

Flood Estimation Report

Template: LIT 65087

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Approval

Revision stage	Analyst:	Approved by:	Amendments	Date
Method statement	Sara Liguori			19/03/25
Calculations - Revision 1				
Calculations - Revision 2				

Abbreviations

Abbreviation	Short for
AEP	annual exceedance probability
AMAX	Annual Maximum
AREA	Catchment area (km ²)
BFI	Base Flow Index
BFIHOST19	Base Flow Index derived using the HOST soil classification, revised in 2019
FARL	FEH index of flood attenuation due to reservoirs and lakes
FEH	Flood Estimation Handbook
GEV	Generalised Extreme Value
GLO	Generalised Logistic
HOST	Hydrology of Soil Types
IF	Impervious Fraction
IRF	Impervious Runoff Factor
LF	Low flow statistics (flow duration curve)
NRFA	National River Flow Archive
POT	Peaks Over a Threshold
QMED	Median Annual Flood (with return period 2 years)
ReFH	Revitalised Flood Hydrograph method
ReFH2	Revitalised Flood Hydrograph 2 method
SAAR	Standard Average Annual Rainfall (mm)
Tp	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	Windows Frequency Analysis Package (software that can be used for FEH statistical method)

1. Summary of assessment

1.1 Summary

Catchment location:

River Avon north of Trowbridge

Purpose of study and complexity:

To derive hydrological boundaries for use in a 1D/2D model of the River Avon at Staverton, just north of Trowbridge. The study can be classified as routine.

Key catchment features:

The catchment is large, essentially rural. Permeability and attenuation from surface water features are not defining characteristics of the catchment.

Flooding mechanisms:

Fluvial

Gauged / ungauged:

The River Avon is gauged at several locations in the upper catchment but not near the site of interest. There is a level gauge at the site and a flow gauge at Bradford on Avon, d/s of the model extent.

Final choice of method:

Peak flow estimates are from:

- FEH Statistical method for %AEPs larger than and equal to 1;
- ReFH2 ratio ($\text{ReFH2 } Q_{\text{peak}} / 1\% \text{AEP ReFH2 } Q_{\text{peak}} * 1\% \text{AEP FEH Statistical } Q_{\text{peak}}$) for %AEPs smaller than 1.

ReFH2 hydrograph shape applied to peaks to derive design hydrographs.

Key limitations / uncertainties in results:

Design hydrographs are informed by catchment descriptors, generalised models and national peak flow dataset. Local level data have not been incorporated in the analysis as a rating relationship is currently not available to convert levels to flows.

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 contain both return period and AEP titles; both rows can be retained, or the relevant row can be retained and the other removed, depending on the requirement of the study.
- 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

Overview and Project Scope:

This document outlines the hydrological assessment undertaken to support the hydraulic modelling of the River Avon at Staverton, north of Trowbridge. The modelling is undertaken to investigate the flood risk associated to the existing CPUK (Cereal Partners UK) factory at NGR 385809, 160941. Design hydrographs are required for the following %AEPs: 5, 1, and 0.1. Additional %AEPs considered in the assessment are not intended for the purposes of the modelling but have been included for completeness of analysis. It should also be noted that the impact of climate change on flood flow estimates will be assessed by applying the appropriate % allowances to the 1%AEP estimate.

2.2 The Catchment

Maps:

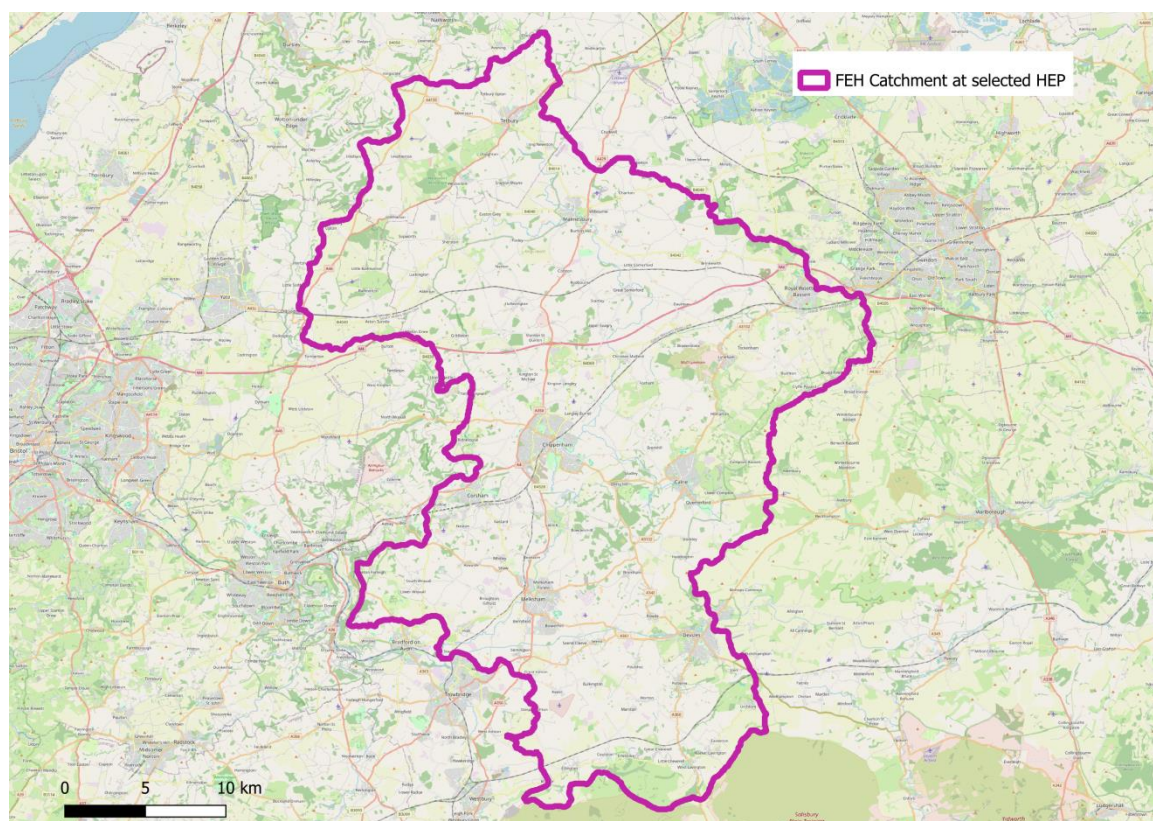


Figure 1 FEH catchment at the selected Hydrological Estimation Point (HEP) at the d/s extent of the model

Catchment Description:

The site of interest is located at NGR 385809, 160941. The River Avon approaches the site from the east and the catchment is approximately 893km² at the d/s extent of the model just d/s of the site of interest.

2.3 Hydrometric Data

Source of flood peak data:

NRFA v13.0.3, released on 29th August 2024. It contains data up to September 2023.

Gauging stations (flow and level):

Watercourse	Station name	Gauging authority number	NRFA number	Catchment area (km ²)	Type (rated / ultrasonic / level...)	Start of record and end if station closed
River Avon	Staverton	530177	NA	891.91	Level	November 2013 - present
River Avon	Bradford on Avon	530176	NA	1011.48	Flow	May 2005 - present

Data available at each flow gauging station:

Station name	Data source	Data type	Start and end of flood peak record	Update for this study?	OK for QMED?	OK for pooling?	Data quality check needed?	Station and flow data quality summary
Staverton	WISKI	15min level	NA	No	No	No	Outside scope	Level station at the site of interest. Data available from the hydrology data explorer for the

Station name	Data source	Data type	Start and end of flood peak record	Update for this study?	OK for QMED?	OK for pooling?	Data quality check needed?	Station and flow data quality summary
								period 2013-2025 to be used in the hydraulic model validation
Bradford on Avon	WISKI	15 min flow	NA	No	No	No	Outside scope	Flow station. Data available from the hydrology data explorer to be used as a check for the analysis results.

Updates or revisions to flood peak data:

Outside scope

Data quality checks carried out:

Data quality checks not carried out

Rating Equations:

Station name	Type of rating e.g., theoretical, empirical; degree of extrapolation	Rating review needed?	Comments and link to any rating reviews
NA			

Rating reviews:

Outside scope

Other data available and how it has been obtained:

Type of data	Data relevant to this study?	Data available?	Source data	of Details
Check flow gaugings	Yes	No	NA	NA
Historical flood data	Yes	Yes	EA	Details of flood events considered for the hydraulic model validation are provided in the model report.
Flow or river level data for events	Yes	Yes	Hydrology Data Explorer	Level records at Staverton
Rainfall data for events	Yes	No	NA	NA
Potential evaporation data	Yes	No	NA	NA
Results from previous studies	Yes	No	NA	NA
Other data or information	No	No	No	No

Conclusions of hydrometric data review:

Station name	Rating suitability	Suitability for flood estimation calculations	Non-stationary analysis requirements
NA			

2.4 Hydrological understanding of the catchment

Plots of flood peak data and interpretation:

NA

Plots of flow data and interpretation:

NA

Plots of stage data and interpretation:

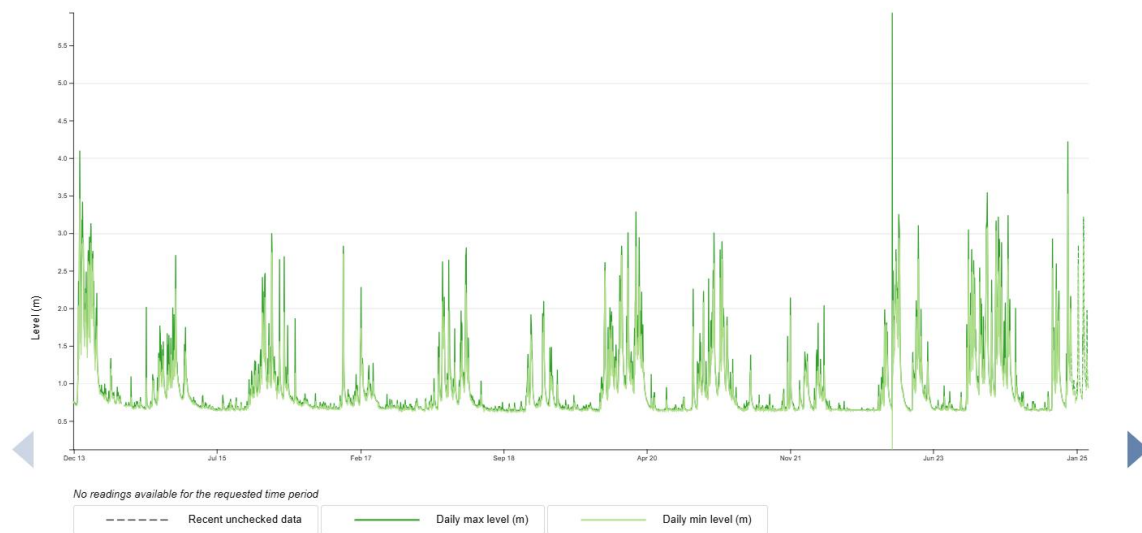


Figure 2 Daily level record at Staverton gauge.

A record of 15min level data is available at Staverton gauge (**Figure 2**). The largest event has been measured at the gauge in December 2022. A rating is not available at the gauge and the development of a rating relationship is outside the scope of this study.

Conceptual model:

The site of interest is the existing CPUK (Cereal Partners UK) factory at NGR 385809, 160941. The main source of flood risk at the site is fluvial from peak flows on the River Avon.

Unusual catchment features:

The River Avon catchment at the site of interest is large and essentially rural. The catchment is not significantly affected by unusual features such as high permeability and attenuation from lakes/reservoirs.

2.5 Initial choice of approach

Are FEH methods appropriate?

FEH methods are appropriate according to current guidance¹.

¹ <https://www.gov.uk/government/publications/river-modelling-technical-standards-and-assessment/estimate-flood-flow-from-rainfall-and-river-flow-data-source>. Environment Agency Guidance - Estimate flood flow from rainfall and river flow data (updated December 2023)

Initial choice of method(s) and reasons:

Both the Statistical and the ReFH2 rainfall-runoff approach will be implemented to derive and compare QMED and growth factors at one estimation point selected at the d/s extent of the hydraulic model (AV01). This is deemed appropriate to the extents of the area of study and to the location of the site of interest for this assessment.

How will hydrograph shapes be derived if needed?

Hydrograph shapes will be derived from ReFH2.

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

Lumped estimates will be derived at the Hydrological Estimation Point (HEP) identified on the River Avon at the d/s extent of the hydraulic model, just d/s of the site of interest, in order to obtain design hydrographs for input as u/s boundaries to the hydraulic model.

Software to be used:

UKCEH FEH web service²

WINFAP5.2³

ReFH2⁴

² <https://fehweb.ceh.ac.uk/> ©UK Centre for Ecology & Hydrology 2025 • Developed by [Wallingford HydroSolutions](#)

³ WINFAP version 5.2 © Wallingford HydroSolutions 2025

⁴ ReFH2 version 4 © Wallingford HydroSolutions 2022

3. Locations where flood estimates are required

3.1 Summary of subject sites

Site code	Type of estimate: lumped (L) or sub-catchment (S)	Water-course	Site name / description	Easting	Northing	AREA on FEH Web Service (km ²)	Revised AREA (if altered) (km ²)
AV01	L	River Avon	d/s extent of hydraulic model	385050	160050	893.185	

3.2 Catchment Descriptors

Final catchment descriptors at each subject site:

Site code	FARL	PROPWET	BFIHOST19	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	URBEXT 1990	URBEXT 2025	FPEXT
AV01	0.99	0.34	0.575	40.82	35.8	755	0.0203	0.026	0.1225

Catchment boundary checks and revisions:

FEH catchment boundaries have been checked against DTM data and found to be appropriate.

URBEXT source and method for updating:

URBEXT2000 has been updated to 2025 using the national average UEF (Urban Expansion Factor)^{Error! Bookmark not defined.}.

BFIHOST source, checks and updates:

BFIHOST values are consistent with information extracted from soils and geology maps. The area of interest mostly includes slowly permeable seasonally wet

loamy and clayey soils and freely draining lime-rich loamy soils lying on a sedimentary bedrock formation (Kellaways and Oxford Clay).

Checks and revisions to other catchment descriptors:

FARL has been checked against OS mapping and found to be appropriate. The remaining catchment descriptors were not subject to any revision.

4. Stationary statistical methods

4.1 Method overview

What is the purpose of applying these methods?

To estimate peak flows at the designated HEP.

What methods will be used to estimate QMED and growth curves?

Site code	Methods used for QMED	Methods used for growth curves
AV01	Estimate from catchment descriptors and adjusted by donor transfer and for urbanisation	Standard pooled analysis

4.2 Estimating QMED

QMED at gauged subject sites:

Site code	Method (AM/ POT/LF)	Initial QMED (m ³ /s)	Number of water years of data used	Adjustment for climatic variation?	Final QMED (m ³ /s)
NA	NA	NA	NA	NA	NA

Methods: AM – Annual maxima; POT – Peaks over threshold; LF – Low flow (flow duration curve) statistics.

QMED at ungauged subject sites:

Site code	Method (CD/DT/BCW)	Initial QMED (rural) from CDs (m ³ /s)	Donors used (NRFA numbers)	Donor distances from subject centroid (km)	Individual donor weights	Combined and weighted donor adjustment factor	Urban adjustment factor	Final QMED (m ³ /s)
AV01	DT	78.680	53013	8.40	0.398	1.146	1.036	93.360
			53018	11.38	0.369			
			53028	12.48	0.360			
			53008	12.86	0.357			
			53023	15.45	0.338			
			53002	17.63	0.323			

Methods: CD - Catchment descriptors alone; DT - catchment descriptors with donor transfer; BCW - catchment descriptors with bankfull channel width.

Urban adjustment of QMED:

Urban adjustment carried out according to WINFAP5. URBAN calculated on URBEXT2025 (i.e. URBEXT2000 updated to 2025).

Search for donor sites:

The subject catchment is ungauged at the site of interest. The search of donor sites was restricted to gauges located within 20km from the subject site. All the identified gauges have been deemed suitable for the purpose of adjusting QMED by donor transfer at the subject site, according to information available on the NRFA. The individual donor adjustment ratios are consistently greater than 1 for the selected donors.

Donor sites chosen and QMED adjustment factors:

NRFA no.	Method (AM/POT/LF)	Adjustment for climatic variation?	QMED from flow data (m ³ /s)	De-urbanised QMED from flow data (m ³ /s) (A)	QMED from catchment descriptors (m ³ /s) (B)	Adjustment ratio (A/B)
53013	AM	No	13.580	13.072	10.107	1.293
53018	AM	No	165.317	158.709	144.975	1.095
53028	AM	No	10.698	10.398	8.416	1.236
53008	AM	No	38.187	37.658	28.915	1.302
53023	AM	No	7.386	7.262	7.103	1.022
53002	AM	No	16.779	16.130	15.281	1.056

Methods: AM – Annual maxima; POT – Peaks over threshold; LF – Low flow (flow duration curve) statistics.

4.3 Estimating growth curves

Derivation of growth curves at subject sites:

Site code	Method (SS, P, ESS, H.)	If P or ESS, name of pooling group	Distribution used and reason for choice	Any urban or non-urban flood years adjustments	Parameters of distribution (location, scale and shape after adjustments)	Growth factor for 100-year return period
AV01	P	AV01	GEV best fit	Urban	Location 0.896 Scale 0.285 Shape 0.034	2.110

Methods: SS - Single Site; P - Pooled; ESS - Enhanced Single Site; H - Historical. Pooled and ESS growth curves were derived using the procedures from Science Report SC050050 (2008). Urban adjustments are carried out using the method of Kjeldsen (2010).

Flood frequency curve plots:

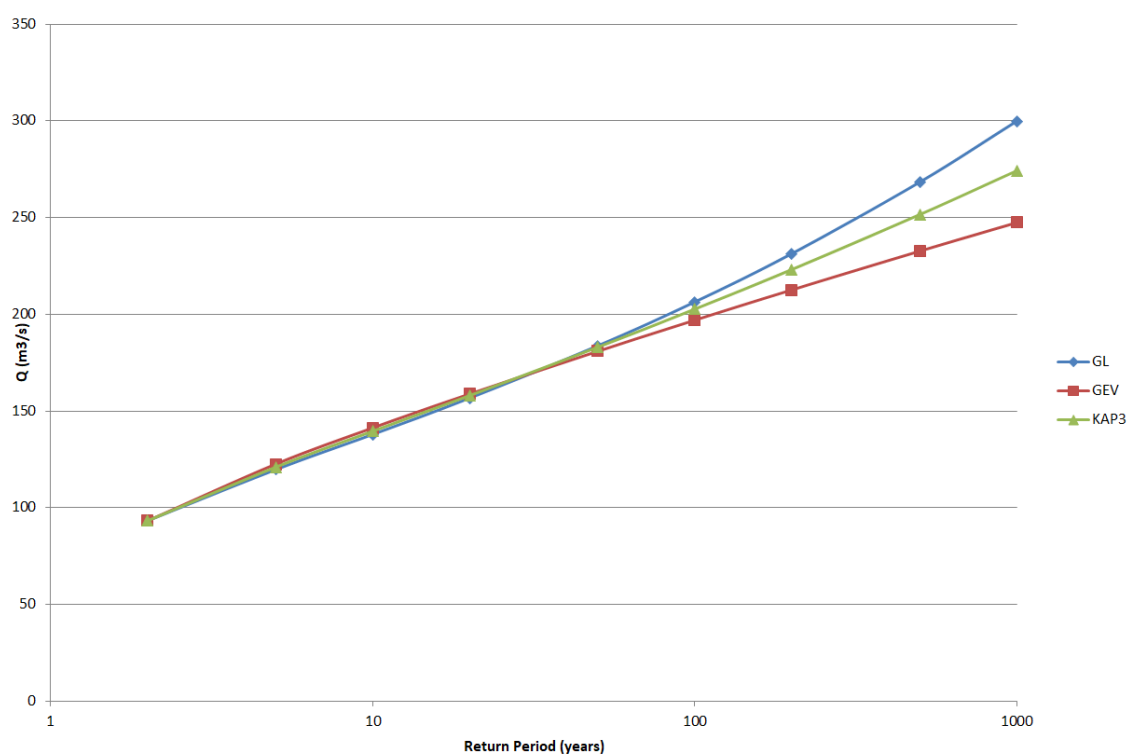


Figure 3 FFCs from stationary statistical analysis at AV01

Derivation of pooling groups:

Name of group	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)?	Small catchment pooling procedure applied?
AV01	AV01	No	0.03	Yes	No

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.

Pooling group composition:

Name of group	Changes made to default pooling group, with reasons	Weighted average L-moments
AV01	The default pooling group was examined on the basis of the distribution of L-moments. The following sites were further investigated using information on the NRFA: 54012 (Tern @ Walcot), 27071 (Swale @ Crakehill), 203010 (Blackwater @ Maydown Bridge), 33034 (Little Ouse @ Abbey Heath), 31004 (Welland @ Tallington Total). The sites were all retained in the pooling group and no further changes to its composition were made.	L-CV 0.185 L-SKEW 0.144

4.4 Final choice of QMED and growth curves

Method choice and reasons:

Site code	Final choice of QMED and reasons	Final choice of flood growth curve method and reasons
AV01	QMED from catchment descriptors adjusted by donor transfer and for urbanisation.	Pooled analysis with GEV distribution, providing the best fit to data, applied.

Final flood estimates from stationary statistical methods:

Site code	2 50%	5 20%	10 10%	20 5%	50 2%	100 1%	200 0.5%	500 0.2%	1000 0.1%
AV01	93.36	122.607	141.352	158.884	180.94	197.01	212.642	232.7	247.444

Flood peak in m³/s for the return periods in years or AEP (%) events.

5. Non-stationary statistical methods

Non-stationary statistical methods are outside the scope of the project and have not been applied.

6. Revitalised flood hydrograph (ReFH1) method

ReFH1 has not been applied for the purposes of the project.

7. Revitalised flood hydrograph 2 (ReFH2) method

7.1 Method Overview

What is the purpose of applying this method?

To derive peak flow estimates for comparison with the Statistical peak estimates.
To derive a design hydrograph shape to apply in the generation of design hydrographs.

Rural and urban catchment sub-divisions:

NA

Version of ReFH2 applied:

ReFH2.4-FEH22

7.2 Model Parameters

Summary of model parameters:

Site code	Method	Tp (hours) rural	Cmax (mm)	BL (hours)	Area modelled as urban (km2)	TP urban scaling factor	IF	IRF	DS
AV01	CD	17.567	496.326	81.53	36.879	0.75	0.4	0.7	0.5

Methods: OPT: Optimisation from event analysis, BR: Baseflow recession fitting, LAG: TP from lag analysis, CD: Catchment descriptors, DT: Data transfer, CAL: model calibration.

Analysis undertaken to derive model parameters:

Model parameters derived from catchment descriptors.

7.3 Model inputs for design events

Design events for lumped catchments:

Site code	Rainfall DDF model	Urban or rural	Highly permeable?	Season of design event	Storm duration (hrs)	Initial soil moisture Cini	Initial baseflow BFO
AV01	DDF22	Rural	No	Winter	33	86.511	17.829

Design events for subcatchments and intervening areas:

Site code(s)	Rainfall DDF model	Season of design event	Storm duration (hrs)	Storm area for ARF	Areal reduction factor ARF	Reason for selecting storm
NA	NA	NA	NA	NA	NA	NA

Storm duration testing:

Storm duration testing has not been undertaken as part of the hydrological assessment.

7.4 Final choice of ReFH2 flow estimates

Method choice and reasons:

Site code	Final choice of design inputs and model parameters
AV01	Lumped model parameters at AV01 derived from catchment descriptors. Design storm at AV01 using ReFH2 recommended storm duration.

Final flood estimates from ReFH2 method:

Site code	2 50%	5 20%	10 10%	20 5%	50 2%	100 1%	200 0.5%	500 0.2%	1000 0.1%
AV01	64.17	82.53	96.380	113.99	142.85	169.87	200.4	244.33	279.15

Flood peak in m³/s for the return periods in years or AEP (%) events.

8. Other Rainfall-Runoff or Hydrograph Methods

Other rainfall-runoff or hydrograph methods are outside the scope of the project and have not been tested.

9. Discussion and summary of results

9.1 Comparison of results from different methods

Site code	<i>Ratio of ReFH2 to stationary statistical peak, 50% AEP</i>	<i>Ratio of ReFH2 to stationary statistical peak, 1% AEP</i>	<i>Ratio of ReFH2 to stationary statistical peak, 0.1% AEP</i>
AV01	0.687	0.862	1.128

9.2 Final choice of method

Choice of method and reasons:

QMED estimates at AV01 has been derived from catchment descriptors and adjusted by donor transfer from suitable donors and for urbanisation. In order to derive peak flow estimates for rarer events, growth factors have been derived at AV01 from statistical pooled analysis for %AEPs ≥ 1 . For %AEPs < 1 , peak flows have been derived by applying the ReFH2 ratio method (i.e. the ratio of ReFH2 peak to the 1%AEP ReFH2 peak is multiplied by the 1%AEP FEH Statistical peak). This approach aims to reconcile the differences between the FEH Statistical method and the ReFH2 rainfall-runoff, the latter producing more conservative estimates for the 0.2 and 0.1 %AEPs.

How will the 0.1% AEP flows be estimated?

ReFH2 ratio.

How will the flows be applied to a hydraulic model?

Design hydrographs derived at AV01 are applied as u/s lumped inflows.

9.3 Final results

Site code	2 50%	5 20%	10 10%	20 5%	50 2%	100 1%	200 0.5%	500 0.2%	1000 0.1%
AV01	93.360	122.607	141.352	158.884	180.940	197.010	232.418	283.366	323.750

Flood peak in m^3/s for the return periods in years or AEP (%) events.

Design storms applied in the hydraulic model:

Site code(s)	Season of design event	Storm duration (hrs)	Storm area for ARF (km ²)	Return period(s)	Reason for selecting storm
AV01	Winter	33	893.185	20, 100, 1000, 100 + cc	Appropriate to the extent covered by the hydrological assessment and to the assessment of flood risk at the site of interest.

Climate change allowances:

Central (26%) and Upper End (71%) climate change allowances for the Avon Bristol and North Somerset Streams⁵ applied to the 1%AEP estimates in line with current guidance⁶.

9.4 Checks

Growth factor checks:

Site code	1% AEP growth factor	0.1% AEP / 1% AEP ratio
AV01	2.110	1.643

Specific discharge:

Site code	2 50%	5 20%	10 10%	20 5%	50 2%	100 1%	200 0.5%	500 0.2%	1000 0.1%
AV01	1.045	1.373	1.583	1.779	2.026	2.206	2.602	3.173	3.625

Flood peak in l/s/ha for the return periods in years or AEP (%) events.

Spatial consistency of results:

Spatial consistency cannot be assessed due to the extent of the study.

⁵

<https://environment.maps.arcgis.com/apps/webappviewer/index.html?id=363522b846b842a4a905829a8d8b3d0c>

⁶ Environment Agency - Flood risk assessments: climate change allowances – Updated May 2022

Return periods for notable historic floods:

A check against notable floods is provided in the hydraulic model report.

Compatibility with longer-term flood history:

The compatibility with the flood history at the site is discussed in the hydraulic model report. As a reference, AMAX values extracted at the Bradford on Avon flow gauge is provided in the table below:

Site	AMAX1	AMAX2	AMAX3
Bradford on Avon	233.573	203.83	175.267

The AMAX values at the gauge would approximately compare as follows with the %AEP estimates produced by this analysis:

- AMAX1: 0.5%AEP
- AMAX2: 1%AEP
- AMAX3: between 5 and 2%AEP

It should be noted, however, that a formal assessment of the gauged record quality has not been undertaken. It should further be noted that the gauged catchment is approximately 1011km² compared to the 893.185km² catchment area which estimates are derived for in this study.

Comparisons with previous studies:

NA

Checks on hydraulic model results:

Checks on the hydraulic model results are discussed in the hydraulic model report.

9.5 Assumptions, limitations, and uncertainty

Assumptions:

- Flood flows can be described via generalised flood estimation methods and information provided by the national peak flow dataset is sufficient to inform estimates at the site of interest.
- ReFH2 recommended storm duration at AV01 is representative of critical storm duration at the site;

- the ReFH2 ratio is able to provide the best estimate of the 0.1%AEP growth factor

Limitations:

- The FEH Statistical Method is based on standard pooled analysis treating the site as ungauged due to the lack of flow records at the site/estimation point.
- ReFH2 parameters are derived from catchment descriptors
- ReFH2 model built from catchment descriptors is used to identify the design storm for the hydraulic modelling;

Uncertainty:

Uncertainty bounds in the table below have been estimated using Table 2 of current guidelines^{Error! Bookmark not defined.}

Site code	50% AEP Lower 95%	50% AEP Upper 95%	5% AEP Lower 95%	5% AEP Upper 95%	1% AEP Lower 95%	1% AEP Upper 95%	0.1% AEP Lower 95%	0.1% AEP Upper 95%
AV01	47.614	183.919	79.442	319.357	96.535	403.871	148.925	699.299

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

Suitability of results for future studies:

Results are suitable to the assessment of flood risk local to the area of study.

Recommendations for future work:

Development of a rating relationship for Staverton level gauge and use of the gauge record in the analysis.

10. Appendix

10.1 Digital files

Input data:

FEH_catchment (.shp, .csv, .xml) at AV01

Project or calculation files:

WINFAP project files:

RA01_v02.wxml

ReFH2 model:

RA01.rxml

Output data:

ReFH2 output

RA01.csv

10.2 Other Supporting Information
