Flood estimation calculation record for single sites

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 a single location.

Contents

Approval

	Name and qualifications
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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	The aim of the study is to derive peak flow estimates using the FEH Statistical and ReFH hydrological methods, for a small catchment south of Leek, Staffordshire. Results will include peak flows for the 100-year and 100-year accounting for climate change (20% increase) flood events.

1.2 Overview of catchment

Item	Comments
Brief description of catchment, or reference to section in accompanying report	The site of interest is a small ungauged catchment of the Leekbrook*, which flows in a westerly direction towards and through the small village of Leekbrook, south of Leek. The Leekbrook is a left-bank tributary of the River Churnet, joining between Leek and Cheddleton. Field and agricultural drains appear to feed into the Leekbrook at its upstream extent. An unnamed tributary flows in a southerly direction, north of Leekbrook, and joins it just upstream of the village. The catchment is essentially rural and impermeable. *The name of the watercourse is not visible on OS mapping; however, the Staffordshire SFRA suggests it is called the Leekbrook and for the purposes of this assessment it will be referred to thusly.

1.3 Source of flood peak data

Was the HiFlows UK dataset used? If so, which version? If not, why not? Record any changes made	Yes – Version 3.1.4, August 2014

1.4 Gauging stations (flow or level)

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

The FEH CD-ROM and HiFlows-UK has been used to search for a potential donor site. Given the data transfer procedures to moderate the effect of a more distant donor site, only donors local to the subject site were considered (15km).

After an initial search for potential gauging stations for donor sites, five gauges within the 15km buffer were found. Only one of these gauges were considered suitable for QMED adjustment, highlighted in bold below, as the other catchments were too large in comparison to the study catchment.

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
River Churnet	Churnet at Basford Bridge	28061	28061	SJ982519	139	N/A	N/A
River Dane	Dane at Hug Bridge	68044	68044	SJ930636	73		
River Trent	Trent at Stoke-On-Trent	28040	28040	SJ891466	53		
River Hamps	Hamps at Waterhouses	28041	28041	SK082501	35		
River Dove	**Dove at Hollinsclough**	**28033**	**28033**	**SK063668**	**8**	**Compound Crump Weir**	**1965 - 2013**

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.
Dove at Hollinsclough	1965 - 2012	N/A	Yes – Theoretical range should be reasonable to QMED	Yes	N/A Beyond the scope of study	Station measures outflow from a small experimental catchment, established to investigate the water balance of a Millstone Grit catchment typical of the area south of the High Peak. Small compound Crump weir in rocky channel. Modular through range. All recorded flows contained by the structure. One rating applied across period of record, based on rating tables not gaugings. Difficult to gauge higher flows, the largest of which suggests rating underestimates flow.

1.6 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	N/A	N/A			
Historic flood data – give link to historic review if carried out.	No	The Staffordshire SFRA[1] refers to the River Churnet SFRM Flood Risk Mapping Study, which was completed in October 2007. Part of the Leekbrook was included in this model, however it does not state how much. The Environment Agency advised that some uncertainties came to light in the modelled flood maps. An internet search was unable to locate the River Churnet Mapping Study report. For information on the flood history see section 5.1 in the Annex.			
Flow data for events	N/A	N/A			

[1] Staffordshire Moorlands District Council: Strategic Flood Risk Assessment for Local Development Framework, Level 1, January 2008

Rainfall data for events	N/A	N/A			
Potential evaporation data	N/A	N/A			
Results from previous studies	N/A	N/A			
Other data or information (e.g. groundwater, tides)	N/A	N/A			

1.7 Initial choice of approach

Is FEH appropriate? (it may not be for very small, heavily urbanised or complex catchments) If not, describe other methods to be used.	An initial review of catchment descriptors indicated that FEH methods are appropriate, as the catchment is essentially rural and there are no unusual catchment features.
Outline the conceptual model, addressing questions such as: • Where are the main sites of interest? • What is likely to cause flooding at those locations? (peak flows, flood volumes, combinations of peaks, groundwater, snowmelt, tides…) • Might those locations flood from runoff generated on part of the catchment only, e.g. downstream of a reservoir? • Is there a need to consider temporary debris dams that could collapse?	The site of interest is a small catchment of the Leekbrook watercourse at the Brooklands Way residential area, flowing in a predominantly westerly direction towards the village of Leekbrook south of Leek. The Leekbrook confluences with the River Churnet as a left-bank tributary, west of the Leekbrook village. Given the relatively small nature of the catchment, flooding is likely to be caused by peak flows. There is potentially a rapid response to rainfall events due to the steepness of the catchment, represented by a high DPSBAR (86 m/km), and the impeded drainage of the clayey soils.
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	There are no unusual catchment features. The site is not considered permeable (BFIHOST=0.37), and there is no reservoir influence or attenuation (FARL=1.00). The catchment is small and is characterised as essentially rural ($URBEXT_{1990}$ = 0.0004).
Initial choice of method(s) and reasons Will the catchment be split into sub-catchments? If so, how?	The methods used, as requested by the client, are: - FEH statistical - ReFH
Software to be used (with version numbers)	FEH CD-ROM v3.02 WINFAP-FEH v3.0.0023 ReFH spreadsheet

[2] FEH CD-ROM v3.0 © NERC (CEH). © Crown copyright. © AA. 2009. All rights reserved.
[3] WINFAP-FEH v3 © Wallingford HydroSolutions Limited and NERC (CEH) 2009.

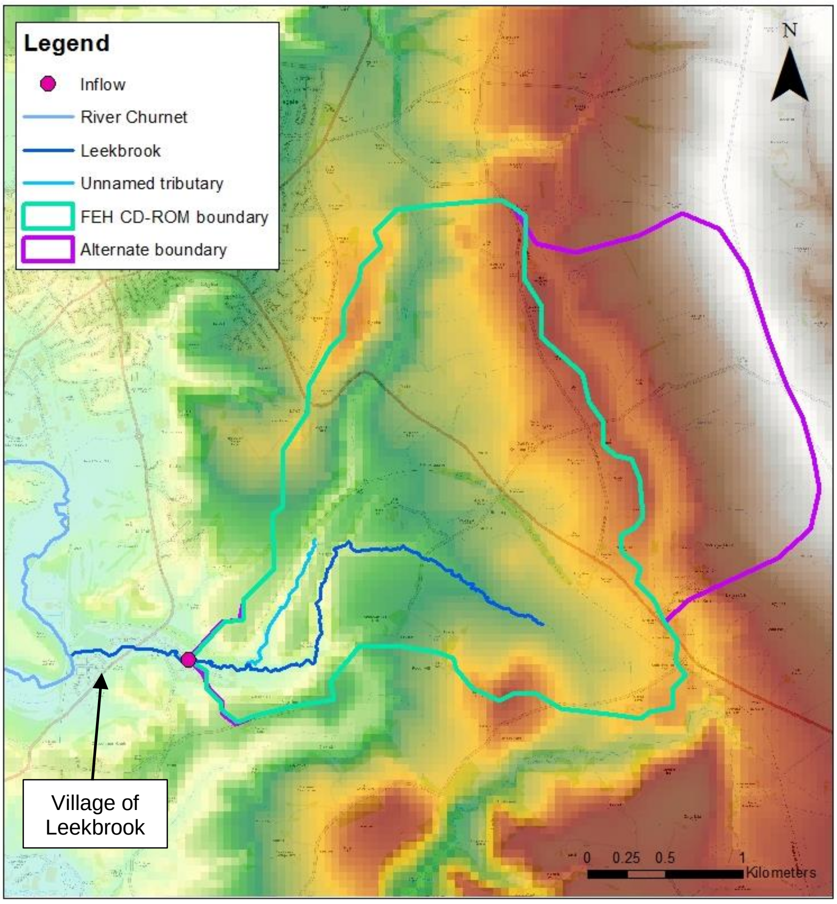
1.8 Site details

Watercourse	Site	Easting	Northing	AREA on FEH CD-ROM (km^2)	Revised AREA if altered
Leekbrook	Brooklands Way, Leekbrook	399250	353850	6.27	N/A

1.9 Catchment descriptors (incorporating and changes made)

FARL	PROPWET	BFIHOST	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	SPRHOST	URBEXT 1990	FPEXT
1.000	0.44	0.373	2.82	86.9	984	36.03	0.0004	0.0279

1.10 Checking catchment descriptors

Record how catchment boundary was checked and describe any changes (refer to maps if needed)	The catchment boundary was checked against elevation contours and local watercourses on OS 1:10,000 and OS 1:50,000 mapping, as well as against broad-scale LIDAR. The catchment from the FEH CD-ROM does not appear to match the watercourses shown on the OS mapping; the OS mapping appears to show the upstream extent of the Leekbrook being fed by drains flowing parallel to each other from the uplands, east of the study catchment. According to the mapped watercourse, the drains feed into both the study catchment and a catchment to the south, which later becomes the Coombes Brook catchment. The Environment Agency surface water drainage maps were checked to see if flow paths do indeed exist between the upland drains and study catchment. The lack of flow paths in the EA maps led to the decision to use the boundary from the FEH CD-ROM, as the surface water in the mapping appeared to follow the watercourse flowing in a southerly direction into the Coombes Brook rather than into the study catchment. **Figure 1: Leekbrook catchment boundary map**  Contains Ordnance Survey data © Crown copyright and database right 2015.

Record how other catchment descriptors (especially soils) were checked and describe any changes. Include before/after table if necessary.	The SPRHOST value was checked against the Soil Map of England and Wales. The soils are described as acidic loamy and clayey soils with impeded drainage throughout the catchment. This is consistent with the SPRHOST values from the FEH CD-ROM.
Source of URBEXT	$URBEXT_{1990}$ (used for ReFH method) $URBEXT_{2000}$ (used for FEH Statistical method)
Method for updating of URBEXT	CPRE formula from FEH Volume 4 for $URBEXT_{1990}$ CPRE formula from 2006 CEH report on $URBEXT_{2000}$.

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2 Statistical method

2.1 Search for donor sites for QMED

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 search for donor stations was undertaken using a 15km buffer around the study catchment. Five gauges were located within the 15km boundary, which were considered from HiFlows-UK. Only one of these stations was considered suitable for QMED adjustment, as the other catchments were too large in comparison. However, the NFRA websites states that the Dove at Hollinsclough gauge underestimates high flows. A review of the AMAX series found QMED to be significantly underestimated compared to the QMED derived from catchment descriptors. Therefore, the lack of confidence in the gauge data of the Dove at Hollinsclough station, and the absence of other suitable donor stations has resulted in donor transfer not being possible for the study catchment.

2.2 Donor sites chosen and QMED adjustment factors

Although the Dove at Hollinsclough station has been rejected for donor transfer it has been included in the table below to show the significant difference in QMED between the data and catchment descriptors.

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)
28033	REJECTED: The NFRA website states that it is difficult to gauge higher flows at this station, the largest of which suggests rating underestimates flow. For this reason, and because of the inconsistency of QMED in the AMAX series compared to the NFRA site and CD QMED it has been rejected as a donor site.	AM	N/A	2.67	7.30	0.361

2.3 Overview of estimation of QMED at each subject site

Site code	Method	Initial estimate of QMED (m^3/s) RURAL	Data transfer: NRFA numbers for donor sites used (see 3.3)	Data transfer: Distance between centroids d_{ij} (km)	Data transfer: Power term, a	Data transfer: Moderated QMED adjustment factor, (A/B)[a]	Data transfer: If more than one donor: Weight	Data transfer: If more than one donor: Weighted average adjustment factor	Final estimate of QMED (m^3/s) URBAN
LB_01	CD	3.85	N/A						3.86

Are the values of QMED consistent, for example at successive points along the watercourse and at confluences?	The QMED value appears consistent with the size and characteristics of the catchment.
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)[4] 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.

2.4 Derivation of pooling groups

The composition of the pooling groups is given in the Annex.

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)
No	Stations removed: 49006 (Camel at Camelford) • Record of data is 6 years which is below the FEH recommended limit (8 years). Other checks have been undertaken looking at flood seasonality, L-moments and site growth curves. The pooling group did not contain any other anomalous stations. Note that the final pooling group is heterogeneous and a review of the pooling group is desirable. Total years: 503. The final pooling group is provided in the Annex.	L-moments: L-CV: 0.253 L-Skew: 0.256
Note: Pooling group was derived using the revised procedures from Science Report SC050050 (2008).		

2.5 Derivation of flood growth curves at subject sites

Method (SS, P, ESS, J)	**Distribution used and reason for choice**	**Note any urban adjustment (and state v2 or v3) or permeable adjustment**	**Parameters of distribution** (location, scale and shape) after adjustments	**Growth factor for 100-year return period**
P	GL and GEV recommended by WINFAP. GL chosen	Urban adjustment (v3)	Location: 1.000 Scale: 0.252 Shape: -0.257	3.21
Notes Methods: SS – Single site; P – Pooled; ESS – Enhanced single site; J – Joint analysis Urban adjustments can be either v2: FEH (1999) updated by Bayliss (2006) or v3: Kjeldsen (2010). Growth curves were derived using the revised procedures from Science Report SC050050 (2008).				

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

2.6 Flood estimates from the statistical method

Flood peak (m^3/s) for the following return periods (in years)	
100	**100+CC**
12.4	14.9

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3 Revitalised flood hydrograph (ReFH) method

3.1 Parameters for ReFH model

As well as calculating peak flows, ReFH provides a suitable means of obtaining a hydrograph for final inflows. Catchment descriptors are used to derive hydrograph shapes, which can then be scaled to the final peak flows and applied to a model.

The tables below record the parameters used in the ReFH model. The hydrograph was derived for a winter rainfall profile and used the ReFH recommended critical storm duration.

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
CD	2.04	285	30.7	0.96
Brief description of any flood event analysis carried out (further details should be given below or in a project report)	The storm duration recommended by ReFH for this catchment was 4.0hrs.			

3.2 Design events for ReFH method

Urban or rural	Season of design event (summer or winter)	Storm duration (hours)	Storm area for ARF (if not catchment area)
Rural	Winter	4.5	0.96

3.3 Flood estimates from the ReFH method

Flood peak (m3/s) for the following return periods (in years)	
100	**100+CC**
9.8	11.8

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4 Discussion and summary of results

4.1 Comparison of results from different methods

This table shows the ratio of the REFH peak flow to Statistical peak flow for the two return period flood events assessed.

Ratio of peak flow to FEH Statistical peak	
Return period 100 years	**Return period 100 years plus CC**
ReFH	**ReFH**
0.79	0.79

4.2 Final choice of method

Choice of method and reasons – include reference to type of study, nature of catchment and type of data available.	The scope of this commission was to carry out peak flow estimates using the FEH statistical method and ReFH methods, choosing a final method that is most appropriate. The Statistical method and ReFH methods produced similar flows, with the Statistical method rendering slightly higher flows. The final choice of method was the FEH statistical method because it is more suitable for small, rural catchments in comparison to the ReFH method. The FEH Statistical benefits from an up-to-date flood peak dataset, sourcing flow estimates on growth curves from hydrologically similar catchments (pooled analysis). The FEH Statistical method has the advantage of avoiding the need to make assumptions about factors such as the nature of the design flood, the rainfall duration, the time of concentration etc. The FEH Statistical method also produced the most conservative results when compared with the ReFH method.

4.3 Assumptions, limitations and uncertainty

List the main assumptions made (specific to this study)	It is assumed that: • QMED estimated from catchment descriptors is representative • The pooling group is representative of the study catchment • The drains of the upland valley to the northwest of the catchment flow into the catchment to the south, rather than the study catchment.
Discuss any particular limitations, e.g. applying methods outside the range of catchment types or return periods for which they were developed	• There are only a low number of small gauged sites in the UK meaning the representation of the pooling group is not ideal. • There is no catchment flow data for the study watercourse to verify the peak flow estimates generated in this study.
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).	Typical confidence intervals for QMED when calculated from catchment descriptors are quoted as 0.49QMED, 2.04QMED (for the 95% confidence interval).
Comment on the suitability of the results for future studies, e.g. at nearby locations or for different purposes.	It is emphasised that the results of the analysis should be considered in the context of the needs of this study. The results of this assessment should be revisited for use on future studies.
Give any other comments on the study, for example suggestions for additional work.	The un-gauged catchment would benefit from local data to refine flow estimates, perhaps a temporary flow logger to be installed on the Leekbrook or unnamed tributary.

4.4 Checks

Are the results consistent, for example at confluences?	The results are consistent with the size and characteristics of the catchment.
What do the results imply regarding the return periods of floods during the period of record?	No return periods of past floods are known.
What is the 100-year growth factor? Is this realistic? (The guidance suggests a typical range of 2.1 to 4.0)	100-year growth factor for FEH Statistical method = 3.21 This appears reasonable for a small catchment.
If 1000-year flows have been derived, what is the range of ratios for 1000-year flow over 100-year flow?	1,000-year peak flows were not required under the scope of the study.
What range of specific runoffs (l/s/ha) do the results equate to? Are there any inconsistencies?	19.76 l/s/ha (100-year) – Statistical
How do the results compare with those of other studies? Explain any differences and conclude which results should be preferred.	No previous studies were available for comparison.
Are the results compatible with the longer-term flood history?	There are no flow records along the rural Leekbrook to set the flows in context. Information from the Staffordshire SFRA: • Records suggest that flash flooding in August 2004 occurred on the Leekbrook at Leekbrook. It is not known, however, how far upstream this flash flooding event affected. • The Leekbrook is identified as experiencing infrequent flooding, including Wardle Gardens and Basford Lane Industrial Estate.
Describe any other checks on the results	N/A

4.5 Final results

The final flows have been derived using the FEH Statistical method.

Flood peak (m^3/s) for the following return periods (in years)	
100	**100+CC**
12.4	14.9

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)	N/A

5 Annex – supporting information

5.1 Historical flooding

In terms of flood history, the River Churnet has two recorded events detailed in the Staffordshire SFRA[5]; the first being November 1959 and the second in December 1964. The Environment Agency's historical flood maps don't give any suggestion that the Leekbrook upstream of the village produced any flooding during these events.

The Staffordshire SFRA does give some reference to records of flash flooding in August 2004 across Staffordshire, including the Leekbrook at Leekbrook. Flooding is therefore known to have occurred in the village of Leekbrook, however an internet search has found no evidence of flooding along the Leekbrook and unknown tributary upstream of the Leekbrook village.

5.2 Pooling group composition

Station ref.	SDM Distance	Years of Data	QMED AM	L-CV	L-Skewness	Discordancy
45816 (Haddeo @ Upton)	0.451	19	3.456	0.324	0.434	0.916
27051 (Crimple @ Burn Bridge)	0.483	40	4.539	0.222	0.149	0.852
28033 (Dove @ Hollinsclough)	0.720	33	4.666	0.266	0.415	0.883
25011 (Langdon Beck @ Langdon)	1.264	26	15.878	0.241	0.326	1.205
25019 (Leven @ Easby)	1.272	34	5.538	0.347	0.394	0.963
47022 (Tory Brook @ Newnham Park)	1.317	19	7.331	0.257	0.071	1.656
26802 (Gypsey Race @ Kirby Grindalythe)	1.390	13	0.109	0.261	0.199	0.394
25003 (Trout Beck @ Moor House)	1.524	39	15.164	0.176	0.291	0.717
206006 (Annalong @ Recorder)	1.530	48	15.330	0.189	0.052	1.690
27010 (Hodge Beck @ Bransdale Weir)	1.551	41	9.420	0.224	0.293	0.192
44008 (South Winterbourne @ Winterbourne Steepleton)	1.640	33	0.420	0.395	0.332	1.399
22003 (Usway Burn @ Shillmoor)	1.768	26	19.220	0.303	0.303	0.450
54022 (Severn @ Plynlimon Flume)	1.838	37	15.031	0.155	0.168	1.326
91802 (Allt Leachdach @ Intake)	1.846	34	6.350	0.153	0.257	1.157
51002 (Horner Water @ West Luccombe)	1.852	31	8.354	0.382	0.326	1.326
203046 (Rathmore Burn @ Rathmore Bridge)	1.858	30	10.934	0.136	0.091	0.875
Total		503				
Weighted means				*0.253*	*0.256*	

[5] Staffordshire Moorlands District Council: Strategic Flood Risk Assessment for Local Development Framework, Level 1, January 2008

Offices at

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Edinburgh

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Limerick

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