Flood estimation report:

Land at Northwest Bicester

Introduction

This report template is 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

Approvals

Revision stage	Analyst / Reviewer name & qualifications	Amendments	Date
Method statement preparation	GEORGE FRISBY	N/A	02/11/2021
Initial calculations preparation	GEORGE FRISBY	N/A	02/11/2021
Calculations - Revision 1 preparation	GEORGE FRISBY	N/A	02/11/2021
Report Update in Response to EA Comments	GEORGE FRISBY		04/02/2022

Review by Matthew Scott

Abbreviations

AEP................................ annual exceedance probability
AM.................................. Annual Maximum
AREA .... Catchment area (km^2)
BFI .... Base Flow Index
BFIHOST .... Base Flow Index derived using the HOST soil classification
CPRE.............................. Council for the Protection of Rural England
FARL............................... FEH index of flood attenuation due to reservoirs and lakes
FEH................................ Flood Estimation Handbook
FSR................................ Flood Studies Report
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)
ReFH .... Revitalised Flood Hydrograph method
ReFH2 .... Revitalised Flood Hydrograph 2 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 SUMMARY OF ASSESSMENT

1.1 Summary

This table provides a summary of the key information contained within the detailed assessment in the following sections. The aim of the table is to enable quick and easy identification of the type of assessment undertaken. This should assist in identifying an appropriate reviewer and the ability to compare different studies more easily.

Catchment location	North Bicester - 457650,224300
Purpose of study and scope	Inflows for hydraulic model – A lumped catchment (DS_R01) and two sub catchments (US_R01 and US_R02).
Key catchment features	Permeable Catchment – Rural
Flooding mechanisms	Fluvial and potential Groundwater
Gauged / ungauged	Ungauged
Final choice of method	FEH
Key limitations / uncertainties in results	Interaction with Groundwater during long duration storm events.

1.2 Note on 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.

Annual exceedance probability (AEP) and related return period reference table

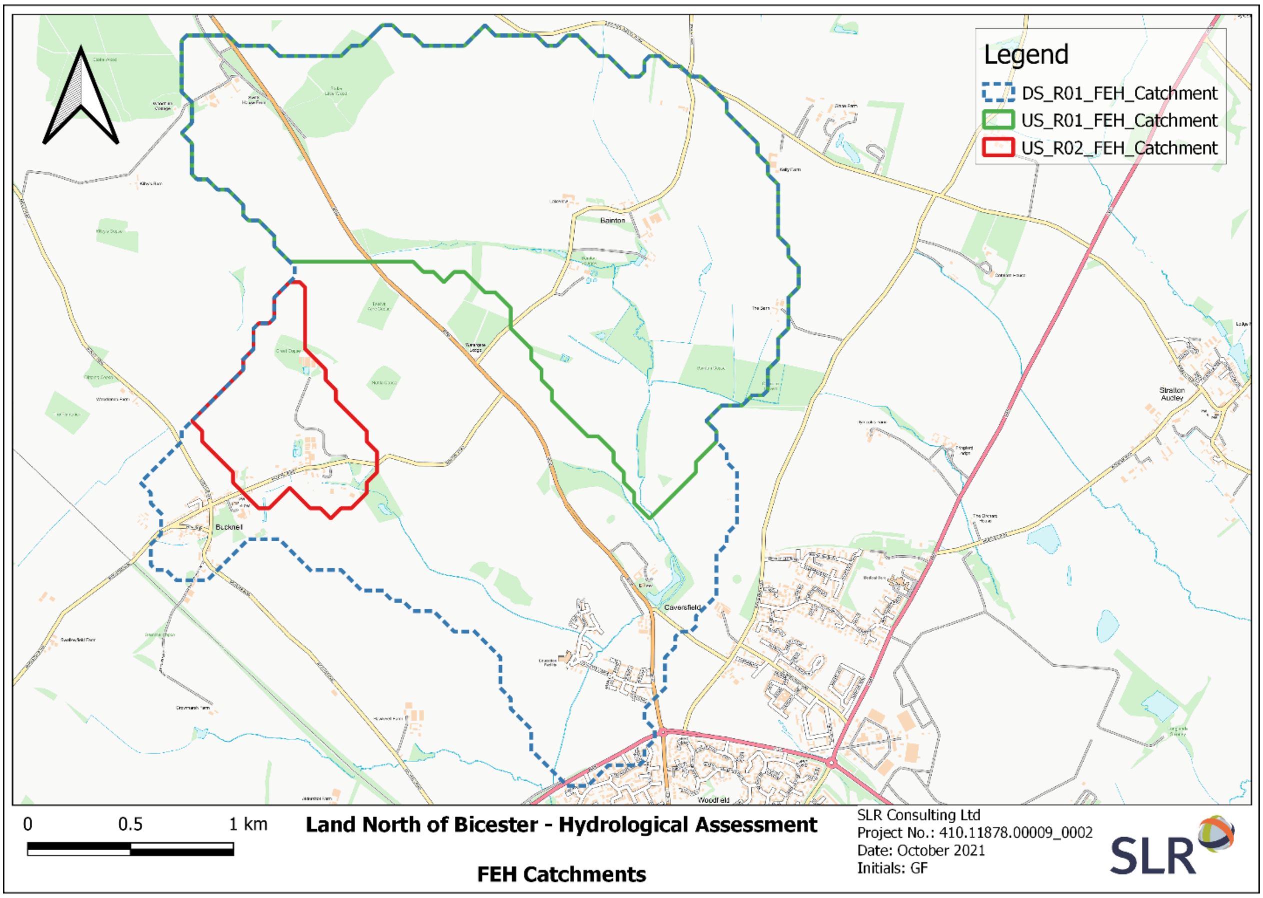
AEP (%)	50	20	10	5	3.33	2	1.33	1	0.5	0.1
AEP	0.5	0.2	0.1	0.05	0.033	0.02	0.0133	0.01	0.005	0.001
Return period (yrs)	2	5	10	20	30	50	75	100	200	1,000

2 METHOD STATEMENT

2.1 Requirements for flood estimates

Overview	Estimate peak flows and generate associated hydrographs for use as upstream boundary conditions/inflows to a hydraulic model covering Bainton, Swallowfield Farm and Caversfield. 1 lumped catchment and 2 sub catchments. 0.05, 0.01 and 0.001 AEP flood events Allowance for climate change (CC) of 15 and 25% (allowance for relevant EA catchment) applied to the 0.01 AEP hydrographs in the hydraulic model.
Project scope	No existing hydrological studies incorporated into this assessment.

2.2 The catchment



Description	The total area is divided into one lumped catchment and 2 sub catchments as shown in the figure above. The two main catchment watercourses converge at 457882, 224889 before flowing south west – under the A4095 Bicester bypass, which forms the lumped catchment (DS_R01) outlet. The Geology of the catchment is predominantly Cornbrash Formation Limestone, with in channel bedrock of Forest Marble Limestone and Mudstone and superficial deposits of alluvium (clay, silt, sand and gravel). The porous limestone in the catchment leads to high levels of permeability. Rural, predominantly agricultural catchment area with low relief, falling from approx. 120m Above Ordnance Datum in the northern upper end of the catchment, to 80m AOD at the Bicester bypass and catchment outlet.

2.3 Source of flood peak data

Source	NRFA peak flows dataset, Version 10, released August 202021. This contains data up to water year 2019/20.

2.4 Gauging stations (flow or level)

All Gauging stations below are deemed suitable for QMED estimates

Water-course	Station name	NRFA number	Distance (km)	BFIHOST	Catchment area (km²)	QMED observed	Pooling Suitability
Bedford	Thornborough Mill	33005	11.34	0.822	387.67	21.8	Yes
Cherwell	Enslow Mill	39021	17.72	0.48	555.45	19.3	Yes
Tove	Cappenham Bridge	33018	22.39	0.59	132.55	17.04	No
Cherwell	Banbury	39026	24.7	0.368	204.59	16.731	No
Evenlode	**Cassington Mill**	**39034**	**24.86**	**0.41**	**427.14**	**20.6**	**Yes**
Thames	Days Weir	39002	29.63	0.699	3480.00	148.014	Yes

2.5 Hydrological understanding of catchment

Conceptual model	Main site of interest is at Caversfield House, and therefore flood risk is dominated by flows in US_R01. Therefore, the critical duration for this reach will dictate the durations for the other catchments.
Unusual catchment features	FEH catchment descriptors indicate the catchment is highly permeable – with very high BFIHOST of 0.822 and a low SPRHOST of 15.59%.

2.6 Initial choice of approach

Is FEH appropriate?	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?	FEH statistical method – Including permeable adjustment method as the SPRHOST of the catchment is below the threshold of 20%. Hydrographs will be derived using ReFH2. FEH statistical method will be completed on the total lumped catchment (DS_R01). ReFH2 completed on the lumped catchment and the sub catchments. US_R01 and US_R02 sub catchment hydrographs to be scaled proportionately using the FEH statical method and the relative peak flows derived from the ReFH2 hydrographs.
Software to be used (with version numbers)	FEH Web Service[1] / WINFAP 42.7282[2] / ReFH spreadsheet / ReFH2.3 / Flood Modeller Pro

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

[2] WINFAP 4 © Wallingford HydroSolutions Limited 2016.

3 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.

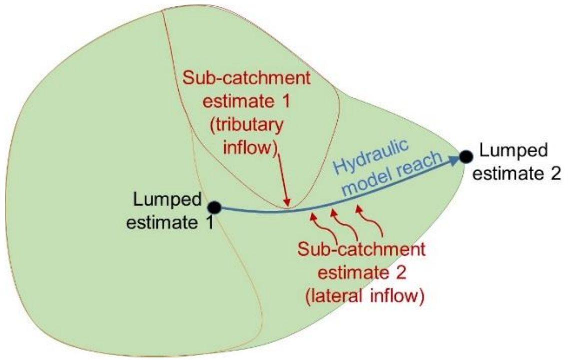
3.1 Summary of subject sites and key catchment descriptors

Site code	Type of estimate L: lumped catchment S: Sub-catchment	Watercourse (all officially unnamed)	Easting	Northing	AREA on FEH Webservice	BFI HOST	SPR HOST (%)	URBEXT 2000	FARL
DS_R01	L	Reach 1	457650	224300	7.60	0.822	15.59	0.0105	0.965
US_R01	S	Reach 1	458100	225550	3.88	0.788	18.08	0.0071	1
US_R02	S	Reach 2	456700	225700	0.53	0.754	20.58	0.0165	1

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.



3.2 Checking catchment descriptors

Record how catchment boundary was checked and describe any changes	The FEH webservice catchment delineation was checked against OS mapping contours and contoured 2m LiDAR data and was found to be an appropriate estimate for the catchment.
Record how other catchment descriptors were checked and describe any changes.	Checked against OS mapping and BGS superficial/bedrock geology and hydrogeology maps. High permeability values were validated due to the predominant limestone geology of the area.

4 STATISTICAL METHOD

4.1 Application of Statistical method

What is the purpose of applying this method?	Statistical method applied only for the overall lumped catchment (DS_R01). This is the only catchment deemed appropriate for this type of analysis – with the subcatchments being too small (less than 5km²)

4.2 Overview of estimation of QMED at each subject site

Site code	QMED (rural) from CDs (m^3/s)	Final method	Data transfer					Urban adjust-ment factor UAF	Final estimate of QMED (m^3/s)
			NRFA numbers for donor sites used (see 4.3)	Distance between centroids d_{ij} (km)	Moderated QMED adjustment factor, $(A/B)^a$	If more than one donor: Weight	If more than one donor: Weighted ave. adjustment		
DS_01	0.290	0.298	1	24.86		1	-	-	**0.298**

Are the values of QMED spatially consistent?		-
Method used for urban adjustment for subject and donor sites		WINFAP v4[3]
Parameters used for WINFAP v4 urban adjustment if applicable		
Impervious fraction for built-up areas, IF	Percentage runoff for impervious surfaces, PR_{imp}	Method for calculating fractional urban cover, URBAN
0.3	70%	From updated URBEXT2000

Notes

Methods: AM – Annual maxima; POT – Peaks over threshold; DT – Data transfer (with urban adjustment); CD – Catchment descriptors alone (with urban adjustment); BCW – Catchment descriptors and bankfull channel width (add details); LF – Low flow statistics (add details).

The QMED adjustment factor A/B for each donor site is 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 (rural) estimate from catchment descriptors.

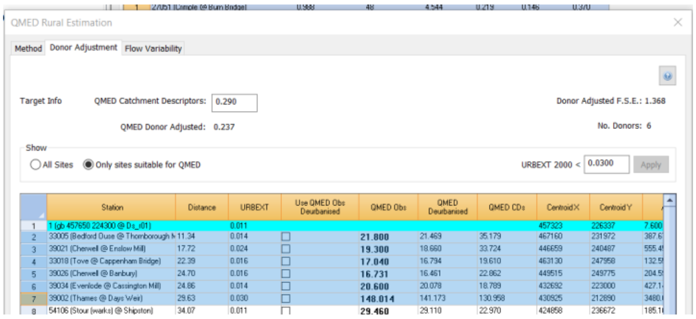
Important note on urban adjustment

The method used to adjust QMED for urbanisation published in Kjeldsen (2010)**Error! Bookmark not defined.** in which PRUAF is c alculated from BFIHOST is not correctly applied in WINFAP-FEH v3.0.003. Significant differences occur only on urban catchments that are highly permeable. This is discussed in Wallingford HydroSolutions (2016)[3].

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

4.3 Search for donor sites for QMED (if applicable)

Comment on potential donor sites	The 5 closest donor sites are listed in Section 2.4. Gauging station 39034 (Evenlode @ Cassington Mill) has been selected as this is the only catchment with similar geology and to DS_R01 – with majority limestone and permeable bedrock. This is reflected in the high value of BFI HOST. Therefore the relationship between the observed and Catchment Descriptor values of QMED (ratio of 1.07) is incorporated in to the QMED estimation. If all 6 geographically nearest gauging stations are used, the donor adjusted estimate for QMED is 0.237. We are therefore using a more conservative (higher) estimate of donor adjusted QMED based upon study of the underlying geology of the local catchments.



4.4 Derivation of pooling groups and growth curves

The pooling group has been generated using WINFAP v.4. Station 206006 (Annalog @ Recorder) has been removed due to old dataset and 72014 (Conder @ Galgate) has been added to being a suitable small catchment. The pooling group can be found in **Appendix 01** along with the details of the application of the permeable adjustment method. Only the GL distribution can be applied to the permeable adjustment method.

4.5 Derivation of flood growth curves at subject sites – Perm adjusted GL distribution

Site code	Flood peak (m³/s) for the following return periods (in years)									
	2	5	10	20	25	50	100	200	500	1000
	Flood peak (m³/s) for the following AEP (%) events									
	50	20	10	5	3.33	2	1.33	1	0.5	0.1
DS_R01	1.000	1.445	1.784	2.161	2.294	2.751	3.285	3.915	4.926	5.854

4.6 Flood estimates from the statistical method

Site code	Flood peak (m³/s) for the following return periods (in years)									
	2	5	10	20	25	50	100	200	500	1000
	Flood peak (m³/s) for the following AEP (%) events									
	50	20	10	5	3.33	2	1.33	1	0.5	0.1
DS_R01	**0.30**	**0.43**	**0.53**	**0.64**	**0.68**	**0.82**	**0.98**	**1.17**	**1.47**	**1.74**

6 REVITALISED FLOOD HYDROGRAPH 2 (REFH2) METHOD

6.1 Application of ReFH2 method

The ReFH2 (version 2.3) method has been applied at all lumped and sub-catchments. The ReFH2 identified critical storm duration for the US-R01 (key reach for the site) catchment has been applied to all other catchments in the study so that uniform storm durations can be applied throughout the hydraulic model.

The ReFH2 full details and parameterisation can be found in **Appendix 02**.

7 DISCUSSION AND SUMMARY OF RESULTS

7.1 Comparison of results from different methods

The table below shows the comparison in ReFH2 and statistical peak flows for the lumped downstream catchment.

Site code	DS_R01 Flood peak (m^3/s) for the following return periods (in years)									
	2	5	10	20	25	50	100	200	500	1000
	DS_R01 Flood peak (m^3/s) for the following AEP (%) events									
	50	20	10	5	3.33	2	1.33	1	0.5	0.1
Statistical Method	**0.30**	**0.43**	**0.53**	**0.64**	**0.68**	**0.82**	**0.98**	**1.17**	**1.47**	**1.74**
ReFH2				**0.84**			**1.24**			**2.19**

Final Peak flows for all sub catchments shown below.

Design Event	Catchment			
	Total	Reach 1	Reach 2	Lateral
	7.60 km^2	3.88 km^2	0.53 km^2	3.19 km^2
1 in 20	0.64	0.33	0.04	0.27
1 in 100	0.98	0.50	0.07	0.41
1 in 100 + 15%CC	1.13	0.58	0.08	0.47
1 in 100 + 25%CC	1.23	0.63	0.09	0.51
1 in 1000	1.74	0.89	0.12	0.73

Due to the catchment being permeable, it is deemed more appropriate to use the peak flows from the statistical method analysis. These include allocation for the permeable adjustment method and adjusted QMED from a suitable donor catchment with similar catchment characteristics and geology. These significant elements of the catchment are not considered fully by the ReFH2 calculations.

The US_R01 ReFH2 (key catchment) hydrograph shape has been used for all catchments to allow for the correct estimation of the lateral inflows. The same hydrograph shape must be applied for all sub catchments and the lumped catchment as the lateral inflow is calculated by subtracting the two upstream sub catchments from the downstream lumped catchment flow. This lateral inflow divided and applied at 10 discrete locations along the model reach as shown in the accompanying hydraulic modelling report.

The ReFH2 hydrograph is scaled using the relationship of the ReFH2 and statistical method peak flows for DS_R01, as this is the only location where the statistical method has been applied. The scaling factor for each sub catchment is based upon the relative catchment areas.

The final scaled hydrographs are contained in **Appendix 03**.