JBA consulting

Flood Estimation Report

Axmi_07, Axminster, East Devon

Final

May 2024

www.jbaconsulting.com

Description

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

Contents

Approval

Revision stage	Analyst	Approved by	Amendments	Date
Method statement	N/A	N/A	N/A	N/A
Calculations - Revision 1	Erica Godsland BSc	Samantha Cogan BSc MSc	N/A	05/04/2024
Calculations - Revision 2				

Revision history

Revision reference	Date issued	Amendments	Issued to
Version 1	May 2024		East Devon District Council

Abbreviations

AEP	annual exceedance probability
AMAX	annual maximum
AREA	catchment area (km^2)
ARF	areal reduction factor
BFI	baseflow index
BFIHOST19	baseflow index derived using the HOST soil classification, revised in 2019
CPRE	Council for the Protection of Rural England
FARL	FEH index of flood attenuation due to reservoirs and lakes
FEH	Flood Estimation Handbook
HOST	Hydrology of Soil Types
NRFA	National River Flow Archive
OS	Ordnance Survey
POT	peaks over a threshold
QMED	median annual flood (with return period 2 years)
ReFH2	Revitalised Flood Hydrograph 2 method
SAAR	standard average annual rainfall (mm)
SFRA	Strategic Flood Risk Assessment
Tp	time to peak of the instantaneous unit hydrograph
URBAN	Flood Studies Report index of fractional urban extent
URBEXT2000	revised index of urban extent
WINFAP	Windows Frequency Analysis Package (software that can be used for FEH Statistical method)

1 Summary of assessment

1.1 Summary

Catchment location:

The main site of interest is the Axminster Carpets factory located off Woodmead Road in Axminster, Devon.

Purpose of study and complexity:

JBA Consulting was commissioned by East Devon District Council to create and run a hydraulic model for a proposed development site in Axminster as part of a Strategic Flood Risk Assessment (SFRA). Within the SFRA Axmi_07 in Axminster was identified as requiring a Level 2 assessment and requires the construction of a fluvial model.

The objective of the study is to accurately assess fluvial flood risk to the site. A new hydrological assessment is required to derive inflow hydrographs for input to the new hydraulic model.

Key catchment features:

The study catchment is predominantly comprised of agricultural land. A number of residential/commercial buildings are located as part of Axminster town towards the west of the catchment at the downstream end of the tributary.

The topography is steep and there are no reservoirs, lakes or unusual features within the catchment.

Flooding mechanisms:

The study site is at risk of fluvial and surface water flooding. The site is shown to be in Flood Zone 2 and 3 for Rivers, affected by the confluence of an unnamed watercourse flowing through the site with the River Axe. This study will focus only on the risk of fluvial flooding from the unnamed watercourse, as the primary flood risk to the site is likely to be driven by peak flows exceeding the capacity of this watercourse.

Gauged / ungauged:

The catchment is ungauged.

Final choice of method:

FEH Statistical.

Key limitations / uncertainties in results:

The catchment is small, and the modelled reach is ungauged (flow) which leads to a high degree of uncertainty in the results.

1.2 Flood frequencies

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

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

2 Method statement

2.1 Requirements for flood estimates

2.1.1 Overview

JBA Consulting were commissioned by East Devon District Council to create and run a hydraulic model for a proposed development site in Axminster as part of an SFRA. Within the SFRA. Axmi_07 in Axminster (SY 29168 97948) was identified as requiring a Level 2 assessment which required the development of a fluvial model in order to accurately assess fluvial flood risk.

Axmi 07 is a brownfield site currently comprising of Axminster Carpets factory and a number of other industrial/commercial businesses off Woodmead Road near the A358. An unnamed watercourse is culverted underneath the site from east to west before flowing into the River Axe. The River Axe flows in a south-westerly direction approximately 80m to the west of the site.

The objective of the study is to accurately assess the fluvial flood risk to the site. A new hydrological assessment is required to derive inflow hydrographs for input to the hydraulic model. This document details the hydrological assessment, which has been undertaken using the latest methods, software, guidance, and data.

Design event peak flow estimates and hydrographs are required for the 3.33%, 1% and 0.1% AEP events. Peak flow estimates were also generated for the 50% AEP event, for information for the FEH Statistical method. The effects of climate change will be accounted for, using the latest guidance[1], by applying both a 46% and 61% uplift to the 3.3%, 1% and 0.1% AEP events peak flow estimates. This represents the central and higher estimates for the 2080s epoch for the East Devon Management Catchment.

2.2 The catchment

Catchment description:

The study catchment (Figure 2-1) is small at 1.38km^2 and is predominantly comprised of agricultural land. A number of residential and commercial buildings are located towards the west of the catchment, at the downstream end of the tributary, and are part of Axminster town.

The topography is steep with a decline from approximately 200mAOD in the southeast to approximately 20mAOD in the west, as shown in Figure 2-2.

1 https://environment.data.gov.uk/hydrology/climate-change-allowances/river-flow

There are no reservoirs, lakes or unusual features within the catchment.

The study watercourse is an unnamed tributary of the River Axe, which flows in a westerly direction before joining the River Axe and flowing southwest.

The Geology of Britain GeoIndex (onshore) Viewer[2] (Figure 2-3) shows the catchment to be predominantly comprised of mudstone, siltstone and sandstone in the lower half of the catchment and mudstone, sandstone and limestone in the upper half. The superficial deposits consist of clay, silt, sand and gravel in the lower half of the catchment.

The soils in the catchment[3] are mixed and comprised of the following:

- Slowly permeable seasonally wet slightly acid but base-rich loamy and clayey soils
- Freely draining slightly acid loamy soils
- Loamy and clayey floodplain soils with naturally high groundwater

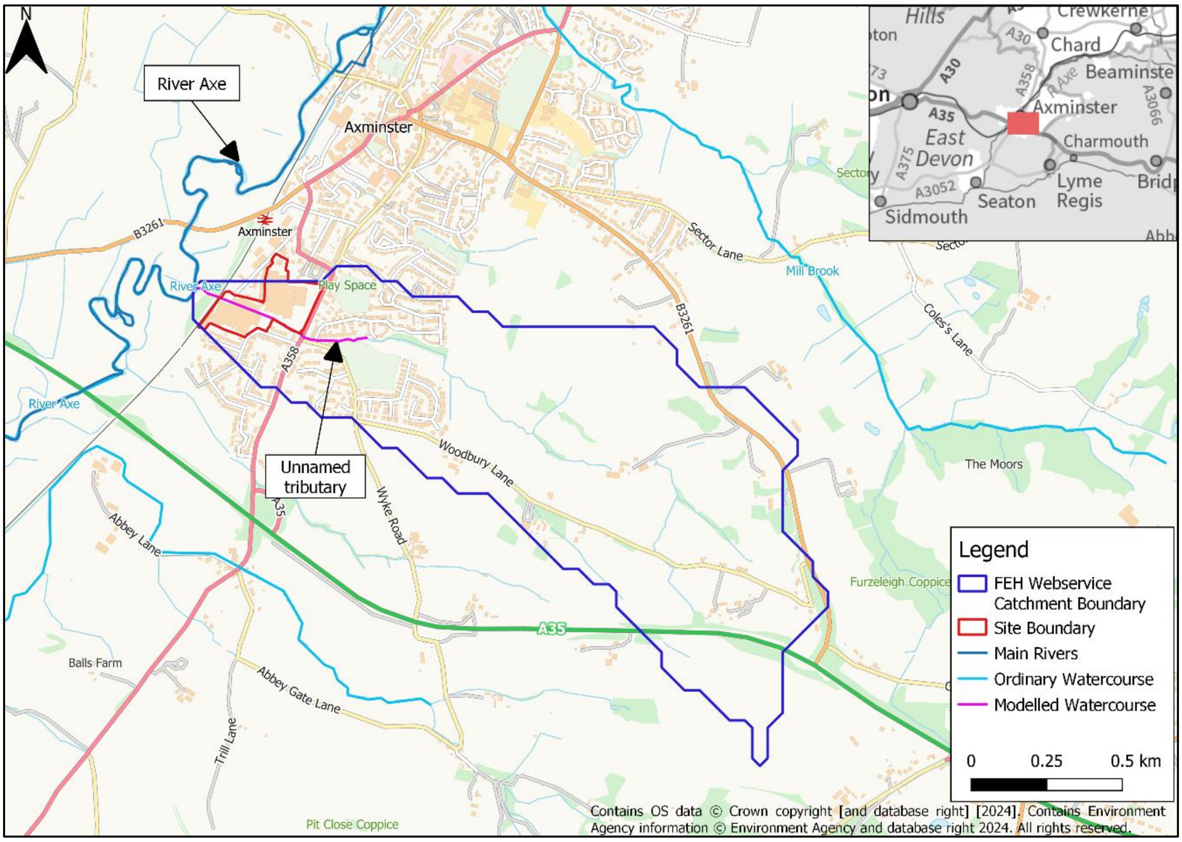

Figure 2-1: Catchment overview

2 https://www.bgs.ac.uk/map-viewers/geoindex-onshore/
3 https://www.landis.org.uk/soilscapes/

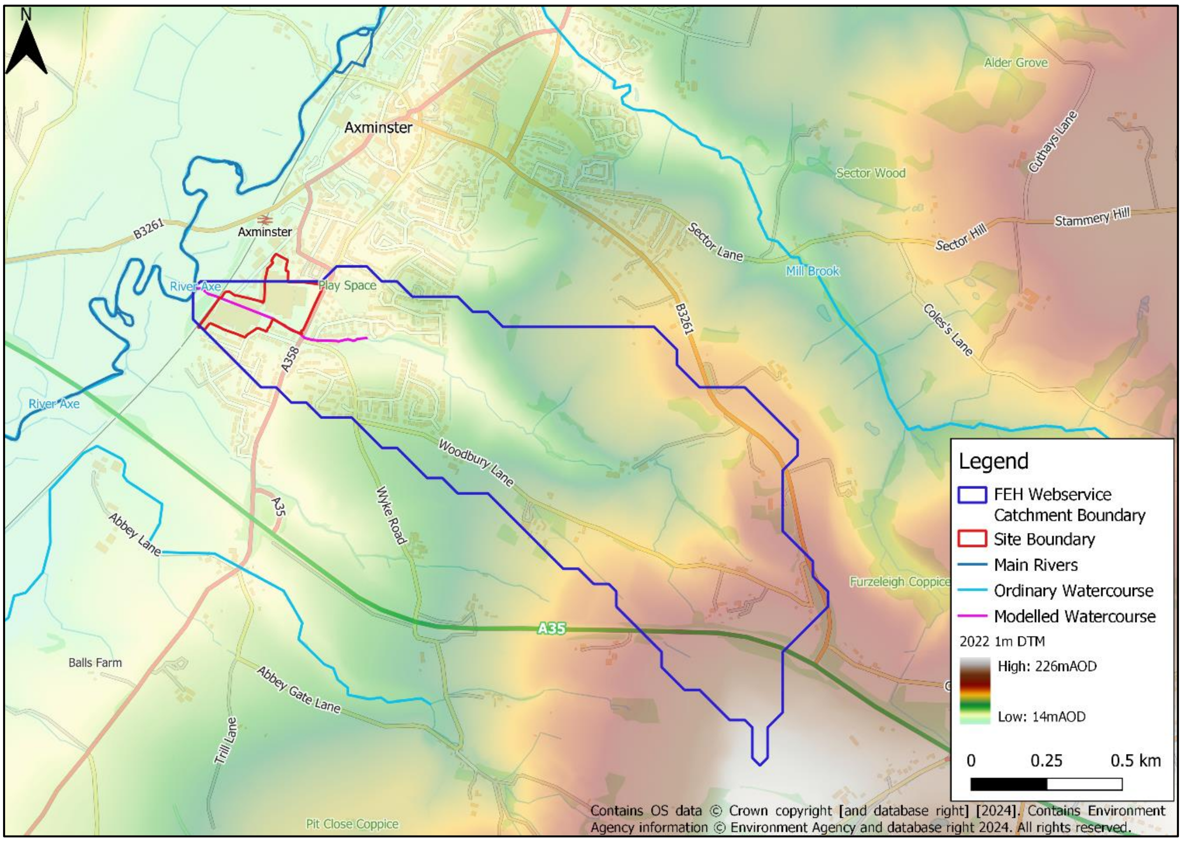

Figure 2-2: Catchment topography

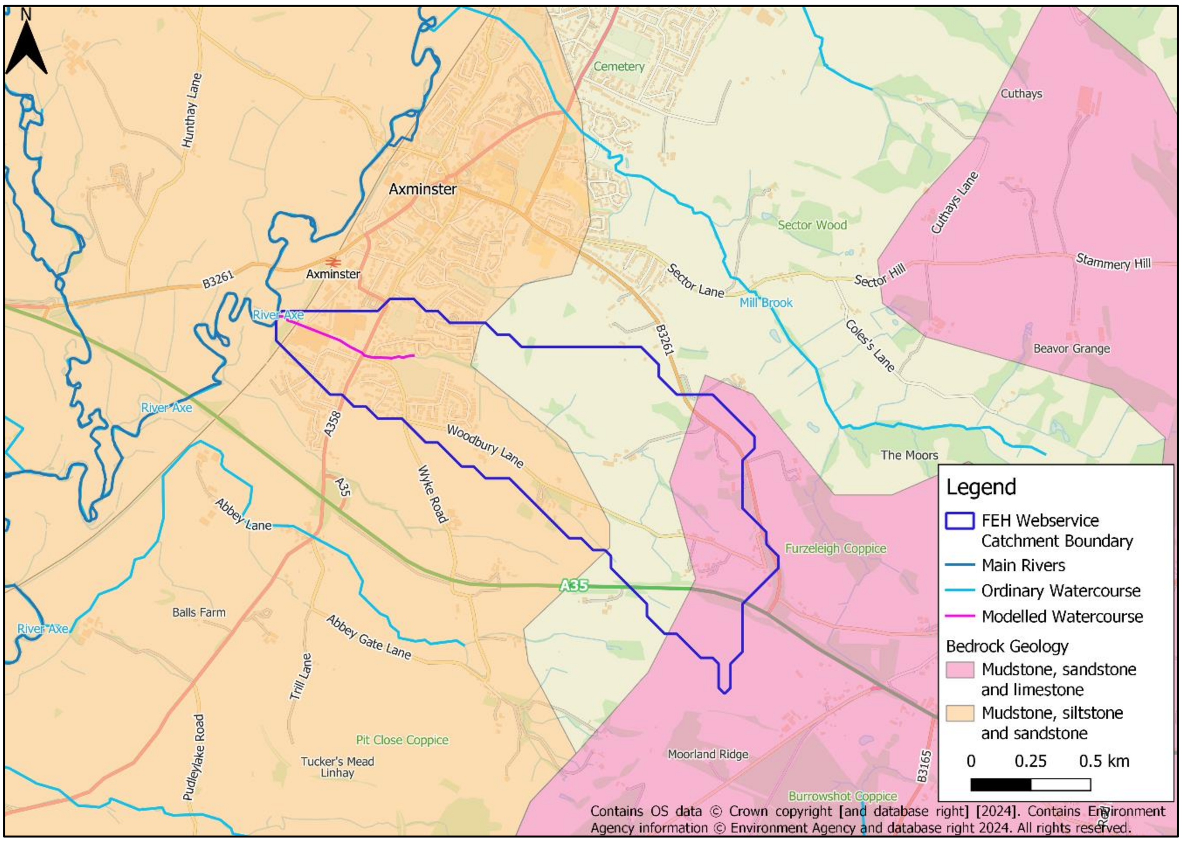

Figure 2-3: Catchment geology

2.3 Data review

The catchment is ungauged. A review of flood history has been carried out and is detailed in Section 2.3.1.

2.3.1 Flood history

Data available

Event date	Flooding source	Details
Dec 2023	Main River	River Axe exceeded capacity along the A358[4] - Shown to impact a small area at the west of the catchment.
Nov 2008	Main River	EA Recorded Flood Outlines - channel capacity exceeded (no raised defences) - Shown to impact a small area at the west of the catchment.
Dec 1992	Main River	EA Recorded Flood Outlines - channel capacity exceeded (no raised defences) - Shown to impact a small area at the west of the catchment.
Jan 1985	Main River	EA Recorded Flood Outlines - channel capacity exceeded (no raised defences) - Shown to impact a small area at the west of the catchment.
Jan 1968	Ordinary Watercourse	EA Recorded Flood Outlines - channel capacity exceeded (no raised defences) - Shown to impact a small area at the west of the catchment.

Uses of the data for this study:

The EA's recorded flood outlines dataset shows flooding within a small area at the west of the catchment at the confluence to the River Axe. Flood history data / information is used to understand the impacts of observed flooding events and may be useful to compare to hydraulic modelling results.

2.3.2 Conclusions of data review:

Data type	Suitability for flood estimation calculations	Suitability for hydraulic modelling	Any further comments
Flood history	N/A	Indicative	N/A

4 https://www.devonlive.com/news/devon-news/river-axe-bursts-banks-floods-8959891

Data type	Suitability for flood estimation calculations	Suitability for hydraulic modelling	Any further comments
		purposes only	

2.4 Hydrological understanding of the catchment

2.4.1 Conceptual model

The main site of interest is the Axminster Carpets factory located off Woodmead Road in Axminster, Devon. The River Axe flows in a south-westerly direction approximately 80m to the west of the site. An unnamed watercourse flows in a westerly direction under Axminster Carpets via a culvert. Flooding at this location is likely to be caused by peak flows exceeding the capacity of the watercourses. Exceedance of culvert capacity and / or blockage of culverts may also result in flooding. There is also potential for backflow from the River Axe up the unnamed watercourse during flooding events, which may contribute to increased flooding at the western edge of the site.

2.4.2 Unusual catchment features

There are no unusual catchment features within the catchment.

2.5 Initial choice of approach

Are FEH methods appropriate?: Yes

Initial choice of method(s) and reasons:

Both the Statistical method and the ReFH2 method will be applied as both are appropriate for the study catchment.

There is no peak flow record available in the study catchment with which to improve the QMED estimate for the Statistical method. Therefore, data from local donors will be assessed and used in this method. The peak flow estimates derived from both methods will be compared and the most appropriate taken forward.

How will hydrograph shapes be derived, if needed?:

Hydrographs will be derived using the ReFH2 model. ReFH2 hydrographs will be scaled to the favoured peak flow estimates explored within this study.

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

The purpose of this study is to create hydraulic model inflows, therefore the catchment will be split into sub-catchments so that design event inflows can be produced for each sub-catchment to allow for varying peak flows. An upstream and downstream

FEP will be used on the unnamed watercourse. However, the downstream FEP will be applied upstream in the hydraulic model, therefore there will be no intervening area.

Software to be used:

- FEH Web Service[5]
- WINFAP 5.1[6]
- ReFH 2.3-FEH22 Calibrated

2.6 Selection of flood estimation locations

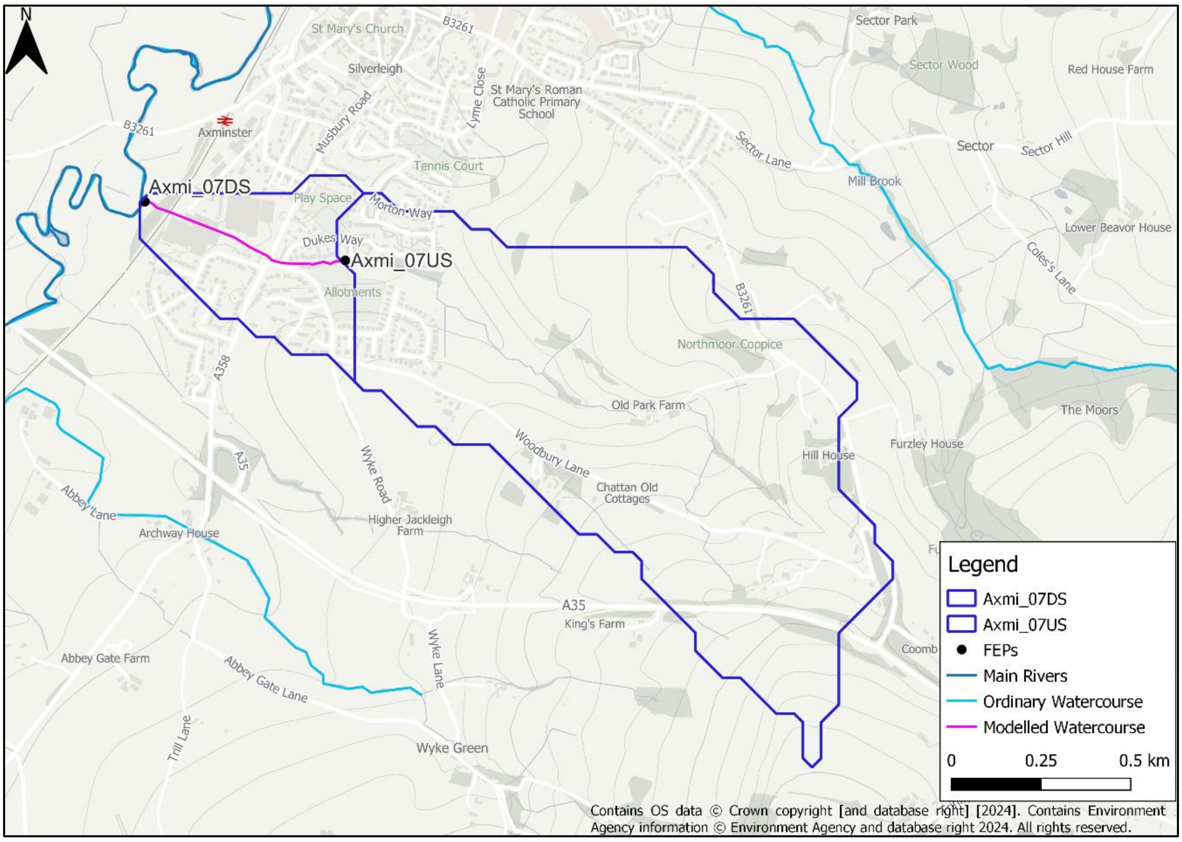

Figure 2-4: Flow estimation points

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

[6] WINFAP 5.1 © Wallingford HydroSolutions Limited 2023.

Site code	Type of estimate:	Watercourse	Site name / description	Easting	Northing
Axmi_07US	L	Unnamed Watercourse	Upstream model extent	329600	97850
Axmi_07DS	L	Unnamed Watercourse	Downstream model extent	329050	98000

L = lumped catchment

3 Locations where flood estimates are required

3.1 Catchment boundary checks and revisions

The FEH Web Service catchment boundary was checked against LiDAR, contour mapping and Ordnance Survey (OS) mapping and has been accepted without change.

3.2 Other catchment descriptor checks and revisions

URBEXT:

The URBEXT2000 value did not include Axminster Carpets and the new housing estate on Dukes Way. The URBEXT2000 value was therefore manually calculated for all buildings, using OS50k mapping and Bayliss et al.'s (2006)[7] mapping relationship between URBAN50k and URBEXT2000, shown below.

Equation: URBEXT2000 = URBAN50k * 0.629

Catchment	Axmi_07DS	Axmi_07US
Area from drawn 50k (m2) (sum)	271,407	158,028
Area of catchment (m2)	1,375,000	1,162,500
URBAN50k from drawn	0.197	0.136
URBEXT2000	**0.124**	**0.086**

BFIHOST:

The FEH BFIHOST19 values for the study catchment appear to be a reasonable representation of local base flow conditions when compared with the geology and soils described in Section 2.2. Therefore, these values have been retained without amendment.

FARL:

The FARL value is 1, which is reasonable considering no reservoirs/lakes are located within the catchment shown on the FEH Web Service.

Version of URBEXT: URBEXT2000

7 Bayliss, A.C; Black, K.B; Fava-Verde, A. & Kjeldsen, T.R. (2006) *URBEXT2000 – A new FEH catchment descriptor. Calculation, dissemination and application.* R&D Technical Report FD1919/TR. London: Defra.

Method for updating URBEXT: URBAN50k

Version of BFIHOST: BFIHOST19

3.3 Derivation of intervening area descriptors

The intervening area descriptors were derived using a back-calculation of the area-weighting method as described in FEH Vol. 5. DPLBAR was derived using the following equation:

(Downstream DPLBAR / Downstream AREA) * IA AREA

3.4 Catchment descriptors

Final catchment descriptors at each subject site:

Manually updated descriptors are shown in red.

Site code	AREA on FEH Web Service (km^2)	Revised AREA (km^2)	BFIHOST19	DPLBAR (km)	DPSBAR (m/km)	FARL	FPEXT	PROPWET	SAAR (mm)	URBEXT 2000
Axmi_07US	1.16	-	0.42	1.16	108.8	1	0	0.4	980	0.09
Axmi_07DS	1.38	-	0.45	1.57	102.0	1	0.01	0.4	974	0.12

4 Stationary statistical methods

4.1 Estimating QMED

4.1.1 QMED at gauged and ungauged subject sites

Site code	Method	Initial QMED (rural) from CDs (m^3/s)	Donors used (NRFA numbers)	Donor distance from subject centroid (km)	Moderation term (α) value	Final donor adjustment factor	Urban adjustment factor	Final QMED (m^3/s)
Axmi_07 US	CD	0.8	45004	7.451	0.411	1.142	1.089	1.0
Axmi_07 DS	CD	0.9	45004	7.426	0.412	1.143	1.136	1.1

QMED estimation methods: **CD** - Catchment descriptors alone

Donor distance weighting method:

Moderation term has been applied.

Parameters used for WINFAP v4 urban adjustment:

Urban adjustment of QMED method (subject site and donors): WINFAP v4[8]

[8] Wallingford HydroSolutions (2016). WINFAP 4 Urban adjustment procedures.

Impervious fraction for built-up areas (IF): 0.3

Percentage runoff for impervious surfaces (PR_{imp}): 0.7

Method for calculating fractional urban cover (URBAN): From updated URBEXT2000

4.1.2 Search for donor sites

Discussion of selected donor sites / rejected donor sites:

A check was made to identify suitable donor sites. Only rural donors have been considered as there is little urbanisation within the study catchment. There are ten potential rural donors within 26km of the catchment centroid.

45004 is the geographically closest donor (located along the River Axe), with observed QMED 108.48 and QMED CD Urban 78.4.

The eight nearest donor stations (up to 21.81km) all show that the catchment descriptor equation underestimates QMED compared to observed QMED, highlighting a regional trend.

Choosing the geographically nearest donor is in line with the recommendations of the draft report for Phase 2 of SC090031 (small catchment hydrology). Therefore 45004 has been used as the donor station to adjust QMED at all flow estimation points. It should be noted that 45004 is also seen to fit the study catchment hydroclimatologically with similar BFIHOST19, SAAR and SPRHOST values.

Donor sites chosen and QMED adjustment factors:

NRFA no.	Method	Adjustment for climatic variation?	QMED from flow data (m^3/s)	Urban adjustment factor	De-urbanised QMED from flow data (m^3/s) (A)	QMED from catchment descriptors (m^3/s) (B)	Adjustment ratio (A/B)
45004	AM	No	108.48	1.013	106.7	77.51	1.382

Methods: **AM** – Annual maxima

4.2 Estimating growth curves

4.2.1 Derivation of pooling groups

Name of group	Small catchment pooling procedure applied?	Site code from whose descriptors group was derived	Subject site treated as gauged? (ESS)	URBEXT2000 threshold applied to pooling group selection	L-moments deurbanised (including subject site for ESS)?
Axmi_07DS	Yes	Axmi_07DS	No	<0.03	L-CV: 0.247 L-Skew: 0.242

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

4.2.2 Pooling group composition

Name of group	Changes made to default pooling group	Weighted average L-moments
Axmi_07DS	None	L-CV: 0.247 L-Skew: 0.242

4.2.3 Derivation of growth curves at subject sites

Site code	Method	If P or ESS, name of pooling group	Distribution used and reason for choice	Any urban or non-flood years adjustments	Parameters of distribution (location, scale and shape after adjustments)	Growth factor for 1% AEP
Axmi_07US	P	Axmi_07DS	KAP3 - Generalised Logistic (GL), Generalised Extreme Value (GEV) and Kappa 3 (KAP3) distributions all gave an acceptable fit to the data. The z-value for KAP3 was closest to zero, indicating the best fit. KAP3 was therefore selected.	Urban adjustment has been applied. The growth curve has not been adjusted for non-flood years as the Environment Agency Flood Estimation Guidelines[9] states that non-flood years adjustment only applies to a GL distribution.	Location: 1.00 Scale: 0.275 Shape: -0.201	3.02
Axmi_07DS					Location: 1.00 Scale: 0.267 Shape: -0.209	3.00

Methods: **P** - Pooled.

9 Environment Agency. December 2022. Instruction: LIT 11832. Flood Estimation Guidelines.

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

4.3 Final choice of QMED and growth curves

Site code	Final choice of QMED and reasons	Final choice of flood growth curve method and reasons
Axmi_07US	QMED derived from donor transfer at 45004	Growth curves pooled using KAP3 distribution.
Axmi_07DS		

4.4 Final flood estimates from stationary statistical methods

Site code	50%	3.3%	1%	0.1%
Axmi_07US	1.02	2.30	3.07	5.14
Axmi_07DS	1.12	2.52	3.36	5.68

Flood peak in m^3/s for the AEP (%) events

5 Revitalised Flood Hydrograph 2 (ReFH2) method

5.1 Model parameters

5.1.1 Summary of rural model parameters:

Site code	Method	Tp (hours) rural	Cmax (mm)	BL (hours)
Axmi_07US	CD	1.34	318.16	28.67
Axmi_07DS	CD	1.62	343.05	31.9

Methods: **CD**: Catchment descriptors

5.1.2 Summary of urban model parameters:

Site code	Area modelled as urban (km^2)	TP urban scaling factor	IF	IRF	DS
Axmi_07US	0.16	0.75	0.4	0.7	0.5
Axmi_07DS	0.27	0.75	0.4	0.7	0.5

5.2 Model inputs for design events

Design events for lumped catchments:

Site code	Urban or rural	Season of design event	Storm duration (hrs)	Initial soil moisture, Cini	Initial baseflow, BF0
Axmi_07US	Rural	Winter	2.75	109.33	0.05
Axmi_07DS	Rural	Winter	3.25	104.08	0.06

Is the catchment groundwater-dominated?:

No

Which rainfall DDF model has been used?:

FEH22

5.3 Final choice of ReFH2 flow estimates

Method choice and reasons:

Site code	Final choice of design inputs and model parameters
Axmi_07US Axmi_07DS	Rural design inputs used for all sub-catchments. Winter season design events used. Catchment descriptors (CDs) used for model parameters. No changes to initial conditions (Cini and BF0).

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

Final rural flood estimates from ReFH2 method:

Site code	50%	3.3%	1%	0.1%
Axmi_07US	0.80	1.80	2.25	3.53
Axmi_07DS	0.79	1.73	2.16	3.46

Flood peak in $m^{3/}$s for AEP (%) events

Values in red highlight that the upstream flood estimates are higher than the downstream.

6 Discussion and summary of results

6.1 Comparison of results from different methods

Site code	ReFH2 Method (X) peak flow (m3/s), 50% AEP	FEH Statistical method (Y) peak flow (m3/s), 50% AEP	ReFH2 Method (X) peak flow (m3/s), 1% AEP	FEH Statistical method (Y) peak flow (m3/s), 1% AEP
Axmi_07US	0.80	1.02	2.25	3.07
Axmi_07DS	0.79	1.12	2.16	3.36

Site code	Ratio (X / Y), 50% AEP	Ratio (X / Y), 1% AEP
Axmi_07US	0.79	0.73
Axmi_07DS	0.70	0.64

6.2 Final choice of method

Choice of method and reasons:

Comparison of the results from the two methods show that the FEH Statistical method produces larger flows for both the 50% AEP and 1% AEP events, with the difference increasing for the 1% AEP event. The variance between the model approaches is likely due to the model limitations of both methodologies for small catchments. The study catchment considered within this study is small, ungauged and as such, all estimated design flows carry appreciable uncertainty.

The ReFH2 method is based on catchment descriptors alone, whilst the FEH Statistical Method uses a donor and pooling group. The Statistical method is often preferred to design event approaches as it is based on a much larger dataset of flood events and has been more directly calibrated to reproduce flood frequency on UK catchments.

Both the unscaled ReFH2 results and the raw FEH Statistical results have been ran through the model, highlighting that the ReFH2 results were underestimating the flows on site, whilst the FEH Statistical method produced flows similar of that to the FMfP. As a result, the FEH Statistical method is preferred for generating the design peak flow estimates for the study catchment at this stage, as the results are considered to be conservative.

How will the 0.1% AEP flows be estimated?

The FEG advises that the FEH Statistical method 1% AEP event peak flow estimates should have the ReFH2 0.1%/1% ratio applied for the 0.1% AEP event. ReFH2 hydrographs will therefore be scaled to fit the Statistical method peaks and applied as a point inflow to the hydraulic model.

6.3 Application of inflows to a hydraulic model

How will the flows be applied to a hydraulic model?

Due to the small catchment size the downstream FEP will have the Statistical method peaks with the ReFH2 ratio applied to the 0.1% AEP event, applied upstream within the hydraulic model.

Design events for hydraulic model testing:

Season of design event	Storm duration (hrs)	ARF	Details of reasons for selection
Winter	3.25	0.97	It is not within the scope of the study to undertake storm duration testing. The storm duration has therefore been chosen based on the downstream catchment ReFH2 design storm duration.

6.4 Checks

Growth factor checks:

Site code	1% AEP growth factor	0.1% AEP / 1% AEP ratio	Comments
Axmi_07US	3.02	1.68	The FEH Statistical growth factors are all within the typical range of 2.1 – 4.0 (based on FSR regional growth curves).
Axmi_07DS	3.00	1.69	

Spatial consistency of results:

Peak flow estimates derived for all design events increase downstream, this is as expected.

The ReFH2 method generates smaller flows at Axmi_07DS (the downstream location) than at Axmi_07US. It is not clear why this is the case. The most likely cause is the change in catchment descriptors and sizes (although this change is small (~15%) and reasonable). The Tp(0) value, which controls the shape of the hydrograph and the peak flow, is proportionally slightly higher than the change in area (~17%). This could be a potential reason for the discrepancy in upstream and downstream flows.

Frequency of notable historical floods:

There is no suitable gauge data to compare the results of the flood frequency estimation against.

Compatibility with longer-term flood history:

There is no local flow data against which to compare the design flow estimates and limited flood history information.

Comparisons with previous studies:

There are no available previous studies to compare results to.

Checks on hydraulic model results:

Modelled levels and flood extents will be sense-checked to ensure that flow inputs result in realistic outputs.

6.5 Assumptions, limitations, and uncertainty

Assumptions:

- 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.
- Application of the Small Catchment Procedure is both suitable and representative of the subject catchment.
- Using the KAP3 distribution for the pooling groups is preferable as the z-values are closest to zero (hence indicating best fit).
- Selecting the geographically closest donor to adjust the FEH Statistical method QMED estimate is appropriate (follows guidance).
- FEH Statistical is the preferred approach and was shown to be conservative when applied to the hydraulic model. The FEH Statistical results have had the ReFH2 ratio applied to the 0.1% event.
- Peak flows, rather than hydrograph volumes, are assumed to be the main control on flood risk at the site.

Limitations:

- The main limitation is that the catchment is ungauged due to there being no river flow gauge data specific to the study area.
- There is no flood history information for the site against which to verify hydraulic model results based on the derived model inflows.
- As the catchments are 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.

Uncertainty:

- It is not possible to directly quantify the uncertainty for the ReFH2 method. The Environment Agency Flood Estimation Guidelines present confidence limits for Statistical method design flows at ungauged sites. There are confidence limits for rural catchments (URBEXT2000 < 0.03) and moderately urbanised catchments (0.03 ≤ URBEXT2000 < 0.15). The 95% confidence limits for a 1% AEP event flood estimate for a rural catchment, such as the study catchment, using one donor are 0.47-2.12 times the best estimate.

6.6 Final results

Final method applied: FEH Statistical peak flow estimates with the ReFH2 0.1%/1% ratio applied for the 0.1% AEP event. Also shown below in Figure 6-1.

Site code	50%	3.3%	1%	0.1%
Axmi_07US	1.02	2.30	3.07	4.81
Axmi_07DS	1.12	2.52	3.36	5.37

Flood peak in m^3/s for the AEP (%) events

Uncertainty:

Site code	50% AEP Lower 95%	50% AEP Upper 95%	1% AEP Lower 95%	1% AEP Upper 95%
Axmi_07US	0.51	2.05	1.44	6.50
Axmi_07DS	0.56	2.26	1.58	7.12

Upper and lower 95% confidence bounds for the flood peak in m^3/s for the AEP (%) events.

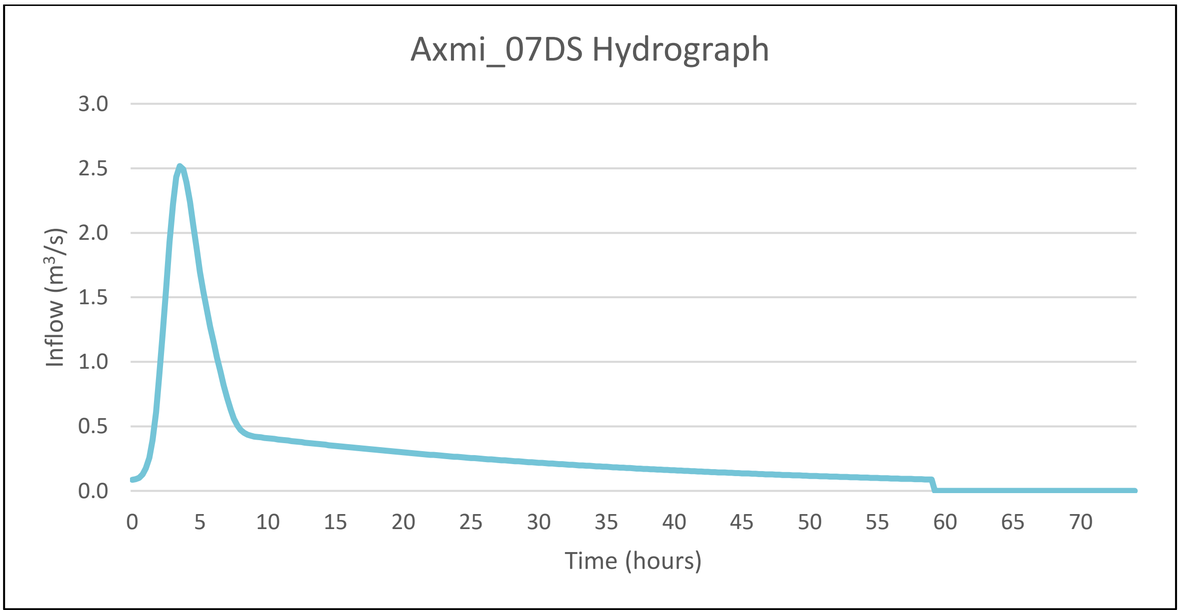

Figure 6-1: Hydrograph

Climate change estimates:

The climate change estimates will be applied to the 3.33%, 1% and 0.1% AEP events as part of the hydraulic modelling process.

Suitability of results for future studies:

The design peak flow estimates were derived for the purposes of this study. If peak flow estimates and hydrographs are required for a different purpose, it is recommended that, at a minimum, a review of the results is carried out.

7 Appendix

7.1 Other supporting information

7.1.1 Pooling groups

Axmi_07DS - Small catchment - URBEXT2000 threshold <0.03								
Station	**Distance (SDM)**	**Years of data**	**QMED AM**	**L-CV Deurbanised**	**L-SKEW Deurbanised**	**Non-flood years**	**Percentage Non-flood years**	**Discordancy**
76011 (Coal Burn @ Coalburn)	0.364	45	1.8	0.171	0.292	0	0.00	0.861
45816 (Haddeo @ Upton)	1.410	29	3.2	0.290	0.431	0	0.00	0.906
27051 (Crimple @ Burn Bridge)	1.459	50	4.6	0.218	0.133	4	8.00	0.378
27073 (Brompton Beck @ Snainton Ings)	1.643	42	0.8	0.213	0.018	2	4.76	1.263
28033 (Dove @ Hollinsclough)	1.666	47	4.2	0.231	0.381	1	2.13	0.790
25019 (Leven @ Easby)	1.950	44	5.4	0.341	0.366	3	6.82	0.971
49005 (Bolingey Stream @ Bolingey Cocks Bridge)	1.956	12	4.9	0.267	0.267	0	0.00	2.570
26016 (Gypsey Race @ Kirby Grindalythe)	2.065	25	0.1	0.309	0.249	3	12.00	0.504
27010 (Hodge Beck @ Bransdale Weir)	2.070	41	9.4	0.224	0.293	1	2.44	0.232
47022 (Tory Brook @ Newnham Park)	2.084	27	6.2	0.248	0.149	1	3.70	0.436
25011 (Langdon Beck @ Langdon)	2.115	36	15.9	0.223	0.320	0	0.00	0.638
44008 (South Winterbourne @ Winterbourne Steepleton)	2.128	31	0.5	0.414	0.267	8	25.81	2.358
206006 (Annalong @ Recorder)	2.455	48	15.3	0.189	0.052	4	8.33	1.767
27032 (Hebden Beck @ Hebden)	2.465	54	4.1	0.198	0.197	2	3.70	0.327
Total		531						
Weighted means				0.247	0.242			
Heterogeneity	Heterogeneous; review desirable							
Goodness-of-fit	GL, GEV & KAP3 give an acceptable fit; KAP3 z-value closest to zero							
One station (44008) with >15% of AMAX record as non-flood years								
No stations with <8yr data; no discordant stations.								

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