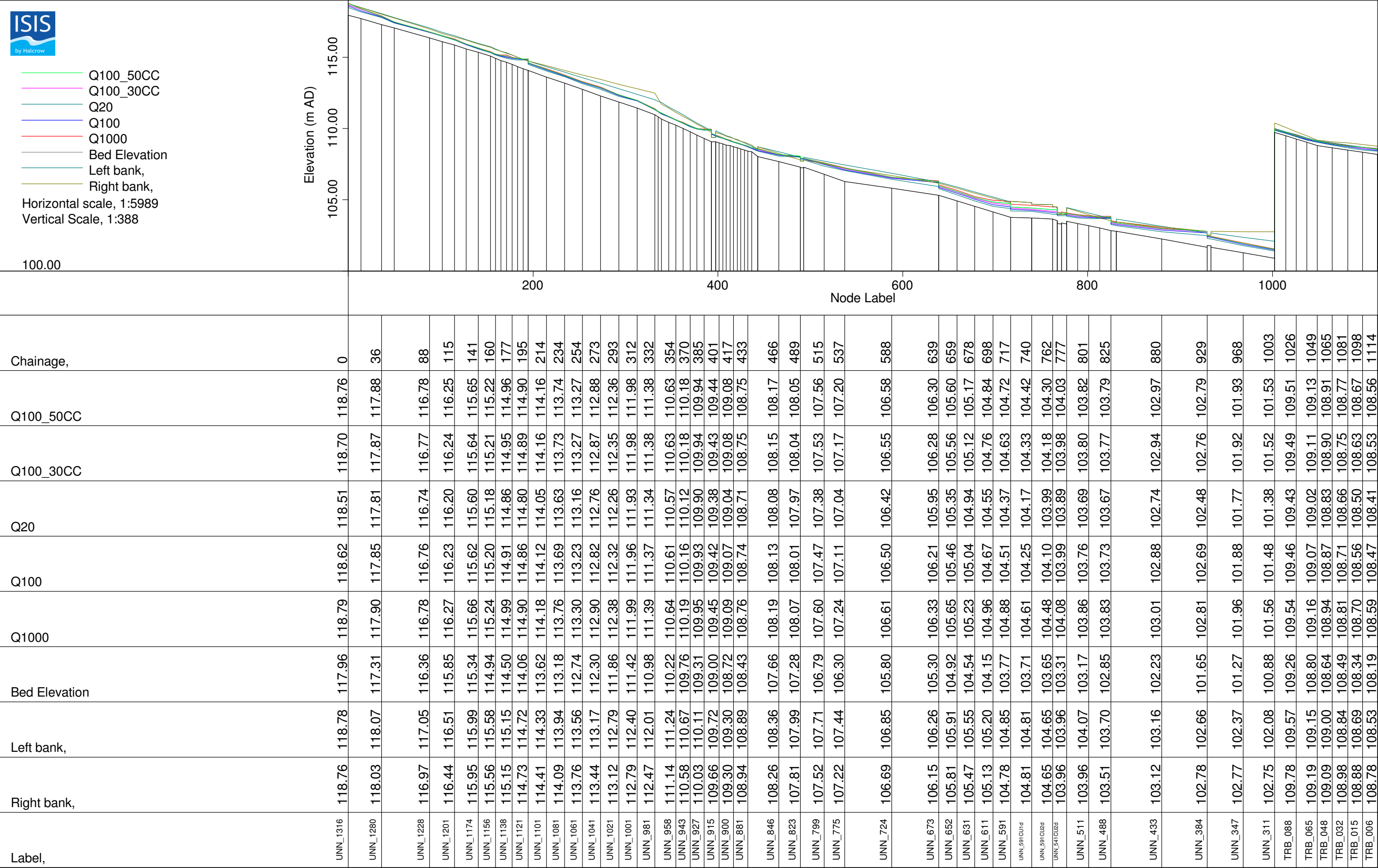
Figure E-1: Node locations



E.2 Long-section plot

Long Section: UNN_1316 - TRB_006 - Maximum Stage; 0.25 - 8 h.

Long Section: UNN_1316 - TRB_006 - Maximum Stage; 0.25 - 8 h.



F Sensitivity analysis

F.1 Sensitivity to flow

Figure E-1 shows the changes in peak water level compared to the baseline 100-year event when an increase of 20% is applied to all inflows.

Figure E-1: Sensitivity to changes in increase in flow

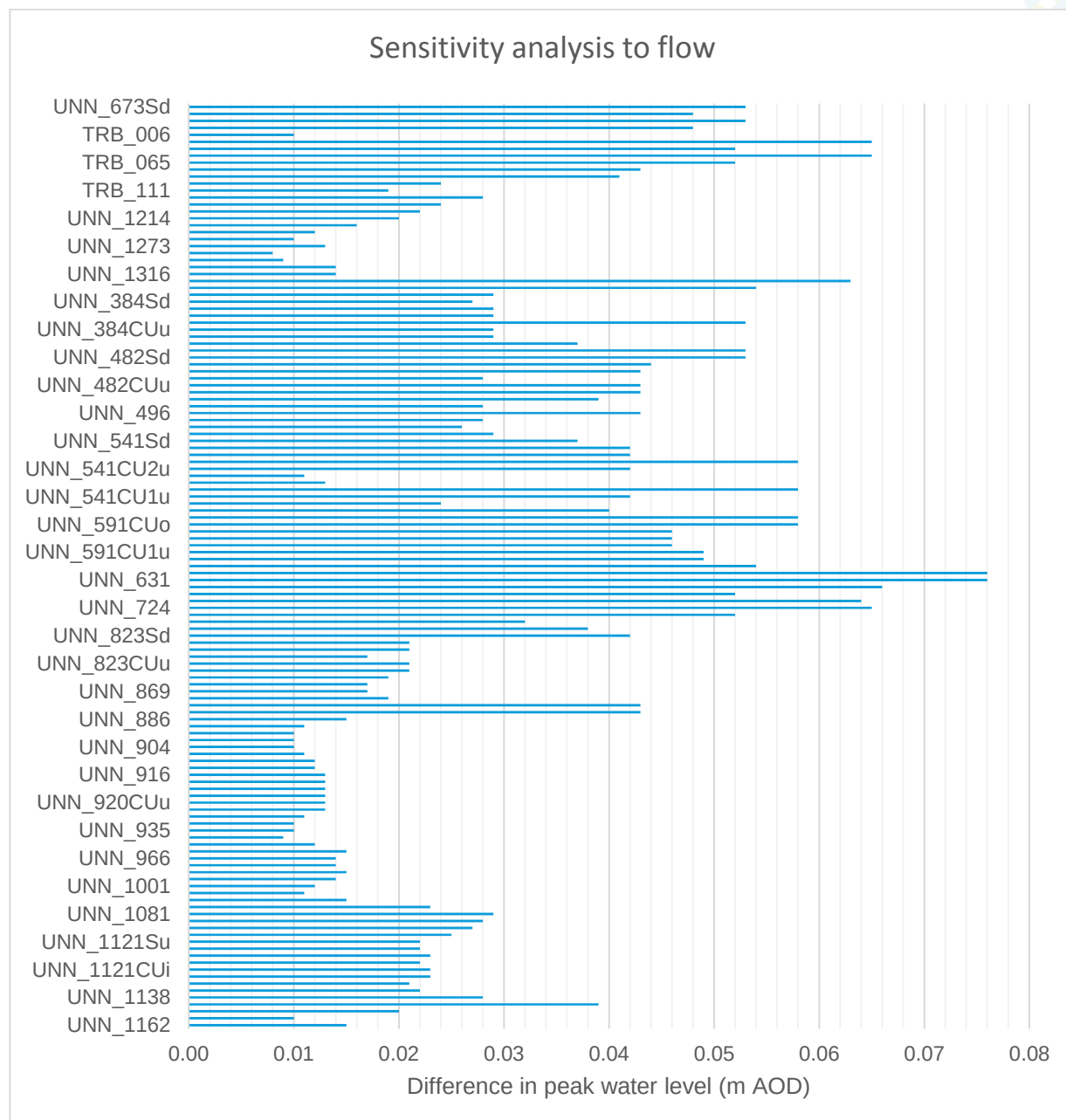


Figure E-1 shows that model results at the site increase by up to 80mm (approximately) when the model inflows are increased by 20%. As a result, the model results at the site are considered to be moderately sensitive to changes in flows.

F.2 Sensitivity to roughness

Figure E-2 shows the changes in peak water level compared to the baseline 100-year event when a change of +20% is applied Manning's 'n' in both the 1D and 2D domains.

Figure E-2: Sensitivity to changes in increase in roughness

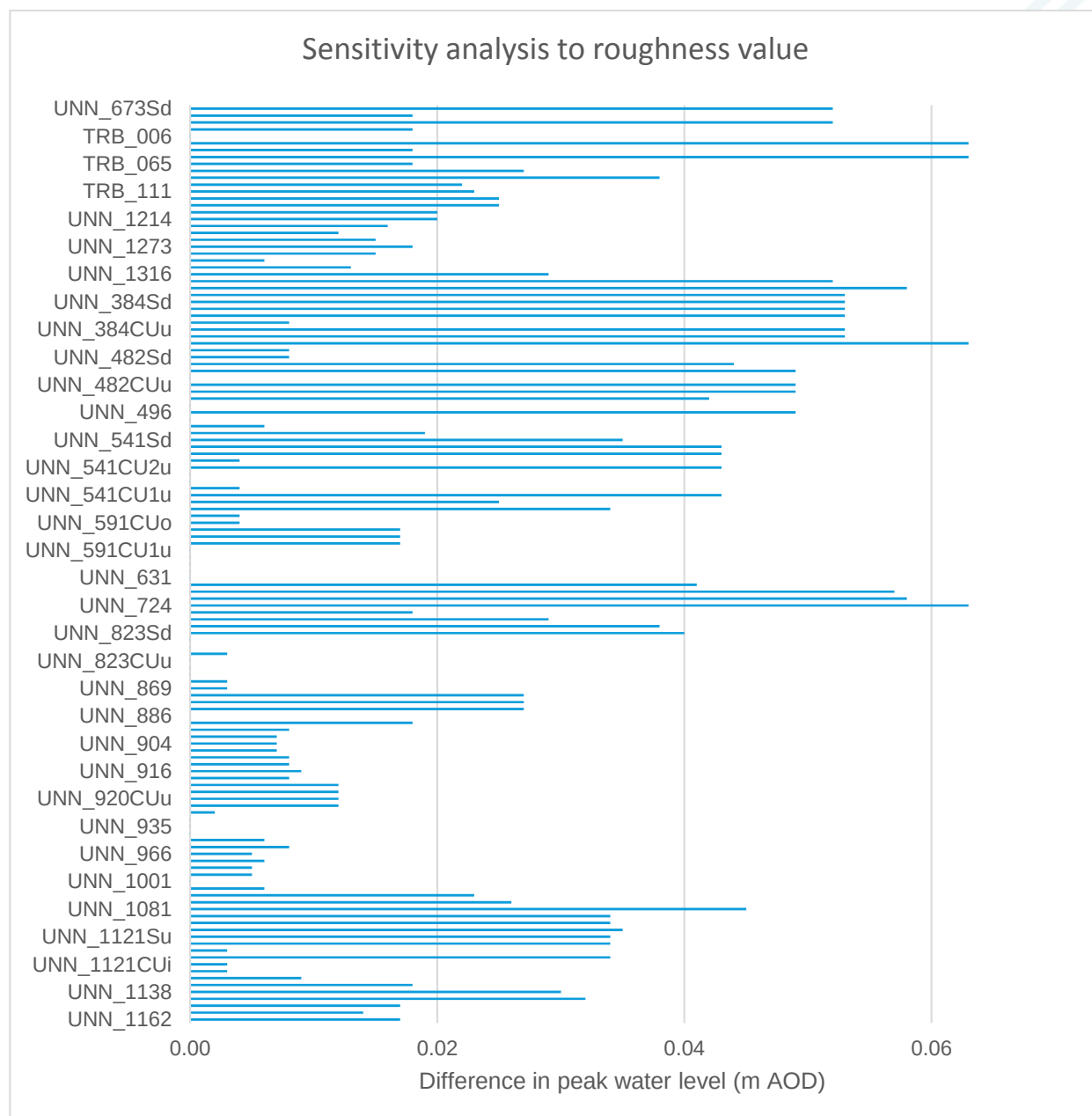


Figure D-2 shows that, when roughness values are increased by 20%, the maximum increase in peak water level at the site is approximately 70mm. As a result, the model results at the site are considered to be moderately sensitive to changes in roughness values.

F.3 Sensitivity to changes in downstream boundary conditions

Figure E-2 shows the changes in peak water level compared to the baseline 100-year event when a change of +250mm is applied to the downstream boundary conditions.

Figure E-3: Sensitivity to changes in downstream boundary conditions

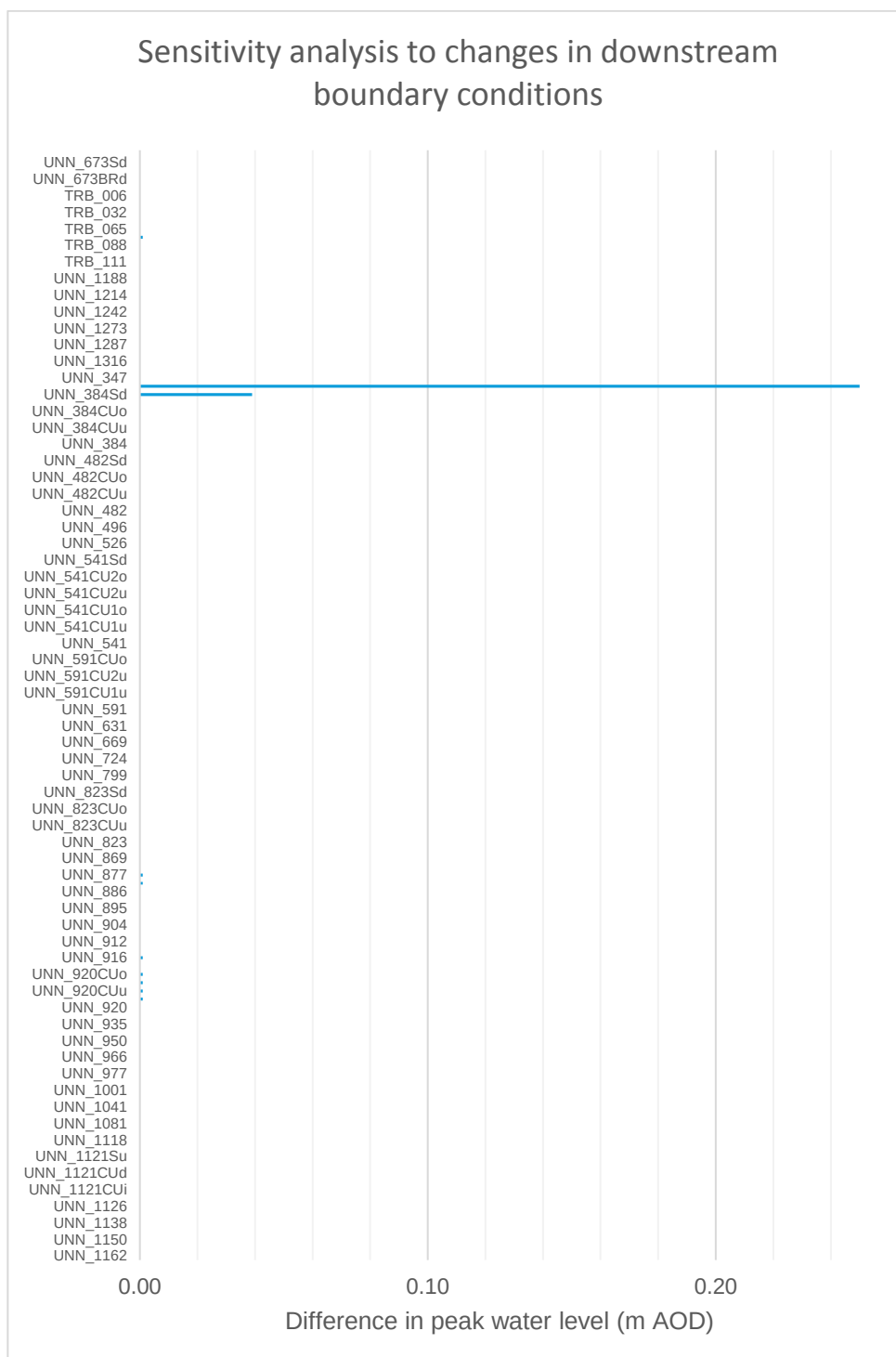


Figure E-3 shows that a 250mm increase in downstream boundary condition generates an increase of approximately 20mm at the downstream end of the site (node: UNN_347). This suggests that the model results at the site are relatively insensitive to changes in downstream boundary conditions.

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Registered Office
1 Broughton Park
Old Lane North
Broughton
SKIPTON
North Yorkshire
BD23 3FD
United Kingdom

+44(0)1756 799919
info@jbaconsulting.com
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