Flood estimation calculation record

Introduction

This calculation record is based on a supporting document to the Environment Agency's flood estimation guidelines (Version 4, 2012). It provides a record of the calculations and decisions made during flood estimation. It will often be complemented by more general hydrological information given in a project report. The information given here should enable the work to be reproduced in the future. This version of the record is for studies where flood estimates are needed at multiple locations.

Contents

Approval

	Name and qualifications
Calculations prepared by:	Matthew Roberts BSc MSc DIC
Calculations checked by:	Vicky Shackle BSc PhD MCIWEM C.WEM

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 Overview of requirements for flood estimates

Item	Comments
Give an overview which includes: • Purpose of study • Approx. no. of flood estimates required • Peak flows or hydrographs? • Range of return periods and locations	This hydrological assessment was undertaken to inform the Surface Water Management Plan for Headcorn, Kent. Peak flows are required for the following Annual Exceedance Probability (AEP) events; 50%, 10%, 5%, 3.33%, 2%, 1.33%, 1% and 0.1%. The effects of climate change are to be considered for the 1% AEP event. For this event, flow will be increased by 20% as stated within the FCDPAG3 Economic Appraisal (DEFRA, 2006).

1.2 Overview of catchment

Item	Comments
Brief description of catchment, or reference to section in accompanying report	Headcorn is a village located approximately 14km south-east of Maidstone, Kent. The two main watercourses that flow through Headcorn are the Moat Farm Stream (Main River) and the River Sherway (Ordinary Watercourse). These catchments are predominantly covered with Arable (Horticultural) land with a mixture of woodland and grassland. The main built-up area is Headcorn and part of Staplehurst is located in the upper Marden drain catchment. The catchments within Headcorn are underlain predominantly by mudstone siltstone and sandstone deposits (Weald Clay formation) and therefore the catchments are quite impermeable and consequently a more flashy response is expected. The upper sections of these catchments are characterised by sandstones and mudstones (Lower Greensand Group) and is therefore slightly more permeable but these deposits are of limited extent within these catchments. This is supported by fairly low BFIHOST values in the range of 0.315 to 0.353; the average SPRHOST value is 45%. These geological formations are overlain by superficial deposits of Alluvium and River Terrace deposits which mainly consist of sands, gravel, clays and silts. These superficial deposits are mostly confined alongside river reaches in the lower catchment. There are also some Head superficial deposits in the upper Moat Farm Stream catchment which consist of clays, silts, sands and gravels. It is likely that the areas that are overlain by these superficial deposits are slightly more permeable than the surrounding parts of the catchment. The soils within the Headcorn catchments predominantly consist of slowly permeable wet clayey soils with impeded drainage. In the lower section of the catchments, the soils are typically more loamy and wet with naturally high groundwater levels. In the upper section of the catchments, the soils are typically more freely draining which is most likely associated with the slightly more permeable Lower Greensand Group geological formation. There is a reasonable gradient across the catchment with the highest elevation point at approximately 160mAOD (Green Hill) and the lowest elevation point at approximately 16mAOD at the downstream model extent.

1.3 Source of flood peak data

Was the HiFlows UK dataset used? If so, which version? If not, why not? Record any	Yes – Version 3.3.4, August 2014

changes made	

1.4 Gauging stations (flow or level)

(at the sites of flood estimates or nearby at potential donor sites)

Water-course	Station name	Gauging authority number	NRFA number (used in FEH)	Grid reference	Catch-ment area (km²)	Type (rated / ultrasonic / level…)	Start and end of flow record
Ungauged catchment.							

1.5 Data available at each flow gauging station

Station name	Start and end of data in HiFlows-UK	Update for this study?	Suitable for QMED?	Suitable for pooling?	Data quality check needed?	Other comments on station and flow data quality e.g. information from HiFlows-UK, trends in flood peaks, outliers.
Ungauged catchment.						
Give link/reference to any further data quality checks carried out	N/A					
Note – include plots of flood peak and flood hydrograph data at relevant gauging stations along with interpretation, e.g. in the Annex.						

1.6 Rating equations

Station name	Type of rating e.g. theoretical, empirical; degree of extrapolation	Rating review needed?	Reasons e.g. availability of recent flow gaugings, amount of scatter in the rating.
N/A			
Give link/reference to any rating reviews carried out	N/A		

1.7 Other data available and how it has been obtained

Type of data	Data relevant to this study?	Data available ?	Source of data and licence reference if from EA	Date obtained	Details
Check flow gaugings (if planned to review ratings)	N/A				
Flow data for events	N/A				
Results from previous studies	N/A				

1.8 Initial choice of approach

<table>
<tr><td>Is FEH appropriate? (it may not be for very small, heavily urbanised or complex catchments) If not, describe other methods to be used.</td><td>Yes. The catchments are fairly small; between 8km^2 (Moat Farm Stream) and 30km^2 (River Sherway) but they are quite impermeable and essentially rural. The catchment sizes and characteristics mean that FEH is appropriate for these catchments.</td></tr>
<tr><td>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?
</td><td>The main area of interest is the village of Headcorn which is located south-east of Maidstone in Kent. The catchments within Headcorn are likely to be impacted by peak flows due to underlying impermeable geological deposits and also within Headcorn due to the increase in impervious urbanised area. There is a small irrigation reservoir (Ringles) which is offline and it is therefore unlikely to impact flows further downstream during normal conditions. In the case of an extreme event i.e. a breach scenario, there would be localised flooding which could be exacerbated by the railway line and the A274. Although, flooding within the main town is likely to be fairly limited. Based on the available information, there are no temporary debris dams within the study catchments.

There is a history of flooding within Headcorn (see table below). It is unclear whether this flooding is associated with high levels in the adjacent Main River catchments. This will be assessed within the flood history report for Headcorn which aims to determine catchment response within Headcorn and whether the flood events are due to insufficient capacity within the drainage network or due to fluvial flooding. This is the main reason for undertaking Direct Rainfall analysis and fluvial analysis to derive a combined fluvial-surface water hydraulic model.
<table>
<tr><th>Date</th><th>Source</th></tr>
<tr><td>2000 (Autumn?)</td><td>Fluvial (Moat Farm Stream and Sherway)</td></tr>
<tr><td>January 2009</td><td>Surface Water</td></tr>
<tr><td>November 2009</td><td>Surface Water and Fluvial (River Sherway)</td></tr>
<tr><td>December 2012 / January 2013</td><td>Foul Sewer</td></tr>
<tr><td>December 2013 / January 2014</td><td>Foul Water / Surface Water</td></tr>
</table></td></tr>
<tr><td>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 – avoid standard ReFH if URBEXT1990>0.125; consider FEH Statistical or other alternatives; 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
</td><td>The catchments within Headcorn are quite impermeable (average BFIHOST is 0.33 and SPRHOST is 45%). As the majority of the catchments are essentially rural, both the FEH Statistical and ReFH methods can be used to derive peak flows.
There is no known pumping within this catchment.</td></tr>
</table>

Initial choice of method(s) and reasons Will the catchment be split into subcatchments? If so, how?	Both the FEH Statistical and ReFH methods will be used as the catchments are suited to either method and will therefore enable comparison between the two recommended flow estimation methods. Inflows will be derived at the upstream model extents with check flows derived at key locations; confluences and downstream model extent.
Software to be used (with version numbers)	FEH CD-ROM v3.0[1] WINFAP-FEH v3.0.002[2]

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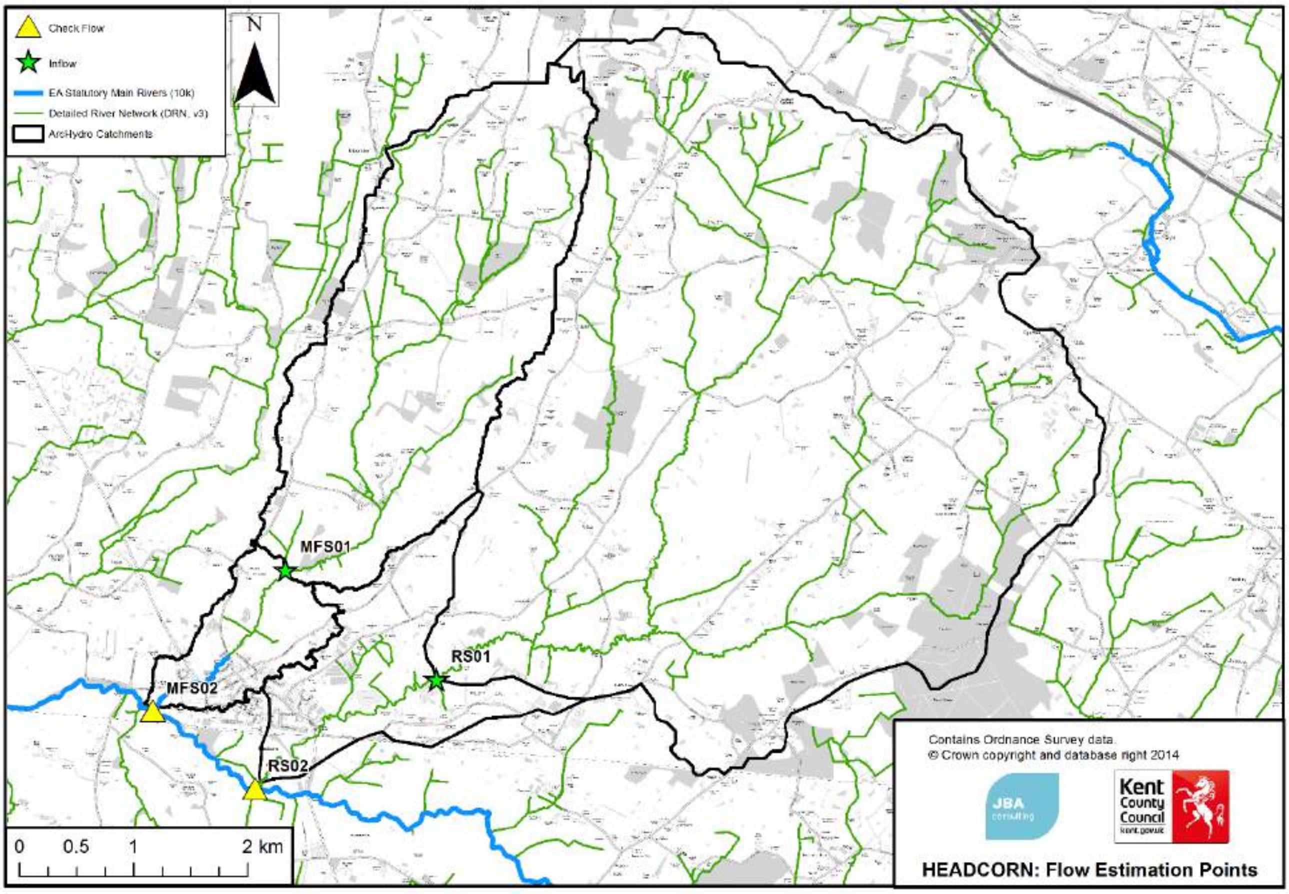
[1] FEH CD-ROM v3.0 © NERC (CEH). © Crown copyright. © AA. 2009. All rights reserved.

[2] WINFAP-FEH v3 © Wallingford HydroSolutions Limited and NERC (CEH) 2009.

2 Locations where flood estimates required

Figure 2-1: Locations of flow estimates



2.1 Summary of subject sites

Site code	Watercourse	Site	Easting	Northing	AREA on FEH CD-ROM (km^2)	Revised AREA if altered
MFS01	Moat Farm Stream	Upstream model extent of Moat Farm Stream	584000	145400	6.2	7.5
MFS02	Moat Farm Stream	Downstream model extent of Moat Farm Stream	582850	144200	8.2	8.8
RS01	River Sherway	Upstream model extent of the River Sherway	585300	144400	26.2	24.5
RS02	River Sherway	Downstream model extent of the River Sherway	583750	143500	29.4	27.0
As there is no gauged data and there are no changes in geology within the modelled reaches, the upstream and downstream model extents were selected as the flow estimation points.						

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)	SPRHOST	URBEXT 1990	URBEXT 2000	FPEXT
MFS01	0.997	0.34	0.323	3.40	31.6	664	45.45	0.0000	0.0004	0.102
MFS02	0.998	0.34	0.353	4.15	27.3	661	44.57	0.0191	0.0211	0.145
RS01	0.999	0.34	0.315	5.62	34.8	676	45.29	0.0015	0.0075	0.141
RS02	0.999	0.34	0.322	7.60	31.9	674	45.15	0.0041	0.0133	0.179

Note: Red text denotes catchment descriptor values which have been changed from the FEH CD-ROM values.

2.3 Checking catchment descriptors

<table>
<tr>
<td>Record how catchment boundary was checked and describe any changes (refer to maps if needed)</td>
<td>The catchment boundaries were checked using 1m resolution DTM data. In the upper catchment, there is a lack of LIDAR coverage and in the absence of any higher resolution data, OS Open Terrain 50k data was used to infer the catchment boundary. In some locations the FEH catchment boundary was amended to take account of the Detailed River Network (DRN v3) so that the rivers do not cut across subcatchment boundaries. The ArcHydro ‘rolling ball’ analysis tool within ArcGIS was used to define the topographical catchment using a composite elevation dataset which consisted mostly of 1m resolution LIDAR data with some OS Open Terrain 50k data in the upper reaches.

For the catchments where AREA has changed significantly (>10%), the FEH DPLBAR value was also updated. This is because DPLBAR is based on catchment area and should therefore be updated to reflect the change in area. The standard equation for DPLBAR, given in the FEH Volume 5, uses a power term of 0.548 which is based on research for the UK as a whole. Rather than use this generalised value a power term for the Moat Farm Stream catchment was derived based on the FEH AREA and DPLBAR values for MFS01 as follows:
$$AREA^x = DPLBAR$$
$$6.24^x = 3.04$$
$$x = \frac{\log(3.04)}{\log(6.24)} = 0.608$$
Although this value is not substantially different to the power term used in the standard equation it results in an updated DPLBAR of 3.40km (for a catchment area of 7.5km^2) rather than 3.01km derived using the standard equation power term.</td>
</tr>
</table>

Record how other catchment descriptors (especially soils) were checked and describe any changes. Include before/after table if necessary.	Soil values (SPRHOST and BFIHOST) were checked against the 1:250,000 Soil Survey of England and Wales map for South East England for both catchments to assess if the FEH CD-ROM values across the study area are reasonable. It was found that the FEH Catchment Descriptors represent the soil types well. The urban areas shown on the FEH CD-ROM (v3) were compared against OS 1:50,000 mapping and were deemed to be representative of the study catchment. Therefore the URBEXT values on the FEH-CD ROM (v3) were retained and updated to 2014 values using the CPRE formulae in accordance with the EA Flood Estimation Guidelines. The FARL value was checked against the OS mapping for surface water features within the study catchment. There are no major surface water within the Marden drain catchments. Therefore the FARL values from the FEH CD-ROM were used as this corresponds with the OS 1:50,000 Mapping.
Source of URBEXT	$URBEXT_{1990}$ has been used for the ReFH method. $URBEXT_{2000}$ has been used for the FEH Statistical method.
Method for updating of URBEXT	$URBEXT_{1990}$ - CPRE formula from FEH Volume 4. $URBEXT_{2000}$ - CPRE formula from 2006 CEH report on $URBEXT_{2000}$.

3 Statistical method

3.1 Search for donor sites for QMED (if applicable)

Comment on potential donor sites Mention: • Number of potential donor sites available • Distances from subject site • Similarity in terms of AREA, BFIHOST, FARL and other catchment descriptors • Quality of flood peak data Include a map if necessary. Note that donor catchments should usually be rural.	A brief assessment of donor stations was carried out for this study using WINFAP-FEH to assess stations that are suitable for QMED within the HiFlows-UK dataset. No suitable donor stations could be located within 50km as the donor catchments were more than 5 times larger than the subject catchment or were not hydrologically representative. Therefore QMED estimates were derived using catchment descriptors.

3.2 Donor sites chosen and QMED adjustment factors

NRFA no.	Reasons for choosing or rejecting	Method (AM or POT)	Adjust-ment for climatic variation?	QMED from flow data (A)	QMED from catchment descriptors (B)	Adjust-ment ratio (A/B)
40005	REJECT: The donor catchment is over 11 times larger than the subject catchment at RS01 and 37 times larger than the subject catchment at MFS01. All other catchment descriptors are fairly similar and the catchment is located approximately 5km away. Given that the donor catchment is significantly larger than the subject catchment and applying this donor adjustment would only result in ~2% reduction in flows, this site was rejected.	AM	N/A	42.1	44.0	0.957
40009	REJECT: The donor catchment is over 5 times larger than the subject catchment at RS01 and nearly 18 times larger than the subject catchment at MFS01. SAAR at the donor catchment is approximately 22% higher than the subject catchment and has a much larger attenuation due to the presence of surface water features such as lakes/ reservoirs (FARL=0.904). The catchment is located approximately 22km away. Given that the donor catchment is not hydrologically similar to the subject catchment and the catchment is located quite far away, this site was rejected.	AM	N/A	28.4	20.7	1.373

3.3 Overview of estimation of QMED at each subject site

			Data transfer						
Site code	Method	Initial estimate of $\text{QMED}_{\text{RURAL}}$ (m^3/s)	NRFA numbers for donor sites used (see 3.3)	Distance between centroids d_{ij} (km)	Power term, a	Moderated QMED adjustment factor, $(A/B)^a$	If more than one donor		Final estimate of $\text{QMED}_{\text{URBAN}}$ (m^3/s)
							Weight	Weighted ave. adjustment	
MFS01	CD	1.97	N/A						1.97
MFS02	CD	2.09	N/A						2.13
RS01	CD	5.80	N/A						5.84
RS02	CD	6.17	N/A						6.24

Are the values of QMED consistent, for example at successive points along the watercourse and at confluences?	Yes, QMED estimates are consistent along successive locations along each reach.

Important note on urban adjustment

The method used to adjust QMED for urbanisation, for both subject sites and donor sites, is that published in Kjeldsen (2010)[3] in which PRUAF is calculated from BFIHOST. The result will differ from that of WINFAP-FEH v3.0.003 which does not correctly implement the urban adjustment of Kjeldsen (2010). Significant differences will occur only on urban catchments that are highly permeable.

Notes

Methods: AM – Annual maxima; POT – Peaks over threshold; DT – Data transfer; CD – Catchment descriptors alone.

When QMED is estimated from POT data, it should also be adjusted for climatic variation. Details should be added below.

The data transfer procedure is the revised one from Science Report SC050050. The QMED adjustment factor A/B for each donor site is given in Table 3.3. 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 times the initial estimate from catchment descriptors.

If more than one donor has been used, use multiple rows for the site and give the weights used in the averaging. Record the weighted average adjustment factor in the penultimate column.

3.4 Derivation of pooling groups

The composition of the pooling groups is given in the Annex. Several subject sites may use the same pooling group. The top three stations within the default pooling group were investigated as these stations will have a greater impact on the growth curve and therefore the final design flow estimates.

Name of group	**Site code from whose descriptors group was derived**	**Subject site treated as gauged? (enhanced single site analysis)**	**Changes made to default pooling group, with reasons** Note also any sites that were investigated but retained in the group.	**Weighted average L-moments,** L-CV and L-skew, (before urban adjustment)
MFS02	MFS02	No	Stations removed 49006 (Camel @ Camelford) - The station record is too short (6 years) and WINFAP-FEH recommends that it should be removed from the pooling group. Stations investigated 27073 (Brompton Beck @ Snainton Ings)	0.259, 0.199

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

Name of group	Site code from whose descriptors group was derived	Subject site treated as gauged? (enhanced single site analysis)	Changes made to default pooling group, with reasons Note also any sites that were investigated but retained in the group.	Weighted average L-moments, L-CV and L-skew, (before urban adjustment)
			- Theoretical rating but gaugings show considerable scatter. - Fully contained with no likelihood of drowning. Theoretical rating should apply for the whole range. - Not representative of the study catchment and variability in the highest AMAX peaks is low (small L-skew) however L-moments are representative of others in the group, although the growth curve is flat there is another site with a similarly shallow growth curve. - As this site is not discordant and fits well with the other stations in the group, the site was retained. 26802 (Gypsey Race @ Kirby Grindalythe) - Hydrological response dominated by groundwater; topographical catchment may not match with the groundwater catchment. - Possibly not particularly representative of the study catchment but not discordant and fits well with the other stations in the group. - Short record and distance measure not much smaller than the next station. - Site is within the main cluster of pooling group stations on the L-CV and L-Kurtosis plots. - Similar catchment descriptors to the subject site and no observable trend in the short AMAX series. Therefore this site was retained. 20002 (West Peffer Burn @ Luffness) - Similar catchment descriptors to the subject site and no observable trend in AMAX series. Mainly impermeable catchment which is consistent with the subject catchment. - Site is within the main cluster of pooling group stations on the L-CV and L-Kurtosis plots. Therefore this site was retained. Total of 515 years; no stations added as unlikely to improve pooling group. The final pooling group composition can be found within the Annex.	
RS02	RS02	No	Stations investigated 20002 (West Peffer Burn @ Luffness) - retained; see above. 33054 (Babingly @ Castle Rising) - Subject to drowning. AMAX3 is just above	0.259, 0.105

Name of group	**Site code from whose descriptors group was derived**	**Subject site treated as gauged? (enhanced single site analysis)**	**Changes made to default pooling group, with reasons** Note also any sites that were investigated but retained in the group.	**Weighted average L-moments,** L-CV and L-skew, (before urban adjustment)
			modular limit. • Chalk catchment. Regime influenced by groundwater abstraction / recharge. • AMAX1 and AMAX2 have the same value and occur in water years 1976 and 1978; AMAX 3 is only slightly lower and occurs in water year 1980. • AMAX values for water years 1983-1986 are almost the same. Similar values for one year following the next: 1994 & 1995, 1997 & 1998, 2002 & 2003. • Some uncertainty in data quality and Chalk not representative of the study catchment but nothing to suggest that retaining this station will skew the growth curve. • Site is within the main cluster of pooling group stations on the L-CV and L-Kurtosis plots. 33032 (Heacham @ Heacham) • Weir never drowns; two crumple weirs in parallel, 3m broad. Small bypass channel with weir upstream of station which rejoins downstream of the weir. • Good fit to gaugings and all flows contained; rating expected to perform well beyond QMED. • Chalk catchment. Regime influenced by groundwater abstraction for PWS and irrigation. • AMAX1 is approximately 2.7 times that of QMED. This is within the expected range for this catchment. • Some uncertainty in data quality and Chalk not representative of the study catchment but nothing to suggest that retaining this station will skew the growth curve. • Site is within the main cluster of pooling group stations on the L-CV and L-Kurtosis plots. Total of 502 years; no stations added as unlikely to improve pooling group. The final pooling group composition can be found within the Annex.	

Notes

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

The weighted average L-moments, before urban adjustment, can be found at the bottom of the Pooling-group details window in WINFAP-FEH.

3.5 Derivation of flood growth curves at subject sites

The rural growth curves for both pooling groups are shown in Figures 3-1 and 3-2.

Site code	Method (SS, P, ESS, J)	If P, ESS or J, name of pooling group	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
MFS01	P	MFS02	Generalised Logistic (GL) distribution selected as GL provides the best fit to the MFS02 pooling group data and GL is the recommended distribution for UK catchments. GEV and P(III) provided the best fit to the RS02 data. However, GL provided the most conservative estimates at higher return periods and was selected for consistency with the other pooling group.	Urban adjustment made using v3 method (Kjeldsen, 2010). No permeable adjustment – SPRHOST >20%.	1.000, 0.264, -0.199	2.99
MFS02	P	MFS02			1.000, 0.261, -0.203	2.98
RS01	P	RS02			1.000, 0.265, -0.106	2.57
RS02	P	RS02			1.000, 0.264, -0.107	2.57

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 v3 method: Kjeldsen (2010).

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

Figure 3-1: MFS02 Final Pooling Group Growth Curve (Rural)

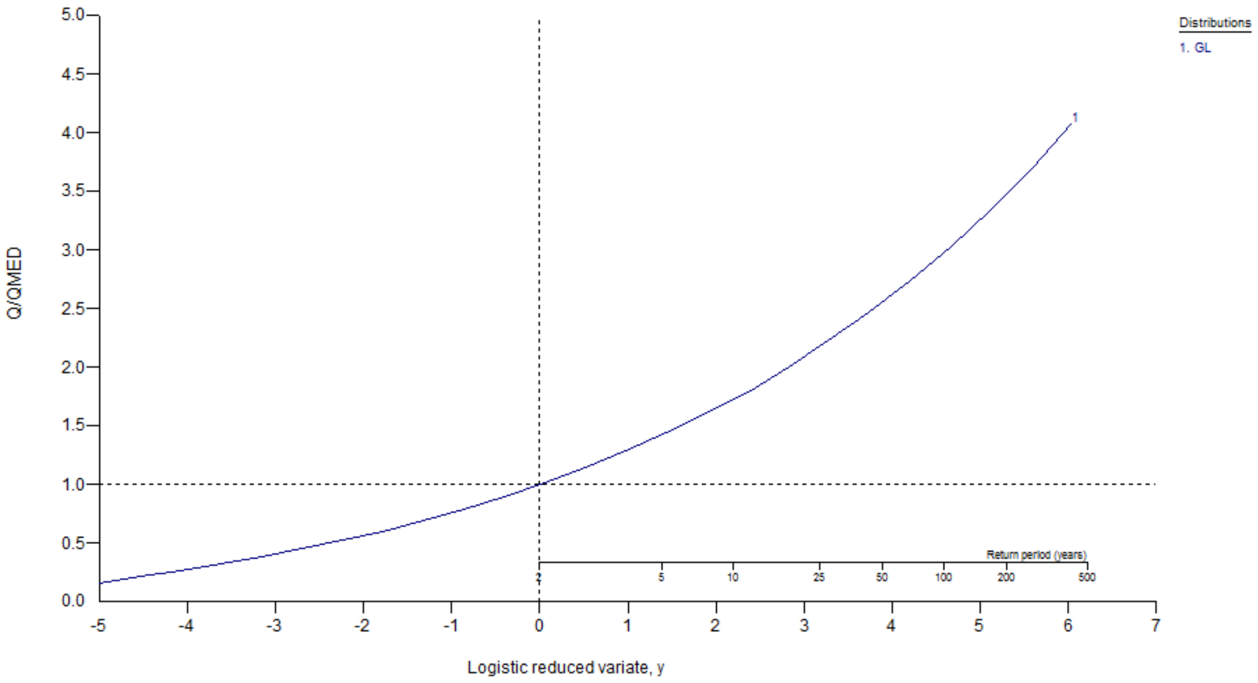
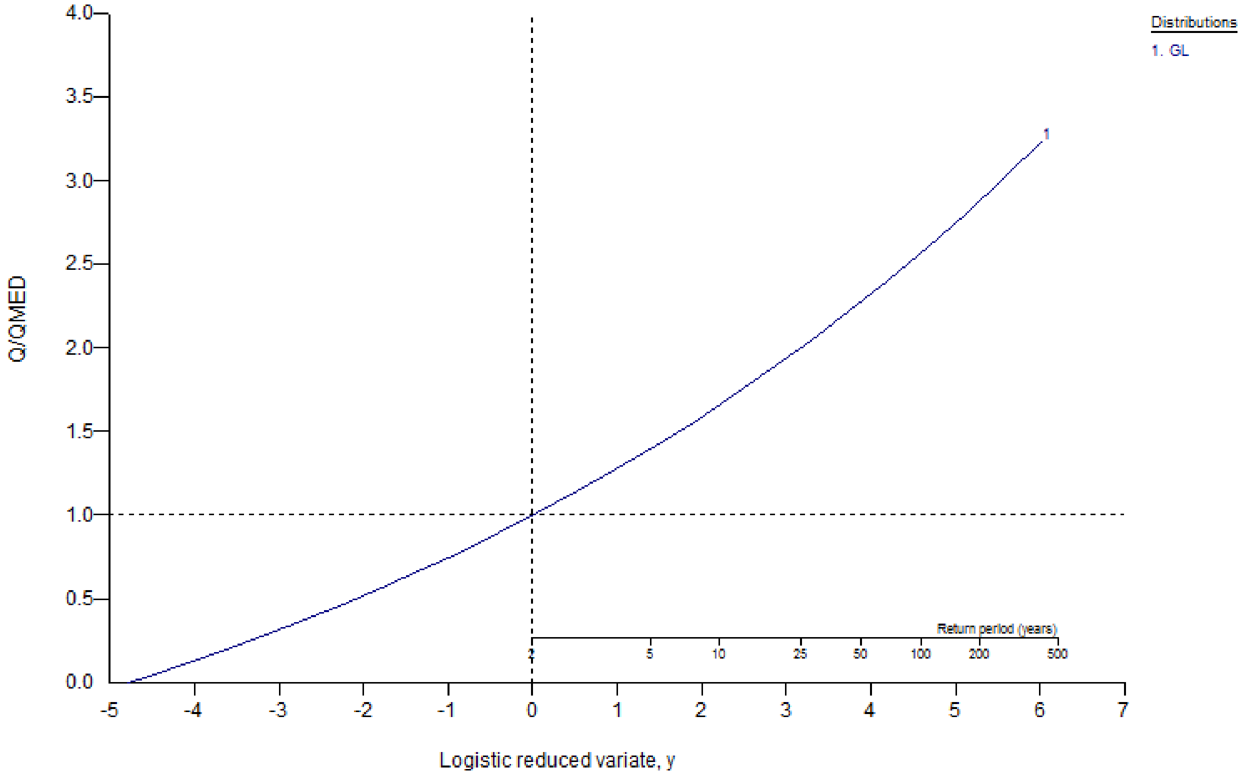


Figure 3-2: RS02 Final Pooling Group Growth Curve (Rural)



3.6 Flood estimates from the statistical method

Site code	Flood peak (m^3/s) for the following Annual Exceedance Probabilities (%)								
	50	**10**	**5**	**3.33**	**2**	**1.33**	**1**	**1 (+CC)**	**0.1**
MFS01	2.0	3.4	4.1	4.5	5.0	5.5	5.9	7.1	9.7
MFS02	2.1	3.7	4.4	4.8	5.4	6.0	6.4	7.6	10.5
RS01	5.8	9.7	11.2	12.1	13.3	14.3	15.0	18.0	21.6
RS02	6.2	10.3	11.9	12.9	14.2	15.2	16.0	19.2	23.1

4 Revitalised flood hydrograph (ReFH) method

4.1 Parameters for ReFH model

Site code	**Method:** OPT: Optimisation BR: Baseflow recession fitting CD: Catchment descriptors DT: Data transfer (give details)	**Tp (hours)** Time to peak	**C_{max} (mm)** Maximum storage capacity	**BL (hours)** Baseflow lag	**BR** Baseflow recharge
MFS01	CD	4.014	264.21	34.30	0.751
MFS02	CD	4.444	287.47	35.36	0.826
RS01	CD	5.258	257.99	37.51	0.731
RS02	CD	6.406	263.43	40.09	0.748
Brief description of any flood event analysis carried out (further details should be given below or in a project report)					

4.2 Design events for ReFH method

Site code	**Urban or rural**	**Season of design event (summer or winter)**	**Storm duration (hours)**	**Storm area for ARF (if not catchment area)**
MFS01	RURAL	WINTER	6.75	Catchment area
MFS02	RURAL	WINTER	7.50	Catchment area
RS01	RURAL	WINTER	9.50	Catchment area
RS02	RURAL	WINTER	10.75	Catchment area
Are the storm durations likely to be changed in the next stage of the study, e.g. by optimisation within a hydraulic model?			The recommended storm durations, based on the standard ReFH equation at the downstream extents of Moat Farm Stream and the River Sherway are 7.376hrs and 10.716hrs respectively. The storm durations used for the two catchments are 7.5hr and 10.75hr respectively. The ARF is 0.961 for the 9.5hr duration. These parameters have also been used to derive the hydrograph shape for the FEH Statistical hydrographs. The majority of Headcorn is affected by the Moat Farm Stream and therefore the critical duration was tested for this catchment. A brief assessment of storm durations and peak flows was carried out in order to determine the critical duration at the downstream location for the hydraulic model. A storm duration of 10.25 hours was found to produce the highest 1% AEP flow estimate at MFS02 (ARF=0.965). As the critical duration is close to the storm duration of the River Sherway, both the 7.5hr and 10.75hr storm will be run through the hydraulic model.	

4.3 Flood estimates from the ReFH method

Site code	**Flood peak (m^3/s) for the following Annual Exceedance Probabilities (%)**								
	50	**10**	**5**	**3.33**	**2**	**1.33**	**1**	**1 (+CC)**	**0.1**
MFS01	2.5	4.1	4.8	5.3	6.0	6.6	7.0	8.4	13.2
MFS02	2.7	4.3	5.0	5.5	6.2	6.8	7.3	8.7	13.5
RS01	7.1	11.4	13.3	14.6	16.4	18.0	19.3	23.2	35.8
RS02	6.9	11.0	12.8	14.0	15.8	17.3	18.5	22.1	34.0

5 Discussion and summary of results

5.1 Comparison of results from different methods

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

Site code	**Ratio of peak flow to FEH Statistical peak**	
	Return period 2 years	**Return period 100 years**
	ReFH	**ReFH**
MFS01	1.28	1.19
MFS02	1.25	1.14
RS01	1.22	1.29
RS02	1.11	1.15

5.2 Final choice of method

Choice of method and reasons – include reference to type of study, nature of catchment and type of data available.	The FEH Statistical method was chosen due to the consistency of flow estimates downstream and as the Moat Farm Stream catchment is fairly small. The ReFH estimates have been provided as a comparison with the FEH Statistical estimates. As hydrographs are required for the hydraulic model, the ReFH hydrograph shapes will be scaled to fit the FEH Statistical peak flow estimates.

5.3 Assumptions, limitations and uncertainty

List the main assumptions made (specific to this study)	The main assumptions in this study are that: • QMED (CD) estimates are suitably representative for these catchments. • The pooling groups derived for each of the two catchments are suitably representative. There is not much change in catchment area so it is thought that one pooling group for each catchment is sufficient. • ReFH hydrograph shape is representative of the catchment response.
Discuss any particular limitations, e.g. applying methods outside the range of catchment types or return periods for which they were developed	The FEH Statistical method is generally believed to only be suitable for return periods up to 200 years. ReFH is calibrated for return periods up to 150 years. Estimates of flows beyond these return periods are extrapolations and have a higher degree of uncertainty.
Give what information you can on uncertainty in the results – e.g. confidence limits for the QMED estimates using FEH 3 12.5 or the factorial standard error from Science Report SC050050 (2008).	It is not possible to easily assess the uncertainty of the larger flood flow estimates. The FEH allows for calculating confidence intervals for QMED based on catchment descriptors (CDs). The 95% confidence intervals for QMED are: MFS01 – QMED: 1.0 – 4.0 m^3/s MFS02 – QMED: 1.0 – 4.4 m^3/s RS01 – QMED: 2.9 – 11.9 m^3/s RS02 – QMED: 3.1 – 12.7 m^3/s

	For ungauged catchments it is not possible to consider uncertainty in pooled flow estimates but they are likely to be considerably larger than the uncertainty in QMED.
Comment on the suitability of the results for future studies, e.g. at nearby locations or for different purposes.	The design flow estimates have been derived for the purposes of this hydrological assessment in order to inform the fluvial component of a Surface Water Management Plan. If peak flow estimates are required for different purposes it is recommended that, at a minimum, a review of results is carried out.
Give any other comments on the study, for example suggestions for additional work.	As in most ungauged catchments, it is recommended that temporary flow gauges be installed to better inform the design peak flow estimates. There are no other specific suggestions relevant to this study.

5.4 Checks

Are the results consistent, for example at confluences?	Yes, the FEH Statistical peak flow estimates are consistent along reaches and at confluences.
What do the results imply regarding the return periods of floods during the period of record?	N/A, ungauged catchments.
What is the 100-year growth factor? Is this realistic? (The guidance suggests a typical range of 2.1 to 4.0)	The 1% AEP event growth factors vary between 2.57 and 2.99 which are within the typical range.
If 1000-year flows have been derived, what is the range of ratios for 1000-year flow over 100-year flow?	The 0.1% / 1% AEP event ratios vary between 1.44 and 1.65 which are within the typical range (1.3 – 1.8).
What range of specific runoffs (l/s/ha) do the results equate to? Are there any inconsistencies?	The 1% AEP specific runoff range between 5.9 and 7.9 l/s/ha which are within the typical range (2 – 10).
How do the results compare with those of other studies? Explain any differences and conclude which results should be preferred.	N/A.
Are the results compatible with the longer-term flood history?	TBC – will be confirmed against model outputs. There is no gauged data within these catchments to compare the design flow estimates against.
Describe any other checks on the results	N/A

5.5 Final results

Site code	**Flood peak (m^3/s) for the following Annual Exceedance Probabilities (%)**								
	50	**10**	**5**	**3.33**	**2**	**1.33**	**1**	**1 (+CC)**	**0.1**
MFS01	2.0	3.4	4.1	4.5	5.0	5.5	5.9	7.1	9.7
MFS02	2.1	3.7	4.4	4.8	5.4	6.0	6.4	7.6	10.5
RS01	5.8	9.7	11.2	12.1	13.3	14.3	15.0	18.0	21.6
RS02	6.2	10.3	11.9	12.9	14.2	15.2	16.0	19.2	23.1

If flood hydrographs are needed for the next stage of the study, where are they provided? (e.g. give filename of spreadsheet, name of ISIS model, or reference to table below)	Flood hydrographs are required for the hydraulic modelling and will be provided in individual ISIS Event Data

	(.IED) files. The majority of Headcorn is affected by the Moat Farm Stream and therefore the critical duration was tested for this catchment. A brief assessment of storm durations and peak flows was carried out in order to determine the critical duration at the downstream location for the hydraulic model. A storm duration of 10.25 hours was found to produce the highest 1% AEP flow estimate at MFS02 (ARF=0.965). As the critical duration is close to the storm duration of the River Sherway, both the 7.5hr and 10.75hr storm will be run through the hydraulic model.

6 Annex – supporting information

6.1 Pooling group composition

Table 6-1: Moat Farm Stream (MFS02) Final Pooling Group

Rank	Station Number	Similarity Distance Measure	Years of Data	AREA	QMED AM	L-CV	L-SKEW	Discordancy
1	27073	1.050	32	8.06	0.197	-0.022	0.771	0.813
2	26802	1.549	13	15.85	0.261	0.199	0.458	0.109
3	20002	1.556	41	26.31	0.292	0.015	1.534	3.299
4	27051	1.557	40	8.15	0.222	0.149	0.654	4.539
5	25019	1.656	34	15.07	0.347	0.394	0.810	5.538
6	203046	1.778	30	22.51	0.136	0.091	1.149	10.934
7	45816	1.922	19	6.81	0.324	0.434	0.839	3.456
8	36010	1.971	45	27.58	0.418	0.228	2.046	6.759
9	27010	2.009	41	18.84	0.224	0.293	0.458	9.420
10	44008	2.036	33	20.17	0.395	0.332	1.064	0.420
11	28033	2.057	33	7.93	0.266	0.415	0.957	4.666
12	47022	2.100	19	13.45	0.257	0.071	0.574	7.331
13	72014	2.134	45	28.99	0.193	0.059	0.746	17.703
14	41020	2.176	43	35.42	0.214	0.208	0.841	13.490
15	73015	2.183	21	30.06	0.156	0.001	0.802	12.239
16	25011	2.187	26	12.79	0.241	0.326	2.297	15.878
	Total		515					
	Weighted					0.259	0.199	

Table 6-2: River Sherway (RS02) Final Pooling Group

Rank	Station Number	Similarity Distance Measure	Years of Data	AREA	QMED AM	L-CV	L-SKEW	Discordancy
1	20002	0.593	41	26.31	3.299	0.292	0.015	1.515
2	33054	1.118	36	48.51	1.129	0.214	0.069	0.116
3	33032	1.244	44	56.18	0.461	0.315	0.099	1.043
4	41020	1.319	43	35.42	13.49	0.214	0.208	1.429
5	26003	1.374	52	59.40	1.739	0.243	-0.015	0.879
6	34005	1.404	51	72.12	3.146	0.281	0.181	0.874
7	36003	1.441	49	56.46	3.841	0.310	0.109	0.741
8	203046	1.471	30	22.51	10.934	0.136	0.091	1.047
9	36010	1.519	45	27.58	6.759	0.418	0.228	1.702
10	72014	1.532	45	28.99	17.703	0.193	0.059	0.951
11	36004	1.560	45	50.32	4.938	0.306	0.199	0.951
12	73015	1.569	21	30.06	12.239	0.156	0.001	0.751
	Total		502					
	Weighted					0.259	0.105	

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