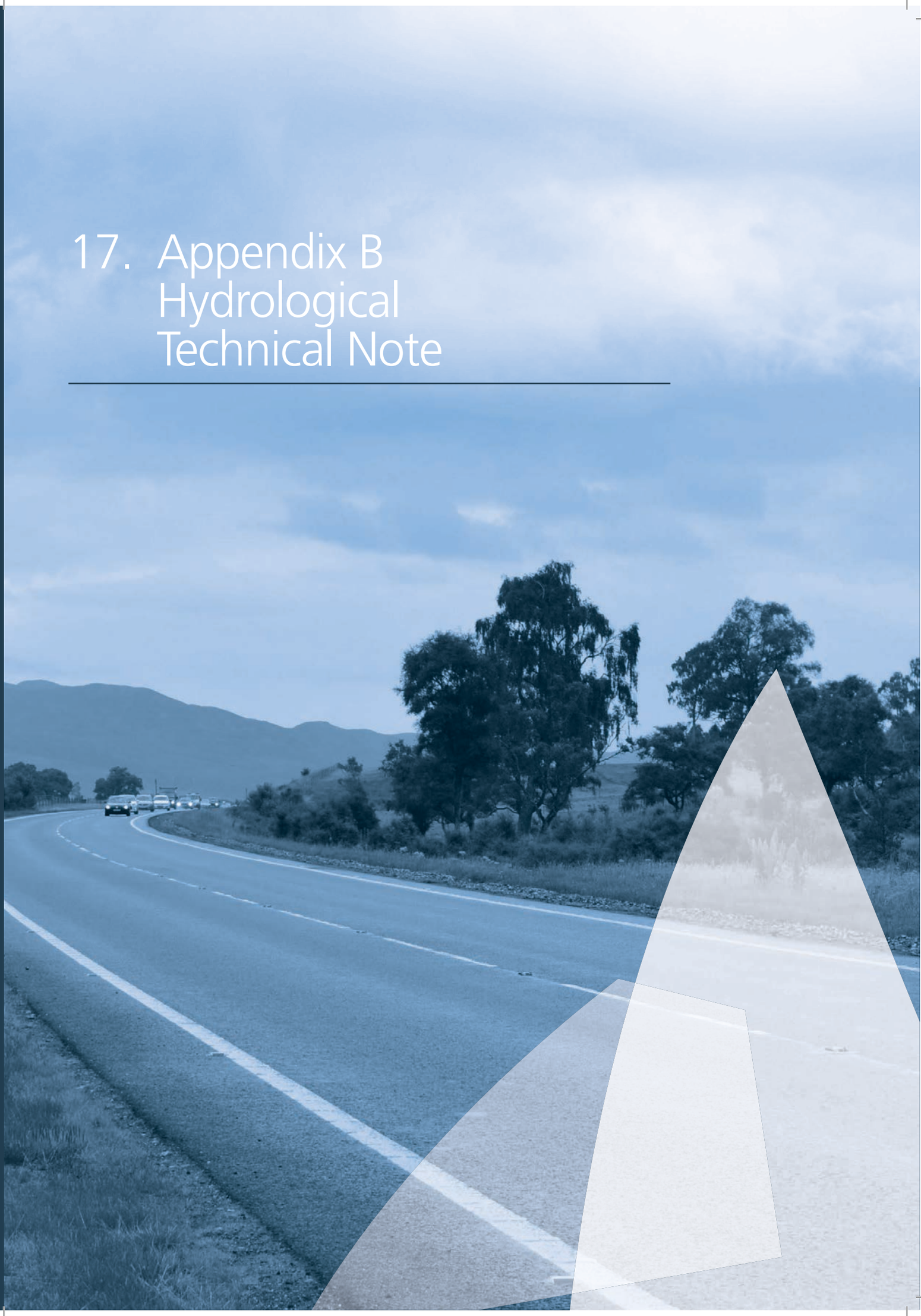
17. Appendix B Hydrological Technical Note



17B. Hydrological Technical Note

Project	A9 Dualling: Kincraig to Dalraddy
Subject	Hydrology Technical note
Date	18th October 2013

1. Introduction

An Environmental Statement (ES) for the proposed A9 Dualling: Kincraig to Dalraddy has been prepared by Atkins and published in November 2013. SEPA highlighted during consultation on the ES that the earthworks at the Allt an Fhearna and Dunachton Burn would potentially encroach onto the Indicative Flood Outlines and recommended a Flood Risk Assessment (FRA) was undertaken to assess any risk to the area.

Hydrological and hydraulic modelling was undertaken to support the FRA. This technical note provides a summary of the hydrological modelling. The Flood Estimation Handbook (FEH) calculation record appended to this document provides fuller detail.

The proposed development crosses six watercourses:

- Unnamed Watercourse at Meadowside (Chainage 0000 metres)
- Dunachton Underpass/Watercourse (Chainage 1660 metres)
- Leault Burn Watercourse (Chainage 3090 metres)
- Baldow Smiddy Underpass/Watercourse (Chainage 3540 metres)
- Unnamed Watercourse at Dalraddy (Chainage 7025)
- Allt an Fhearna Underpass/Watercourse (Chainage 7050 metres).

The proposed structures are detailed in the FRA. During consultation (dated 19.12.12), SEPA expressed concern that the proposed embankments for the A9 Dualling at the Allt an Fhearna were encroaching onto the functional flood plain. The SEPA Indicative Flood Risk Map also showed flooding at the Dunachton Burn crossing. Historical flood records showed reports of flooding at a property adjacent to the unnamed watercourse at Meadowside.

The aim of the hydrological analysis was to derive design flow estimation for input into the InfoWorks RS hydraulic model. Design peak flows and hydrographs were derived using the Flood Estimation Handbook (FEH) for the following events: 50%, 20%, 10%, 5%, 1%, 0.5% and 0.5% with 20% increase in flow as climate change allowance. The hydrological model was built in accordance with UK industry procedures set out in FEH and subsequent related research. This technical note summaries the FEH calculation record, which follows this document.

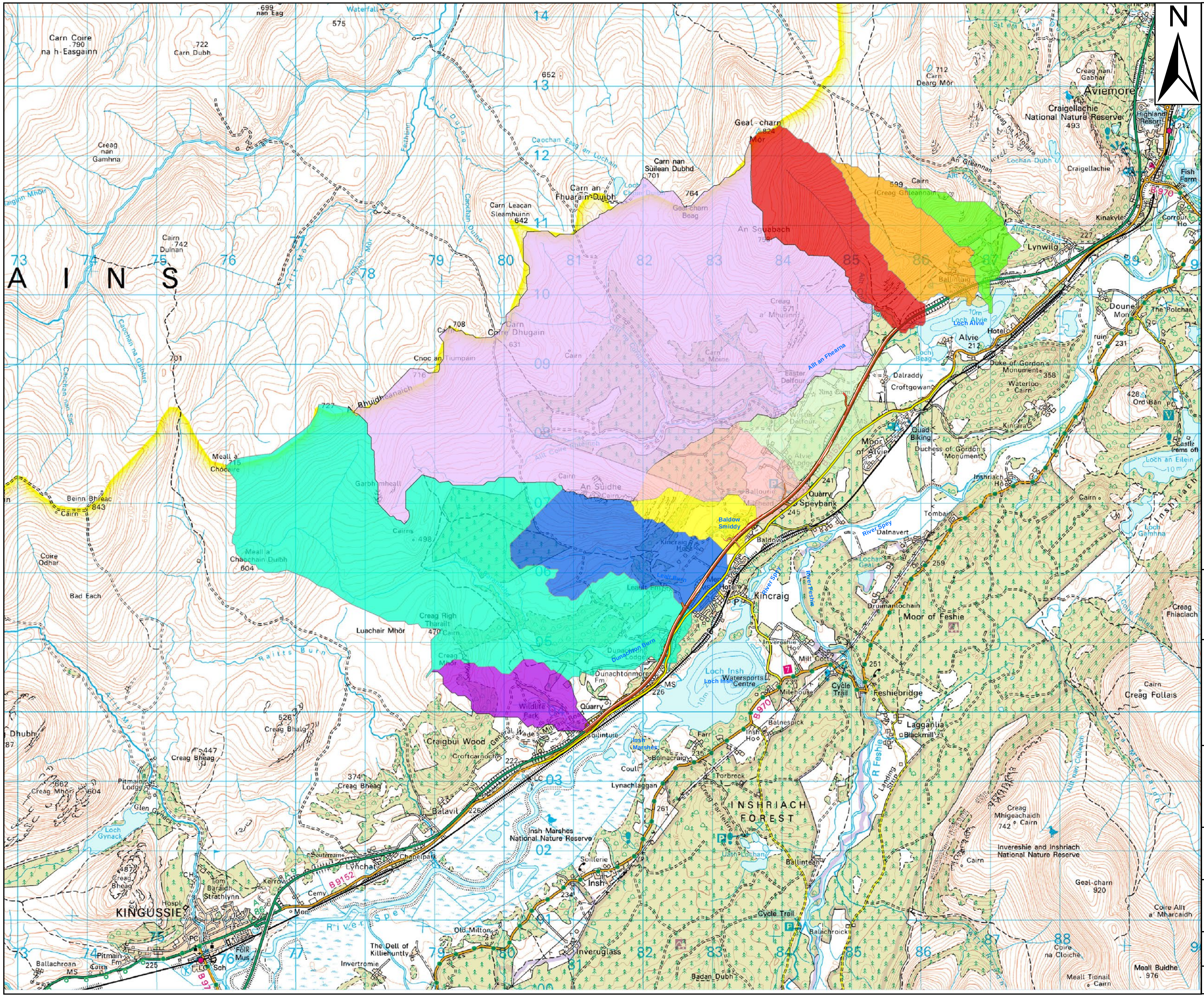
2. Hydrometric Data

There was no hydrometric data on any of the watercourses that are crossed by the proposed Scheme. The nearest gauging station to the site is Spey at Kinrara (8002), which is located on the River Spey approximately 1.36 miles upstream of the confluence of the subject sites. The FEH catchment area for the Spey at Kinrara is 1009 km^2 which is 50 times greater than the catchment for the largest watercourse within the subject site. It is also influenced by Loch Inch. Due to the differences in catchment descriptors the gauging station was considered not suitable within this study.

3. Catchment Delineation

Catchment boundaries for each subject site were delineated using the FEH CD Rom (version 3.0) and checked using OS mapping, with adjustments to the boundaries where necessary. The table and figure below highlight the catchments assessed (Table 3.1 and Figure 3.1).

Watercourse	Site	Easting	Northing	AREA on FEH CD-ROM (km2)	Revised AREA if altered
Dunachton Burn	Where A9 crosses watercourse	282400	804750	11.92	12.56
Leault Burn	Where A9 crosses watercourse	283200	806050	11.92	3.40
Baldow Smiddy	Where A9 crosses watercourse	283450	806300	0.91	1.06
Unnamed watercourse at Dalraddy	Where A9 crosses watercourse	285550	809100	1.78	1.74
Allt na Fhearna	Where A9 crosses watercourse	285300	809100	20.03	20.00
Loch Alvie outflow	Downstream of the loch – includes Allt an Fhearna and unnamed watercourse as well as rivers flowing directly into the loch	287290	809390	31.56	31.82
Unnamed watercourse at Meadowside	Where A9 crosses watercourse at the entrance to the Wildlife Park. (approximately 1.1km from scheme)	281140	803720	1.38	NA
Lower Milehead	Lateral	284000	806950		1.84
Allt Chriochaidh (Loch Alvie 1)	Inflow to Loch Alvie	286000	809600	2.81	2.98
Caochan Ruadh (Loch Alvie 2)	Upstream of Ballinluig inflow to Loch Alvie	286700	809850	1.91	1.84
Unnamed watercourse 3 (Loch Alvie 3)	Inflow to Loch Alvie south of Ballinluig	287000	809750	0.99	1.01



LEGEND

- Proposed New Embankment Works
- Lower Milehead
- Allt Na Fhearna
- Baldow Smiddy
- Dunachton Burn
- Leault Burn
- Unamed Watercourse at Meadowside
- Unamed Watercourse at Dalraddy
- Loch Alvie 1
- Loch Alvie 2
- Loch Alvvie 3

NB: STUDY AREA LIES WITHIN CAIRNGORMS NATIONAL PARK

M
200 0 200

CLIENT NAME: TRANSPORT SCOTLAND

LICENCE NUMBER: SE 100046668 2012

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Consulting Engineers
The Hub,
500 Park Ave,
Bristol,
South Gloucestershire,
England,
BS32 4RZ
Tel: +44(0)1454 662 000
Fax: +44(0)1454 663 333
www.atkinsglobal.com

Client
TRANSPORT SCOTLAND
The Scottish Government

Project
A9 DUALLING PERTH TO INVERNESS
Kincraig to Dalraddy

Title
FIGURE 3.1
CATCHMENT BOUNDARIES

Sheet Size	Original Scale	Designed / Drawn	Checked	Authorised
A3	1:50,000	LG	EM	XX
		Date 18/10/13	Date 18/10/13	Date 18/10/13

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4. Design Flow Estimates

A number of hydrological estimation techniques were used as both hydrographs and peak flows were required. The FEH statistical method and rainfall runoff method were used to obtain the peak flow and hydrographs. The IH124 was also used as it is suitable for smaller catchments. Results were compared and final peak flows were determined.

4.1. FEH Statistical Method

The statistical method uses an index flood, the median annual flood (QMED). This is multiplied by a growth curve to obtain a flood frequency curve. The flood frequency curve is based on a sample of 500 years of data from catchments identified as being similar to the subject site. All calculations were undertaken using WINFAP FEH 3 software and are recorded in a FEH Calculation Record, which is appended to this technical note.

QMED values estimated for the subject sites are shown in Table 4.1. QMED was derived from catchment descriptors. As there were no suitable donor catchments no adjustments were made. The confidence intervals are shown in the FEH Calculation Record.

Table 4-1 Qmed Estimates

Site	QMED (m^3/s) derived from Catchment Descriptors
Dunachton Burn	5.33
Leault Burn	0.98
Baldow Smiddy	0.20
Unnamed watercourse at Dalraddy	0.19
Allt na Fhearna	10.39
Loch Alvie outflow	11.01
Unnamed watercourse at Meadowside	0.4
Lower Milehead	0.50
Allt Chriochaidh (Loch Alvie 1)	1.98
Caochan Ruadh (Loch Alvie 2)	0.90
Unnamed watercourse 3 (Loch Alvie 3)	0.34

Growth curves were established using the pooled analysis, with the growth curve factors for the 100 year return period shown in Table 4.2 below.

Table 4-2 Growth Curves from Pooled Analysis

Site	Growth Curve Factor for 100-year return period
Dunachton Burn	2.94
Leault Burn	2.92
Baldow Smiddy	2.92
Unnamed watercourse at Dalraddy	2.91
Allt na Fhearna	2.69
Loch Alvie outflow	2.54
Unnamed watercourse at Meadowside	2.92
Lower Milehead	2.86
Allt Chriochaidh (Loch Alvie 1)	2.95
Caochan Ruadh (Loch Alvie 2)	2.92
Unnamed watercourse 3 (Loch Alvie 3)	2.91

4.2. FEH Rainfall Runoff Method

The rainfall runoff method uses the FEH DDF (depth duration frequency) model to estimate rainfall totals which are then distributed according to either a 75% winter or 50% summer profile. They take account of the Catchment Wetness index (CWI) which is estimated for the SAAR (Standard Average Annual Rainfall) and base flow which is calculated using equation 2.19 in the FEH volume 4. Flows are estimated using the unit hydrograph and losses model. For the design events, the rainfall totals, rainfall profiles, CWI, base flow and unit hydrograph and losses model for each sub-catchment were estimated using FEH boundaries in ISIS modelling software.

The design storm duration was calculated using the Time to peak (Tp) and Standard Average Annual Rainfall (SAAR) using equation 3.1 in FEH volume 4. Table 4.3 shows the initial storm duration used to estimate the design flows.

Table 4-3 Initial Storm Duration

Site	Storm Duration (hrs)
Dunachton Burn	5.5
Leault Burn	3.5
Baldow Smiddy	2.1
Unnamed watercourse at Dalraddy	3.9
Allt na Fhearna	4.9
Loch Alvie outflow	5.1
Unnamed watercourse at Meadowside	2.7
Lower Milehead	2.7
Allt Chriochaidh (Loch Alvie 1)	3.3
Caochan Ruadh (Loch Alvie 2)	2.7
Unnamed watercourse 3 (Loch Alvie 3)	2.3

The rainfall runoff peak flows were estimated from FEH boundary units in ISIS and are shown in Table 4.4 below.

Table 4-4 Rainfall Runoff Peak Flows (m3/s)

Site	50%	20%	10%	5%	2%	1%	0.5%	0.5%+ cc
Dunachton Burn	7.22	9.87	11.75	14.52	17.33	20.00	23.19	27.83
Leault Burn	2.00	2.78	3.34	4.15	4.85	5.72	6.71	8.27
Baldow Smiddy	0.59	0.84	1.01	1.03	1.49	1.71	2.06	2.59
Unnamed watercourse at Dalraddy	0.51	0.69	0.81	0.99	1.13	1.36	1.62	2.01
Allt na Fhearna	13.27	18.14	21.60	26.59	31.73	36.62	42.44	51.52
Loch Alvie outflow	17.42	23.62	28.00	34.30	40.75	47.04	54.48	66.08
Unnamed watercourse at Meadowside	0.92	1.30	1.57	1.97	2.30	2.69	3.19	3.83
Lower Milehead	1.36	1.90	2.28	2.85	3.33	3.88	4.57	5.48
Allt Chriochaidh (Loch Alvie 1)	2.31	3.15	3.74	4.59	5.32	6.20	7.21	8.65
Caochan Ruadh (Loch Alvie 2)	1.42	1.95	2.33	2.88	3.34	3.84	4.50	5.40
Unnamed watercourse 3 (Loch Alvie 3)	0.65	0.89	1.06	1.32	1.53	1.74	2.06	2.47

4.3. Institute of Hydrology Report 124

The IH124 method calculates the Tp and QBAR (mean annual flood) for small catchments using the following parameters:

- AREA;
- SAAR;
- Soil; and
- Urban Extent

The value derived for QBAR is multiplied by the regional growth curve value, which is presented in the Flood Studies Report supplementary report No. 14.

The peak flows for the unnamed catchment were calculated using this method, with the results shown in Table 4.5 below.

Table 4-5 Peak Flows from Unnamed Catchment

Site	50%	20%	10%	5%	2%	1%	0.5%	0.5%+ cc
Dunachton Burn	0.69	0.92	1.10	1.39	1.90	2.14	2.57	2.49
Unnamed watercourse 1	0.88	1.17	1.41	1.76	2.06	2.41	2.72	3.26
Unnamed watercourse 2	0.91	1.21	1.46	1.82	2.13	2.49	2.82	3.38
Lower Milehead	1.18	1.57	1.90	2.37	2.77	3.24	3.66	4.39
Loch Alvie 1	2.36	3.15	3.81	4.75	5.57	6.51	7.35	8.82
Loch Alvie 2	1.33	1.77	2.14	2.67	3.13	3.66	4.13	4.95
Loch Alvie 3	0.74	0.98	1.19	1.48	1.74	2.03	2.29	2.75

4.4 Final Hydrological Estimates

A hybrid approach was used for the final inflow to the hydraulic model. The rainfall runoff hydrograph were scaled to the statistical peak flows. In general the FEH statistical method is preferred to the rainfall-runoff method for estimating design flood flows. This is because the statistical method is based on a much larger data set of flood events and also it has been more directly calibrated to reproduce flood frequency in UK catchments. Recent guidance from the Environment Agency (June 2012) stated the FEH statistical method should be the preferred option as this method uses flow datasets based on real data. The statistical peak flows were chosen as final estimates for all catchments to maintain continuity in approach. The rainfall runoff peaks were used in the model as a sensitivity check (see Hydraulic Technical Note) following consultation with SEPA.

The flood frequency was calculated for all sites using pooled growth curves. Hydrograph shapes were obtained using the FEH rainfall-runoff method and scaled to fit the peak estimated using the statistical method. The final flow estimations for the model inflows are shown in Table 4.6. Peak flows were also estimated at the downstream model extent as a check.

Site	50%	20%	10%	5%	2%	1%	0.5%	0.5%+ cc	0.2%
Dunachton Burn	5.21	7.17	8.67	10.93	12.96	15.35	18.16	21.79	22.69
Leault Burn	0.98	1.34	1.61	2.04	2.42	2.87	3.41	4.09	4.28
Baldow Smiddy	0.20	0.28	0.34	0.42	0.50	0.59	0.71	0.85	0.89
Unnamed watercourse 1	0.19	0.26	0.32	0.40	0.48	0.56	0.68	0.816	0.84
Allt na Fhearna	10.39	13.99	16.65	20.56	23.98	27.90	32.43	38.92	39.55
Loch Alvie outflow	11.01	14.77	17.43	21.20	24.39	27.93	31.92	38.30	37.96
Unnamed watercourse 2	0.40	0.54	0.65	0.82	0.97	1.16	1.37	1.64	1.72
Lower Milehead	0.50	0.68	0.82	1.03	1.21	1.44	1.70	2.04	2.12
Loch Alvie 1	1.98	2.70	3.26	4.12	5.91	5.84	6.95	8.34	8.76
Loch Alvie 2	0.90	1.23	1.48	1.87	2.22	2.63	3.13	3.76	3.93
Loch Alvie 3	0.34	0.46	0.56	0.70	0.84	0.99	1.18	1.42	1.48

Flood estimation calculation record

Introduction

This document is a supporting document to the Environment Agency's flood estimation guidelines. 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

	Signature	Name and qualifications	For Environment Agency staff: Competence level (see below)
Calculations prepared by:		Evelyn Mackay	
Calculations checked by:		Rhona Hutton	
Calculations approved by:		Mike Vaughan	

Environment Agency competence levels are covered in Section 2.1 of the flood estimation guidelines:

- Level 1 – Hydrologist with minimum approved experience in flood estimation
- Level 2 – Senior Hydrologist
- Level 3 – Senior Hydrologist with extensive experience of flood estimation

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 • Approx. time available	Estimates required for six watercourses crossing the A9 between Kincraig and Dalraddy. These are the unnamed watercourse at Meadowside (281140 803720), Dunachton Burn, Leault Burn, Baldow Smiddy, Allt an Fhearna, an unnamed watercourse at Dalraddy (285238, 808892). In addition inflows are required for the three tributaries to Loch Alvie and for the Lower Milehead which is a lateral flow. Hydrographs for all estimates are required. Return periods required are: 2, 5, 10, 25, 50, 100, 200, 500, and 200+20% increase for climate change

1.2 Overview of catchment

Item	Comments
Brief description of catchment, or reference to section in accompanying report	All watercourses are tributaries to the River Spey. The area of interest is where these watercourses cross the A9. Downstream of this is Loch Alvie, the Insh Marshes and Loch Insh. The River Spey is one of the largest rivers in Scotland, the study area is in the middle reach of the Spey. The proposed A9 dualling reach is located parallel to the River Spey. The six tributaries that are being assessed have a predominantly rural catchment.

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 3.1.2, December 2011

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
Spey	Spey at Kinrara	PR008001	8002	NH88100820	1011.7	VA	1951 - Present

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.

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.
Spey at Kinrara	1951 - 2001	N/A	Yes	Yes		380km^2 developed for hydropower with diversions and storage; substantial net export. Reservoirs for hydropower; Spey dam (1944), Loch an T-Seilish (1941), and Cuaich (1961)
Give link/reference to any further data quality checks carried out						

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.
Spey at Kinrara	theoretical	No	Max stage to 2m
Give link/reference to any rating reviews carried out			

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)		No			
Historic flood data – give link to historic review if carried out.	Yes	Yes – Biennial Flood Reports	Highland Council	May 2013	See FRA for historical flooding details
Flow data for events		No			
Rainfall data for events		No			
Potential evaporation data		No			
Results from previous studies		No known studies			
Other data or information (e.g. groundwater, tides)		No			

1.8 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.	Yes. For the both unnamed watercourse, Baldow Smiddy Lower Milehead and the three Loch Alvie inflows IH 124 will also be used as the catchment is 1.74km^2, 1.33km^2, 1.06km^2, 1.84km^2, 2.98km^2, 1.84km^2 and 1.01km^2 .

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?	1. Sites of interest are where the A9 crosses the tributaries, These are listed below. a. Dunachton Burn – 282330, 804880 b. Leault Burn – 282960, 806030 c. Baldow Smiddy – 283290, 809440 d. Unnamed watercourse at Dalraddy – 285220, 808880 e. Allt an Fhearna – 285350, 809150 f. Unnamed tributary at Meadowside 281200, 803750 g. Lower Milehead – 284000 806950 Likely cause of flooding would be volume of runoff. At Allt an Fhearna, immediately downstream of the A9 crossing, the area is characterised as marshy wetlands as water flows into Loch Alvie and Loch Beag.
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	Lower Milehead has a FARL value of 0.878. This is not a catchment which will be hydraulically modelled.
Initial choice of method(s) and reasons Will the catchment be split into subcatchments? If so, how?	Allt an Fhearna catchment split into the Allt an Fhearna and the unnamed watercourse at Dalraddy. A larger catchment incorporating these two watercourses is assessed at the inflow of Loch Alvie. All flows estimated using FEH statistical method, IH124 methodology used as a check for the unnamed watercourse and Baldow Smiddy as the catchment is 1.74km^2 and 1.06km^2.
Software to be used (with version numbers)	FEH CD-ROM v3.0[1] WINFAP-FEH v3.0.002[2] ISIS

[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

The table below lists the locations of subject sites. The site codes listed below are used in all subsequent tables to save space.

2.1 Summary of subject sites

Site code	Watercourse	Site	Easting	Northing	AREA on FEH CD-ROM (km^2)	Revised AREA if altered
Dun_1	Dunachton Burn	Where A9 crosses watercourse	282400	804750	11.92	12.56
Lea_2	Leault Burn	Where A9 crosses watercourse	283200	806050	2.74	3.40
Bal_3	Baldow Smiddy	Where A9 crosses watercourse	283450	806300	0.91	1.06
Unn_4	Unnamed watercourse at Dalraddy	Where A9 crosses watercourse	285550	809100	1.78	1.74
All_5	Allt na Fhearna	Where A9 crosses watercourse	285300	809100	20.03	20.00
Loch_6	Loch Alvie outflow	Dowsntream of the loch – includes Allt an Fhearna and unnamed watercourse as well as rivers flowing directly into the loch	287290	809390	31.56	31.82
Unn_7	Unnamed watercourse at Meadowside	Where the A9 crosses the watercourse at the entrance to the Wildlife Park.	281140	803720	1.38	-
Lower Mile 1	Lower Milehead	Lateral area to account for flow crossing the A9 at Milehead	284000	806950		1.84
Loch Alvie 1	Allt Chriochaidh	Inflow to Loch Alvie	286000	809600	2.81	2.98
Loch Alvie 2	Caochan Ruadh	Upstream of Ballinluig inflow to Loch Alvie	286700	809850	1.91	1.84
Loch Alvie 3	Unnamed	Inflow to Loch Alvie south of Ballinluig	287000	809750	0.99	1.01
Reasons for choosing above locations		Loch Alvie 1-3 were chosen as direct inflows to Loch Alvie, as flooding is reported to be influence by levels in the loch level. Loch_6 is the downstream boundary for the model. All other inflows are locations where the A9 dualling crosses the watercourses.				

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
Dun_01	1	0.68	0.494	5.33	114.2	1015	46.37	0.000
Lea_02	1	0.68	0.583	2.29	139.3	912	39.08	0.000
Bal_3	1	0.68	0.687	0.95	125	851	30.31	0.000
Unn_4	1	0.68	0.816	1.76	44.7	850	20.08	0.000

Site code	FARL	PROPWET	BFIHOST	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	SPRHOST	URBEXT
All_5	1	0.68	0.435	5.23	182.8	1075	47.1	0.000
Loch_6	0.991	0.68	0.511	5.45	161.5	1025	41.15	0.000
Unn_7	1.	0.68	0.619	1.48	112.4	876	37.88	0.000
Lower Mile 1	0.878	0.68	0.494	1.43	103	881	41.24	0.000
Loch Alvie 1	1	0.68	0.468	2.6	209.5	1108	41.36	0.000
Loch Alvie 2	1	0.68	0.517	1.74	190.2	977	38.73	0.000
Loch Alvie 3	1	0.68	0.623	1.6	198.3	933	31.77	0.000

2.3 Checking catchment descriptors

Record how catchment boundary was checked and describe any changes (refer to maps if needed)	Catchment boundaries were checked using the OS Open data – 1:50 000 and adjusted accordingly. .
Record how other catchment descriptors (especially soils) were checked and describe any changes. Include before/after table if necessary.	WRAP maps from FSR were checked. The study area has WRAP class 5 – Soils of the wet uplands.
Source of URBEXT	URBEXT2000
Method for updating of URBEXT	CPRE formula from FEH Volume 4

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.	No donor sites were identified. The closest gauging station is Spey at Kinrara(8002), which is located on the River Spey approximately 1.36miles upstream of the confluence of the subject sites. The AREA of the Spey at Kinrara is 1009km^2 which is 50 times greater than the largest subject site. The subjects site are not influenced by the lochs and therefore have a FARL of 1.00. Spey at Kinrara is influence by the Loch Inch and therefore not considered a suitable donor site.

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)
8002	Influence by Loch Inch FARL 0.927 and is **rejected**.	AMAX	-	145.5	295.686	0.492
Which version of the urban adjustment was used for QMED at donor sites, and why? Note: The guidelines recommend great caution in urban adjustment of QMED on catchments that are also highly permeable (BFIHOST>0.8).				WINFAP-FEH v3.0.003		

3.3 Overview of estimation of QMED at each subject site

Site code	Method	Initial estimate of QMED (m^3/s)	Data transfer						Final estimate of QMED (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		
							Weight	Weighted average adjustment factor	
Dun_1	CD	5.33	None	-	-	-	-	-	5.33
Lea_2	CD	0.98	None	-	-	-	-	-	0.98
Bal_3	CD	0.20	None	-	-	-	-	-	0.20
Unn_4	CD	0.19	None	-	-	-	-	-	0.19
All_5	CD	10.392	None	-	-	-	-	-	10.39
Loch_6	CD	11.008	None	-	-	-	-	-	11.01
Unn_7	CD	0.396	None	-	-	-	-	-	0.40
Lower Mile	CD	0.501	None						0.50

Site code	Method	Initial estimate of QMED (m^3/s)	Data transfer						Final estimate of QMED (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		
							Weight	Weighted average adjustment factor	
Loch Alvie 1	CD	1.976	None						1.98
Loch Alvie 2	CD	0.9	None						0.90
Loch Alvie 3	CD	0.34	None						0.34
Are the values of QMED consistent, for example at successive points along the watercourse and at confluences?						Yes			
Which version of the urban adjustment was used for QMED, and why?						N/A			

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.

When QMED is estimated from catchment descriptors, the revised 2008 equation from Science Report SC050050**Error! Bookmark not defined.** Should be used. If the original FEH equation has been used, say so and give he reason why.

The guidelines recommend great caution in urban adjustment of QMED on catchments that are also highly permeable (BFIHOST>0.8). The adjustment method used in WINFAP-FEH v3.0.003 is likely to overestimate adjustment factors for such catchments. In this case the only reliable flood estimates are likely to be derived from local flow data.

The data transfer procedure is 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.

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)
Dun_1		n	Removed 44006 Sydling Water@Sydling St Nicholas – Predominantly chalk catchment, SPRHOST = 13.35 Removed 44009 Wey@Broadwey – predominantly limestone, SPRHOST = 17.16 Removed 26802 Gypsey Race@kirby Grindalythe – hydrological response predominantly dominated by groundwater, SPRHOST = 5.67 Removed 44008 Sth Winterbourne@W'bourne Steepleton – chalk catchment, SPRHOST=19.55 Removed 22003 Usway Burn@Shillmoor – L-moments negatively skewed,, record length 13 years which is a little short. Removed 32029 Flore @experimental as it had a short record – 5 years. SAAR low. Removed 50009 Lew @Norley Bridge – Negative L-skew, gauge is bypassed. Flat growth curve indicates that highest flows are not captured by the gauge. Removed 73015 Keer@High Keer Weir – flat Amax Removed 44809 Piddle@Puddle – chalk catchment. SPR low at 12.27 Removed other sites to bring length of record closer to 500 years	L-CV = 0.229 L-skew = 0.248

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)
Lea_2			Removed 44009 Wey@Broadwey – predominantly limestone, SPRHOST = 17.16 Removed 32029 Flore@Experimental catchment, Record only 5 years, SAAR low Removed 44006 Sydling Water@Sydling St Nicholas – Predominantly chalk catchment, SPRHOST = 13.35 Removed 26802 Gypsey Race@kirby Grindalythe – hydrological response predominantly dominated by groundwater, SPRHOST = 5.67 Removed 54091 Severn@ Hafren Flume – flat Amax, negative skew, drowning may occur following big floods owing to sediment deposited d/s, user should apply own judgement as whether to include in pooling group. Removed 54092 Severn @Hore Flume – Flat Amax, drowning may occur following big floods owing to sediment deposited d/s, user should apply own judgement as whether to include in pooling group. Removed 44008 S'th Winterbourne@W'bourne – chalk catchment, SPR 19.55 Removed 50009 Lew@norley Bridge – discordant, negative Lskew and gauge is bypassed. Flat growth curve indicates that highest flows are not captured by the gauge. Removed 22003 Usway Burn@Shillmoor, L-moments negatively skewed, record length a little short (13 years) Removed 27032 Hebden Beck @ Hebden – flat Amax series with few peaks. Removed 27073 Brompton Beck@Snainton Ings – large groundwater component, unresponsive catchment, SPR 17.77.	L-CV = 0.221 L-Skew = 0.259

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)
Bal_03			Removed 32029 Flore@Experimental catchment, Record only 5 years, SAAR low Removed 44009 Wey@Broadwey – predominantly limestone, SPRHOST = 17.16 Removed 26802 Gypsey Race@kirby Grindalythe – hydrological response predominantly dominated by groundwater, SPRHOST = 5.67 Removed 44006 Sydling Water@Sydling St Nicholas – Predominantly chalk catchment, SPRHOST = 13.35 Removed 54092 Severn@Hore Flume – flat Amax, negative skew, drowning may occur following big floods owing to sediment deposited d/s, user should apply own judgement as whether to include in pooling group. Removed 54091 Severn@Halfren – flat Amax, drowning may occur following big floods owing to sediment deposited d/s, user should apply own judgement as whether to include in pooling group. Removed 27073 Hebden Beck@Hebden – flat Amax with few peaks Removed 44008 Sth Winterbourne@W'bourne – chalk catchment SPR 19.55 Removed 50009 Lew@Norley Bridge discordant, negative Lskew and gauge is bypassed. Flat growth curve indicates that highest flows are not captured by the gauge. Removed 22003 Usway Burn @shillmoor – L-moments negatively skewed, record length 13 years	L-CV = 0.220 L-Skew = 0.260

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)
Unn_4			Removed 26802 Gypsey Race@kirby Grindalythe – hydrological response predominantly dominated by groundwater, SPRHOST = 5.67 Removed 44009 Wey@Broadwey – predominantly limestone, SPRHOST = 17.16 Removed 44006 Sydling Water@Sydling St Nicholas – Predominantly chalk catchment, SPRHOST = 13.35 Removed 32029 Flore@Experimental catchment, Record only 5 years, SAAR low Removed 27073 Brompton Beck@Snainton Ings – large groundwater component, non responsive catchment unrepresentative of topographical area, SPRHOST = 17.77 Removed 54091 Severn@Halfren – Flat Amax drowning may occur following big floods owing to sediment deposited d/s, user should apply own judgement as whether to include in pooling group. Removed 54092 Severn @ Hore Flume – Flat Amax negative skew, drowning may occur following big floods owing to sediment deposited d/s, user should apply own judgement as whether to include in pooling group. Removed 44008 – S'th Winterbourne @ W'bourne chalk catchment SPR 19.55 Removed 50009 Lew@ Norley Bridge discordant, negative Lskew and gauge is bypassed. Flat growth curve indicates that highest flows are not captured by the gauge. Removed 22003 Usway Burn@Shillmoor – L moments negatively skewed, record length 13 years	L-CV = 0.219 L-Skew = 0.260

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)
All_5			Removed 44008 Sth Winterbourne@W'bourne Steepleton – chalk catchment, SPRHOST=19.55 Removed 22003 Usway Burn@Shillmoor – L-moments negatively skewed, record length 13 years which is a little short. Removed 44809 Piddle @LittlePuddle. Predominantly lower chalk, SPRHOST= 12.27 Removed 26802 Gypsey Race@kirby Grindalythe – hydrological response predominantly dominated by groundwater, SPRHOST = 5.67 Removed 44006 Sydling Water@Sydling St Nicholas – Predominantly chalk catchment, SPRHOST = 13.35 Removed 50009 Lew@Norley Bridge discordant, negative Lskew and gauge is bypassed. Flat growth curve indicates that highest flows are not captured by the gauge. Removed 73015 Keer@High Keer Weir – flat Amax Removed 206004 Bessbrook@Carnbane – Low SPR, flat Amax Other sites removed to bring length of record to 500 years	L-CV = 0.214 L-Skew = 0.217
Loch_6			Removed 44008 Sth Winterbourne@W'bourne Steepleton – chalk catchment, SPRHOST=19.55 Removed 22003 Usway Burn@Shillmoor – L-moments negatively skewed, record length 13 years which is a little short. Removed 44809 Piddle @LittlePuddle. Predominantly lower chalk, SPRHOST= 12.27 Removed 43806 Wylie @Brixton. Chalk catchment, SPR=8.34 Removed 50009 Lew @Norley Bridge discordant, negative Lskew and gauge is bypassed. Flat growth curve indicates that highest flows are not captured by the gauge. Removed 73015 Keer @High Keer Weir – Flat Amax Removed 206004 BessBrock. Low SPR Flat Amax graph Removed 203046 Rathmore – Flat Amax graph 76811 – Dacre Beck @ Dacre Bridge. Short record length. 49004 – Gannel @ Gwills. With Caution, scatter in gauging, potential bypassing.	L-CV = 0.215 L-Skew = 0.175

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)
Unn_7			Removed 54092 Severn @ Hore Flume discordant, negative skew. Flat Amax, drowning may occur following big floods owing to sediment deposited d/s User should apply own judgement as to whether to include in pooling group. Removed 54091 Severn@ Hafren Flume – flat Amax, negative skew, drowning may occur following big floods owing to sediment deposited d/s, user should apply own judgement as whether to include in pooling group. Removed 44009 Wey@Broadwey – predominantly limestone, SPRHOST = 17.16 Removed 32029 Flore @experimental as it had a short record – 5 years. SAAR low. Removed 44006 Sydling Water@Sydling St Nicholas – Predominantly chalk catchment, SPRHOST = 13.35 Removed 26802 Gypsey Race@kirby Grindalythe – hydrological response predominantly dominated by groundwater, SPRHOST = 5.67 Removed 27073 Brompton Beck@Snainton Ings – large groundwater component, unresponsive catchment, SPR 17.77. Removed 44008 Sth Winterbourne@W'bourne Steepleton – chalk catchment, SPRHOST=19.55 Removed 50009 Lew @Norley Bridge – Negative L-skew, gauge is bypassed. Flat growth curve indicates that highest flows are not captured by the gauge. Removed 22003 Usway Burn@Shillmoor – L-moments negatively skewed, Record length 13 years – too short.	L-CV = 0.221 L-Skew = 0.260

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)
Lower Mile			Removed 44009 Wey@Broadwey – predominantly limestone, SPRHOST = 17.16 Removed 32029 Flore @experimental as it had a short record – 5 years. SAAR low. Removed 54092 Severn @ Hore Flume discordant, negative skew. Flat Amax, drowning may occur following big floods owing to sediment deposited d/s User should apply own judgement as to whether to include in pooling group. Removed 54091 Severn@ Hafren Flume – flat Amax, negative skew, drowning may occur following big floods owing to sediment deposited d/s, user should apply own judgement as whether to include in pooling group. Removed 44006 Sydling Water@Sydling St Nicholas – Predominantly chalk catchment, SPRHOST = 13.35 Removed 27073 Brompton Beck@Snainton Ings – large groundwater component, unresponsive catchment, SPR 17.77. Removed 26802 Gypsey Race@kirby Grindalythe – hydrological response predominantly dominated by groundwater, SPRHOST = 5.67 Removed 44008 Sth Winterbourne@W'bourne Steepleton – chalk catchment, SPRHOST=19.55 Removed 50009 Lew @Norley Bridge – Negative L-skew, gauge is bypassed. Flat growth curve indicates that highest flows are not captured by the gauge. Removed 22003 Usway Burn@Shillmoor – L-moments negatively skewed, Record length 13 years – too short.	L-CV:0.218 L-Skew:0.252

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)
Loch Alvie 1			Removed 44009 Wey@Broadwey – predominantly limestone, SPRHOST = 17.16 Removed 54092 Severn @ Hore Flume discordant, negative skew. Flat Amax, drowning may occur following big floods owing to sediment deposited d/s User should apply own judgement as to whether to include in pooling group. Removed 54091 Severn@ Hafren Flume – flat Amax, negative skew, drowning may occur following big floods owing to sediment deposited d/s, user should apply own judgement as whether to include in pooling group. Removed 32029 Flore @experimental as it had a short record – 5 years. SAAR low. Removed 26802 Gypsey Race@kirby Grindalythe – hydrological response predominantly dominated by groundwater, SPRHOST = 5.67 Removed 44006 Sydling Water@Sydling St Nicholas – Predominantly chalk catchment, SPRHOST = 13.35 Removed 44008 Sth Winterbourne@W'bourne Steepleton – chalk catchment, SPRHOST=19.55 Removed 50009 Lew @Norley Bridge – Negative L-skew, gauge is bypassed. Flat growth curve indicates that highest flows are not captured by the gauge. Removed 22003 Usway Burn@Shillmoor – L-moments negatively skewed, Record length 13 years – too short. Additional sites removed to reduce pooling group to ~500years	L-CV: 0.222 L-Skew:0.265

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)
Loch Alvie 2			Removed 54092 Severn @ Hore Flume discordant, negative skew. Flat Amax, drowning may occur following big floods owing to sediment deposited d/s User should apply own judgement as to whether to include in pooling group. Removed 54091 Severn@ Hafren Flume – flat Amax, negative skew, drowning may occur following big floods owing to sediment deposited d/s, user should apply own judgement as whether to include in pooling group. Removed 44009 Wey@Broadwey – predominantly limestone, SPRHOST = 17.16 Removed 32029 Flore @experimental as it had a short record – 5 years. SAAR low. Removed 44006 Sydling Water@Sydling St Nicholas – Predominantly chalk catchment, SPRHOST = 13.35 Removed 26802 Gypsey Race@kirby Grindalythe – hydrological response predominantly dominated by groundwater, SPRHOST = 5.67 Removed 27073 Brompton Beck@Snainton Ings – large groundwater component, unresponsive catchment, SPR 17.77. Removed 44008 Sth Winterbourne@W'bourne Steepleton – chalk catchment, SPRHOST=19.55 Removed 50009 Lew @Norley Bridge – Negative L-skew, gauge is bypassed. Flat growth curve indicates that highest flows are not captured by the gauge. Removed 22003 Usway Burn@Shillmoor – L-moments negatively skewed, Record length 13 years – too short.	L-CV: 0.221 L-Skew: 0.260

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)
Loch Alvie3			Removed 54092 Severn @ Hore Flume discordant, negative skew. Flat Amax, drowning may occur following big floods owing to sediment deposited d/s User should apply own judgement as to whether to include in pooling group. Removed 54091 Severn@ Hafren Flume – flat Amax, negative skew, drowning may occur following big floods owing to sediment deposited d/s, user should apply own judgement as whether to include in pooling group. Removed 44009 Wey@Broadwey – predominantly limestone, SPRHOST = 17.16 Removed 32029 Flore @experimental as it had a short record – 5 years. SAAR low. Removed 44006 Sydling Water@Sydling St Nicholas – Predominantly chalk catchment, SPRHOST = 13.35 Removed 26802 Gypsey Race@kirby Grindalythe – hydrological response predominantly dominated by groundwater, SPRHOST = 5.67 Removed 44008 Sth Winterbourne@W'bourne Steepleton – chalk catchment, SPRHOST=19.55 Removed 27073 Brompton Beck@Snainton Ings – large groundwater component, unresponsive catchment, SPR 17.77. Removed 50009 Lew @Norley Bridge – Negative L-skew, gauge is bypassed. Flat growth curve indicates that highest flows are not captured by the gauge. Removed 22003 Usway Burn@Shillmoor – L-moments negatively skewed, Record length 13 years – too short.	L-CV:0.220 L-Skew:0.260

Notes

Pooling groups were derived using the revised procedures from Science Report SC050050 (2008). Amend if not applicable.

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

Site code	Method (SS, P, ESS, J)	If P, ESS or J, name of pooling group (3.4)	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
Dun_1	P	Dunachton_3	GL – Recommended for UK Flood data. Selected by WINFAP as best fit	N/A	Location: 1.00 Scale: 0.227 Shape: -0.248	2.943
Lea_2	P	Leault_3	GL – Recommended for UK Flood, Z Value indicated no preferred distribution	N/A	Location: 1.00 Scale: 0.218 Shape: -0.259	2.921
Bal_3	P	Baldow_3	GL – Recommended for UK Flood data, Z Value indicated no preferred distribution	N/A	Location: 1.00 Scale: 0.216 Shape: -0.260	2.915
Unn_4	P	Unnamed_3	GL – Recommended for UK Flood data., Z Value indicated no preferred distribution.	N/A	Location: 1.00 Scale: 0.215 Shape: -0.260	2.908
All_5	P	AlltanFhearn_3	GL - Recommended for UK Flood data GEV also provides an acceptable fit but not used	N/A	Location: 1.00 Scale:0.214 Shape: -0.217	2.685
Loch_6	P	Downstream of Loch_3	GL - Recommended for UK Flood data GEV also provides an acceptable fit but not used	N/A	Location: 1.00 Scale:0.218 I Shape: -0.175	2.537
Unn_7	P	Unnamed_7	GL – Recommended for UK Flood data, Z Value indicated no preferred distribution.	N/A	Location: 1.00 Scale: 0.217 Shape: -0.260	2.919
Lower Milehead	P		GL – Recommended for UK Flood data, Z Value indicated no preferred distribution.	N/A	Location:1.00 Scale: 0.215 Shape:-0.252	2.863

Site code	Method (SS, P, ESS, J)	If P, ESS or J, name of pooling group (3.4)	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
Loch Alvie 1	P	Loch Alvie 1	GL – Recommended for UK Flood data, Z Value indicated no preferred distribution	N/A	Location:1.00 Scale: 0.218 Shape: -0.264	2.954
Loch Alvie 2	P	Loch Alvie 2	GL – Recommended for UK Flood data, Z Value indicated no preferred distribution	N/A	Location: 1.00 Scale: 0.217 Shape:-0.260	2.923
Loch Alvie 3	P	Loch Alvie 3	GL – Recommended for UK Flood data, Z Value indicated no preferred distribution.	N/A	Locatiion:1.00 Scale: 0.216 Shape: -0.260	2.914

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 to growth curves should use the version 3 option in WINFAP-FEH: Kjeldsen (2010).

Growth curves were derived using the revised procedures from Science Report SC050050 (2008). Amend if not applicable.

Any relevant frequency plots from WINFAP-FEH, particularly showing any comparisons between single-site and pooled growth curves (including flood peak data on the plot), should be shown here or in a project report.

3.6 Flood estimates from the statistical method

Site code	Flood peak (m^3/s) for the following return periods (in years)								
	2	5	10	25	50	100	200	200+CC	500
DUN_1	5.33	7.33	8.86	11.17	13.25	15.69	18.56	22.27	23.20
Lea_2	0.98	1.34	1.61	2.04	2.42	2.87	3.41	4.09	4.28
Bal_3	0.20	0.28	0.34	0.42	0.50	0.59	0.71	0.85	0.89
Unn_4	0.19	0.26	0.32	0.40	0.48	0.56	0.68	0.81	0.84
All_5	10.39	13.99	16.65	20.56	23.98	27.90	32.43	38.92	39.55
Loch_6	11.01	14.77	17.43	21.20	24.39	27.93	31.92	38.30	37.96
Unn_7	0.40	0.54	0.65	0.82	0.97	1.16	1.37	1.64	1.72
Lower Milehead	0.50	0.68	0.82	1.03	1.21	1.44	1.70	2.04	2.12
Loch Alvie 1	1.98	2.70	3.26	4.12	5.91	5.84	6.95	8.34	8.76
Loch Alvie 2	0.90	1.23	1.48	1.87	2.22	2.63	3.13	3.76	3.93
Loch Alvie 3	0.34	0.46	0.56	0.70	0.84	0.99	1.18	1.42	1.48

4 FEH rainfall-runoff method

4.1 Parameters for FEH rainfall-runoff model

Methods: FEA : Flood event analysis
LAG : Catchment lag
DT : Catchment descriptors with data transfer from donor catchment
CD : Catchment descriptors alone
BFI : SPR derived from baseflow index calculated from flow data

Site code	Rural (R) or urban (U)	Tp(0): method	Tp(0): value (hours)	SPR: method	SPR: value (%)	BF: method	BF: value (m^3/s)	If DT, numbers of donor sites used (see Section 5.2) and reasons
DUN_01	R	CD	2.783	CD	46.370	CD	0.379	
LEA_02	R	CD	1.666	CD	39.080	CD	0.083	
BAL_03	R	CD	1.093	CD	30.310	CD	0.023	
UNN_04	R	CD	2.136	CD	20.080	CD	0.043	
ALL_05	R	CD	2.345	CD	47.100	CD	0.641	
LOCH_06	R	CD	2.499	CD	41.15	CD	0.970	
Unn_07	R	CD	1.426	CD	37.88	CD	0.035	
Lower Milehead	R	CD	1.443	CD	41.24	CD	0.047	
Loch Alvie 1	R	CD	1.55	CD	41.36	CD	0.098	
Loch Alvie 2	R	CD	1.299	CD	38.73	CD	0.053	
Loch Alvie 3	R	CD	1.226	CD	31.77	CD	0.028	

4.2 Donor sites for FEH rainfall-runoff parameters

No.	Watercourse	Station	Tp(0) from data (A)	Tp(0) from CDs (B)	Adjustment ratio for Tp(0) (A/B)	SPR from data (C)	SPR from CDs (D)	Adjust-ment ratio for SPR (C/D)
1								
2								

4.3 Inputs to and outputs from FEH rainfall-runoff model

Site code	Storm duration (hours)	Storm area for ARF (if not catchment area)	Flood peaks (m^3/s) for the following return periods (in years)								
			2	5	10	25	50	100	200	200+CC	500
Dun_01	5.5		7.22	9.87	11.75	14.52	17.33	20.00	23.19	27.83	28.16
Lea_02	3.5		2.00	2.78	3.34	4.15	4.85	5.72	6.71	8.05	8.27
Bal_03	2.1		0.59	0.84	1.01	1.027	1.49	1.71	2.06	2.47	2.59
Unn_04	3.9		0.51	0.69	0.81	0.99	1.13	1.36	1.62	1.94	2.01
All_05	4.9		13.27	18.14	21.60	26.59	31.73	36.62	42.44	50.93	51.52
Loch_06	5.1		17.42	23.62	28.00	34.30	40.75	47.04	54.48	65.38	66.08
UNN_7	2.7		0.92	1.30	1.57	1.97	2.30	2.69	3.19	3.83	3.96

Site code	Storm duration (hours)	Storm area for ARF (if not catchment area)	Flood peaks (m^3/s) for the following return periods (in years)								
			2	5	10	25	50	100	200	200+CC	500
Lower Milehead	2.7		1.36	1.90	2.28	2.85	3.33	3.88	4.57	5.48	5.64
Loch Alvie 1	3.3		2.31	3.15	3.74	4.59	5.32	6.20	7.21	8.65	8.76
Loch Alvie 2	2.7		1.42	1.95	2.33	2.88	3.34	3.84	4.50	5.4	5.51
Loch Alvie 3	2.3		0.65	0.89	1.06	1.32	1.53	1.74	2.06	2.47	2.55
Are the storm durations likely to be changed in the next stage of the study, e.g. by optimisation within a hydraulic model?			Storm durations to be optimised within the hydraulic models.								

5 Small catchment methods

This section records any estimates of design flows for small catchments using methods other than the FEH. In this case, the Institute of Hydrology Report 124 method has been used as an alternative. Other methods can be added or substituted if needed.

5.1 Parameters for IH Report 124 method

Site code	Area (km^2)	$SAAR_{4170}$ (mm)	URBAN (fraction)	Fraction of catchment covered by WRAP class (soil types given on Figure I 4.18 in FSR Volume 5)					Hydrometric area
				1	2	3	4	5	
BAL_3	1.055	851	0.0					1	1
UNN_4	1.739	850	0.0					1	1
UNN_7	1.38	876	0.0					1	1
Lower Milehead	1.84	881	0.0					1	1
Loch Alvie 1	2.98	1108	0.0					1	1
Loch Alvie 2	1.84	977	0.0					1	1
Loch Alvie 3	1.01	933	0.0					1	1

5.2 Flood estimates from the IH Report 124 method at each subject site

Site code	Flood peak (m^3/s) for the following return periods (in years)								
	2	5	10	25	50	100	200	200+cc	500
BAL_3	0.69	0.92	1.10	1.39	1.62	1.90	2.14	2.57	2.49
UNN_4	0.88	1.17	1.41	1.76	2.06	2.41	2.72	3.26	3.16
UNN_7	0.91	1.21	1.46	1.82	2.13	2.49	2.82	3.38	3.27
Lower Milehead	1.18	1.57	1.90	2.37	2.77	3.24	3.66	4.39	4.25
Loch Alvie 1	2.36	3.15	3.81	4.75	5.57	6.51	7.35	8.82	8.53
Loch Alvie 2	1.33	1.77	2.14	2.67	3.13	3.66	4.13	4.95	4.79
Loch Alvie 3	0.74	0.98	1.19	1.48	1.74	2.03	2.29	2.75	2.66

6 Discussion and summary of results

6.1 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	
	Rainfall Runoff	IH124	Rainfall Runoff	IH124
DUN_01	1.35		1.27	
LEA_02	2.04		1.99	
BAL_03	2.95	3.45	2.90	3.22
UNN_04	2.68	4.40	2.43	4.08
ALL_05	1.28		1.31	
LOCH_06	1.58		1.46	
UNN_07	2.30	2.28	2.32	2.15
Lower Milehead	2.72	2.36	2.69	2.25
Loch Alvie 1	1.17	1.19	1.06	1.11
Loch Alvie 2	1.58	1.48	1.46	1.39
Loch Alvie 3	1.91	2.18	1.76	2.05

Site Code	QMED	QBAR	Ratio
BAL_03	0.20	0.77	3.85
UNN_04	0.19	0.97	5.11
UNN_07	0.396	1.01	2.55
Lower Milehead	0.501	1.31	2.61
Loch Alvie 1	1.976	2.63	1.33
Loch Alvie 2	0.9	1.47	1.63
Loch Alvie 3	0.34	0.82	2.41

6.2 Final choice of method

Choice of method and reasons – include reference to type of study, nature of catchment and type of data available.	FEH statistical method has been used to provide the peak flows with the FEH rainfall runoff being used to generate the hydrographs. The statistical approach was chosen for peak flows as this is based on a calibrated dataset for the pooling group and hence the growth curve, rather than catchment descriptors alone.

6.3 Assumptions, limitations and uncertainty

List the main assumptions made (specific to this study)	
Discuss any particular limitations, e.g. applying methods outside the range of catchment types or return periods for which they were	There is uncertainty attached with the results as this is an ungauged catchment, and there is no known anecdotal information to compare results against.

developed	
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).	Uncertainty in QMED estimated from catchment descriptors for the 68% and 95% confidence interval is shown below for each catchment including the upper and lower confidence intervals. 68% Confidence Interval Dun_01 = (5.33/1.43, 5.33x1.43) 3.72, 7.62 Lea_02 = (0.983/1.43, 0.983x1.43) 0.687, 1.406 Bal_03 = (0.204/1.43, 0.204x1.43) 0.143, 0.292 Unn_04 = (0.194/1.43, 0.194x1.43) 0.136, 0.28 All_05 = (10.392/1.43, 10.392x1.43) 7.267, 14.861 Loch_06 = (11.008/1.43, 11.008x1.43) 7.698, 7.698 Unn_07 = (0.396/1.43, 0.396x1.43) 0.28, 0.57 Lower Milehead = (0.501/1.43, 0.501x1.43) 0.35, 0.72 Loch Alvie 1 = (1.976/1.43, 1.976x1.43) 1.38, 2.83 Loch Alvie 2 = (0.90/1.43, 0.90x1.43) 0.63, 1.29 Loch Alvie 3 = (0.34/1.43, 0.34x1.43) 0.24, 0.49 95% Confidence Interval Dun_01 = (5.33/2.04, 5.33x2.04) 2.61, 10.87 Lea_02 = (0.983/2.04, 0.983x2.04) 0.482, 2.01 Bal_03 = (0.204/2.04, 0.204x2.04) 0.1, 0.416 Unn_04 = (0.194/2.04, 0.194x2.04), 0.095, 0.396 All_05 = (10.392/2.04, 10.392x2.04) 5.094, 21.20 Loch_06 = (11.008/2.04, 11.008x2.04) 5.396, 22.456 Unn_07 = (0.396/2.04, 0.396x2.04) 0.19, 0.81 Lower Milehead = (0.501/2.04, 0.501x2.04) 0.25, 1.02 Loch Alvie 1 = (1.976/2.04, 1.976x2.04) 0.97, 4.03 Loch Alvie 2 = (0.90/2.04, 0.90x2.04) 0.44, 1.84 Loch Alvie 3 = (0.34/2.04, 0.34x2.04) 0.17, 0.69 Based on a fraction error of 1.43 from Flood Estimation Guidelines: Operational Instructions 197_08 Issued June 2012
Comment on the suitability of the results for future studies, e.g. at nearby locations or for different purposes.	Suitable for use for studies immediately downstream of A9 crossings.
Give any other comments on the study, for example suggestions for additional work.	

6.4 Checks

Are the results consistent, for example at confluences?	
What do the results imply regarding the return periods of floods during the period of record?	
What is the 100-year growth factor? Is this realistic? (The guidance suggests a typical range of 2.1 to 4.0)	All within range
If 1000-year flows have been derived, what is the range of ratios for 1000-year flow over 100-year	N/A

flow?	
What range of specific runoffs (l/s/ha) do the results equate to? Are there any inconsistencies?	
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?	
Describe any other checks on the results	N/A

6.5 Final results

Site code	Flood peak (m^3/s) for the following return periods (in years)								
	2	5	10	25	50	100	200	200+CC	500
DUN_01	5.21	7.17	8.67	10.93	12.96	15.35	18.16	21.79	22.69
Lea_02	0.98	1.34	1.61	2.04	2.42	2.87	3.41	4.09	4.28
Bal_03	0.20	0.28	0.34	0.42	0.50	0.59	0.71	0.85	0.89
Unn_04	0.19	0.26	0.32	0.40	0.48	0.56	0.68	0.82	0.84
All_05	10.39	13.99	16.65	20.56	23.98	27.90	32.43	38.92	39.55
Loch_06	11.01	14.77	17.43	21.20	24.39	27.93	31.92	38.30	37.96
Unn_07	0.40	0.54	0.65	0.82	0.97	1.16	1.37	1.64	1.72
Lower Milehead	0.50	0.68	0.82	1.03	1.21	1.44	1.70	2.04	2.12
Loch Alvie 1	1.98	2.70	3.26	4.12	5.91	5.84	6.95	8.34	8.76
Loch Alvie 2	0.90	1.23	1.48	1.87	2.22	2.63	3.13	3.76	3.93
Loch Alvie 3	0.34	0.46	0.56	0.70	0.84	0.99	1.18	1.42	1.48

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)	FEH_MC.add FEH P:\GBGWA\Environment\Rivers & Coastal\Projects\5109850 A9 Kincraig to Dalraddy\060 - Work Process, General\063 - Calculations\Hydrology\Rainfall Runoff

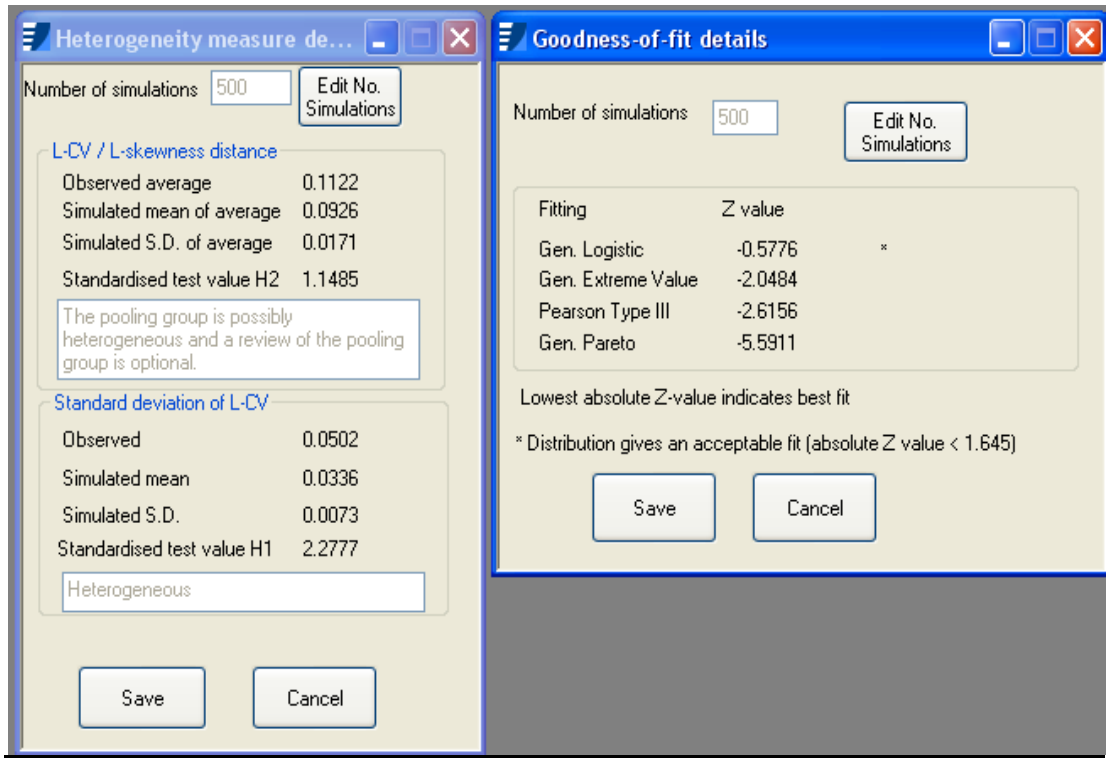
7 Annex - supporting information

7.1 Pooling group composition

Dunn_001

Station		Years of data
25019	Leven @ Easby	31
27010	Hodge Beck @ Bransdale Weir	41
27051	Crimple @ Burn Bridge	37
25011	Langdon Beck @ Langdon	23
28033	Dove @ Hollinsclough	30
45816	Haddeo @ Upton	16
203046	Rathmore Burn @ Rathmore Bridge	27
206006	Annalong @ Recorder 1895	48
27032	Hebden Beck @ Hebden	43
48009	st Neot @ Craigshill Wood	12
48004	Warleggan @ Trengoffe	40
25003	Trout Beck @ Moor House	36
203049	Clady @ Clady Bridge	27
49003	de Lank @ de Lank	43
25012	Harwood Beck @ Harwood	40
72014	Conder @ Galgate	42

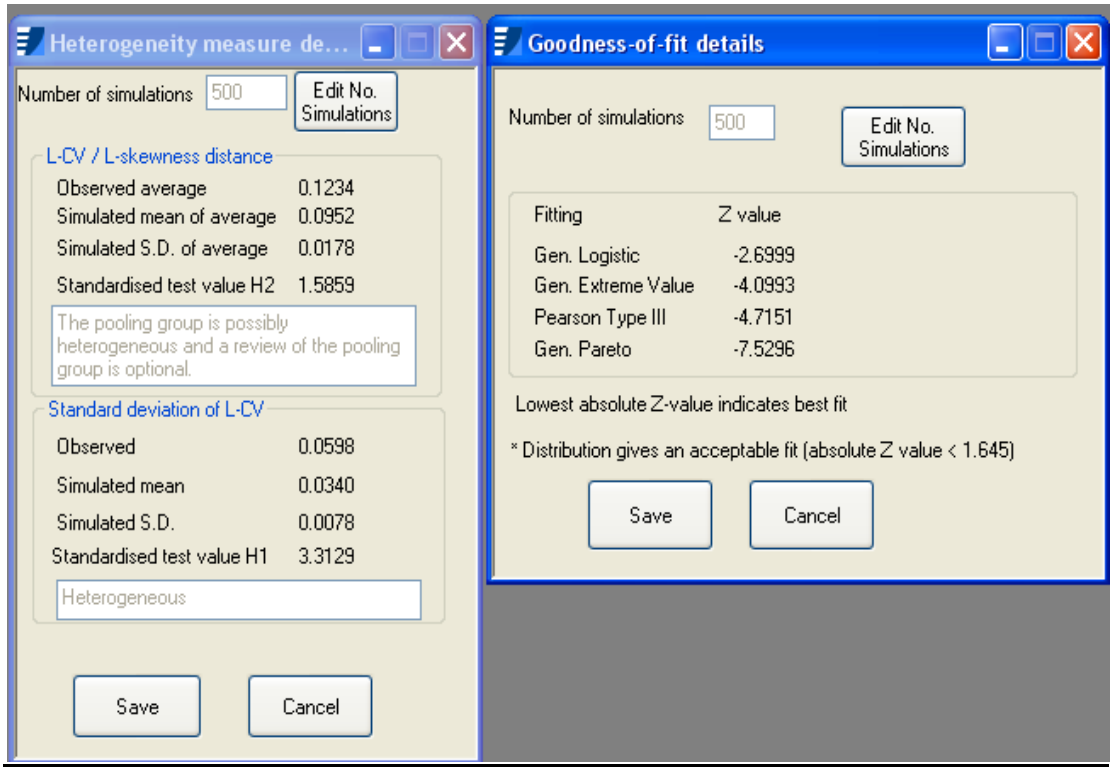
Total 536
Weighted means L-CV: 0.229 L-SKEW: 0.248



Lea 02

Station		Years of data
45817	Rhb Trib to Haddeo @ Upton trib	16
76011	Coal Burn @ Coalburn	32
45816	Haddeo @ Upton	16
27051	Crimple @ Burn Bridge	37
28033	Dove @ Hollinsclough	30
25011	Langdon Beck @ Langdon	23
25019	Leven @ Easby	31
91802	Allt Leachdach @ Intake	34
25003	Trout Beck @ Moor House	36
206006	Annalong @ Recorder 1895	48
54022	Severn @ Plynlimon Flume	38
27010	Hodge Beck @ Bransdale Weir	41
203046	Rathmore Burn @ Rathmore Bridge	27
56007	Senni @ Pont Hen Hafod	41
48009	st Neot @ Craigshill Wood	12
48004	Warleggan @ Trengoffe	40

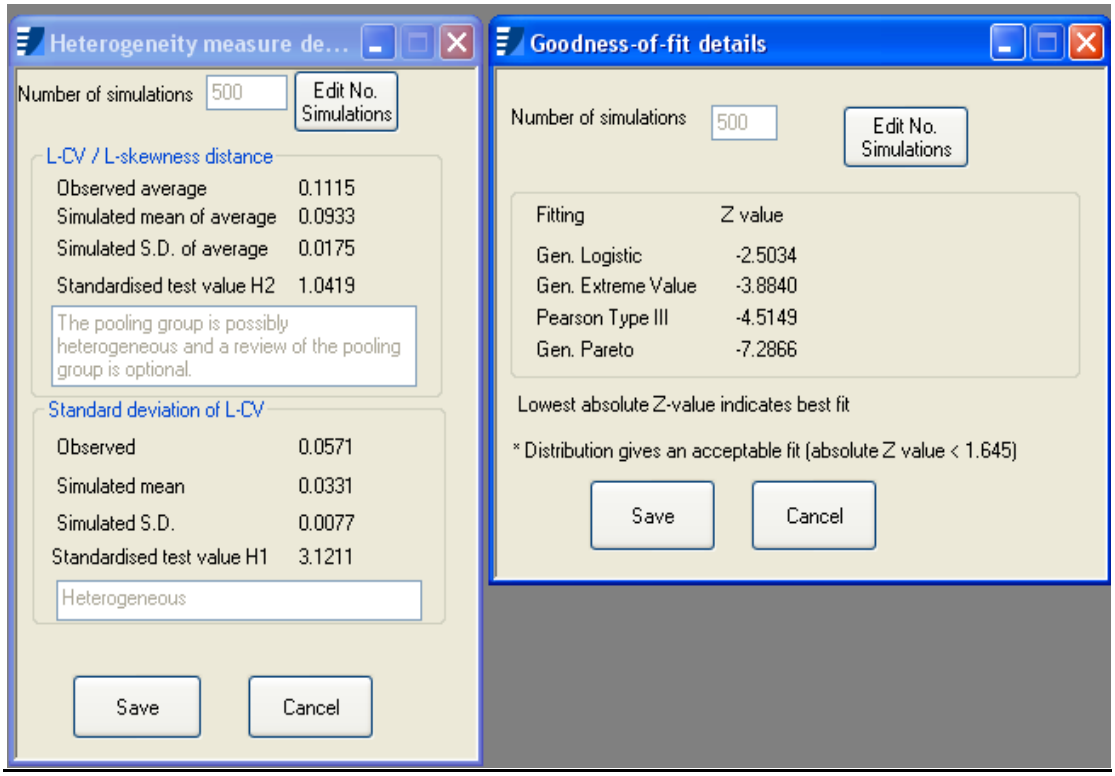
Total 502
Weighted means L-CV: 0.223 L-SKEW: 0.260



Bal 03

Station		Years of data
45817	Rhb Trib to Haddeo @ Upton trib	16
76011	Coal Burn @ Coalburn	32
45816	Haddeo @ Upton	16
27051	Crimple @ Burn Bridge	37
28033	Dove @ Hollinsclough	30
91802	Allt Leachdach @ Intake	34
54022	Severn @ Plynlimon Flume	38
25011	Langdon Beck @ Langdon	23
25003	Trout Beck @ Moor House	36
25019	Leven @ Easby	31
206006	Annalong @ Recorder 1895	48
27010	Hodge Beck @ Bransdale Weir	41
203046	Rathmore Burn @ Rathmore Bridge	27
27032	Hebden Beck @ Hebden	43
56007	Senni @ Pont Hen Hafod	41
49003	de Lank @ de Lank	43

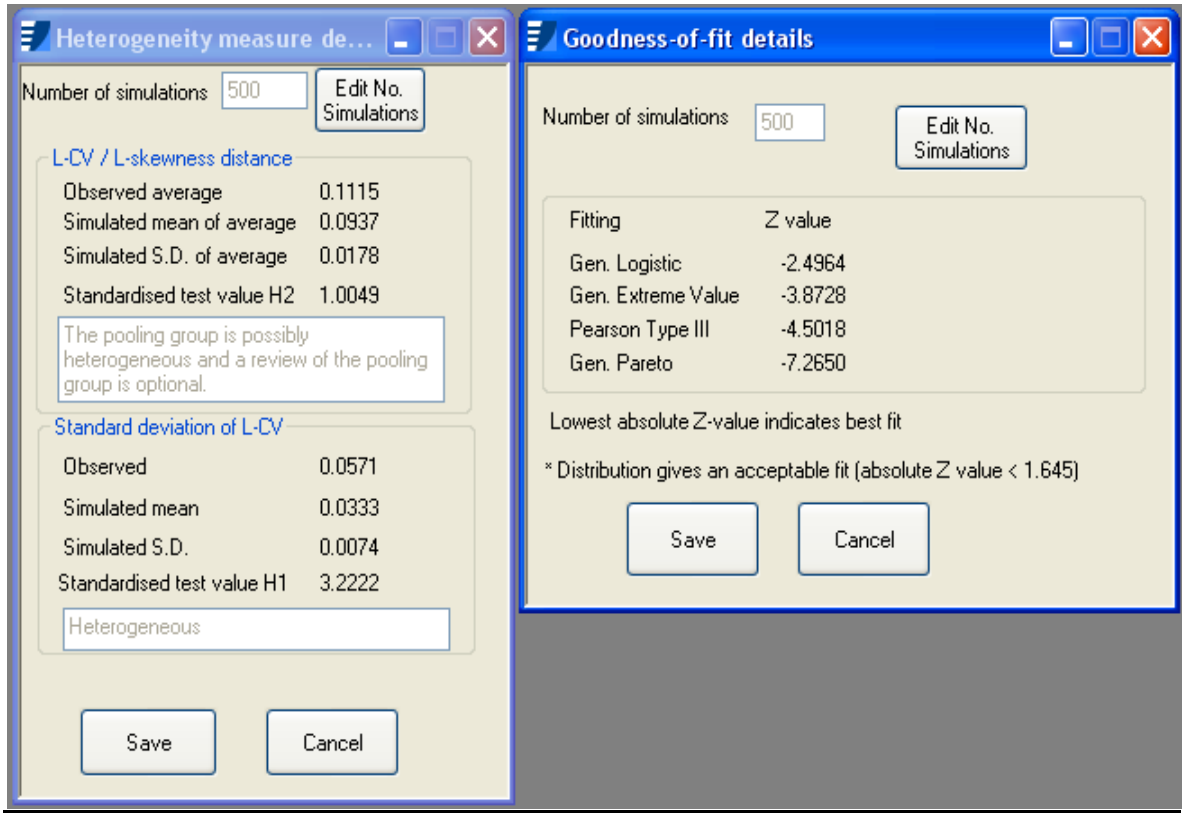
Total 536
Weighted means L-CV: 0.220 L-SKEW: 0.260



Unn_004

Station		Years of data
76011	(Coal Burn @ Coalburn)	32
45817	(Rhb Trib to Haddeo @ Upton (trib))	16
45816	(Haddeo @ Upton)	16
27051	(Crimple @ Burn Bridge)	37
28033 (	Dove @ Hollinsclough)	30
91802	(Allt Leachdach @ Intake)	34
25011	(Langdon Beck @ Langdon)	23
25003	(Trout Beck @ Moor House)	36
25019	(Leven @ Easby)	31
54022	(Severn @ Plynlimon Flume)	38
206006	(Annalong @ Recorder 1895)	48
27010	(Hodge Beck @ Bransdale Weir)	41
203046	(Rathmore Burn @ Rathmore Bridge)	27
49003	(de Lank @ de Lank)	43
56007	(Senni @ Pont Hen Hafod)	41
27032	(Hebden Beck @ Hebden)	43

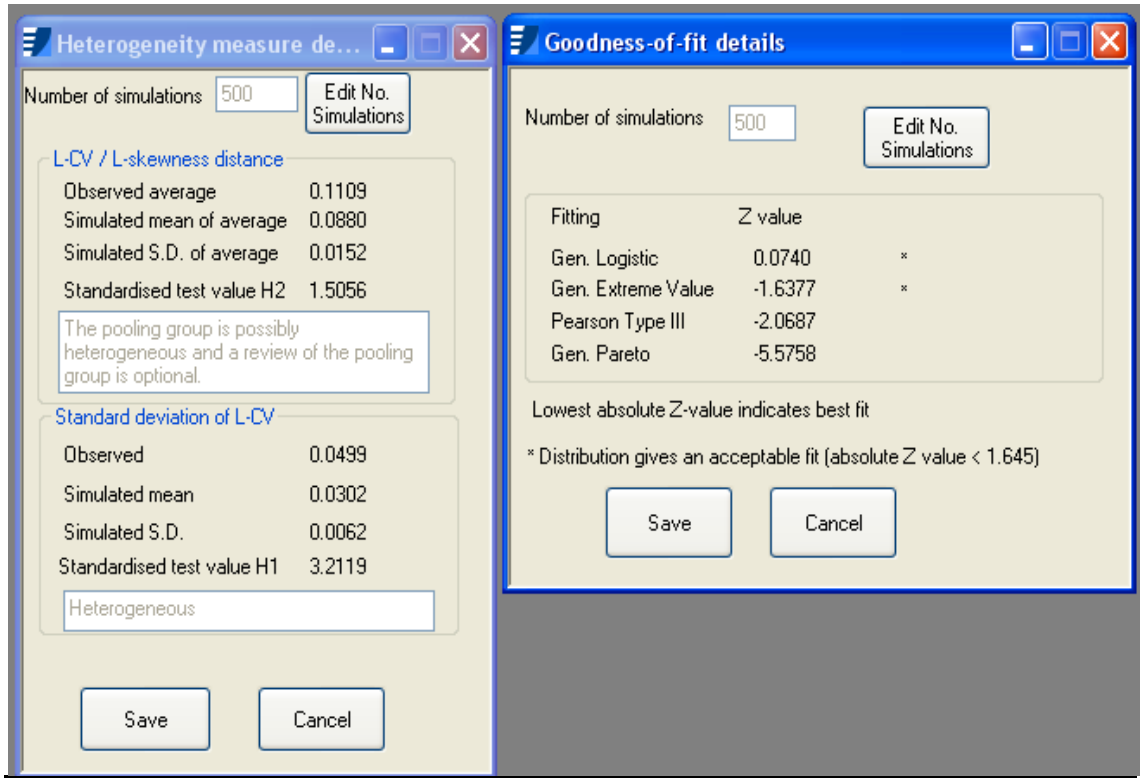
Total 536
Weighted means L-CV: 0.219 L-SKEW: 0.260



All 05

Station		Years of data
27010	(Hodge Beck @ Bransdale Weir)	41
27032	(Hebden Beck @ Hebden)	43
25019	(Leven @ Easby)	31
203046	(Rathmore Burn @ Rathmore Bridge)	27
48009	(st Neot @ Craigshill Wood)	12
48004	(Warleggan @ Trengoffe)	40
203049	(Clady @ Clady Bridge)	27
48803	(Carnon @ Bissoe)	15
25012	(Harwood Beck @ Harwood)	40
24006	(Rookhope Burn @ Eastgate)	20
25011	(Langdon Beck @ Langdon)	23
51003	(Washford @ Beggearn Huish)	42
28041	(Hamps @ Waterhouses)	24
72007	(Brock @ U/s a6)	31
72014	(Conder @ Galgate)	42
47009	(Tiddy @ Tideford)	40

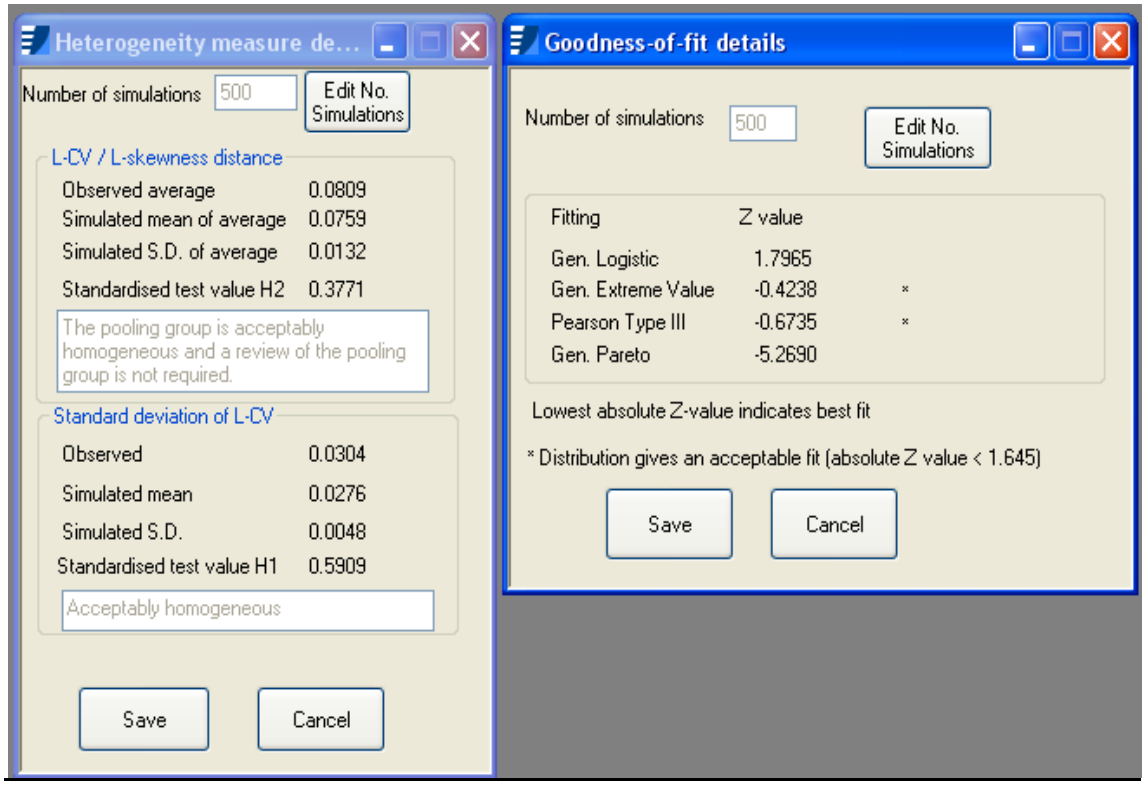
Total 498
Weighted means L-CV: 0.213 L-SKEW: 0.215



Loch_006

Station		Years of data
28041	(Hamps @ Waterhouses)	24
48803	(Carnon @ Bissoe)	15
203049	(Clady @ Clady Bridge)	27
24006	(Rookhope Burn @ Eastgate)	20
49004	(Gannel @ Gwills)	38
51003	(Washford @ Beggearn Huish)	42
47009	(Tiddy @ Tideford)	40
41020	(Bevern Stream @ Clappers Bridge)	40
72007	(Brock @ U/s a6)	31
48010	(Seaton @ Trebrownbridge)	37
49002	(Hayle @ st Erth)	52
72014	(Conder @ Galgate)	42
44003	(Asker @ Bridport)	27
24007	(Browney @ Lanchester)	15
48004	(Warleggan @ Trengoffe)	40
76811	(Dacre Beck @ Dacre Bridge)	10

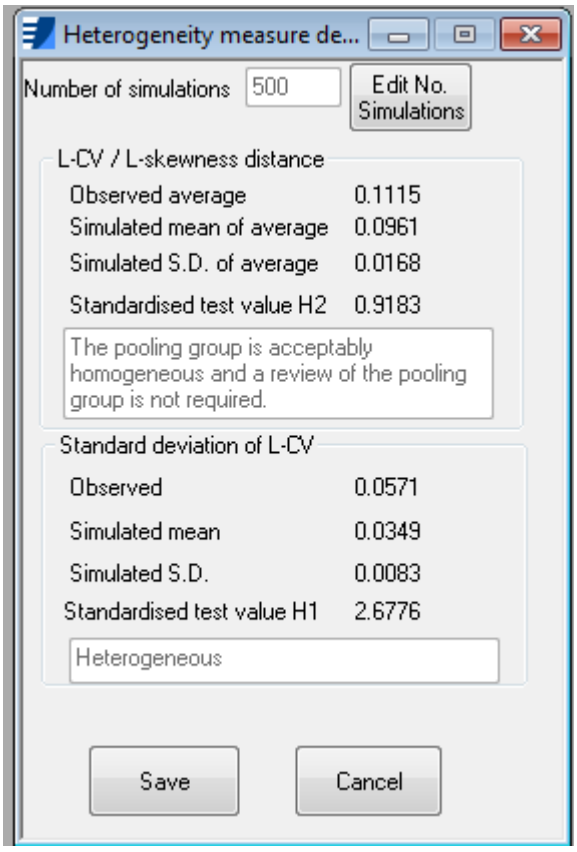
Total 500
Weighted means L-CV: 0.216 L-SKEW: 0.173

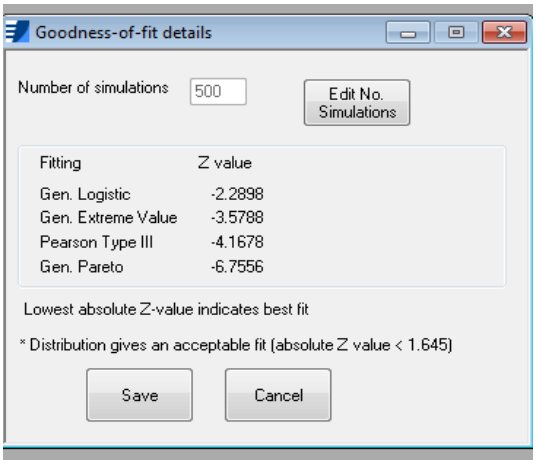


UNN_07

Station		Years of data
45817	Rhb Trib to Haddeo @ Upton (trib)	16
76011	Coal Burn @ Coalburn	32
45816	Haddeo @ Upton	16
27051	Crimple @ Burn Bridge	37
28033	Dove @ HOllinsclough	30
91802	Allt Leachdach @ Intake	34
54022	Severn @ Plynlimon Flume	38
25011	Langdon Beck @ Langdon	23
25003	Trout Beck @ Moor House	36
25019	Leven @ Easby	31
206006	Annalong@ Recorder 1895	48
27010	Hodge Beck @ Hebden	43
203046	Rathmore Burn @ Rathmore Bridges	27
56007	Senni @ Pont Hen Hafod	41
49003	de Lank @ de Lank	43

Total 536
Weighted means L-CV: 0.221 L-Skew: 0.260

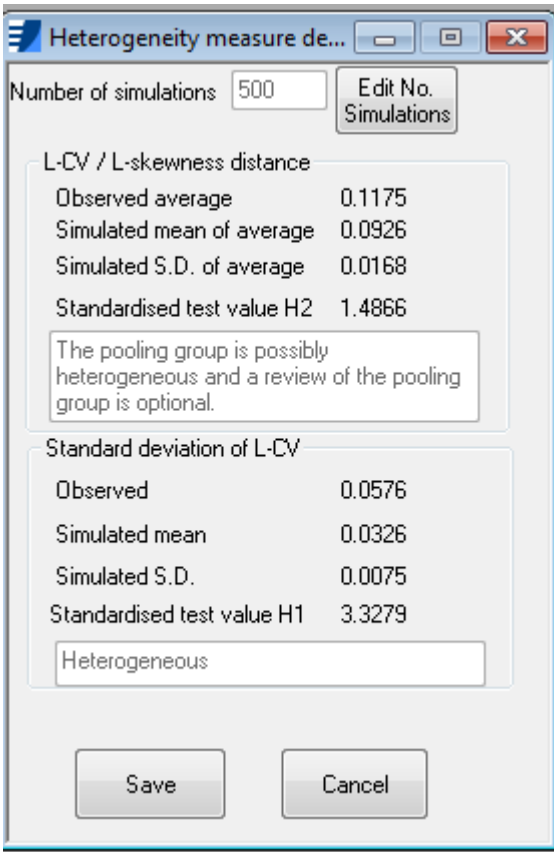


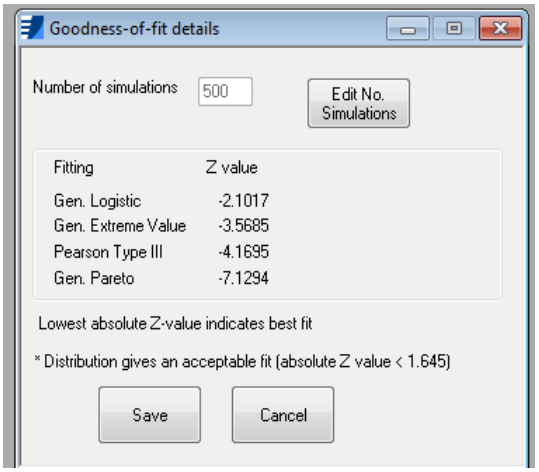


Lower Milehead

Station		Years of data
76011	Coalburn @ Coalburn	32
45817	Rhb Trib to Haddeo @ Upton (trib)	16
45816	Haddeo @ Upton	16
27051	Crimple @ Burn Bridge	37
28033	Dove @ Hollinsclough	30
91802	Allt Leachdach @ Intake	34
25011	Langdon Beck @ Langdon	23
25003	Trout Beck @ Moor House	36
25019	Leven @ Easby	31
54022	Severn @ Plynlimon Flume	38
206006	Annalong @ Recorder 1895	48
27010	Hodge Beck @ Bransdale Weir	41
203046	Rathmore Burn @ Rathmore Bridge	27
73006	Cunsey Beck @ Eel House Bridge	37
49003	de Lank @ de Lank	43
56007	Senni @ Pont Hen Hafod	41

Total 530
Weighted Means L-CV : 0.218 L-Skew : 0.252

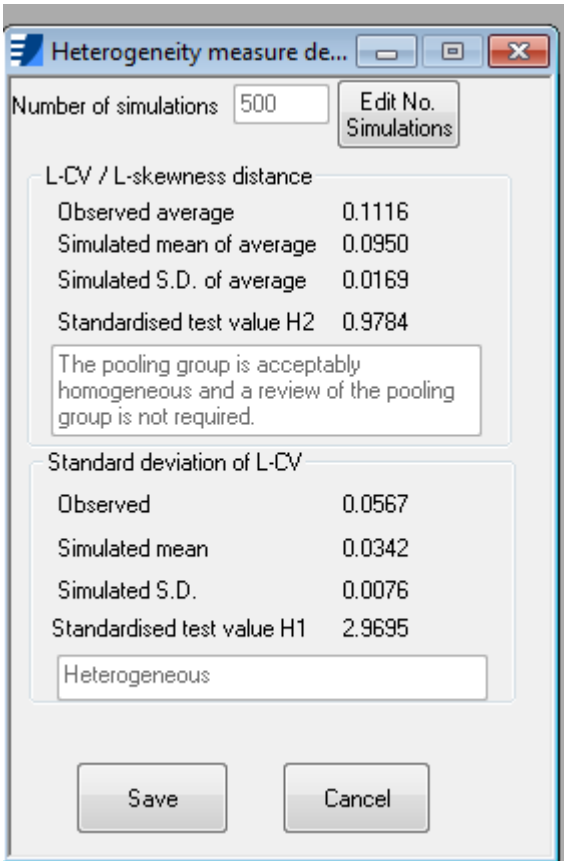


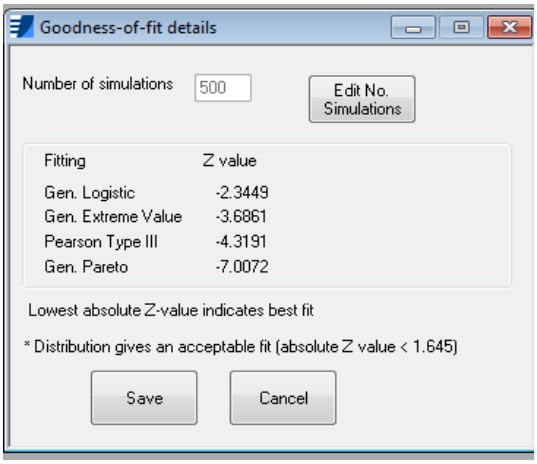


Loch Alvie 1

Station		of data
45817	Rhb Trib to Haddeo @ Upton (trib)	16
76011	Coal Burn @ Coalburn	32
28033	Dove @ Hollinsclough	30
27051	Crimple @ Burn Bridge	37
91802	Allt Leachdach @ Intake	34
25011	Langdon Beck @ Moor House	36
206006	Annalong @ Recorder 1895	48
25019	Leven @ Easby	31
27010	Hodge Beck @ Bransdale Weir	41
27032	Hebden Beck @ Hebden	43
56007	Senni @ Pomt Hen Hafod	41
203046	Rathmore Burn @ Rathmore Bridge	27
48009	st Neot @ Craigshill Wood	12
49003	de Lank @ de Lank	43

Total 548
Weight means L-CV: 0.222 L=Skew: 0.264

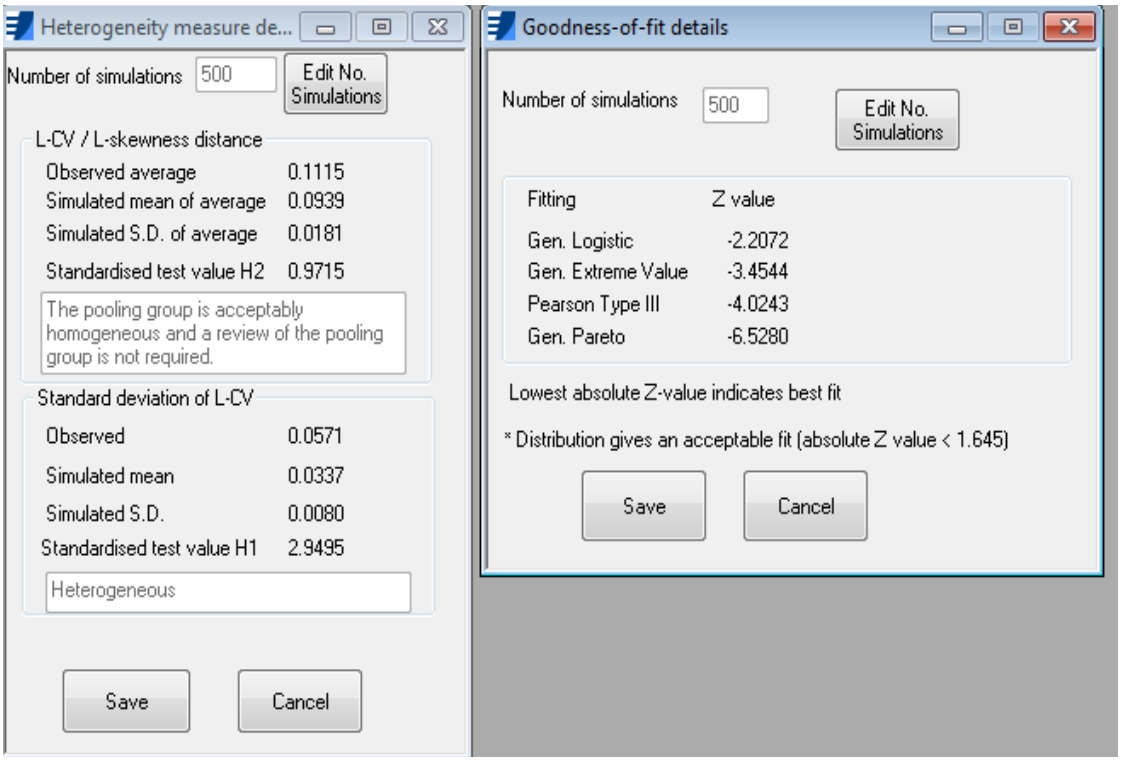




Loch Alvie 2

Station		of data
45817	Rhb Trib to Haddeo @ Upton trib	16
76011	Coal Burn @ Coalburn	32
45816	Haddeo @ Upton	16
27051	Crimple @ Burn Bridge	37
28033	Dove @ Hollinsclough	30
91802	Allt Leachdach @ Intake	34
54022	Severn @ Plynlimon Flume	38
25011	Langdon Beck @ Langdon	23
25003	Trout Beck @ Moor House	36
25019	Leven @ Easby	31
206006	Annalong @ Recorder 1895	48
27010	Hodge Beck @ Bransdale Weir	41
203046	Rathmore Burn @ Rathmore Bridge	27
56007	Senni @ Pont Hen Hafod	41
27032	Hebden Beck @ Hebden	43
49003	de Lank @ de Lank	43

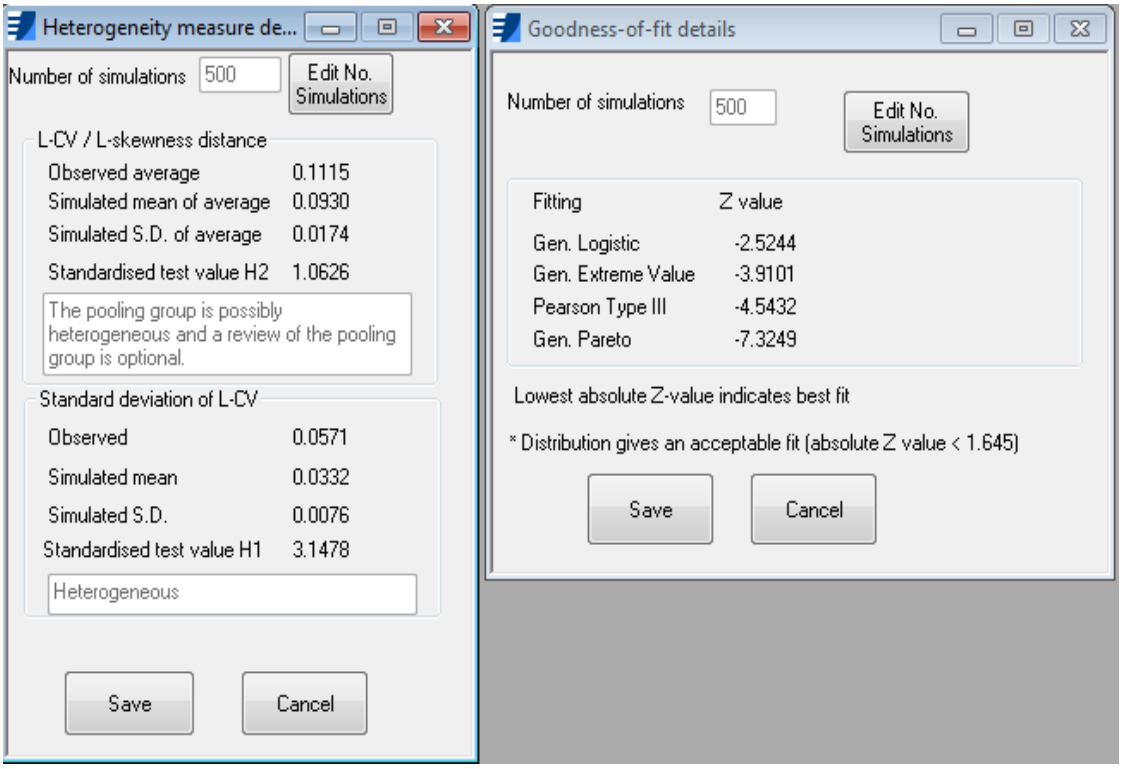
Total 536
Weighted means L-CV: 0.221 L-SKEW: 0.260



Loch Alvie 3

Station		Years of data
76011	Coal Burn @ Coalburn	32
45817	Rhb Trib to Haddeo @ Upton trib	16
45816	Haddeo @ Upton	16
27051	Crimple @ Burn Bridge	37
28033	Dove @ Hollinsclough	30
91802	Allt Leachdach @ Intake	34
54022	Severn @ Plynlimon Flume	38
25011	Langdon Beck @ Langdon	23
25003	Trout Beck @ Moor House	36
25019	Leven @ Easby	31
206006	Annalong @ Recorder 1895	48
27010	Hodge Beck @ Bransdale Weir	41
56007	Senni @ Pont Hen Hafod	41
203046	Rathmore Burn @ Rathmore Bridge	27
27032	Hebden Beck @ Hebden	43
49003	de Lank @ de Lank	43

Total 536
Weighted means L-CV: 0.220 L-SKEW: 0.260



7.2 Additional supporting information

See hydrological technical note for catchment boundaries