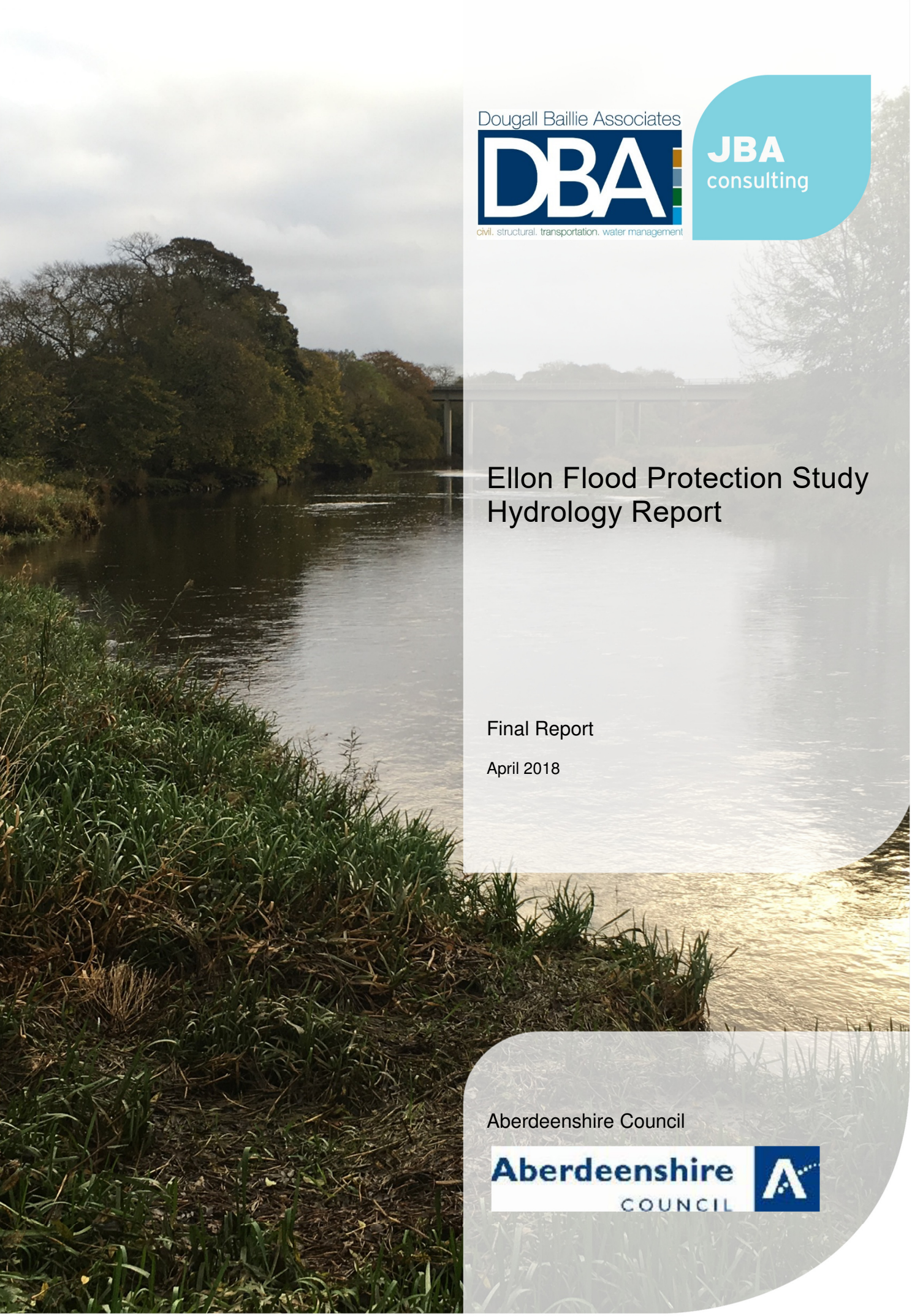

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Ellon Flood Protection Study Hydrology Report

Final Report

April 2018

Aberdeenshire Council

Aberdeenshire COUNCIL

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This report describes work commissioned by Gavin Penman, on behalf of Aberdeenshire Council, on 10 October 2017 by Purchase Order Number 1095192. Dougall Baillie's representative for the contract was Scott Macphail and Aberdeenshire Council's representative for the contract was Alistair Scotland. Grace Thompson, Briony McIntosh, David Cameron and Caroline Anderton of JBA Consulting carried out this work.

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Purpose

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Executive Summary

This report describes historical flooding and the input hydrology estimates developed for use in the Ellon Flood Protection Study for Aberdeenshire Council. The Ythan has a history of flooding dating back to at least 1642 and the main risk area is at Ellon. In addition to direct flood risk from the fluvial Ythan, flood risk at Ellon is complicated by a tidal influence and by four small watercourses (the Broomies, Modley, Hillhead and Fortree Burns). Hydrology estimates were therefore required as input to a linked 1D/2D hydraulic model of the Ythan for use in flood mapping. Those estimates included the following.

- **Peak flow estimates** on the:
    - **River Ythan at Ellon** gauging station. FEH statistical methods were investigated for peak flow estimation and the adopted method was Single Site (SS) analysis with a Generalised Logistic (GL) distribution using an extended AMAX series with data transfer from the Ardlethen gauge. A new rating, agreed with SEPA for use in this study, was applied to the Ellon data, prior to the analysis being undertaken. The 0.5% Annual Probability (AP, 200 year flood) was estimated to be circa 212.22 m^3/s for the Ythan.
    - **Modley Burn, Broomies Burn, Hillhead Burn and Fortree Burn** at their confluence with the River Ythan. A variety of methods were investigated for peak flow estimation, and the adopted method in each case was the FEH Rainfall Runoff method (on the basis of the FEH Rainfall Runoff method yielding similar time to peak values as those calculated from observed data at the nearest small catchment gauge, the level only gauge at Mill of Keithfield). The 0.5% Annual Probability (AP, 200 year flood) flood was estimated to be 4.90 m^3/s, 3.09 m^3/s, 0.81 m^3/s and 2.34 m^3/s for the Broomies, Modley, Hillhead and Fortree Burns respectively using their default critical storm durations (these will be adjusted during model runs). With respect to modelling for design events, the peak flows from the FEH Rainfall Runoff method will be used to scale hydrographs derived from ReFH units within the model.
- **Fluvial hydrographs and critical storm durations**. As there is a gauge on the Ythan at Ellon, a design hydrograph for the Ythan was derived from observed data for design model runs. This was based on the November 2009 event in order to avoid double peaked effects. For design model runs, this hydrograph will be scaled to the FEH statistical estimates. The Ythan and burns have very different catchment areas and it is recommended that two critical durations be tested in the hydraulic modelling: one long (17 h, based on the Ythan) and one short (6.75 h, based on the Modley and Broomies Burn). The Hillhead and Fortree Burns will be modelled separately.
- **Coastal still water levels for the tidal element**. These were obtained from the Coastal Flood Boundary method for the nearest estuary CFBD data point. The 0.5% AP (200 year) event was estimated to be 3.18 mAOD.
- **Tidal stage hydrograph**. This was derived from a representative event at the Aberdeen tide gauge.
- **Joint probability**. The joint probability between flow on the Ythan at Ellon and surge on the Ythan estuary was considered using the published FD2308 approach. A local chi value was also calculated between Aberdeen and Ellon and was found to be similar to the published value, showing a low correlation between flow and surge.

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Abbreviations

1D	One Dimensional (modelling)
2D	Two Dimensional (modelling)
ALTBAR	Mean catchment altitude (m above sea level)
AMAX	Annual Maximum
ARF	Areal Reduction Factor
BFIHOST	Base Flow Index estimated from soil type
CWI	Catchment Wetness Index
DPLBAR	Index describing catchment size and drainage path configuration
FARL	FEH index of flood attenuation due to reservoirs and lakes
FEH	Flood Estimation Handbook
FPEXT	FEH index describing floodplain extent
FRA	Flood Risk Assessment
GEV	General Extreme Value Distribution
GL	General Logistic Distribution
mAOD	metres Above Ordnance Datum
NGR	National Grid Reference
NNR	National Nature Reserve
OS	Ordnance Survey
OS NGR	Ordnance Survey National Grid Reference
QMED	Median Annual Flood (with return period 2 years)
ReFH	Revitalised Flood Hydrograph method
RR	Rainfall-Runoff
SAAR	Standard Average Annual Rainfall (mm)
SCF	Spreadsheet compatible format (file from Hydrolog)
SEPA	Scottish Environment Protection Agency
SPR	Standard percentage runoff
SPRHOST	Standard percentage runoff estimated from soil type
SSSI	Site of Special Scientific Interest
TBR	Tipping Bucket Raingauge
Tp	Time to Peak
URBEXT	FEH index of fractional urban extent
Z	Reflectivity

1 Introduction

1.1 Report objectives and approach

The purpose of this report is to provide details of the hydrology required to drive the hydraulic modelling and associated flood mapping for the River Ythan between Ardlethen at Ordnance Survey National Grid Reference (OS NGR) NJ 923 310 and downstream of the A90 road bridge, OS NGR NJ 986 300. Peak flow estimates and hydrological analysis were required for the following watercourses (Figure 1-1):

- The River Ythan at the upstream boundary of the model (near Bridge of Ardlethen) and the downstream model boundary (east of the A90 road bridge).
- The River Ythan at Ellon gauging station.
- The Broomies Burn, Modley Burn, Hillhead Burn and Fortree Burn at their confluence with the River Ythan.
- In addition, the Burn of Keithfield was important for storm duration analysis for the small burn catchments.
- The River Ythan is tidally influenced from approximately 600 m upstream of the A90 road bridge, therefore coastal water levels, together with consideration of joint probability were required.

FEH Statistical and a variety of Rainfall Runoff alternatives were explored for peak flow estimation. The recommended values are provided within the main body of the report with supplementary information provided in the Appendix.

The hydrographs required for the hydraulic modelling will utilise a design hydrograph derived from the Ellon gauge for the Ythan, and ReFH hydrographs for the burns. These hydrographs will be scaled to the peak flows recommended in this report. This will be undertaken within the modelling software at the modelling stage.

1.2 Catchment summary and relevant hydrometry

The catchment draining to Ellon covers a total area of approximately 550 km^2 (to the A90 road bridge) and is traversed by a number of watercourses. The River Ythan is the primary watercourse which originates north of the Grampian Mountains at Ythanwells, approximately 30 km northwest of Ellon. The river flows first north then southeast towards Ellon discharging into the North Sea approximately 10 km downstream of the town. The River Ythan is tidally influenced at the downstream extent of Ellon with the National Tidal Limit (NTL) being approximately 600 m upstream of the A90 road bridge. The Ythan estuary is a Site of Special Scientific Interest (SSSI) and is part of the Forvie National Nature Reserve (NNR). A number of tributaries discharge into the River Ythan with the Modley Burn and Broomies Burn on the left bank, and the Fortree Burn and Hillhead Burn on the right bank of the Ythan being key subcatchments of interest (Figure 1-1). Historical flooding on the Ythan has been recorded since at least 1642[1]. There are no formal or informal flood defences in the area.

Elevation ranges from approximately 300 meters above Ordnance Datum (mAOD) at the headwaters of the River Ythan to sea level at Ellon. Average annual rainfall is approximately 826 mm (catchment descriptors derived from the FEH CD-ROM[2] for the River Ythan at Ellon gauging station, listed in Table 1-1). The catchment is predominantly rural ($URBEXT_{2000}$ of 0.002) with localised urban areas ($URBEXT_{2000}$ of 0.055 for the Fortree Burn). The underlying bedrock geology is metamorphic psammite and pelites with areas of igneous intrusions, overlain by superficial glacial deposits, alluvium and small areas of peat[3]. The overall catchment is therefore dominated by relatively impermeable bedrock and superficial deposits, and will therefore exhibit a moderately rapid response to rainfall as reflected in the catchment BFIHOST (Baseflow Index based on soil type) of 0.62 and SPRHOST (Standard percentage runoff based on soil type) of c. 28%.

1 Minot, C. 1887. The Great Floods of August 1829 in the Province of Moray and Adjoining Districts. https://archive.org/stream/greatfloodsaugu00laudgoog#page/n1/mode/2up/search/ythan [Accessed: March 2018]

2 The FEH CD-ROM v3 was used as the primary source of catchment descriptor information throughout this study. FEH13 rainfall information was obtained from the FEH Webservice.

3 British Geological Survey http://mapapps.bgs.ac.uk/geologyofbritain/home.html [Accessed: December 2017]

Tipping bucket raingauges (TBR) within the catchment include Esslemont House, Fyvie Castle and Rothienorman. Additional manual raingauges include Cairnorrie, Haddow House and Meldrum House (Table 1-2). HiFlows-UK gauging stations include the Ythan at Ellon (10003) which replaced the Ythan at Ardlethen (10001, located c. 3 km upstream of Ellon) in 1982. A level only gauge, the Mill of Keithfiled located on the Burn of Keithfield, and was used in basic LAG analysis to inform time to peak (Tp) and storm durations for the smaller subcatchments at Ellon. A summary of the catchment and its hydrometry is provided in Table 1-2 and Figure 1-1.

Table 1-1: Catchment descriptors

Catchment descriptors	River Ythan at Ellon Gauging Station	Modley Burn	Broomies Burn	Fortree Burn	Hillhead Burn	Mill of Keithfield
AREA (km^2)	533.77 adjusted (532.15 default)	3.62 adjusted (3.75 default)	6.13 adjusted (5.78 default)	2.067 adjusted (2.123 default)	0.713 adjusted (2.123 default)	18.36 default
ALTBAR (m above sea level)	108	52	56	45	45	112
BFIHOST	0.62	0.547	0.514	0.562	0.562	0.587
DPLBAR (km)	24.92	2.48	3.05	36.2	36.2	3.55
FARL	0.993	1	1	1	1	0.998
FPEXT	0.0469	0.1117	0.0909	0.0789	0.0789	0.0415
FPDBAR	0.406	0.593	0.601	0.367	0.367	0.332
SAAR (mm)	826	769	770	752	752	831
SAAR4170 (mm)	857	819	821	785	785	819
SPRHOST (%)	27.83	28.78	31.64	28.98	28.98	28.82
URBEXT 1990	0.002 adjusted (0.0015 default)	0.022 adjusted (0.020 default)	0.0002 adjusted (0.0002 default)	0.061 adjusted (0.057 default)	0.061 adjusted (0.057 default)	0.0003 adjusted (0.0003 default)
URBEXT 2000	0.002 adjusted (0.0024 default)	0.029 adjusted (0.028 default)	0.001 adjusted (0.001 default)	0.063 adjusted (0.061 default)	0.063 adjusted (0.061 default)	0.0001 adjusted (0.0001 default)

Table 1-2: Catchment hydrometry summary information

Station number	Watercourse	Name	Type	Periods of record (water years)	Comments
10003	Ythan	Ellon	Primary	1983 - present	The gauge at Ellon is located in an open channel section (with cableway) of the River Ythan c. 20 m upstream of a large arched bridge (a former railway bridge and now the Formartine and Buchan Way). The stilling well is located in the gauging hut on the right bank and provides telemetered level data in real time. Replacement for the Ythan at Ardlethen (10001). Small amounts of bypassing on LB during extreme flows. A new rating was developed for Ellon using hydraulic modelling in 2018. The new rating has been applied to the AMAX record above a stage of 2.98 m.
10001	Ythan	Ardelthen	Primary	1939 - 1985	Station closed in 1982 and was replaced by the Ythan at Ellon (10003). The gauge was located in an open channel section with cableway upstream of the Bridge of Ardlethen. The bridge was a partial high flow control. Weed growth produced a variable rating in summer[4]. Previous regression analysis by Andrew Black, Dundee University and previously supplied by SEPA [5] means flows at Ardlethen can be transferred to Ellon gauging station thus extending the period of record at Ellon.
	Keithfield Burn	Mill of Keithfield	Primary	2009 - present	Used in basic LAG analysis to inform storm duration. Level only, non-cableway site. Suffers from weed issues during the

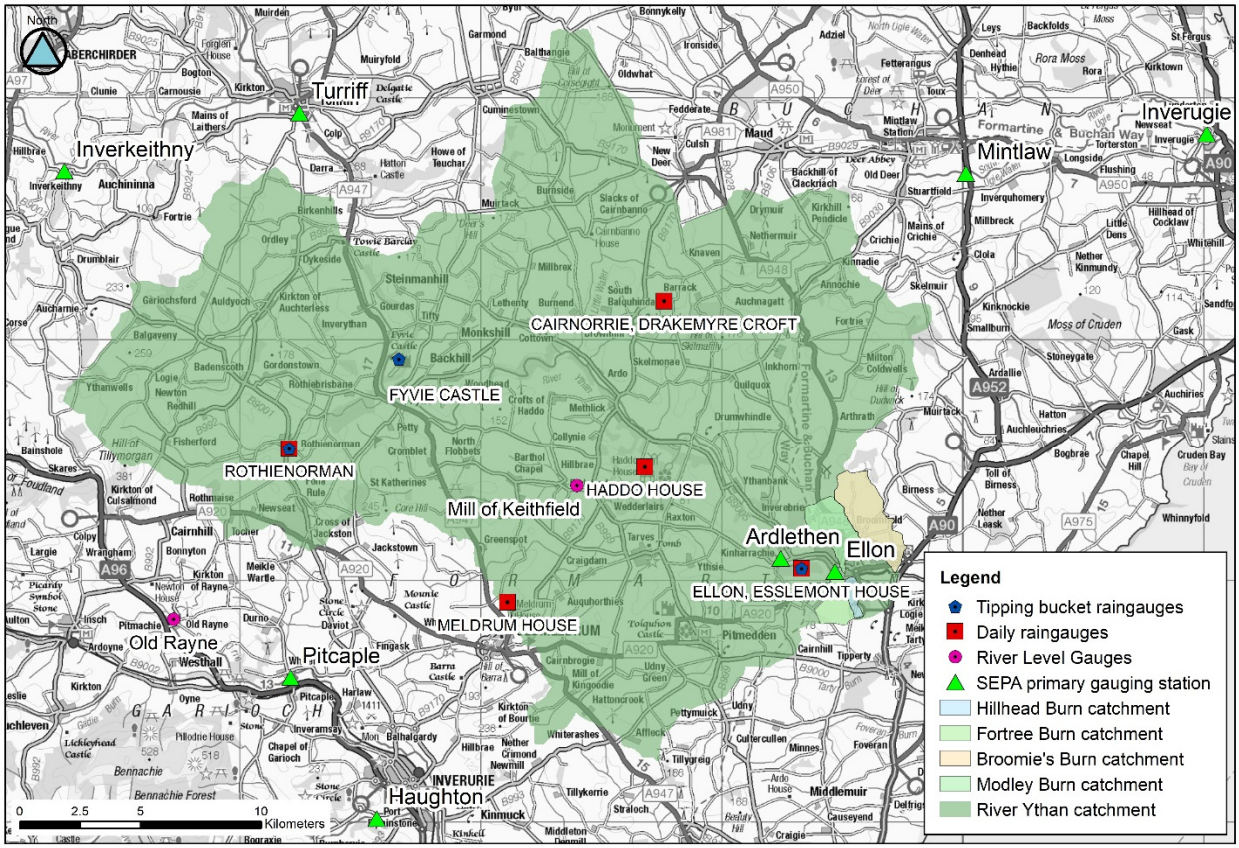
4 NRFA http://nrfa.ceh.ac.uk/data/station/info/10001 [Accessed February 2018]

5 Email communication between Caroline Anderton (JBA) and Derek Fraser (SEPA), 18 February 2005. Project: 2005s1059 Ellon Flood Study Final.

					summer months. Ratings under review[6].
		Rothienorman	Tipping Bucket raingauge	2001 - present	15 minute recording rainfall. Used in basic LAG analysis to inform storm duration at both Mill of Keithfield and the Ythan at Ellon. No information on quality provided by SEPA.
		Esslemont House	Tipping Bucket raingauge	2008 - present	15 minute recording rainfall. Will be used in model calibration for the Ellon tributaries. No information on quality provided by SEPA.
	Ythan	Ellon (A90 road bridge)	Water level logger	February 2006 - July 2006	Water level logger installed during previous JBA Ellon Flood Study[10]. Purpose was to determine a relationship between the tide gauge at Aberdeen for which there is an extensive historical record, and use this relationship to adjust the extreme sea level data (Proudman Oceanoraphic Laboratory) for Aberdeen to create extreme sea level values for the River Ythan at Ellon

6 Email correspondence with Danni Murren, SEPA, 9 January 2018.

Figure 1-1: Catchment and hydrometry



2 Flood History

2.1 Introduction

The River Ythan has been susceptible to flooding over the past several decades with the earliest recorded flooding occurring in 1642 (Table 2-1). Ellon falls within Potentially Vulnerable Area (PVA) 06/12. The greatest risk is from the River Ythan in addition to the Broomies Burn and Modley Burn. This section will discuss the details of key flood events, as well as the impacts these events have caused based upon a review of the SEPA Flood Risk Management Strategy (FRMS), in addition to other readily available sources of information such as the British Hydrological Society Chronology of British Hydrological Events (CBHE). The major events are summarised in Table 2-1. Historical flood information is considered in the flood estimation as described in Section 3.

The largest recorded flooding since records began occurred in January 2016 with a stage of 4.4 m recorded at the Ellon gauging station.

Table 2-1: Flood history

Date	Description	Source
1642	'….Ythan grew so great that it drowned out the fires in some men's houses in Ellon and Newburgh, far beyond the wonted course, many thinking this to be prodigious tokens.'	The Great Floods of August 1829 in the Province of Moray and Adjoining Districts[1] [https://archive.org/stream/greatfloodsaugu00laudgoog#page/n6/mode/2up accessed: March 2018]
1829	'…the recent flood hereabouts seems to have exceeded that of 1768 by fully 2 feet…'	The Great Floods of August 1829 in the Province of Moray and Adjoining Districts[1] [https://archive.org/stream/greatfloodsaugu00laudgoog#page/n6/mode/2up accessed: March 2018]
21/07/1893	1893 July 21 p[22]: "Thunderstorms and very heavy rain, producing floods at Fraserburgh and Banff, in the N.E. of Scotland."	CBHE[7]
08/02/1894	1894 August 2 p[21]: "along the Don and Ury many fields were swept clean of all their crops, also along the Ythan in Buchan."	CBHE[7]
08/05/1913	1913 May 8-11 Rainfall observer at House of Schivas noted (p[14]) "Rain 3.10 in. causing the highest flood in the river remember in May."	CBHE[7]
08/05/1913	1913 May 8-11 Observer, Haddo, at Ellon (house of Schivas), Aberdeenshire, noted p[59] "The river Ythan was in greater flood than seen for many years in May, when 3.1 fell from 8th to 11th inclusive…."	CBHE[7]
06/11/1951	2.78 m recorded at Ardlethen gauging station (10001) highest recorded stage within the Ardlethen series (1940-1984)	SEPA hydrometric data
1986	River Ythan flooding across the floodplain with photographs from Ellon Bridge.	BBC [http://www.bbc.co.uk/history/domesday/dblock/GB-392000-828000/picture/2 accessed: 10.11.17]
12/09/1995	SEPA extent - Babties interpolated flood outlines from a limited number of points. Ellon Gauging station 12/09/1995 records stage of 3.011 m	SEPA hydrometric data[8]

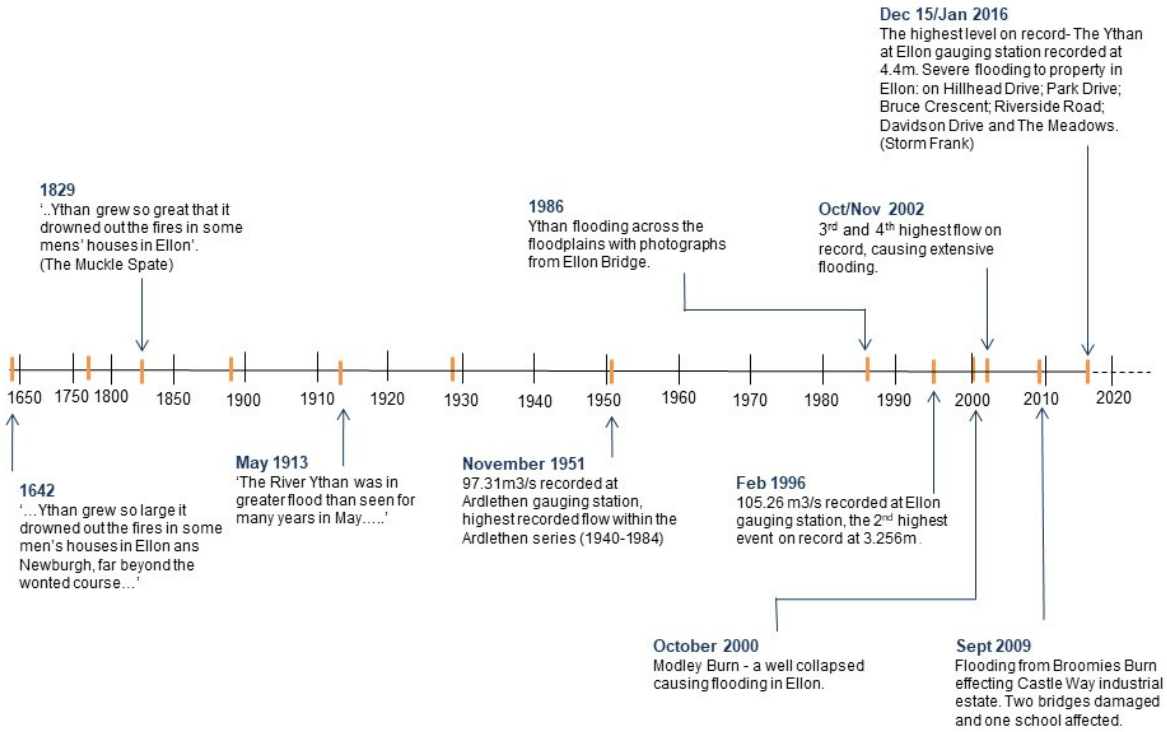
7 CBHE found online at http://cbhe.hydrology.org.uk/ [accessed on 10/11/17]

	River Ythan reported to have risen by approx. 1.2 m (C. 350 m downstream of Old Bridge of Ellon)	
10/02/1996	105.26 m^3/s recorded at Ellon gauging station (10003) - 4th highest recorded flow in record (including Ardlethen data)	SEPA hydrometric data[9]
2000	Modley Burn in Ellon, a wall collapsed causing flooding	SEPA FRMS[9]
22/10/2002	22-23 October 2002 - 5th highest recorded stage at Ellon gauging station	Flood Risk Report[9]
21/11/2002	21-22 November 2002	Flood Risk Report[9]
10/ 2002 11/2002	SEPA received letter from resident at 3 Provost Cordiner Road, Ellon. Photographs showing river near to garden, resident wanted an embankment built.	SEPA[9]
10/2002 11/2002	7 Properties flooded by River Ythan. Woodhead Road, Methlick. Flooding from blocked culvert in private land-Balqholly-Auchterless	4th Biennial Report-Aberdeenshire County Council[9]
11/2002	SEPA extent - Trash line survey SEPA	SEPA Extent[9]
2002	Modley Burn, Ellon - a basement of a property located on the culvert section of the burn flooded due to water backing up.	SEPA FRMS[9]
2002	SEPA flood photos of Ellon catchment	Photos supplied by SEPA
2004	Two properties in Findhorn Gardens flooded due to runoff from the adjacent housing development.	SEPA FRMS[9]
2009	Flood from Broomies Burn, which affected Castle Way Industrial Estate, Ellon and damaged two bridges. Two industrial units and a school were affected.	SEPA FRMS[9]
Sept 2009	Ellon Golf course flooded	YouTube [https://www.youtube.com/watch?v=fUrmZl8UzLI accessed on 20/10/17]
04/01/2016	Main road (A90) outside of Ellon closed due to flooding	Press and Journal [https://www.pressandjournal.co.uk/fp/news/aberdeenshire/795688/road-outside-ellon-closed-due-flooding/ accessed on 10.11.17]
08/01/2016	River Ythan floods the centre of Ellon. Flooding on fields beside Esslemont Circle.	YouTube [https://www.youtube.com/watch?v=9u3RUvxaDaw accessed on 20.10.17]
08/01/2016	'The River Ythan also burst its banks, with flow levels breaking previous records at Ellon…….18 homes in Ellon were evacuated'	BBC News [http://www.bbc.co.uk/news/uk-scotland-35259398 accessed on 10.11.17]
08/01/2016	' In Ellon, the Ythan stood at 4.4m (14.4ft) at its peak, 1.2m (3.93ft) above the previous record level in 1983, according to Scottish Environmental Protection Agency (SEPA) figures.' *[4.4m was recorded at Ellon gauging station on 08/01/2016. Previous record level was 3.34m on 23/12/2012. It is suggested 1983 is a mis-print in this article.]*	Press and Journal [https://www.pressandjournal.co.uk/fp/news/aberdeenshire/799591/pictures-ellon-flooded-ythan-explodes-town/ accessed on 10.11.17]
08/01/2016	SEPA gauging station Ythan at Ellon; Highest event on record - stage 4.46 m	SEPA hydrometric data
08/01/2016	Overtopping of Burn opposite 87 Hillhead Drive; flow pathway down Hillhead drive. Trash line evident from photos (see appendix A) near 32 and 34 Patey Road. River Ythan overtopped into Bruce Crescent adjacent	Client record.

	to 32 Bruce Crescent. Flooding exasperated by surface water from Riverside Road/Provost Davidson Drive and drainage backing up in Bruce Crescent. Flooding to Ythan Court, The Meadows flooding. Overland flow path from playing fields to the North and flooding from the Broomies Burn to the east of the flood area. Flooding from the River Ythan evident from the west of the flood area.	
08/01/2016	Video footage of the highest flow on record at Ythan, showing flood extents.	YouTube [https://www.youtube.com/watch?v=_SzdPOEmK8g accessed on 20.10.17]
2016	Flood levels and extents supplied by SEPA (Appendix E)	Data supplied by SEPA

In summary Ellon has experienced flooding in 1642, 1829, 1894, 1913, 1951, 1986, 1996, 2000, 2002, 2004, 2009, 2015 and 2016 (Figure 2-1).

Figure 2-1: Key flood events in Ellon



2.2 Previous Flood Estimates

JBA Consulting undertook a Flood Risk and Mechanisms review of the Ythan at Ellon in 2005, finalised in August 2006[8]. This work included peak flow estimation on the River Ythan at Ellon as well as analysis and incorporation of the Ardlethen data. Extreme sea levels and joint probability analysis was also undertaken. Estimates were based upon the techniques available at the time. In the case of the 2005 report comparisons were made between the statistical pooling group analysis and single site (SS) approach. Subsequently, in July 2010 JBA undertook a Flood Risk Assessment (FRA) for Cromleybank, Ellon[9] which involved updating peak flow estimates and extreme sea levels from the 2005 Ellon Flood Study using updated methodologies and data. Comparisons were made between the statistical SS and Enhanced Single Site (ESS) methodologies.

Final peak flow estimates for the 2005 study were derived using the statistical pooling methodology using an extended AMAX (Annual Maxima) series (transferring the Ardlethen flows to Ellon, see Section 3.2.1 for details) with a GEV distribution. The 2010 peak flows were derived using the updated ESS methodology with a GEV distribution, also utilising an extended AMAX series. Peak flow estimates from these reports are summarised below (Table 2-2). It can be seen the estimates are very similar with the 0.5% AP (200 year) peak flow in 2005 being estimated at 137.0 m^3/s and 146.7 m^3/s in 2010.

Table 2-2: Peak flow estimates from the 2005 and 2010 JBA studies

Return Period (years)	Annual Probability [AP] (T)	2005 study River Ythan at Ellon. Statistical pooling group analysis: GEV (m^3/s)	2010 study River Ythan at Ellon, Statistical ESS analysis: GEV (m^3/s)
2	50	57.7	58.8
5	2	78.6	79.4
10	10	91.6	92.9
25	4	106.9	109.8
50	2	117.5	122.3
75	1.3	123.2	129.5
100	1	127.5	134.5
200	0.5	137.0	146.7
200 +CC	0.5 +CC	171.3	176.0

8 JBA Consulting. August 2005. The Study of Flooding Mechanisms and the Areas at Risk from Flooding. The Ythan at Ellon, Aberdeenshire. Final Report.

9 JBA Consulting. July 2010. Cromleybank, Ellon. Flood Risk Assessment. Draft Report. 2010s4246.

3 Flood Estimation: River Ythan and Overall Approach

3.1 Peak Flows: overall approach

Important inputs into a flood study are the analysis of historic floods (where data are available), and estimation of flood flows for a range of annual probabilities or 'design' events. Flood estimates for catchments of this size and type are undertaken using the Flood Estimation Handbook (FEH). The FEH offers three methods for analysing design flood flows: the Statistical, the Rainfall Runoff, and hybrid methods. The Statistical method combines estimation of the median annual maximum flood (QMED) at the subject site with a growth curve, derived from one of three methods; (a) a pooling group of gauged catchments that are considered hydrologically similar to the subject site, (b) through single site analysis of a nearby gauge, or (c) a combination of the two through the use of enhanced single site. The Rainfall Runoff method combines design rainfall with a unit hydrograph derived for the subject site (the Rainfall Runoff method has recently been updated as ReFH2[10]). Hybrid methods involve a combination of the two. Both the Statistical and Rainfall Runoff procedures require the derivation of catchment descriptors (Table 1-1).

Adjustments were then made to catchment area (using OS background mapping) and URBEXT (using the national growth model through the year of study, 2018, per FEH Volume 5). The FEH CD-ROM BFIHOST values appeared reasonable in comparison to the available geological information[11].

The Statistical Method was selected as the most appropriate choice of method of peak flow estimation for the River Ythan. This was because of the relatively large, rural nature of this catchment and the good record of gauged data available. For the other catchments, comparisons were made between the Statistical method and different Rainfall Runoff methods. Following this comparison, it was assumed that the most appropriate approach was to use the Rainfall Runoff method.

In addition to peak flow and tidal level estimates, the hydraulic model also required the following information:

- Fluvial hydrographs for the model upstream limit on the Ythan, and also the Modley, Broomies, Fortree and Hillhead Burns.
- Appropriate storm durations for flood mapping. As the Ythan and the burns have very different catchment areas, and following storm duration analysis, two catchment wide storm durations (one long and one short) were considered independently for the modelling.
- Stage hydrograph for the downstream boundary.

These items are also discussed in the following sections.

[10] Wallingford Hydro Solutions (WHS) The Revitalised Flood Hydrograph, ReFH2: Technical Guidance. 2015

[11] http://mapapps.bgs.ac.uk/geologyofbritain/home.html

3.2 River Ythan Flood Estimation

3.2.1 Ythan at Ellon

There is a SEPA gauging station at Ellon (station number 10003) with 33 years of AMAX data available (spanning water years[12] 1984 to 2017). JBA Consulting undertook a rating review of the gauging station and developed a new high flow rating using hydraulic modelling[13]. The original SEPA AMAX series was kept pre-1994 due to a change in flow regime. The station has been gauged up to 2.98 m, the existing SEPA rating has been applied below this level and the new rating only applied to the post-1994 AMAX series above this stage. The AMAX series is given in Table 3-1 and Figure 3-1 (with a comparison to the original series in Appendix C).

The Ellon gauging station is a replacement of the Ythan at Ardlethen (station number 10001) located approximately 3 km upstream of Ellon. This station closed in 1984 with 44 years of AMAX data (spanning water years 1940 - 1984). During the Ellon Flood Study[8] a regression model was utilised to relate the flows between the two gauges and subsequently extend the length of the AMAX series available for Ellon. The regression analysis was originally undertaken by Andrew Black (Dundee University) and was supplied to JBA by SEPA[14]. The regression equation (Equation 3-1) resulting from the analysis is displayed below:

Equation 3-1: Regression between Ardlethen and Ellon Gauging Stations

$$Y = 1.1603\ X - 1.556$$
$$r^2 = 0.9983$$
Y = Ellon, X = Ardlethen

This regression was used to transfer the Ardlethen flows to Ellon thereby giving an extend AMAX record at Ellon covering water years 1940 to 2017 (Table 3-3 and Figure 3-2).

Given size of the catchment, reasonable record length at Ellon (with the ability to extend the record length through transfer of the Ardelthen flows, giving 78 years of AMAX data) in addition to the rating review (which should reduce the uncertainty of high flows), it was anticipated that the statistical approach of SS and ESS analysis would be the most suitable approach at this location, with the Rainfall Runoff approach provided for comparison only.

The SS analysis was carried out using only the Ellon data (Table 3-1,Table 3-2) and again for the extended Ellon record along with the ESS analysis (Table 3-3, Table 3-4). In both cases the Generalised Logistic (GL) and Generalised Extreme Value (GEV) distribution curves were tested. Additional information on the ESS pooling approach is provided in Appendix A. A QMED value of 59.09 m^3/s for the Ellon only record, and 56.82 m^3/s for the extended record, as derived from the observed AMAX data, was used in each case.

From these results, it can be seen all curves fit the observed data well up to approximately the 30 year return period event (Figure 3-3). The SS GL and ESS GL results provide steeper growth curves than the GEV results. In all cases, the frequency of the 2016 flood (260 m^3/s; this flow value assumes that the corresponding stage value was not artificially influenced during the flood event; e.g. via debris within the channel Appendix D or blockage at the bridge) was estimated to be very rare, ranging from an AP value of over 0.25% (400 years; under the SS analysis with a GL growth curve) to over 0.1% AP (1000 years, using ESS with the GEV growth curve). Statistically, it could be argued that the ESS approach is the most suitable as it uses the largest sample size and is less likely to be influenced by large outlier events (such as 2016). The Z statistic approach available within WINFAP indicated that the GL distribution had the best goodness of fit to the ESS pooling group.

The corresponding AP estimate for the 2016 event using this ESS approach is in excess of 0.2% (500 years); using the SS approach the AP value is 0.25% (400 years). In either case, this is estimated to be a very rare event, and unfortunately no quantified ranked flood history appears to be available for the Ythan. However, it was possible to make a very approximate estimate based upon applying simplifying assumptions to the flood history which was available (Table 2-1), as follows:

12 A water year is defined as the period between 1 October in one year and 30 September in the next year.

13 JBA Consulting. 2017s7016. Ellon Gauging Station Rating Review. Draft Report. February 2018.

14 Email communication between Caroline Anderton (JBA) and Derek Fraser (SEPA), 18 February 2005

- Changes in the physical catchment and climatic conditions since 1642 were disregarded (this is clearly a very big assumption).
- Applying Gringorten plotting positions to the period 1642 to 2017, yielded an estimate of 0.15% AP (672 years) for the largest flood event during that period and 0.41% (241 years) for the second largest.

For the ESS estimate of the 2016 event to be consistent with the historical analysis, it would therefore need to be assumed that the 2016 event was the largest event between 1642 and 2017. This may or may not be correct, and in the absence of quantifiable ranked historical information to support this assumption, it was concluded that the SS analysis was more appropriate in this particular case.

As in any flood frequency analysis, the findings may be subject to change following large floods and extrapolation to large floods (e.g. the 0.1% AP, 1000 year) events may be more uncertain than under a pooled approach. In order to provide an indication of uncertainty, 95% confidence limits for the SS curves generated via high resampling through the bootstrapping method available in WINFAP are shown in Figure 3-4, Figure 3-5 (for the GL and GEV growth curves, respectively) and Table 3-5. The width of the confidence band increases with return period and is marginally wider for the GEV (e.g. a range of 121 to 325 m^3/s for the 0.5% AP, 200 year, event). It can be seen that the 2016 event is an outlier from the rest of the AMAX series, but it does lie within the confidence intervals. A sensitivity test was therefore undertaken whereby the 2016 event was removed from the AMAX data and the SS analysis re-run. This resulted in a large change in the estimate of the 0.5% AP (200) year event, which reduced to 159 m^3/s, which is not dissimilar to the values estimated in previous studies (Table 3-6). This indicates that the flow value of the 2016 has a large influence upon the results. A further test was therefore undertaken using AMAX stage data only for the full period of record (i.e. including the 2016 event) at the Ellon gauge (using only the 34 years of Ellon stage data as it was not possible to directly transfer the stage data from Ardlethen). Application of a single site analysis to the stage AMAX resulted in an AP value for the 2016 stage (4.46 m) of between circa 0.85% (117 years) and 0.38% (260 years). While the stage analysis was based upon a shorter record length than the flow analysis using the combined Ardlethen and Ellon series, and may therefore be slightly more uncertain, it does still indicate that the 2016 event was very large and at least in excess of 1% AP (100 years).

Previous JBA studies have adopted a pooled/ESS GEV approach to peak flow estimation for the Ythan. However, based on the SS confidence interval and ESS WINFAP analysis on the extended Ellon AMAX record adoption of the GL distribution is considered more appropriate. Arguably either the SS or ESS approaches could be adopted however, on the basis of the historical discussion above, the SS GL approach has been adopted for this study.

Table 3-1: Ellon AMAX series

Date/Time	Stage (m)	Q (m^3/s)	Comment
29/01/1984 10:45	2.474	57.13	Original SEPA Q
04/11/1984 10:15	3.023	93.63	Original SEPA Q
01/12/1985 14:15	2.870	82.32	Original SEPA Q
11/04/1987 13:45	2.463	56.51	Original SEPA Q
25/01/1988 14:45	2.895	84.10	Original SEPA Q
20/10/1988 06:15	2.685	69.84	Original SEPA Q
17/12/1989 12:45	1.348	14.01	Original SEPA Q
05/03/1991 08:00	2.158	40.98	Original SEPA Q
04/11/1991 19:30	1.967	32.40	Original SEPA Q
01/10/1992 09:15	1.955	31.90	Original SEPA Q
01/03/1994 14:45	2.791	77.69	Original SEPA Q
12/09/1995 14:00	3.011	97.25	JBA Rating
10/02/1996 20:00	3.256	117.61	JBA Rating
04/12/1996 10:30	1.995	39.86	Original SEPA Rating
05/04/1998 14:00	2.367	56.40	Original SEPA Rating
15/11/1998 08:45	2.198	48.62	Original SEPA Rating
27/04/2000 02:15	2.848	80.74	Original SEPA Rating
12/03/2001 20:30	2.594	67.49	Original SEPA Rating
20/07/2002 20:15	2.109	44.70	Original SEPA Rating
23/10/2002 03:30	3.189	111.59	JBA Rating
19/01/2004 21:45	2.038	41.66	Original SEPA Rating
08/01/2005 16:45	1.906	36.22	Original SEPA Rating
25/03/2006 17:00	2.324	54.38	Original SEPA Rating
12/02/2007 01:45	2.481	61.88	Original SEPA Rating
22/11/2007 14:15	2.464	61.05	Original SEPA Rating
04/09/2009 13:00	2.784	77.32	Original SEPA Rating
02/11/2009 03:30	3.320	123.53	JBA Rating
11/12/2010 10:45	2.922	84.76	Original SEPA Rating
14/08/2012 14:45	1.707	28.55	Original SEPA Rating
23/12/2012 11:00	3.344	125.80	JBA Rating
06/02/2014 07:30	2.211	49.21	Original SEPA Rating
07/10/2014 23:45	2.362	56.16	Original SEPA Rating
08/01/2016 04:45	4.460	260.30	JBA Rating
08/02/2017 05:00	2.137	45.92	Original SEPA Rating

Table 3-2: Peak flow estimates: statistical estimates for the Ythan at Ellon

Annual Probability [AP] (%)	Return Period (years)	River Ythan at Ellon Gauging Station. Single Site Statistical Method Flow: GL (m^3/s)	River Ythan at Ellon Gauging Station. Single Site Statistical Method Flow: GEV (m^3/s)
50	2	59.07	60.21
20	5	89.95	93.41
10	10	115.09	119.90
4	25	155.09	159.54
3.33	30	164.28	168.23
2	50	192.71	194.19
1.33	75	218.48	216.67
1	100	238.72	233.72
0.5	200	295.29	278.97
0.2	500	390.73	349.10
0.1	1000	482.77	411.28
3.33 +CC	30 +CC	203.70	208.60
0.5 +CC	200 +CC	366.15	345.92
0.5 specific discharge	200	0.55	0.52
1 growth factor	100	4.04	3.88

Table 3-3: Extended Ellon AMAX series (transfer from Ardlethen)

Date	Stage (m)	Q (m^3/s)	Comment
07 Feb 1940	1.65	36.93	Equation 3-1 applied
06 Nov 1940	2.01	56.44	Equation 3-1 applied
11 Nov 1941	2.18	67.69	Equation 3-1 applied
09 May 1943	1.84	46.53	Equation 3-1 applied
13 Nov 1943	1.35	24.62	Equation 3-1 applied
07 Feb 1945	1.98	54.60	Equation 3-1 applied
28 Oct 1945	2.47	90.26	Equation 3-1 applied
20 Nov 1946	2.15	65.61	Equation 3-1 applied
11 Jan 1948	1.94	52.20	Equation 3-1 applied
11 Dec 1948	2.00	55.82	Equation 3-1 applied
25 Sep 1950	2.26	73.48	Equation 3-1 applied
10 Jan 1951	1.89	49.31	Equation 3-1 applied
06 Nov 1951	2.78	119.55	Equation 3-1 applied
22 Sep 1953	1.91	50.46	Equation 3-1 applied
06 May 1954	1.79	43.86	Equation 3-1 applied
24 Nov 1954	2.33	78.81	Equation 3-1 applied
16 Dec 1955	2.03	57.70	Equation 3-1 applied
20 Jul 1957	2.14	64.92	Equation 3-1 applied
11 Dec 1957	2.49	91.98	Equation 3-1 applied
12 Dec 1958	2.01	56.44	Equation 3-1 applied
22 Jan 1960	2.06	59.61	Equation 3-1 applied
01 Nov 1960	2.19	68.40	Equation 3-1 applied
12 Jan 1962	1.99	55.21	Equation 3-1 applied
03 Sep 1963	2.09	61.56	Equation 3-1 applied
25 Mar 1964	1.83	45.99	Equation 3-1 applied
18 Sep 1965	1.80	44.38	Equation 3-1 applied
03 Dec 1965	2.17	66.99	Equation 3-1 applied
06 May 1967	2.06	59.61	Equation 3-1 applied
05 May 1968	2.27	74.23	Equation 3-1 applied
07 Jan 1969	2.08	60.91	Equation 3-1 applied
15 Jan 1970	2.06	59.61	Equation 3-1 applied
19 Mar 1971	1.98	54.60	Equation 3-1 applied
04 Feb 1972	1.94	52.20	Equation 3-1 applied
20 Nov 1972	0.89	11.55	Equation 3-1 applied
20 Dec 1973	2.11	62.89	Equation 3-1 applied
29 Oct 1974	1.62	35.55	Equation 3-1 applied
29 Jan 1976	1.57	33.32	Equation 3-1 applied
21 Jan 1977	1.88	48.75	Equation 3-1 applied
23 Feb 1978	2.39	83.59	Equation 3-1 applied
25 Dec 1978	1.60	34.64	Equation 3-1 applied
04 Oct 1979	2.64	105.62	Equation 3-1 applied
24 Nov 1980	1.82	45.45	Equation 3-1 applied
31 Dec 1981	2.10	62.23	Equation 3-1 applied
13 Oct 1982	1.90	49.88	Equation 3-1 applied
29 Jan 1984	2.47	57.13	Original SEPA Q

04 Nov 1984	3.02	93.63	Original SEPA Q
01 Dec 1985	2.87	82.32	Original SEPA Q
11 Apr 1987	2.46	56.51	Original SEPA Q
25 Jan 1988	2.90	84.10	Original SEPA Q
20 Oct 1988	2.69	69.84	Original SEPA Q
17 Dec 1989	1.35	14.01	Original SEPA Q
05 Mar 1991	2.16	40.98	Original SEPA Q
04 Nov 1991	1.97	32.40	Original SEPA Q
01 Oct 1992	1.96	31.90	Original SEPA Q
01 Mar 1994	2.79	77.69	Original SEPA Q
12 Sep 1995	3.01	97.25	JBA Rating
10 Feb 1996	3.26	117.61	JBA Rating
04 Dec 1996	2.00	39.86	Original SEPA Rating
05 Apr 1998	2.37	56.40	Original SEPA Rating
15 Nov 1998	2.20	48.63	Original SEPA Rating
27 Apr 2000	2.85	80.74	Original SEPA Rating
12 Mar 2001	2.59	67.49	Original SEPA Rating
20 Jul 2002	2.11	44.70	Original SEPA Rating
23 Oct 2002	3.19	111.59	JBA Rating
19 Jan 2004	2.04	41.66	Original SEPA Rating
08 Jan 2005	1.91	36.22	Original SEPA Rating
25 Mar 2006	2.32	54.38	Original SEPA Rating
12 Feb 2007	2.48	61.88	Original SEPA Rating
22 Nov 2007	2.46	61.05	Original SEPA Rating
04 Sep 2009	2.78	77.32	Original SEPA Rating
02 Nov 2009	3.32	123.53	JBA Rating
11 Dec 2010	2.92	84.76	Original SEPA Rating
14 Aug 2012	1.71	28.55	Original SEPA Rating
23 Dec 2012	3.34	125.80	JBA Rating
06 Feb 2014	2.21	49.21	Original SEPA Rating
07 Oct 2014	2.36	56.16	Original SEPA Rating
08 Jan 2016	4.46	260.30	JBA Rating

Table 3-4: Peak flow estimates: statistical estimates for the extended Ythan at Ellon record with adjusted catchment area

Annual Probability [AP] (%)	Return Period (years)	River Ythan at Ellon Gauging Station. Single Site Statistical Method Flow: GL (m^3/s)	River Ythan at Ellon Gauging Station. Single Site Statistical Method Flow: GEV (m^3/s)	River Ythan at Ellon Gauging Station. Enhanced Single Site Statistical Method Flow: GL (m^3/s)	River Ythan at Ellon Gauging Station. Enhanced Single Site Statistical Method Flow: GEV (m^3/s)
50	2	56.82	57.12	56.82	56.83
20	5	79.66	81.89	78.99	81.06
10	10	97.35	100.48	95.83	98.82
4	25	124.37	126.81	121.13	123.41
3.33	30	130.42	132.37	126.74	128.53
2	50	148.82	148.62	143.69	143.36
1.33	75	165.14	162.27	158.60	155.66
1	100	177.76	172.40	170.06	164.71
0.5	200	212.22	198.41	201.05	187.65
0.2	500	268.21	236.66	250.68	220.67
0.1	1000	320.25	268.86	296.15	247.89
3.33 +CC	30 +CC	161.72	164.14	157.16	159.38
0.5 +CC	200 +CC	263.15	246.03	249.30	232.68
0.5 specific discharge	200	0.40	0.37	0.38	0.35
1 growth factor	100	3.13	3.02	2.99	2.90

Table 3-5: Peak flow estimates: confidence limits for the extended Ythan at Ellon

Annual Probability [AP] (%)	Return Period (years)	River Ythan at Ellon Single Site Statistical Method Flow: GL (m^3/s)	River Ythan at Ellon Single Site Statistical Method Flow: GL confidence limits (m^3/s)	River Ythan at Ellon Single Site Statistical Method Flow: GEV (m^3/s)	River Ythan at Ellon Single Site Statistical Method Flow: GEV confidence limits (m^3/s)
50	2	57.60	52.587 - 62.648	57.13	51.966 - 62.141
20	5	80.46	72.011 - 89.891	81.88	73.221 - 91.992
10	10	98.17	84.214 - 115.264	100.45	86.116 - 118.760
4	25	125.20	99.861 - 158.818	126.75	100.137 - 164.200
3.33	30	131.26	103.029 - 169.272	132.3	102.471 - 175.010
2	50	149.67	112.146 - 203.315	148.52	108.992 - 207.749
1.33	75	165.99	119.657 - 234.707	162.15	113.646 - 237.761
1	100	178.62	124.685 - 261.059	172.26	116.497 - 260.089
0.5	200	213.07	136.909 - 336.998	198.22	120.790 - 324.509
0.2	500	269.04	152.785 - 478.252	236.37	125.638 - 433.665
0.1	1000	321.06	166.442 - 625.617	268.47	128.033 - 538.880

Table 3-6: Peak flow estimate comparison between the 2005 and 2010 reports and the extended Ellon record excluding the 2016 event

Return Period (years)	Annual Probability [AP] (T)	2005 study River Ythan at Ellon. Statistical pooling group analysis: GEV (m^3/s)	2010 study River Ythan at Ellon, Statistical ESS analysis: GEV (m^3/s)	2018 study River Ythan at Ellon, Statistical SS analysis: GL excluding 2016 (m^3/s)
2	50	57.7	58.8	56.47
5	2	78.6	79.4	76.00
10	10	91.6	92.9	89.47
25	4	106.9	109.8	108.16
50	2	117.5	122.3	123.62
75	1.3	123.2	129.5	133.34
100	1	127.5	134.5	140.59
200	0.5	137.0	146.7	159.32
200 +CC	0.5 +CC	171.3	176.0	197.56

Figure 3-1: AMAX series at Ellon

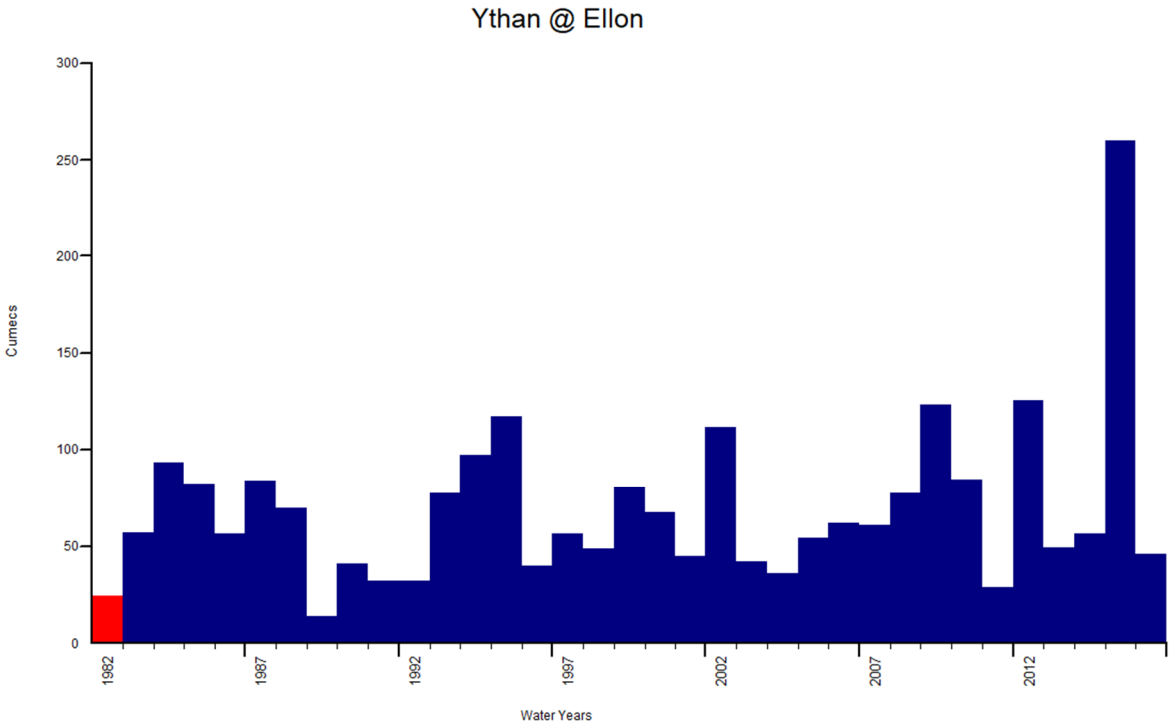


Figure 3-2: Extended AMAX series at Ellon

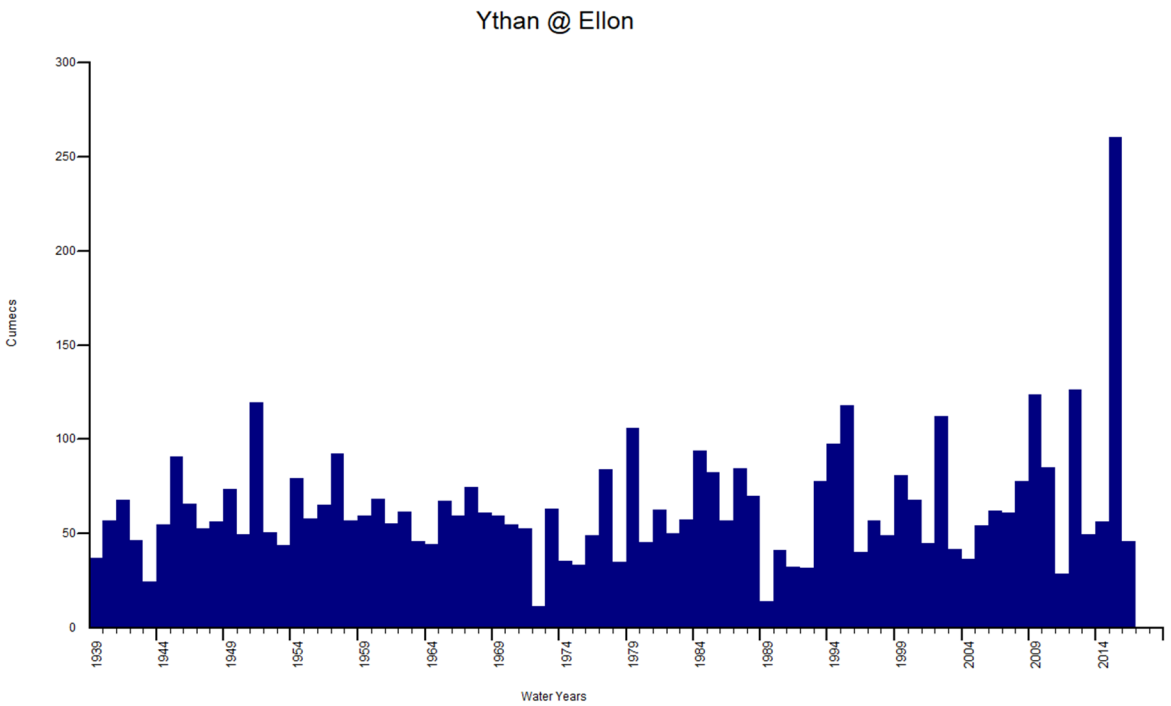


Figure 3-3: Growth curves for the extended Ellon record

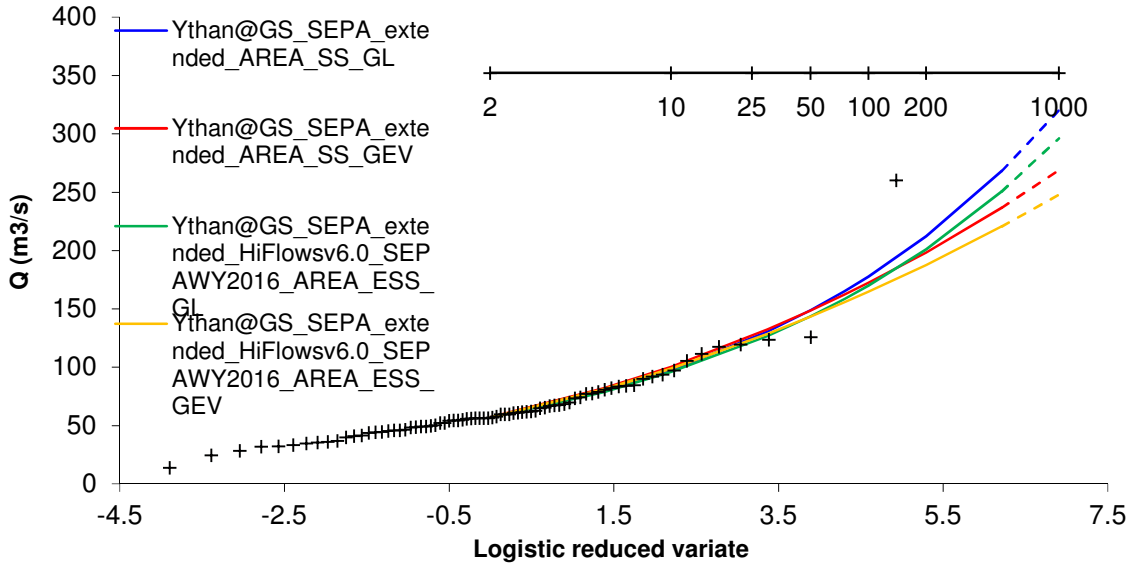


Figure 3-4: SS and ESS growth curves for the extended record at Ellon with SS GL 95% confidence limits

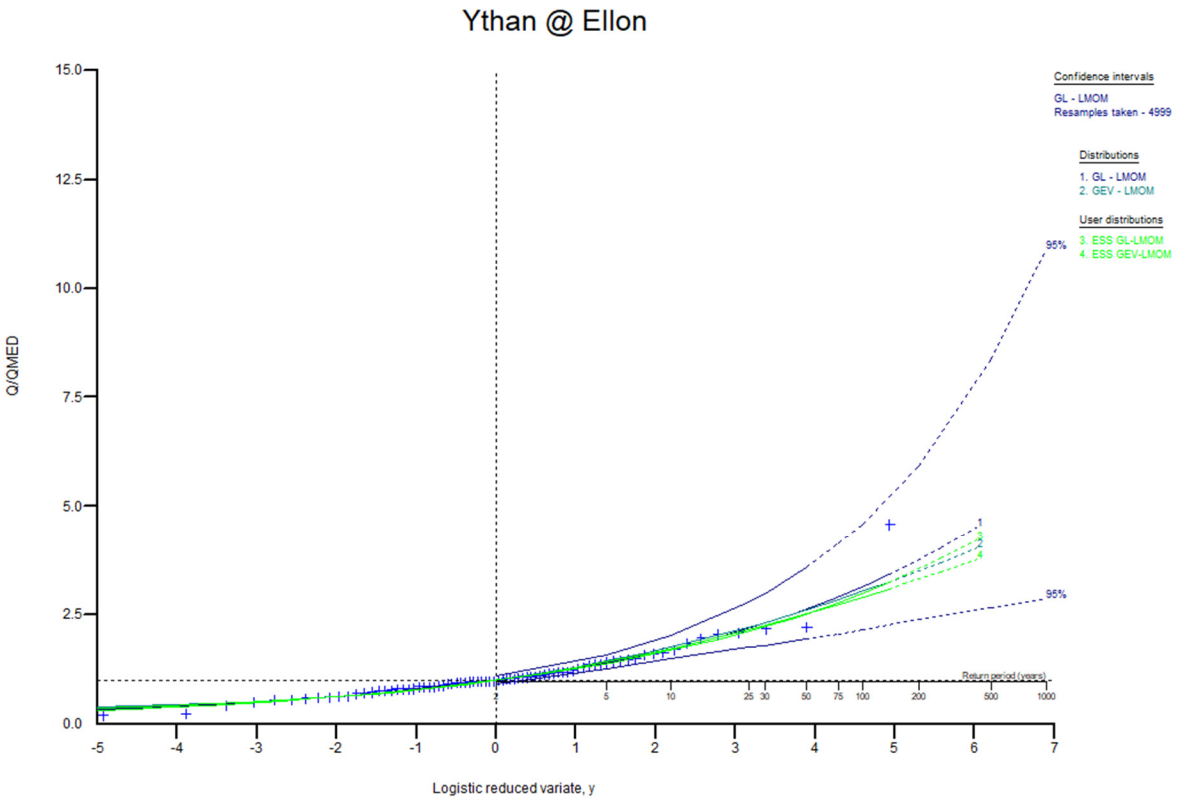
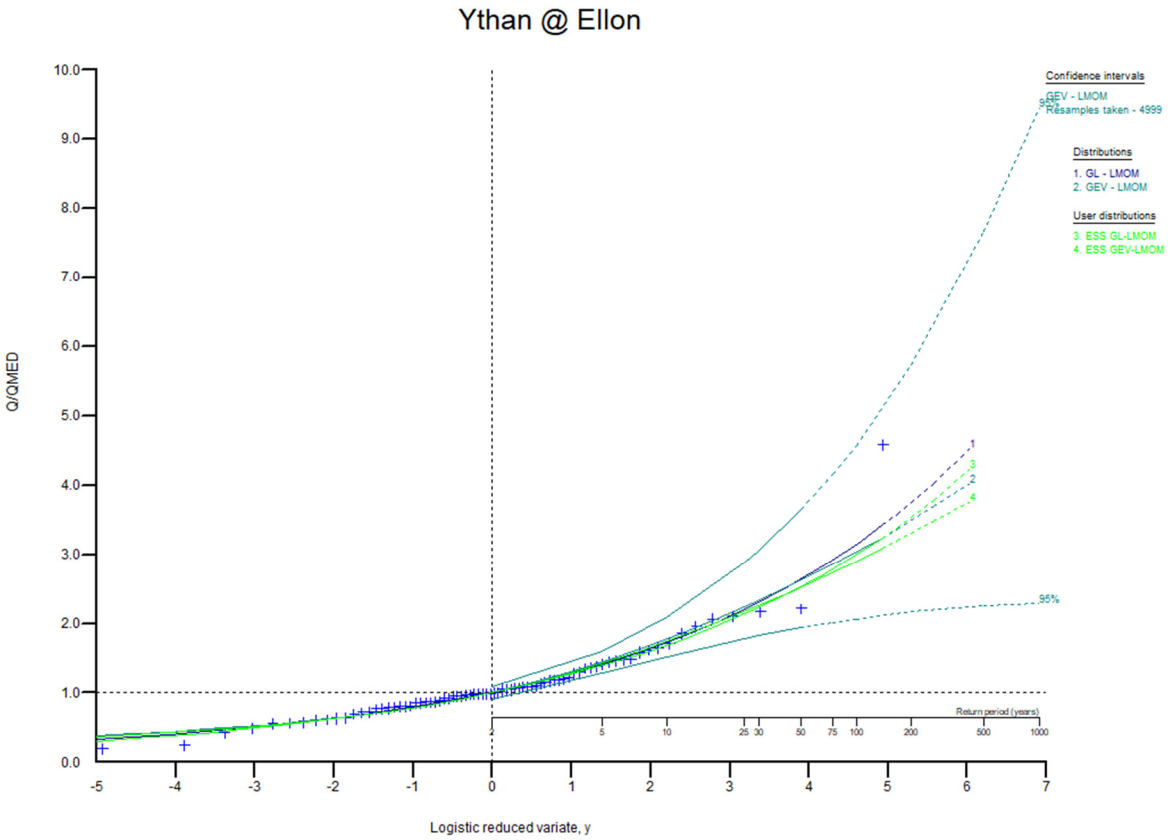


Figure 3-5: SS and ESS growth curves for the extended record at Ellon with SS GEV 95% confidence limits



3.3 River Ythan Observed Event Analysis: design hydrographs

For the Ythan, observed hydrographs at Ellon were investigated in order to identify whether or not they could be used as the basis for a design hydrograph. Figure 3-6 shows example stage hydrographs for the 10 largest flood events at Ellon, together with an average hydrograph calculated from those events. In each case, the hydrographs have been normalised by peak stage in order to bring them to a common scale. It can be seen that several of the hydrographs have double peaks including the 2016 and 2012 events - the first and second largest events on record. Additionally, a number of the hydrographs have peaks on the falling limb.

Observed hydrograph information was also considered together with rainfall data from the Rothienorman TBR in order to provide an estimate of lag time (LAG) at Ellon and therefore guide an appropriate catchment wide storm duration. The Rothienorman gauge is the nearest TBR to the upper catchment (the next nearest TBR, Esslemont House, and the manual raingauges at Meldrum House and Haddow House, are located further downstream in the catchment away from the Ythan headwaters and are therefore less likely to be representative of rainfall in the upper catchment which is usually very important in contributing to flood response; also note that Met Office raingauge and radar data at the required 15 min interval were not available). The Rothienorman data only covers the period 2001 to 2018, therefore LAG analysis was carried out on the 10 largest events within that period.

Combined analysis of the top 10 events within the period 2001 to 2017 yielded a geometric mean LAG value of 10.5 h with a range of 3.0 h for the November 2009 event to 18.8 h for the October 2014 event. Back-calculation from this LAG value yielded a Tp of 8.21 h and storm duration of 15 h[15].

Following this analysis the November 2009 event hydrograph was selected as the model input hydrograph. This was because the 2009 event: (i) shows a smooth rising and falling limb; (ii) represents the third largest event on record at the gauging station and (iii) analysis of observed rainfall showed it has a similar storm duration (17 h from the onset of rainfall to the end of the rainfall event) to that calculated from the combined basic LAG analysis. As the design hydrograph has been estimated from observed data, the adopted storm duration was 17 h[16], with an overall hydrograph duration of approximately 194 h (Figure 3-8).

For modelling, for a given AP value, the hydrograph will be scaled using the peak flow at Ellon estimated using the FEH Statistical method (single site analysis, Table 3-4).

15 Per equations 2.9 and 3.1 of FEH Volume 4.

16 Note that this is a catchment wide storm duration, appropriate to the River Ythan. Smaller tributaries such as the Broomies, Modley, Fortree and Hillhead Burn will have a shorter time to peak and critical storm duration. Detailed consideration and modelling of these watercourses is given in Section 4.

Figure 3-6: Normalised hydrographs for the top 10 events at Ellon

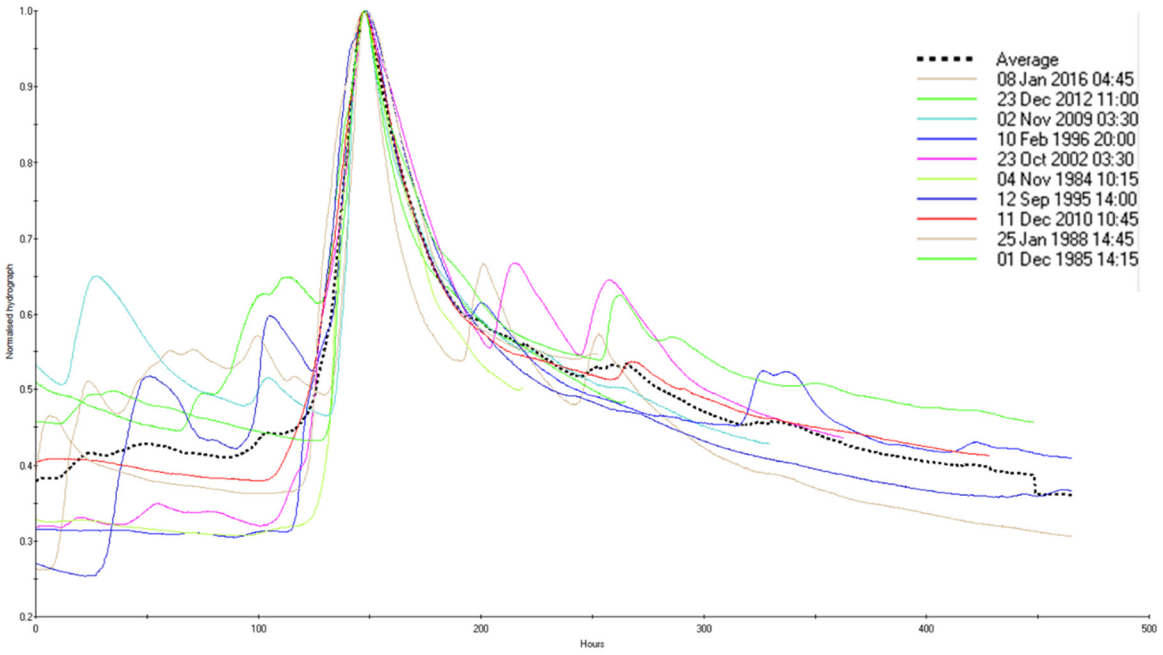


Figure 3-7: November 2009 storm duration analysis

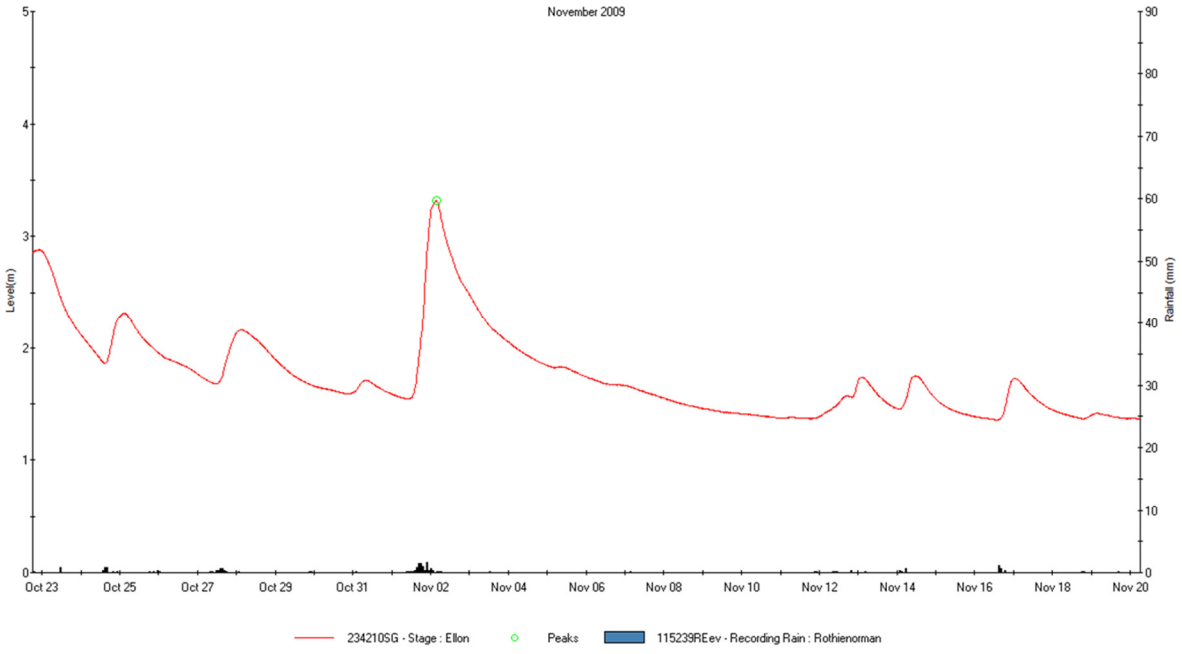
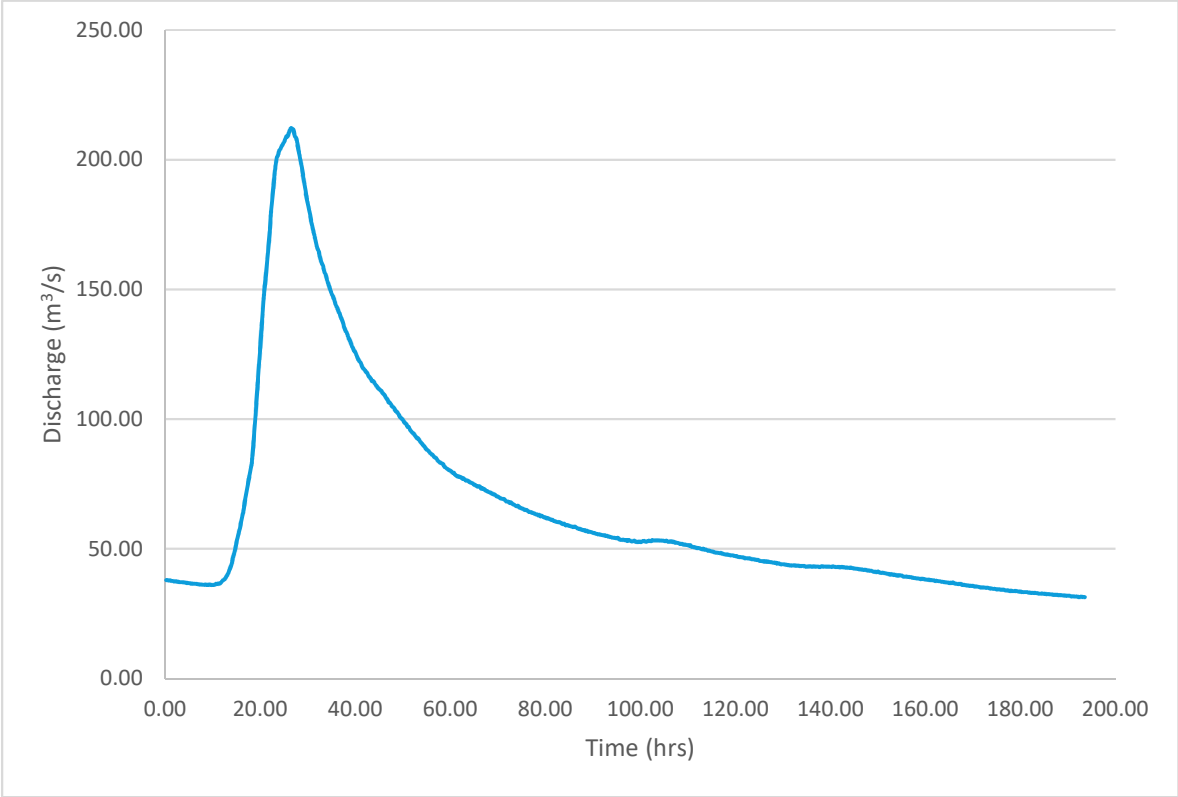


Figure 3-8: Observed November 2009 hydrograph at Ellon scaled to the SS GL 200 year peak flow.



3.4 River Ythan Observed Event Analysis: tidal influence

3.4.1 Analysis of observed data: tidal influence

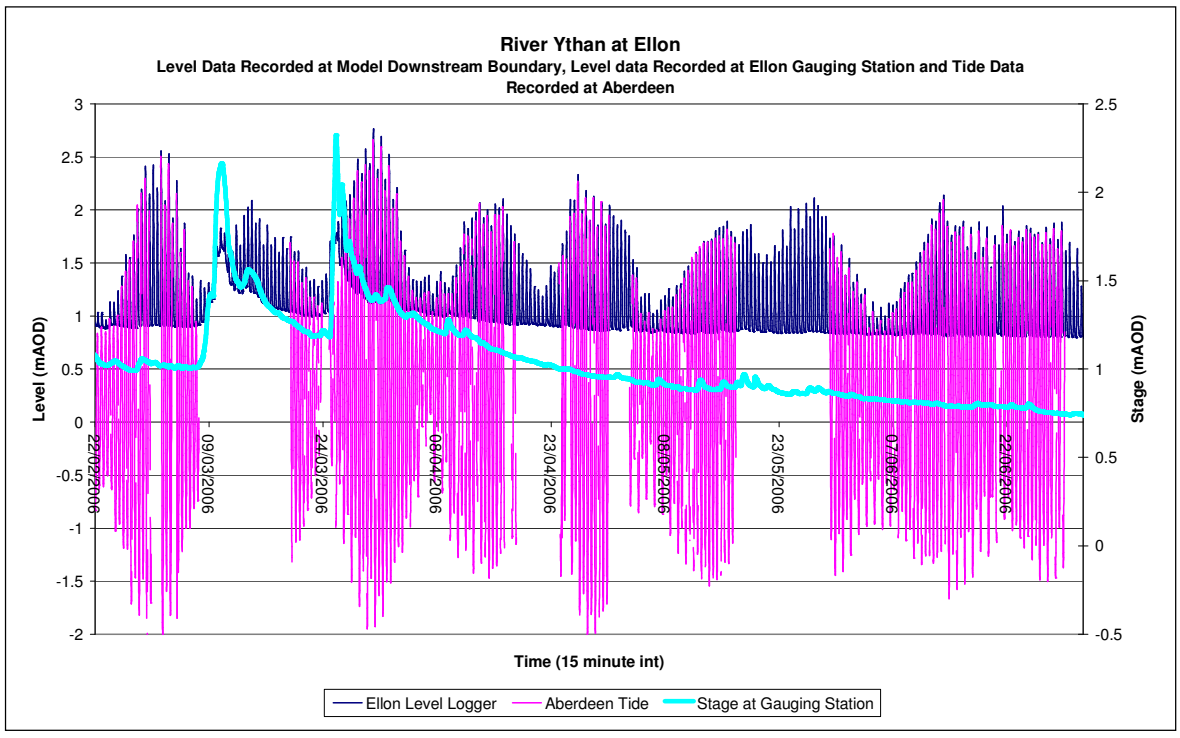
The National Tidal Limit (NTL) is located approximately 600 m upstream of the A90. The hydraulic modelling undertaken within the Ellon Flood Study[8] indicated the lower reach of the model to be tidally influenced, and it is therefore necessary to consider the potential flood risk to the site from extreme sea levels.

As part of the 2005 Flood Study, a water level logger with stageboard was installed by Mountain Environments Ltd adjacent to the right pier of the A90 road bridge on 17 February 2006 on behalf of Aberdeenshire Council. This was situated at the downstream boundary of the hydraulic model and was set to record level data at 15 minute intervals. At the time of undertaking analysis, data had been recorded from 17 February 2006 at 13:33 to 5 July 2006 at 14:59, giving five months of 15 minute data.

Tide levels for the tidal gauge at Aberdeen were downloaded from the British Oceanographic Data Centre (BODC) website[17] for the period 17 February 2006 to 5 July 2006 along with stage data from the Ellon gauging station and is plotted in Figure 3-9. On inspection of Figure 3-9 it can be seen that unfortunately there are extended gaps within the Aberdeen tidal data; this was due to technical issues.

Data collected at the Aberdeen tide gauge show a typical sine curve. As the logger is situated near to the upper limit of the tide, the base level of the level data recorded at the A90 road bridge logger at times of low tide (or no tidal influence) is controlled by flows and hence the normal river level.

Figure 3-9: River Level and Tidal Data - River Ythan at Ellon



17 The data were supplied by the British Oceanographic Data Centre as part of the function of the National Tidal & Sea Level Facility, hosted by the Proudman Oceanographic Laboratory and funded by the Department for Environment, Food & Rural Affairs and the Natural Environment Research Council. https://www.bodc.ac.uk/data/hosted_data_systems/sea_level/uk_tide_gauge_network/ [Accessed 9 February 2018]

The aim of analysis on the stage data recorded at A90 road bridge Ellon was to determine a relationship between levels at Ellon and the tide gauge at Aberdeen, for which there is an extensive historical record, and hence use this relationship to adjust the extreme sea level data for Aberdeen to create extreme sea level values for the River Ythan at Ellon. The resulting regression equation is displayed below.

Equation 3-2: Tidal Regression between Aberdeen and Ellon

$$Y = 0.1052\ X^2 + 0.5964\ X + 0.441$$
$$r^2 = 0.9874$$
$$Y = \text{Ellon},\ X = \text{Aberdeen}$$

This equation will be used to adjust observed tidal data at Aberdeen to Ellon for calibration runs.

3.4.2 Design tidal levels

Appropriate tidal levels were required as a downstream boundary condition to the hydraulic model. Design tidal levels were therefore estimated using the standard techniques for estimating coastal flood boundary (CFB) conditions[18], updated from the base year of 2008 to the study year of 2018 (Table 3-7). In order to provide an allowance for climate change on the tidal estimates, the 95th percentile to 2080 for the UKCP09 high emissions scenario was obtained[19]. This corresponds to a 0.46 m rise in sea level by the 2080s from 2018 (Table 3-7).

The CFB estuarine output for the nearest estuary CFBD data point within the Ythan (3208-8-Main-M, located at OS NGR NJ 981 300 approximately 800 m downstream of the A90 road bridge near the downstream point of the model) gives a 2018 0.5% AP (200 year) still water level (SWL) of 3.18 mAOD for the River Ythan. These levels in the CFB are derived solely on tidal constituents and surge predictions at the mouth of the Ythan and do not integrate any fluvial predictions. Within estuaries, CFB levels rely on the CFB predictions derived from coastal gauges adapted to better represent the estuary using typical surge characteristics for UK estuaries. This is largely appropriate for extreme levels within estuaries for large return periods.

Table 3-7: Design Tide Levels

Annual Probability [AP] (%)	Return period (years)	Level (mAOD) (2008)	Level (mAOD) (2018)	Level (mAOD) (2080s)
50	2	2.70	2.75	3.21
20	5	2.79	2.84	3.30
10	10	2.86	2.91	3.37
4	25	2.95	3.00	3.46
3.33	30	2.96	3.02	3.47
2	50	3.01	3.06	3.52
1.33	75	3.05	3.10	3.56
1	100	3.07	3.12	3.58
0.5	200	3.13	3.18	3.64
0.2	500	3.20	3.25	3.71
0.1	1000	3.26	3.31	3.77

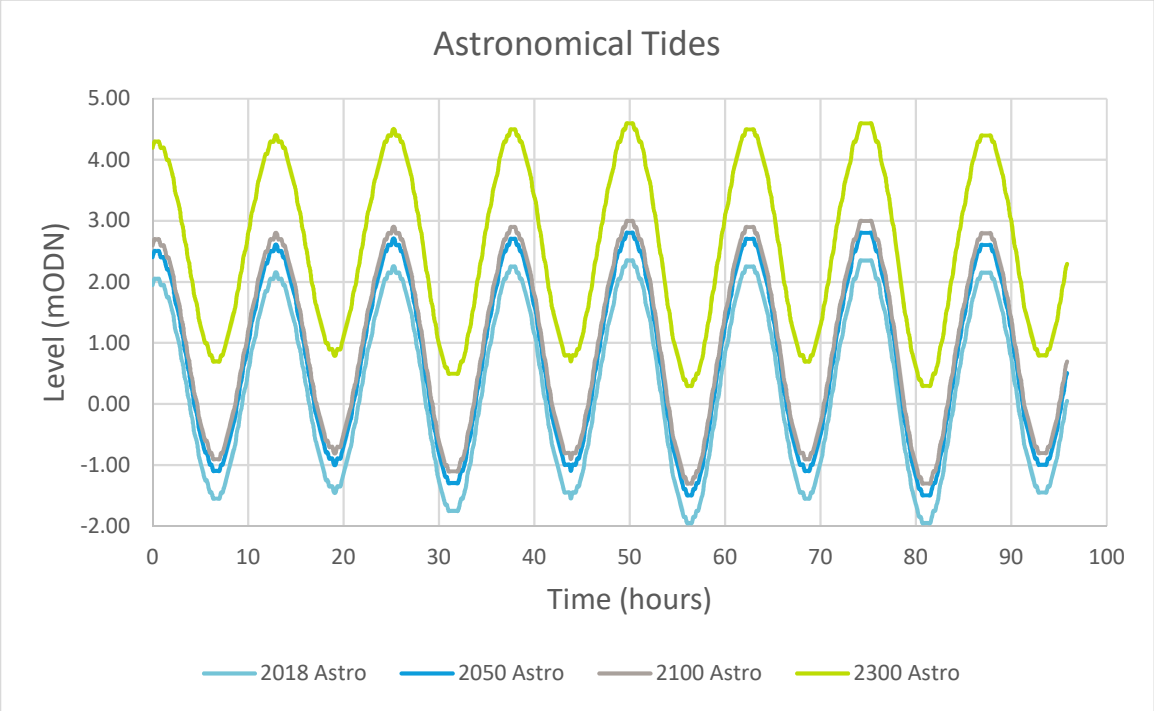
18 The Environment Agency (2011) Coastal flood boundary conditions for UK mainland and islands Project: SC060064/TR2: Design sea levels

19 http://ukclimateprojections-ui.defra.gov.uk/ui/admin/login.php

3.4.3 Design stage hydrograph

A design stage hydrograph was obtained from Admiralty Total Tide (ATT) for the Ythan and was scaled to the appropriate still water levels (above) for the hydraulic model runs.

Figure 3-10: Design Tidal Levels



3.4.4 Joint Probability Analysis

In order to examine the degree of dependence between tide and flow, published Defra and Environment Agency[20] guidance was consulted. This guidance uses the measure χ as an indication of dependence, where low values of χ indicate low correlation and high values of χ indicate strong correlation. The published values[21] include a χ value of 0.01 calculated between daily mean flow data from Ellon and surge data at Aberdeen, with 95% confidence limits for a χ of between -0.01 and 0.04. This indicates low level of correlation between flow and surge. The published χ value of 0.01 was used and a Joint Probability Matrix calculated (Table 3-8). This matrix shows various combinations of marginal return periods that result in a joint probability return period event. As the level of correlation is low, the influence of one source is greater e.g. either predominantly fluvial or tidal. For example, in this case, a 0.5% AP (200 year) event could come from many different combinations including a 0.5% AP (200 year) fluvial (or tidal) event with occurring with a less than 1 year tidal (or fluvial) event or it could come from a 1% AP (100 year) fluvial (or tidal) event occurring with a less than 1 year fluvial (or tidal) event.

A local estimate of χ was also calculated using local data from the Aberdeen tide gauge (where the surge component was extracted by subtracting the astronomical tide at Ellon calculated using Total Tide software) and daily mean flow data for the Ythan. The period of data was available at the time of the analysis was May 1983 to December 2016, this resulted in a χ value of -0.015 which is approximately similar to the published value of 0.01 and 95% confidence limits. Given the longer period of record used in the published study, a χ value of 0.01 was adopted for this work.

20 Defra / Environment Agency Flood and Coastal Defence R&D Programme Use of Joint Probability Methods in Flood Management A Guide to Best Practice R&D Technical Report FD2308/TR2 March 2005

21 Defra / Environment Agency Flood and Coastal Defence R&D Programme Joint Probability: Dependence Mapping and Best Practice: Technical Report on Dependence Mapping R&D Technical Report FD2308/TR1

Table 3-8: Joint probability matrix calculated using the published χ value of 0.01

Joint return period (years)									
		1	2	10	30	50	100	200	1000
Marginal return period (years) for still water level or flow									
Marginal return period (years) for flow or still water level	0.1	0.001	0.004	0.025	0.100	0.900	10.000	40.000	1000.000
	0.16	0.001	0.003	0.016	0.063	0.563	6.250	25.000	625.000
	0.5	0.000	0.001	0.005	0.020	0.180	2.000	8.000	200.000
	1		0.000	0.001	0.005	0.045	0.500	2.000	50.000
	2			0.001	0.002	0.018	0.200	0.800	20.000
	5				0.001	0.009	0.100	0.400	10.000
	10					0.004	0.040	0.160	4.000
	25					0.003	0.033	0.133	3.333
	30						0.020	0.080	2.000
	50						0.013	0.053	1.333
	100						0.010	0.040	1.000
	200							0.020	0.500
	500								0.200
	1000								0.100

4 Flood Estimation: Modley, Broomies, Fortree and Hillhead Burns

4.1 Peak flows: overall approach

The four tributaries are ungauged and have small catchment areas and a Rainfall Runoff type approach was therefore explored for flood estimation for those catchments, with checks also made using the FEH Statistical method. There are currently two main alternative rainfall runoff approaches which are accepted for use by SEPA in Scotland:

1. FEH Rainfall Runoff (RR) method. This is the traditional method which uses FEH99[22] rainfall information. An assumption of the FEH Rainfall Runoff method is that, for floods with AP values of greater than 0.1% (i.e. more frequent than 1000 years), the AP value of the underlying rainfall event is smaller than that of the flow event. For example, the 0.5% AP (200 year) event is estimated to be generated from a rainstorm with an AP value of 0.41% (247 years). An Areal Reduction Factor (ARF) is used to apply the point storm depth across the catchment and losses (used to calculate net rainfall) are calculated from Standard Percentage Runoff (SPR) and the Catchment Wetness Index (CWI).
2. ReFH2. This is the Revitalised Rainfall Runoff method, calibrated for Scotland and using FEH13[23] rainfall. FEH13 refers to an updated approach to the design rainfall calculation which is based on a more extensive rain gauge network than was available for FEH99 and should therefore be more accurate (ReFH2 can also optionally be run with FEH99 rainfall). In general, for Scotland, FEH13 often generates higher rainfall amounts for short duration storms than FEH99. An assumption of ReFH2 is that the AP value of the underlying rainfall event is equal to that of the flow event. For example, the 0.5% AP (200 year) event is estimated to be generated from a rainstorm with an AP value of 0.5% (200 years). ReFH2 uses both an ARF and also a Seasonal Correction Factor (SCF) to apply seasonally dependent rainfall across the catchment. Losses are calculated using a more formal representation of soil storage than that used in the FEH Rainfall Runoff method.

While both methods were considered for each site, following basic LAG analysis using available hydrometric data in the River Ythan area (the Keithfield Burn at Mill of Keithfield and Rothienorman TBR), along with statistical pooling analysis to inform the choice of method, the RR methodology was selected as the most appropriate choice of peak flow.

4.1.1 Basic LAG analysis at Mill of Keithfield

The Keithfield Burn has a level only gauging station at Mill of Keithfield. This donor site is located approximately 12 km northwest of Ellon and has a relatively steep catchment which drains east towards the River Ythan and has a catchment area of approximately 18 km^2. The geology of the area comprises metamorphic bedrock overlain with superficial glacial deposits. Land use is predominately arable and pasture with some forest habitats. This catchment was selected because of its similarity and geographical closeness to the subject sites and for which both rainfall and stage data were available. The TBR at Rothienorman was selected as the source of 15 min rainfall data. This raingauge is located circa 9 km northwest of the Keithfield Burn catchment, but it is the nearest TBR to the upper catchment and was therefore used out of necessity (the next nearest raingauges at Meldrum House and Haddow House, were located further downstream in the catchment away from the Keithfield Burn headwaters and are therefore likely to be less representative of rainfall in the upper catchment which is usually very important in contributing to flood response; also note that Met Office raingauge and radar data at the required 15 min interval were not available).

Observed hydrograph information from the Mill of Keithfield gauge was considered together with rainfall data from the Rothienorman TBR in order to provide an estimate of lag time (LAG) and therefore back calculate storm duration. Combined analysis of the top 8 events yielded a geometric mean LAG value of 5.85 h with a range of 2.7 h for the December 2012 event to 8.6 h for the December 2010 event. Back-calculation from this LAG value yielded a Tp of 4.72 h and storm duration of 8.64 h. A similar storm duration was estimated at Mill of Keithfield using the FEH Rainfall Runoff method with catchment descriptors (Tp of 4.33 h and storm duration of 8.25 h). The ReFH2 methodology in contrast had a significantly different Tp and storm duration (Table 4-1). As the

22 FEH99 refers to the design rainfall approach originally published in FEH Volume 2: Rainfall Frequency Estimation (1999).

23 The FEH13 approach was published in the Environment Agency report - Reservoir Safety - Long Return Period Rainfall, Project: FD2613 WS 194/2/39, 2013.

Keithfield Burn is similar to the burns draining to the Ythan, it was assumed that the FEH Rainfall Runoff method would not need modification (with respect to Tp) if it was adopted for peak flow estimation. ReFH2 was less consistent with the observed analysis.

Table 4-1: Storm duration comparison at Mill of Keithfield

	Mill of Keithfield observed data	RR	ReFH2
Geomean LAG	5.85		
Tp	4.72	4.33	3.51
Duration (h)	8.64	8.25	6.50

4.1.2 Peak flow estimates for the Ellon burns

A comparison of the methods used (statistical and rainfall runoff variants) for the burns are provided in the following tables.

In all cases, the following conclusions were made:

- The Statistical pooling method gave the highest flow estimates for the Broomies Burn and Modley Burn. For example, for the Broomies Burn the 0.5% AP (200 year) event is estimated to be circa 5.34 m^3/s using the pooling method and 5.10 m^3/s using the RR method.
- In contrast, the FEH RR method gave the largest estimates for the Fortree and Hillhead Burns on the right bank of the Ythan. For example, for the Fortree Burn 0.5% AP (200 year) event is estimated to be circa 2.34 m^3/s using the RR method and 1.88 m^3/s using the statistical pooling method.
- In all cases ReFH2 with FEH99 rainfall gave higher peak flow estimates than using FEH13 rainfall.
- The FEH statistical method and RR results are relatively similar. For example, for the Modley Burn, the 0.5% AP (200 year) event is estimated to be 3.09 m^3/s using the RR approach and 3.18 m^3/s using statistical method. This is compared to the ReFH2 with FEH13 method which gives a 0.5% AP (200 year) event of 2.06 m^3/s.

The agreement between the FEH statistical and RR methods, along with the LAG analysis at Mill of Keithfield supported the use of FEH RR for peak flow estimation on the Ellon tributaries. The FEH Rainfall Runoff method was therefore adopted for peak flow estimation.

Table 4-2: Broomies Burn with adjusted area peak flow comparison

Annual Probability [AP] (%)	Return Period (years)	FEH Rainfall Runoff flow (m^3/s)	ReFH2 with FEH99 rainfall flow (m^3/s)	ReFH2 with FEH13 rainfall flow (m^3/s)	Statistical pooling flow (m^3/s)
50	2	1.64	1.44	1.26	1.53
20	5	2.24	1.79	1.64	2.09
10	10	2.61	2.07	1.94	2.53
4	25	3.30	2.51	2.41	3.19
3.33	30	3.45	2.61	2.51	3.34
2	50	3.88	2.91	2.83	3.79
1.33	75	4.18	3.17	3.09	4.19
1	100	4.44	3.38	3.28	4.50
0.5	200	5.10	3.93	3.78	5.34
0.2	500	6.12	4.82	4.47	6.71
0.1	1000	7.19	5.65	5.02	7.98
3.33 +CC	30 +CC	4.28	3.24	3.12	4.14
0.5 +CC	200 +CC	6.32	4.87	4.68	6.62
Critical duration (hrs)		8.25	6.30	6.30	

Table 4-3: Modley Burn with adjusted area peak flow comparison

Annual Probability [AP] (%)	Return Period (years)	FEH Rainfall Runoff flow (m^3/s)	ReFH2 with FEH199 rainfall flow (m^3/s)	ReFH2 with FEH13 rainfall flow (m^3/s)	Statistical pooling flow (m^3/s)
50	2	0.99	0.82	0.68	0.91
20	5	1.36	1.02	0.88	1.24
10	10	1.58	1.19	1.05	1.50
4	25	1.97	1.44	1.30	1.89
3.33	30	2.06	1.49	1.36	1.98
2	50	2.34	1.66	1.53	2.25
1.33	75	2.52	1.82	1.68	2.49
1	100	2.68	1.93	1.79	2.67
0.5	200	3.09	2.25	2.06	3.18
0.2	500	3.72	2.76	2.44	4.00
0.1	1000	4.39	3.23	2.75	4.77
3.33 +CC	30 +CC	2.55	1.85	1.68	2.46
0.5 +CC	200 +CC	3.38	2.79	2.55	3.94
Critical storm duration (hrs)		6.75	6.30	6.30	

Table 4-4: Hillhead Burn with adjusted area peak flow comparison

Annual Probability [AP] (%)	Return Period (years)	FEH Rainfall Runoff flow (m^3/s)	ReFH2 with FEH99 rainfall flow (m^3/s)	ReFH2 with FEH13 rainfall flow (m^3/s)	Statistical pooling flow (m^3/s)
50	2	0.26	0.18	0.14	0.22
20	5	0.37	0.22	0.19	0.29
10	10	0.43	0.26	0.23	0.36
4	25	0.52	0.32	0.28	0.45
3.33	30	0.54	0.33	0.30	0.47
2	50	0.59	0.37	0.33	0.54
1.33	75	0.65	0.40	0.37	0.59
1	100	0.70	0.42	0.39	0.64
0.5	200	0.81	0.49	0.45	0.76
0.2	500	0.98	0.61	0.54	0.96
0.1	1000	1.16	0.71	0.60	1.15
3.33 +CC	30 +CC	0.67	0.41	0.37	0.58
0.5 +CC	200 +CC	1.00	0.61	0.56	0.94
Critical storm duration (hrs)		3.75	5.30	5.30	

Table 4-5: Fortree Burn with adjusted area peak flow comparison

Annual Probability [AP] (%)	Return Period (years)	FEH Rainfall Runoff flow (m^3/s)	ReFH2 with FEH99 rainfall flow (m^3/s)	ReFH2 with FEH13 rainfall flow (m^3/s)	Statistical pooling flow (m^3/s)
50	2	0.76	0.52	0.41	0.54
20	5	1.06	0.64	0.54	0.73
10	10	1.24	0.75	0.65	0.88
4	25	1.50	0.91	0.81	1.11
3.33	30	1.55	0.94	0.85	1.16
2	50	1.72	1.05	0.96	1.32
1.33	75	1.88	1.15	1.05	1.46
1	100	2.01	1.22	1.12	1.57
0.5	200	2.34	1.42	1.29	1.88
0.2	500	2.84	1.74	1.54	2.38
0.1	1000	3.36	2.04	1.73	2.85
3.33 +CC	30 +CC	1.92	1.17	1.05	1.44
0.5 +CC	200 +CC	2.90	1.76	1.60	2.33
Critical storm duration (hrs)		3.75	5.30	5.30	

4.1.3 Storm durations

Two storm durations are to be modelled to represent the tributary inflows. These are: 17 h based on the Ythan and 6.75 h based on the Broomies and Modley Burns. Inclusion of the Hillhead and Frotree Burns in the Ythan model would also require a 3.75 h storm duration, but these burns may be modelled separately. Peak flows for these storm durations using the FEH RR approach are given below.

Table 4-6: RR peak flow estimates for the Broomies Burn for the three storm durations

Annual Probability [AP] (%)	Return period (years)	FEH Rainfall Runoff Storm duration 17 hours (m^3/s)	FEH Rainfall Runoff Storm duration 6.75 hours (m^3/s)	FEH Rainfall Runoff Storm duration 3.75 hours (m^3/s)
50	2	1.62	1.59	1.37
20	5	2.27	2.17	1.88
10	10	2.72	2.53	2.21
4	25	3.37	3.15	2.65
3.33	30	3.52	3.28	2.75
2	50	3.94	3.71	3.03
1.33	75	4.23	4.01	3.32
1	100	4.48	4.25	3.55
0.5	200	5.12	4.90	4.10
0.2	500	6.11	5.88	4.97
0.1	1000	7.15	6.92	5.87
3.33 +CC	30 +CC	4.36	4.07	3.41
0.5 +CC	200 +CC	6.35	6.08	5.08

Table 4-7: RR peak flow estimates for the Modley Burn for the three storm durations

Annual Probability [AP] (%)	Return period (years)	FEH Rainfall Runoff Storm duration 17 hours (m^3/s)	FEH Rainfall Runoff Storm duration 6.75 hours (m^3/s)	FEH Rainfall Runoff Storm duration 3.75 hours (m^3/s)
50	2	0.95	0.99	0.87
20	5	1.33	1.36	1.20
10	10	1.61	1.58	1.41
4	25	2.00	1.97	1.70
3.33	30	2.08	2.06	1.76
2	50	2.33	2.34	1.94
1.33	75	2.51	2.52	2.13
1	100	2.66	2.68	2.27
0.5	200	3.04	3.09	2.64
0.2	500	3.64	3.72	3.20
0.1	1000	4.27	4.39	3.80
3.33 +CC	30 +CC	2.58	2.55	2.18
0.5 +CC	200 +CC	3.77	3.83	3.27

Table 4-8: RR peak flow estimates for the Hillhead Burn for the three storm durations

Annual Probability [AP] (%)	Return period (years)	FEH Rainfall Runoff Storm duration 17 hours (m^3/s)	FEH Rainfall Runoff Storm duration 6.75 hours (m^3/s)	FEH Rainfall Runoff Storm duration 3.75 hours (m^3/s)
50	2	0.22	0.27	0.26
20	5	0.32	0.37	0.37
10	10	0.38	0.44	0.43
4	25	0.47	0.55	0.52
3.33	30	0.49	0.57	0.54
2	50	0.55	0.65	0.59
1.33	75	0.60	0.70	0.65
1	100	0.63	0.74	0.70
0.5	200	0.72	0.86	0.81
0.2	500	0.86	1.03	0.98
0.1	1000	1.01	1.22	1.16
3.33 +CC	30 +CC	0.61	0.71	0.67
0.5 +CC	200 +CC	0.89	1.07	1.00

Table 4-9: RR peak flow estimates for the Fortree Burn for the three storm durations

Annual Probability [AP] (%)	Return period (years)	FEH Rainfall Runoff Storm duration 17 hours (m^3/s)	FEH Rainfall Runoff Storm duration 6.75 hours (m^3/s)	FEH Rainfall Runoff Storm duration 3.75 hours (m^3/s)
50	2	0.65	0.78	0.76
20	5	0.91	1.08	1.06
10	10	1.10	1.26	1.24
4	25	1.37	1.58	1.50
3.33	30	1.42	1.65	1.55
2	50	1.60	1.87	1.72
1.33	75	1.72	2.02	1.88
1	100	1.82	2.14	2.01
0.5	200	2.08	2.47	2.34
0.2	500	2.49	2.98	2.84
0.1	1000	2.91	3.51	3.36
3.33 +CC	30 +CC	1.76	2.05	1.92
0.5 +CC	200 +CC	2.58	3.06	2.90

4.2 Lateral inflows for modelling of the Ythan

Within the hydraulic model, lateral inflows to the Ythan will be modelled using ReFH unit hydrographs. Calibration runs will be undertaken using rainfall data from the Esslemont House raingauge. Lateral inflows for the design runs will be represented using ReFH unit hydrographs scaled to the RR estimates detailed in Section 4.1.3.

5 Comparison between the 2005, 2010 and 2018 studies

The 2005 JBA study provided peak flow estimates for the Ythan at Ellon which were updated in 2010. Those estimates, together with the corresponding values obtained in this study are listed in the accompanying table. In summary, the differences are as follows:

- Peak flows in the 2005 study were obtained using the statistical pooling group analysis with a GEV distribution, whereas the 2010 study used the updated statistical approach of ESS analysis but again using the GEV distribution. This study will use the SS GL approach.
- The 0.5% AP (200 year) peak flow was estimated to be 137 m^3/s in 2005, 147 m^3/s in 2010 and 212.22 in 2018.
- The difference between the present and previous studies can be attributed to the very large 2016 event (260 m^3/s, assuming no artificial influences upon stage such as bridge/debris blockage during this event, Appendix E).

Table 5-1: Comparison with 2005 and 2010 estimates

Return Period (years)	Annual Probability [AP] (T)	2005 study River Ythan at Ellon. Statistical pooling group analysis: GEV (m^3/s)	2010 study River Ythan at Ellon, Statistical ESS analysis: GEV (m^3/s)	2018 study River Ythan at Ellon, Statistical SS analysis: GL (m^3/s)
2	50	57.7	58.8	56.82
5	2	78.6	79.4	79.66
10	10	91.6	92.9	97.35
25	4	106.9	109.8	124.37
50	2	117.5	122.3	148.82
75	1.3	123.2	129.5	165.14
100	1	127.5	134.5	177.76
200	0.5	137.0	146.7	212.22
200 +CC	0.5 +CC	171.3	176.0	263.15

6 Conclusions

The River Ythan has a history of flooding dating back to at least 1642 and the main risk area is at Ellon. In addition to direct flood risk from the fluvial Ythan, flood risk at Ellon is complicated by a tidal influence and by four small watercourses (the Modley, Broomies, Hillhead and Fortree Burns). Hydrology estimates were required as input to a linked 1D/2D hydraulic model of the Ythan for use in flood mapping. Those estimates included the following.

- **Peak flow estimates** on the:
  - **River Ythan at Ellon** gauging station. FEH statistical methods were investigated for peak flow estimation and the adopted method was Single Site (SS) analysis with a GL distribution using an extended AMAX series from the Ardlethen gauge. A new rating, previously agreed with SEPA for use in this study, was applied to the Ythan data, prior to the analysis being undertaken. The 0.5% Annual Probability (AP, 200 year flood) was estimated to be circa 212.22 m^3/s for the Ythan.
  - **Modley Burn, Broomies Burn, Hillhead Burn and Fortree Burn** at their confluence with the River Ythan. A variety of methods were investigated for peak flow estimation, and the adopted method in each case was the FEH RR method. The 0.5% Annual Probability (AP, 200 year flood) flood was estimated to be 4.90 m^3/s, 3.09 m^3/s, 0.81 m^3/s and 2.34 m^3/s for the Broomies, Modley, Hillhead and Fortree Burns respectively for their given critical storm duration.
- **Fluvial hydrographs and critical storm durations**. Hydrograph analysis indicated many of the historical flood events on the Ythan are double peaked. The November 2009 event hydrograph (the third largest event on record) was therefore selected as the design hydrograph as it is single peaked and has a similar storm duration (17 h) to that derived from the basic LAG analysis. Basic LAG analysis at Ellon on the combined top 10 events yielded a time to peak (Tp) of 8.21 h and storm duration of 15 h. The 2009 design hydrograph will be scaled to the FEH statistical estimates for use in modelling. The Ythan and burns have very different catchment areas and it was recommended that two critical durations be tested in the hydraulic modelling: one long (17 h, based on the Ythan) and one short (6.75 h, based on the Modley and Broomies Burn). These values were based upon the RR critical storm duration.
- **Coastal still water levels for the tidal element**. These were obtained from the Coastal Flood Boundary method. The 0.5% AP (200 year) event was estimated to be 3.18 mAOD.
- **Tidal stage hydrograph**. This was derived from a representative event at the Aberdeen tide gauge.
- **Joint probability**. The joint probability between flow on the Ythan at Ellon and surge on the Ythan estuary was considered using the published FD2308 approach. A local chi value was also calculated between Aberdeen and Ellon and was found to be similar to the published value, showing a low correlation between flow and surge. The resulting joint probability matrix will be applied in the model runs.

Table 6-1: Summary of design peak flows

Annual Probability [AP] (%)	Return Period (years)	River Ythan at Ellon Gauging Station. Single Site Statistical Method Flow: GL (m^3/s)	Broomies Burn FEH Rainfall Runoff storm duration 6.75 hours (m^3/s)	Modley Burn FEH Rainfall Runoff storm duration 6.75 hours (m^3/s)	Hillhead Burn FEH Rainfall Runoff storm duration 3.75 hours (m^3/s)	Fortree Burn FEH Rainfall Runoff storm duration 3.75 hours (m^3/s)
50	2	56.82	1.59	0.99	0.26	0.76
20	5	79.66	2.17	1.36	0.37	1.06
10	10	97.35	2.53	1.58	0.43	1.24
4	25	124.37	3.15	1.97	0.52	1.50
3.33	30	130.42	3.28	2.06	0.54	1.55
2	50	148.82	3.71	2.34	0.59	1.72
1.33	75	165.14	4.01	2.52	0.65	1.88
1	100	177.76	4.25	2.68	0.70	2.01
0.5	200	212.22	4.90	3.09	0.81	2.34
0.2	500	268.21	5.88	3.72	0.98	2.84
0.1	1000	320.25	6.92	4.39	1.16	3.36
3.33 +CC	30 +CC	161.72	4.07	2.55	0.67	1.92
0.5 +CC	200 +CC	263.15	6.08	3.83	1.00	2.90
0.5 specific discharge	200	0.40	0.80	0.85	1.14	1.13
Critical duration for modelling (h)		17	6.75	6.75	3.75	3.75

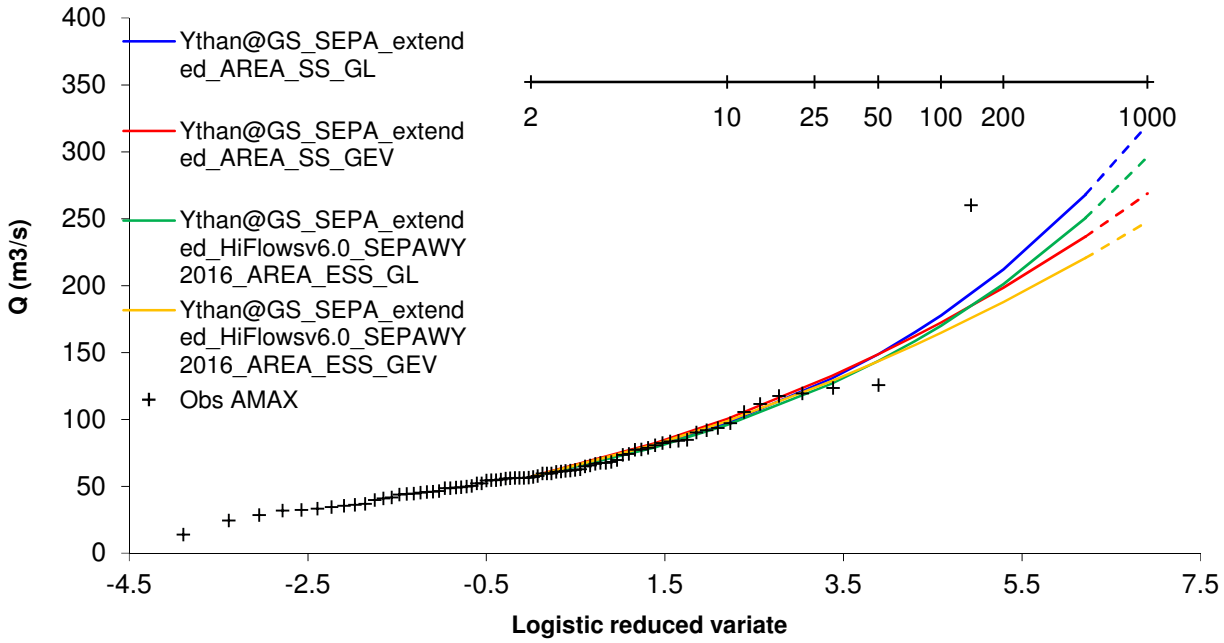
Appendices

A Statistical Method - Additional Outputs

This section provides further information on the statistical method.

A.1 Ythan at Ellon

FEH STATISTICAL FLOOD ESTIMATION SUMMARY SHEET			
Site	Ellon Gauging Station		
NGR	NJ946303		
Type of problem/objective of	Peak flows for model		
	2, 5, 10, 25, 30, 50, 75, 100, 200, 200cc, 500, 1000		
Type of catchment	Rural		
QMED site cd	56.8	m^3/s	
Donor/ Analogue Sites Considered			
Site name	Ythan@Ellon		
Station number	10003		
NGR	NJ946303		
Proximity (km)	0.00		
Adjustment	1.0532		
Site Chosen	Y		
QMED site adjusted by data transfer (m^3/s)	56.8	**Specific Q (l/s/ha)**	1.1
Q_{100} growth curve factor	3.13	**Q100/ area (l/s/ha)**	3.3
Q_{100} (m^3/s)	**177.8**		
Summary Data			
FEH catchment area	532.15	km^2	
Adjusted catchment area	533.77	km^2	
URBEXT 1990	0.002		
URBEXT 2010	0.002		
URBEXT Adjustment Method	Urbext2000		
SAAR	826		
Method Used	FEH Statistical Method		
Variation from Chosen Method	The Ellon AMAX gauge record has been extended via regression with the Ardlethen gauge (upstream) and results on this sheet, including QMED correspond to this merged record.		
Index Used	BFIHOST		
QMED	56.82	m^3/s	
5	79.66	m^3/s	
10	97.35	m^3/s	
30	130.42	m^3/s	
50	148.82	m^3/s	
75	165.14	m^3/s	
100	177.76	m^3/s	
200	212.22	m^3/s	
1000	320.25	m^3/s	
Climate Change Region	Eastern Scotland		
Climate change adjustment	24.0%		
200 + cc	263.1	m^3/s	
Donor/ Analogues Used			
Calcs by:	Briony McIntosh	Date:	20/03/2018
Checked by:	David Cameron	Date:	21/03/2018



POOLING GROUP DETAILS

Original Default Pooling Group

Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
10003 (Ythan @ Ellon)	0.000	78	56.819	0.240	0.259	0.184
22001 (Coquet @ Morwick)	0.148	53	152.176	0.270	0.277	0.309
10001 (Ythan @ Ardlethen)	0.217	46	50.180	0.179	0.116	1.496
43008 (Wylye @ South Newton)	0.269	45	12.620	0.256	0.154	0.759
11003 (Don @ Bridge of Alford)	0.330	44	101.115	0.225	0.273	0.309
21031 (Till @ Etal)	0.334	28	82.895	0.273	0.282	0.285
21806 (Till @ Heaton Mill)	0.368	14	133.121	0.343	0.297	1.625
24001 (Wear @ Sunderland Bridge)	0.416	59	186.152	0.191	0.231	1.720
9001 (Deveron @ Avochie)	0.448	58	129.725	0.243	0.187	0.633
39034 (Evenlode @ Cassington Mill)	0.546	45	20.900	0.164	0.286	2.207
24008 (Wear @ Witton Park)	0.568	42	212.945	0.163	0.070	1.473
Total		512				
Weighted means				0.238	0.232	

Default Pooling Group Catchment Descriptors

Station	Distance SDM	AREA	SAAR	FPEXT	FARL	URBEXT 2000
10003 (Ythan @ Ellon)	0.000	532.290	826.000	0.047	0.993	0.002
22001 (Coquet @ Morwick)	0.148	578.250	850.000	0.040	0.993	0.002
10001 (Ythan @ Ardlethen)	0.217	457.120	830.000	0.043	0.992	0.001
43008 (Wylye @ South Newton)	0.269	448.170	830.000	0.052	0.976	0.010
11003 (Don @ Bridge of Alford)	0.330	509.940	967.000	0.036	0.996	0.000
21031 (Till @ Etal)	0.334	634.680	827.000	0.067	0.992	0.002
21806 (Till @ Heaton Mill)	0.368	655.540	822.000	0.067	0.992	0.002
24001 (Wear @ Sunderland Bridge)	0.416	661.170	932.000	0.035	0.978	0.019
9001 (Deveron @ Avochie)	0.448	444.910	988.000	0.034	0.998	0.002
39034 (Evenlode @ Cassington Mill)	0.546	427.140	691.000	0.068	0.965	0.014
24008 (Wear @ Witton Park)	0.568	454.630	1035.000	0.024	0.970	0.004

Final Pooling Group

Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
10003 (Ythan @ Ellon)	0.000	78	56.819	0.240	0.259	0.237
22001 (Coquet @ Morwick)	0.148	53	152.176	0.270	0.277	0.255
11003 (Don @ Bridge of Alford)	0.330	44	101.115	0.225	0.273	0.150
21031 (Till @ Etal)	0.334	28	82.895	0.273	0.282	0.309
21806 (Till @ Heaton Mill)	0.368	14	133.121	0.343	0.297	2.036
24001 (Wear @ Sunderland Bridge)	0.416	59	186.152	0.191	0.231	1.256
9001 (Deveron @ Avochie)	0.448	58	129.725	0.243	0.187	0.698
39034 (Evenlode @ Cassington Mill)	0.546	45	20.900	0.164	0.286	2.483
24008 (Wear @ Witton Park)	0.568	42	212.945	0.163	0.070	1.253
11002 (Don @ Haughton)	0.593	46	111.687	0.237	0.320	0.559
27090 (Swale @ Catterick Bridge)	0.603	23	313.732	0.163	0.041	2.377
8004 (Avon @ Delnashaugh)	0.611	62	210.551	0.194	0.208	0.388
Total		552				
Weighted means				0.238	0.241	

Final Pooling Group

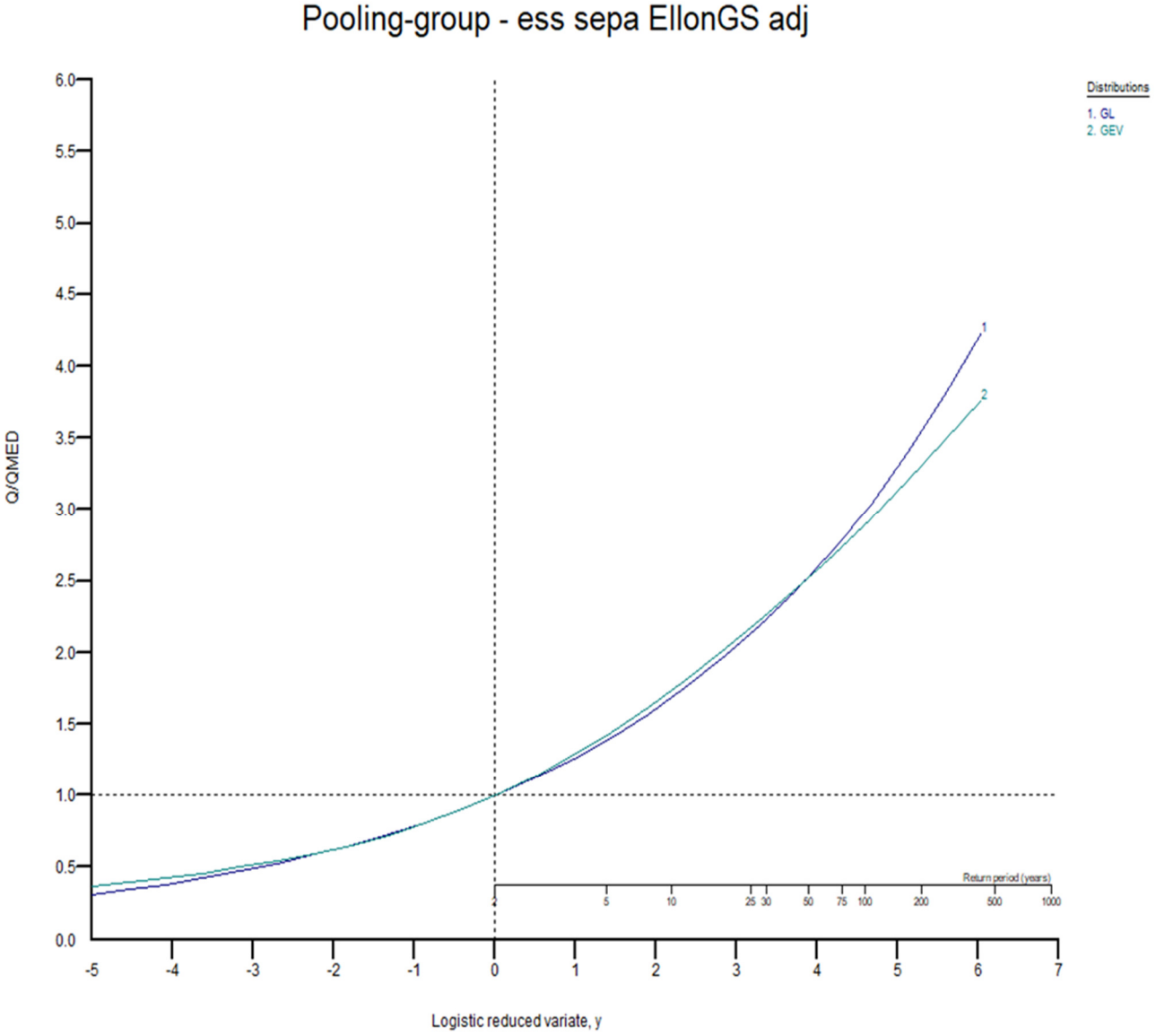
Station	Distance SDM	AREA	SAAR	FPEXT	FARL	URBEXT 2000
10003 (Ythan @ Ellon)	0.000	532.290	826.000	0.047	0.993	0.002
22001 (Coquet @ Morwick)	0.148	578.250	850.000	0.040	0.993	0.002
11003 (Don @ Bridge of Alford)	0.330	509.940	967.000	0.036	0.996	0.000
21031 (Till @ Etal)	0.334	634.680	827.000	0.067	0.992	0.002
21806 (Till @ Heaton Mill)	0.368	655.540	822.000	0.067	0.992	0.002
24001 (Wear @ Sunderland Bridge)	0.416	661.170	932.000	0.035	0.978	0.019
9001 (Deveron @ Avochie)	0.448	444.910	988.000	0.034	0.998	0.002
39034 (Evenlode @ Cassington Mill)	0.546	427.140	691.000	0.068	0.965	0.014
24008 (Wear @ Witton Park)	0.568	454.630	1035.000	0.024	0.970	0.004
11002 (Don @ Haughton)	0.593	792.670	916.000	0.051	0.997	0.002
27090 (Swale @ Catterick Bridge)	0.603	497.560	1123.000	0.038	0.998	0.008
8004 (Avon @ Delnashaugh)	0.611	540.750	1108.000	0.026	0.989	0.000

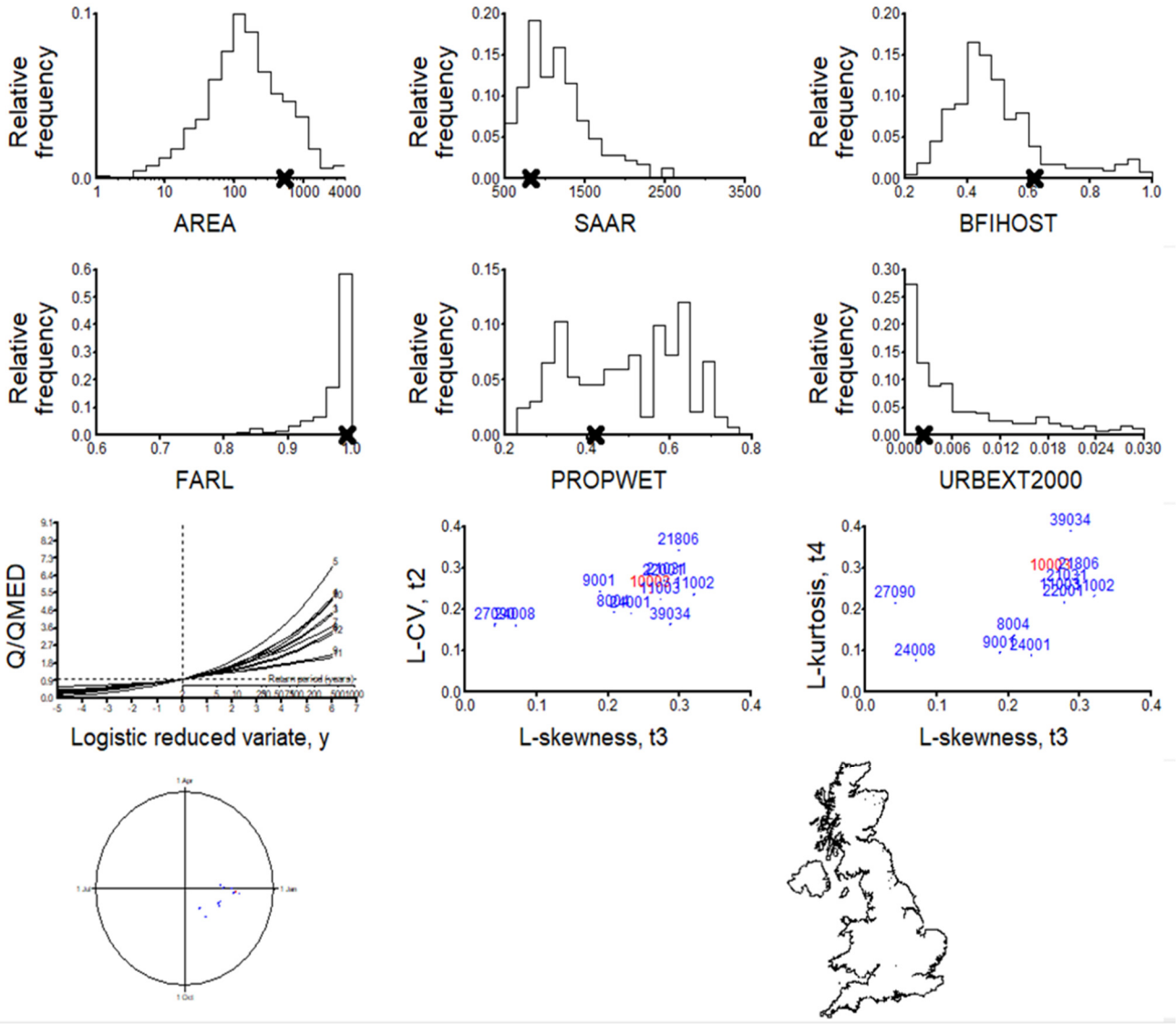
DERIVING A POOLED GROWTH CURVE			
Site	Ellon gauging station		Ungauged site
NGR	NJ946303	√	Gauged site
Attached Printouts			
	WINFAP-FEH station details		
	WINFAP-FEH summary information if gauged site		
Initial Pooling Group Details			
Name	ess_sepa_EllonGS_default		
Site of interest	Gauging Station		
Return period of interest	2, 5, 10, 25, 30, 75, 100, 200, 500, 1000 years		
Other information	Till@Etal and Till@Eden do not have overlapping records.		
Version of WIN-FAP FEH	Version 3.0		
Data Files	Other		
If 'Other' chosen in Data Files enter file path here	HiFlows v6.0 with SEPA stations updated through WY2016		

Adjustment/ Changes made to Default Pooling Group.
Also note sites that were investigated but retained in the group (i.e. for discordancy)

Station number	Name	Addition/ Deletion/ Move/ Investigate	Reason
10003	Ythan@Ardlethen	D	Flows transferred to Ellon
43008	Wylye@SouthNewton	D	BFIHOST >0.85
11002	Don@Haughton	A	increase record length
27090	Swale@Catterick Bridge	A	increase record length
8004	Avon@Delnashaugh	A	increase record length

Final Pooling Group Details		
Heterogeneity Measure		
H1	Heterogeneous	
H2	Acceptably Homogeneous	
Goodness of Fit		
Acceptable Fit	**Distribution**	
√	Generalised Logistic	
√	Generalised Extreme Value	
	Pearson Type iii	
	Generalised Pareto	
Growth Curve Fittings		
Attached print outs	√	WINFAP-FEH growth curve fittings
	√	WINFAP-FEH growth curve
Name of Final Pooling Group	ess_sepa_EllonGS_adj	


Pooling-group - ess sepa EllonGS adj
Distributions
1. GL
2. GEV
Q/QMED
Logistic reduced variate, y
Return period (years)
2
5
10
25
30
50
75
100
200
500
1000


Relative frequency
AREA
SAAR
BFIHOST
FARL
PROPWET
URBEXT2000
Q/QMED
Logistic reduced variate, y
L-CV, t2
L-skewness, t3
L-kurtosis, t4
L-skewness, t3
21806
9001
11003
11002
39034
27090
24008
8004
24001

A.3 Broomies, Modley, Fortree and Hillhead Burns

A.3.1 Broomies Burn

FEH STATISTICAL FLOOD ESTIMATION SUMMARY SHEET			
Site	Broomies Burn		
NGR	NJ 97145 30445		
Type of problem/objective of	Peak flows for model		
	30, 100, 200, 200cc, 500, 1000		
Type of catchment	Rural		
QMED site cd	1.5	m^3/s	
Donor/ Analogue Sites Considered			
Site name	Ythan@Ardlethen		
Station number	10001		
NGR	NJ924309		
Proximity (km)	16.17	0.00	
Adjustment	1.011	0.00	
Site Chosen	Y		
QMED site adjusted by data transfer (m^3/s)	1.5	**Specific Q (l/s/ha)**	2.5
Q_{100} growth curve factor	2.94	**Q100/ area (l/s/ha)**	7.2
Q_{100} (m^3/s)	**4.4**		
Summary Data			
FEH catchment area	5.78	km^2	
Adjusted catchment area	6.13	km^2	
URBEXT 1990	0.002		
URBEXT 2010	0.001		
URBEXT Adjustment Method	Urbext2000		
SAAR	770		
Method Used	FEH Statistical Method		
Variation from Chosen Method			
Index Used	BFI		
QMED	1.50	m^3/s	
5	2.09	m^3/s	
10	2.53	m^3/s	
30	3.34	m^3/s	
50	3.79	m^3/s	
100	4.50	m^3/s	
200	5.34	m^3/s	
500	6.71	m^3/s	
1000	7.98	m^3/s	
Climate Change Region	Eastern Scotland		
Climate change adjustment	24.0%		
200 + cc	6.6	m^3/s	
Donor/ Analogues Used			
Calcs by:	Grace Thompson	Date:	16/02/2018
Checked by:	David Cameron	Date:	21/03/2018

POOLING GROUP DETAILS

Original Default Pooling Group

Station name	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
27051 (Crimple @ Burn Bridge)	1.013	44	4.54	0.22	0.16	0.20
45816 (Haddeo @ Upton)	1.26	23	3.46	0.31	0.42	0.64
28033 (Dove @ Hollinsclough)	1.484	37	4.20	0.24	0.42	0.64
26802 (Gypsey Race @ Kirby Grindalythe)	1.564	17	0.12	0.27	0.24	0.14
25019 (Leven @ Easby)	1.567	38	5.33	0.34	0.39	1.10
27073 (Brompton Beck @ Snainton Ings)	1.706	35	0.82	0.20	0.05	0.58
49005 (Bollingey Stream @ Bolingey Cocks	1.722	6	6.51	0.27	0.06	2.39
49006 (Camel @ Camelford)	1.815	10	11.35	0.12	-0.27	3.23
47022 (Tory Brook @ Newnham Park)	1.847	23	7.12	0.26	0.12	0.45
25011 (Langdon Beck @ Langdon)	1.873	28	15.88	0.24	0.32	0.91
76011 (Coal Burn @ Coalburn)	1.903	39	1.84	0.16	0.32	0.99
27010 (Hodge Beck @ Bransdale Weir)	1.944	41	9.42	0.22	0.29	0.15
203046 (Rathmore Burn @ Rathmore Bridg	1.997	34	10.79	0.15	0.14	0.60
44008 (South Winterbourne @ Winterbourne	2.011	37	0.45	0.42	0.33	2.51
25003 (Trout Beck @ Moor House)	2.052	43	15.16	0.17	0.29	0.68
71003 (Croasdale Beck @ Croasdale Flum	2.087	37	10.90	0.21	0.32	0.34
206006 (Annalong @ Recorder)	2.129	48	15.33	0.19	0.05	1.46
Total		540				
Weighted means				0.236	0.233	

Default Pooling Group Catchment Descriptors

Station	Distance SDM	AREA	SAAR	FPEXT	FARL	URBEXT 2000
27051 (Crimple @ Burn Bridge)	1.01	8.17	855	0.013	1.000	0.006
45816 (Haddeo @ Upton)	1.26	6.81	1210	0.011	1.000	0.005
28033 (Dove @ Hollinsclough)	1.48	7.92	1346	0.007	1.000	0.000
26802 (Gypsey Race @ Kirby Grindalythe)	1.56	15.85	757	0.030	1.000	0.000
25019 (Leven @ Easby)	1.57	15.09	830	0.020	1.000	0.004
27073 (Brompton Beck @ Snainton Ings)	1.71	8.06	721	0.237	1.000	0.008
49005 (Bollingey Stream @ Bolingey Cocl	1.72	16.08	1044	0.023	0.991	0.006
49006 (Camel @ Camelford)	1.82	12.52	1418	0.013	1.000	0.003
47022 (Tory Brook @ Newnham Park)	1.85	13.43	1403	0.023	0.942	0.014
25011 (Langdon Beck @ Langdon)	1.87	12.79	1463	0.012	1.000	0.001
76011 (Coal Burn @ Coalburn)	1.90	1.63	1096	0.074	1.000	0.000
27010 (Hodge Beck @ Bransdale Weir)	1.94	18.82	987	0.009	1.000	0.001
203046 (Rathmore Burn @ Rathmore Bric	2.00	22.50	1043	0.072	1.000	0.000
44008 (South Winterbourne @ Winterbou	2.01	20.18	1012	0.015	1.000	0.004
25003 (Trout Beck @ Moor House)	2.05	11.40	1905	0.041	1.000	0.000
71003 (Croasdale Beck @ Croasdale Flu	2.09	10.71	1882	0.016	1.000	0.000
206006 (Annalong @ Recorder)	2.13	14.44	1704	0.023	0.981	0.000

Final Pooling Group Catchment Descriptors

Station name	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
27051 (Crimple @ Burn Bridge)	1.013	44	4.54	0.22	0.16	0.42
45816 (Haddeo @ Upton)	1.26	23	3.46	0.31	0.42	0.88
28033 (Dove @ Hollinsclough)	1.484	37	4.20	0.24	0.42	0.93
25019 (Leven @ Easby)	1.567	38	5.33	0.34	0.39	2.15
25011 (Langdon Beck @ Langdon)	1.873	28	15.88	0.24	0.32	1.53
76011 (Coal Burn @ Coalburn)	1.903	39	1.84	0.16	0.32	1.51
27010 (Hodge Beck @ Bransdale Weir)	1.944	41	9.42	0.22	0.29	0.09
203046 (Rathmore Burn @ Rathmore Bridg	1.997	34	10.79	0.15	0.14	0.65
71003 (Croasdale Beck @ Croasdale Flum	2.087	37	10.90	0.21	0.32	0.33
22003 (Usway Burn @ Shillmoor)	2.173	13	16.17	0.28	0.31	1.44
49003 (de Lank @ de Lank)	2.353	50	13.99	0.23	0.22	0.08
27032 (Hebden Beck @ Hebden)	2.361	50	3.92	0.21	0.25	0.57
41020 (Bevern Stream @ Clappers Bridge)	2.556	47	13.90	0.21	0.17	1.42
28058 (Henmore Brook @ Ashbourne)	2.755	12	9.01	0.16	-0.06	2.35
24006 (Rookhope Burn @ Eastgate)	2.802	20	24.62	0.15	0.12	0.65
Total		513				
Weighted means				0.224	0.258	

Station	Distance SDM	AREA	SAAR	FPEXT	FARL	URBEXT 2000
27051 (Crimple @ Burn Bridge)	1.01	8.17	855	0.01	1.00	0.006
45816 (Haddeo @ Upton)	1.26	6.81	1210	0.01	1.00	0.005
28033 (Dove @ Hollinsclough)	1.48	7.92	1346	0.01	1.00	0.000
25019 (Leven @ Easby)	1.57	15.09	830	0.02	1.00	0.004
25011 (Langdon Beck @ Langdon)	1.87	12.79	1463	0.01	1.00	0.001
76011 (Coal Burn @ Coalburn)	1.90	1.63	1096	0.07	1.00	0.000
27010 (Hodge Beck @ Bransdale Weir)	1.94	18.82	987	0.01	1.00	0.001
203046 (Rathmore Burn @ Rathmore Bric	2.00	22.50	1043	0.07	1.00	0.000
71003 (Croasdale Beck @ Croasdale Flu	2.09	10.71	1882	0.02	1.00	0.000
22003 (Usway Burn @ Shillmoor)	2.17	21.88	1056	0.01	1.00	0.000
49003 (de Lank @ de Lank)	2.35	21.61	1628	0.06	1.00	0.000
27032 (Hebden Beck @ Hebden)	2.36	22.25	1433	0.02	1.00	0.000
41020 (Bevern Stream @ Clappers Bridge	2.56	35.48	886	0.08	0.99	0.013
28058 (Henmore Brook @ Ashbourne)	2.76	38.52	895	0.03	0.98	0.021
24006 (Rookhope Burn @ Eastgate)	2.80	36.60	1126	0.02	0.99	0.000

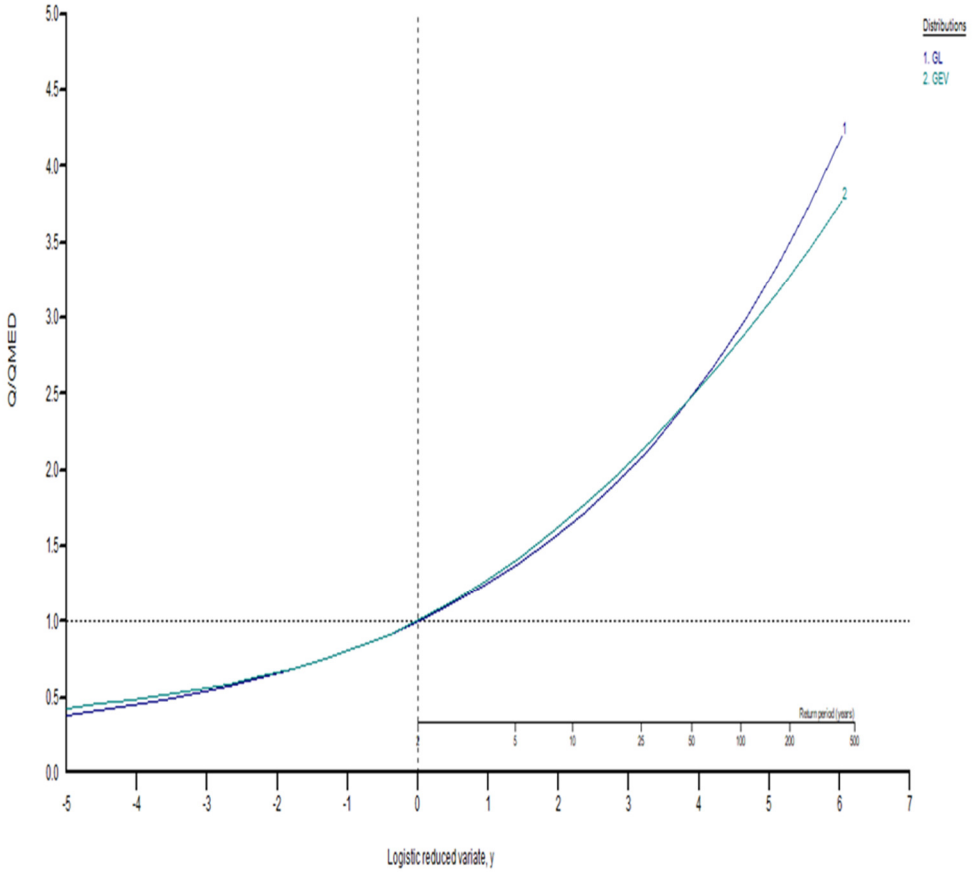
DERIVING A POOLED GROWTH CURVE			
Site	Broomies Burn@Ythan	√	Ungauged site
NGR	NJ 97145 30445		Gauged site
Attached Printouts			
	WINFAP-FEH station details		
	WINFAP-FEH summary information if gauged site		

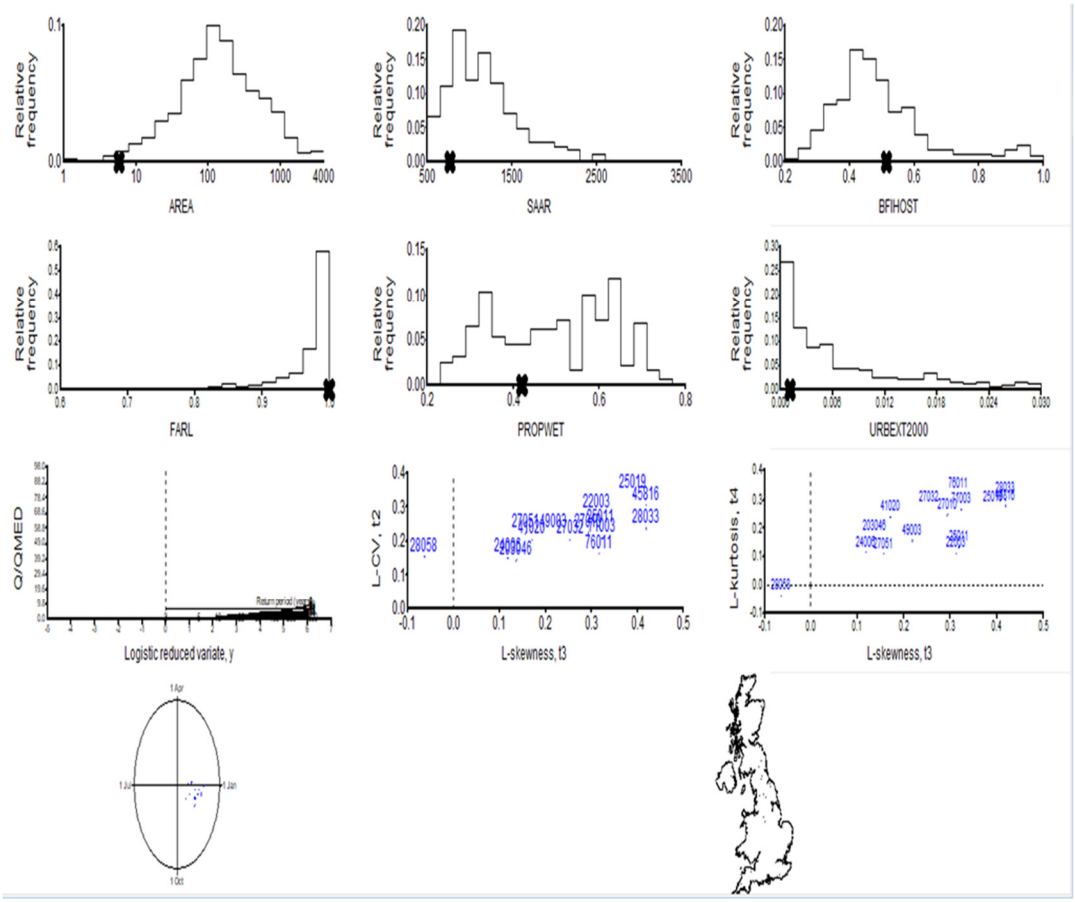
Initial Pooling Group Details	
Name	Broomies Burn
Site of interest	Broomies Burn @ Ythan
Return period of interest	200 years
Other information	
Version of WIN-FAP FEH	Version 3.0
Data Files	Other
If 'Other' chosen in Data Files enter file path here	

Adjustment/ Changes made to Default Pooling Group.
Also note sites that were investigated but retained in the group (i.e. for discordancy)

Station number	Name	Addition/ Deletion/ Move/ Investigate	Reason
206006	Annalong@Recorder	D	Theoretical discharge values
26802	Gypsy Race @ Kirby Grindalythe	D	BFI 0.959
49006	Camel@Camelford	D	Outlier on Lmoments
49005	Boilingey Stream @ Boilingey Cocks Bridge	D	5 years data only
47022	Tory Brook @Newham Park	D	FARL 0.942
27073	Brompton Beck @ Snainton ings	D	BFI 0.887
44008	South Winterbourn@ Winterbourn Steepleton	D	BFI 0.811
25003	Trout Beck@Moor House	D	SAAR 1905
27032	Hebden Beck @ Hebden	A	Increase record length
49003	de Lank@ de Lank	A	Increase record length
41020	Bevern Stream @ Clappers Bridge	A	Increase record length
28058	Henmore Brook @Ashborne	A	Increase record length
24006	Rookhope Burn @ Eastgate	A	Increase record length
22003	Usway Burn @ Shilmoor	A	Increase record length

Final Pooling Group Details	
Heterogeneity Measure	
H1	Heterogeneous
H2	Acceptably Homogeneous
Goodness of Fit	
Acceptable Fit	**Distribution**
√	Generalised Logistic
√	Generalised Extreme Value
	Pearson Type iii
	Generalised Pareto
Growth Curve Fittings	
Attached print outs	WINFAP-FEH growth curve fittings
	WINFAP-FEH growth curve
Name of Final Pooling Group	Pooling-group-999200


Distributions
1. GL
2. GEV
Q/QMED
Logistic reduced variate, y
Return period (years)


Relative frequency
AREA
SAAR
BFIHOST
FARL
PROPWET
URBEXT2000
Q/QMED
Logistic reduced variate, y
L-CV, t2
L-skewness, t3
L-kurtosis, t4
L-skewness, t3

6.1.1 Modley Burn

FEH STATISTICAL FLOOD ESTIMATION SUMMARY SHEET			
Site	Modley Burn@Ythan		
NGR	NJ95084 30292		
Type of problem/objective of	Peak flows for model		
	30, 100, 200, 200cc, 500, 1000		
Type of catchment	Rural		
QMED site cd	0.9	m^3/s	
Donor/ Analogue Sites Considered			
Site name	Ythan@Ardlethen		
Station number	10001		
NGR	NJ9234309		
Proximity (km)	14.93	0.00	
Adjustment	1.011	0.00	
Site Chosen	Y		
QMED site adjusted by data transfer (m^3/s)	0.9	**Specific Q (l/s/ha)**	2.5
Q_{100} growth curve factor	2.92	**Q100/ area (l/s/ha)**	7.3
Q_{100} (m^3/s)	**2.7**		
Summary Data			
FEH catchment area	3.75	km^2	
Adjusted catchment area	3.62	km^2	
URBEXT 1990	0.020		
URBEXT 2010	0.028		
URBEXT Adjustment Method	Urbext2000		
SAAR	769		
Method Used	FEH Statistical Method		
Variation from Chosen Method			
Index Used	BFI		
QMED	0.91	m^3/s	
5	1.24	m^3/s	
10	1.50	m^3/s	
30	1.98	m^3/s	
50	2.25	m^3/s	
100	2.67	m^3/s	
200	3.18	m^3/s	
500	4.00	m^3/s	
1000	4.77	m^3/s	
Climate Change Region	Eastern Scotland		
Climate change adjustment	24.0%		
200 + cc	3.9	m^3/s	
Donor/ Analogues Used			
Calcs by:	Grace Thompson	Date:	28/02/2018
Checked by:	David Cameron	Date:	21/03/2018

POOLING GROUP DETAILS

Original Default Pooling Group

Station name	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
76011 (Coal Burn @ Coalburn)	1.41	39	1.8	0.16	0.32	1.10
27051 (Crimple @ Burn Bridge)	1.56	44	4.5	0.22	0.16	0.18
45816 (Haddeo @ Upton)	1.64	23	3.5	0.31	0.42	1.00
27073 (Brompton Beck @ Snainton Ings)	1.77	35	0.8	0.20	0.05	0.52
28033 (Dove @ Hollinsclough)	1.90	37	4.2	0.24	0.42	0.58
25019 (Leven @ Easby)	2.21	38	5.3	0.34	0.39	2.00
26802 (Gypsey Race @ Kirby Grindalythe)	2.21	17	0.1	0.27	0.24	0.38
49006 (Camel @ Camelford)	2.33	10	11.4	0.12	-0.27	3.03
49005 (Bollingey Stream @ Bolingey Cocks	2.34	6	6.5	0.27	0.06	2.33
47022 (Tory Brook @ Newnham Park)	2.37	23	7.1	0.26	0.12	0.60
25011 (Langdon Beck @ Langdon)	2.38	28	15.9	0.24	0.32	0.84
25003 (Trout Beck @ Moor House)	2.46	43	15.2	0.17	0.29	0.82
71003 (Croasdale Beck @ Croasdale Flum	2.49	37	10.9	0.21	0.32	0.30
27010 (Hodge Beck @ Bransdale Weir)	2.57	41	9.4	0.22	0.29	0.13
203046 (Rathmore Burn @ Rathmore Bridg	2.61	34	10.8	0.15	0.14	0.80
206006 (Annalong @ Recorder)	2.62	48	15.3	0.19	0.05	1.41
Total		503				
Weighted means				0.223	0.226	

Default Pooling Group Catchment Descriptors

Station	Distance SDM	AREA	SAAR	FPEXT	FARL	URBEXT 2000
76011 (Coal Burn @ Coalburn)	1.41	1.63	1096	0.07	1.00	0.000
27051 (Crimple @ Burn Bridge)	1.56	8.17	855	0.01	1.00	0.006
45816 (Haddeo @ Upton)	1.64	6.81	1210	0.01	1.00	0.005
27073 (Brompton Beck @ Snainton Ings)	1.77	8.06	721	0.24	1.00	0.008
28033 (Dove @ Hollinsclough)	1.90	7.92	1346	0.01	1.00	0.000
25019 (Leven @ Easby)	2.21	15.09	830	0.02	1.00	0.004
26802 (Gypsey Race @ Kirby Grindalythe)	2.21	15.85	757	0.03	1.00	0.000
49006 (Camel @ Camelford)	2.33	12.52	1418	0.01	1.00	0.003
49005 (Bollingey Stream @ Bolingey Coc	2.34	16.08	1044	0.02	0.99	0.006
47022 (Tory Brook @ Newnham Park)	2.37	13.43	1403	0.02	0.94	0.014
25011 (Langdon Beck @ Langdon)	2.38	12.79	1463	0.01	1.00	0.001
25003 (Trout Beck @ Moor House)	2.46	11.4	1905	0.04	1.00	0.000
71003 (Croasdale Beck @ Croasdale Flu	2.49	10.71	1882	0.02	1.00	0.000
27010 (Hodge Beck @ Bransdale Weir)	2.57	18.82	987	0.01	1.00	0.001
203046 (Rathmore Burn @ Rathmore Bric	2.61	22.5	1043	0.07	1.00	0.000
206006 (Annalong @ Recorder)	2.62	14.44	1704	0.02	0.98	0.000

Station name	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
76011 (Coal Burn @ Coalburn)	1.41	39	1.84	0.164	0.316	1.51
27051 (Crimple @ Burn Bridge)	1.56	44	4.54	0.223	0.156	0.42
45816 (Haddeo @ Upton)	1.64	23	3.46	0.307	0.418	0.88
28033 (Dove @ Hollinsclough)	1.90	37	4.20	0.237	0.418	0.93
25019 (Leven @ Easby)	2.21	38	5.33	0.338	0.391	2.15
25011 (Langdon Beck @ Langdon)	2.38	28	15.88	0.238	0.318	1.53
71003 (Croasdale Beck @ Croasdale Flum	2.49	37	10.90	0.212	0.323	0.33
27010 (Hodge Beck @ Bransdale Weir)	2.57	41	9.42	0.224	0.293	0.09
203046 (Rathmore Burn @ Rathmore Bridg	2.61	34	10.79	0.146	0.136	0.65
22003 (Usway Burn @ Shillmoor)	2.80	13	16.17	0.282	0.311	1.44
49003 (de Lank @ de Lank)	2.89	50	13.99	0.225	0.217	0.08
27032 (Hebden Beck @ Hebden)	2.94	50	3.92	0.207	0.253	0.57
41020 (Bevern Stream @ Clappers Bridge)	3.18	47	13.90	0.205	0.17	1.42
28058 (Henmore Brook @ Ashbourne)	3.40	12	9.01	0.155	-0.064	2.35
24006 (Rookhope Burn @ Eastgate)	3.43	20	24.62	0.152	0.117	0.65
Total		513				
Weighted means				0.223	0.258	

Final Pooling Group Catchment Descriptors

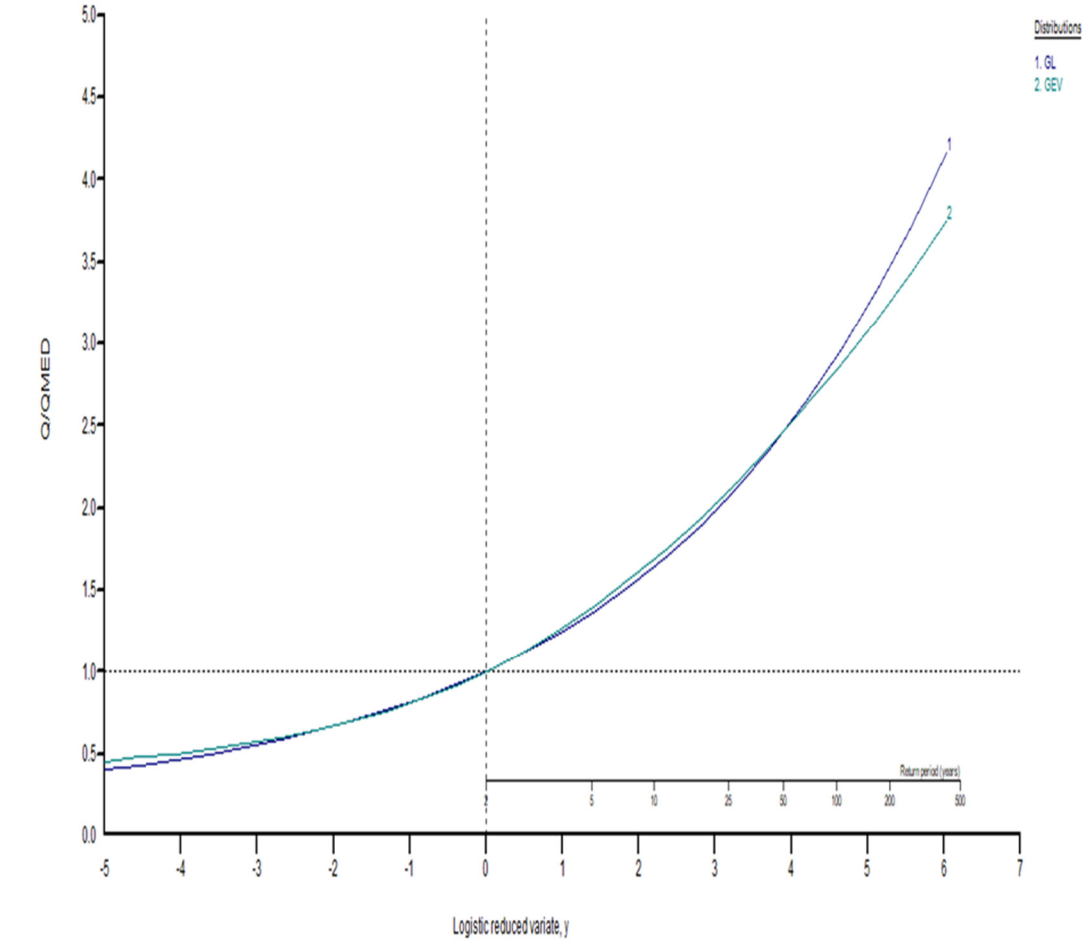
Station	Distance SDM	AREA	SAAR	FPEXT	FARL	URBEXT 2000
76011 (Coal Burn @ Coalburn)	1.41	1.63	1096	0.07	1.00	0.000
27051 (Crimple @ Burn Bridge)	1.56	8.17	855	0.01	1.00	0.006
45816 (Haddeo @ Upton)	1.64	6.81	1210	0.01	1.00	0.005
28033 (Dove @ Hollinsclough)	1.90	7.92	1346	0.01	1.00	0.000
25019 (Leven @ Easby)	2.21	15.09	830	0.02	1.00	0.004
25011 (Langdon Beck @ Langdon)	2.38	12.79	1463	0.01	1.00	0.001
71003 (Croasdale Beck @ Croasdale Flu	2.49	10.71	1882	0.02	1.00	0.000
27010 (Hodge Beck @ Bransdale Weir)	2.57	18.82	987	0.01	1.00	0.001
203046 (Rathmore Burn @ Rathmore Bric	2.61	22.5	1043	0.07	1.00	0.000
22003 (Usway Burn @ Shillmoor)	2.80	21.88	1056	0.01	1.00	0.000
49003 (de Lank @ de Lank)	2.89	21.61	1628	0.06	1.00	0.000
27032 (Hebden Beck @ Hebden)	2.94	22.25	1433	0.02	1.00	0.000
41020 (Bevern Stream @ Clappers Bridge	3.18	35.48	886	0.08	0.99	0.013
28058 (Henmore Brook @ Ashbourne)	3.40	38.52	895	0.03	0.98	0.021
24006 (Rookhope Burn @ Eastgate)	3.43	36.6	1126	0.02	0.99	0.000

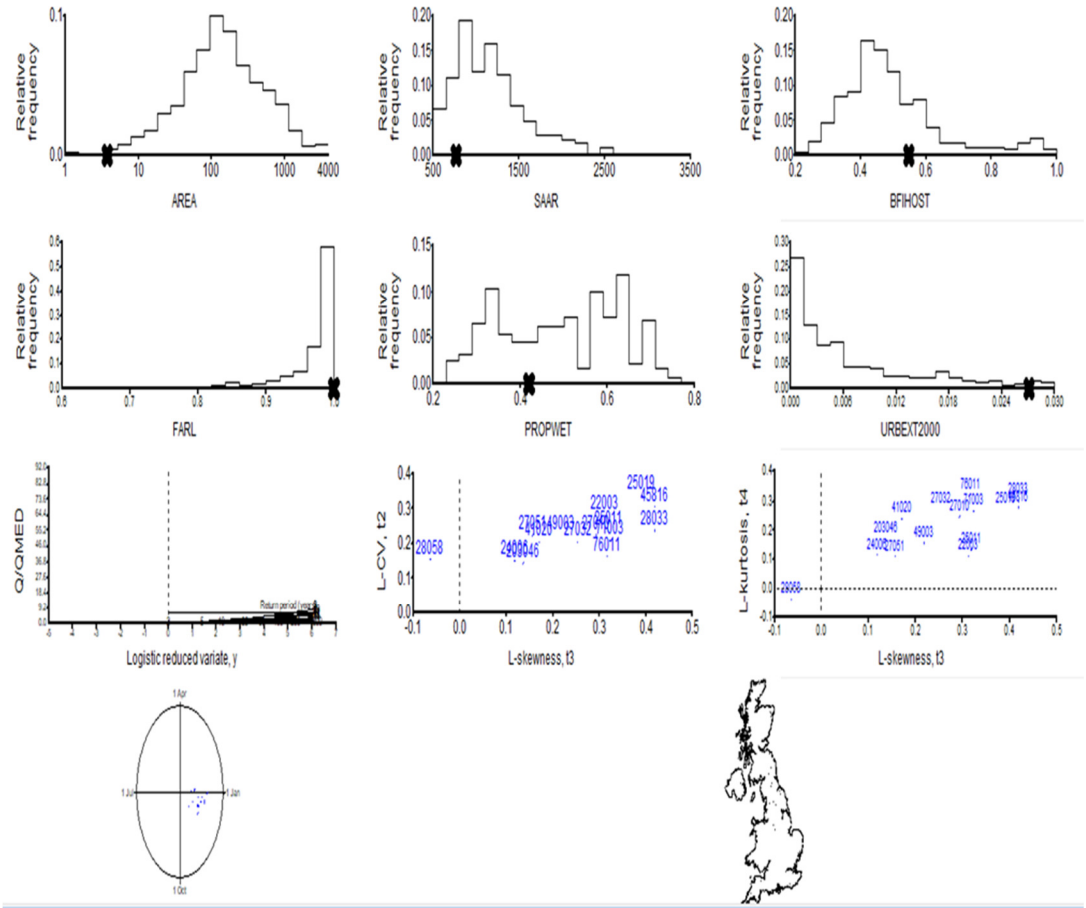
DERIVING A POOLED GROWTH CURVE			
Site	Modley Burn	√	Ungauged site
NGR	NJ 95084 30292		Gauged site
Attached Printouts			
	WINFAP-FEH station details		
	WINFAP-FEH summary information if gauged site		
Initial Pooling Group Details			
Name	Modley Burn		
Site of interest	Modley Burn @ Ythan		
Return period of interest	200 years		
Other information			
Version of WIN-FAP FEH	Version 3.0		
Data Files	Other		
If 'Other' chosen in Data Files enter file path here			

Adjustment/ Changes made to Default Pooling Group.
Also note sites that were investigated but retained in the group (i.e. for discordancy)

Station number	Name	Addition/ Deletion/ Move/ Investigate	Reason
206006	Annalong@Recorder	D	Theoriecal discharge values
268 02	Gypsey Race @Kirkby Grindalythe	D	BFI 0.959
49006	Camel@Camelford	D	Outlier on Lmoments
49005	ingey stream@Boilingey cocks Bri	D	5 years data only
47022	rook@Newham Park	D	FARL 0.942
27073	Brompton Beck@ Snainton ings	D	BFI 0.887
44008	uth winterbourn@ Winterbourn Stee	D	BFI 0.811
25003	Trout Beck @ Moor House	D	SAAR 1905
27032	Hebden Beck @Hebden	A	Increase record legnth
49003	De Lank@De lank	A	Increase record legnth
41020	Bevern Stream @Clappers Bridge	A	Increase record legnth
28058	Henmore Brook @Ashborne	A	Increase record legnth
24006	Rookhope Burn@Eastgate	A	Increase record legnth
22003	Usway Burn@Shilmoor	A	Increase record legnth

Final Pooling Group Details		
Heterogeneity Measure		
H1	Heterogeneous	
H2	Acceptably Homogeneous	
Goodness of Fit		
Acceptable Fit	**Distribution**	
√	Generalised Logistic	
√	Generalised Extreme Value	
	Pearson Type iii	
	Generalised Pareto	
Growth Curve Fittings		
Attached print outs		WINFAP-FEH growth curve fittings
		WINFAP-FEH growth curve
Name of Final Pooling Group		Modley Burn_Default


Distributions
1. GL
2. GEV
Q/QMED
Logistic reduced variate, y
Return period (years)


Relative frequency
AREA
SAAR
BFIHOST
FARL
PROPWET
URBEXT2000
Q/QMED
Logistic reduced variate, y
L-CV, t2
L-skewness, t3
L-kurtosis, t4
L-skewness, t3

A.3.2 Fortree Burn

FEH STATISTICAL FLOOD ESTIMATION SUMMARY SHEET			
Site	Fortree Burn		
NGR	NJ94845 29353		
Type of problem/objective of	Peak flows for model		
	30, 100, 200, 200cc, 500, 1000		
Type of catchment	Rural		
QMED site cd	0.5	m^3/s	
Donor/ Analogue Sites Considered			
Site name	Ythan@Ardlethen		
Station number	10001		
NGR	NJ924309		
Proximity (km)	16.88	0.00	
Adjustment	1.011	0.00	
Site Chosen	Y		
QMED site adjusted by data transfer (m^3/s)	0.5	**Specific Q (l/s/ha)**	2.6
Q_{100} growth curve factor	2.92	**Q100/ area (l/s/ha)**	7.6
Q_{100} (m^3/s)	**1.6**		
Summary Data			
FEH catchment area	2.15	km^2	
Adjusted catchment area	2.07	km^2	
URBEXT 1990	0.057		
URBEXT 2010	0.061		
URBEXT Adjustment Method	Urbext2000		
SAAR	752		
Method Used	FEH Statistical Method		
Variation from Chosen Method			
Index Used	BFI		
QMED	0.54	m^3/s	
5	0.73	m^3/s	
10	0.88	m^3/s	
25	1.11	m^3/s	
50	1.32	m^3/s	
100	1.57	m^3/s	
200	1.88	m^3/s	
500	2.38	m^3/s	
1000	2.85	m^3/s	
Climate Change Region	Eastern Scotland		
Climate change adjustment	24.0%		
200 + cc	2.3	m^3/s	
Donor/ Analogues Used			
Calcs by:	Grace Thompson	Date:	28/02/2018
Checked by:	David Cameron	Date:	21/03/2018

POOLING GROUP DETAILS

Original Default Pooling Group

Station name	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
76011 (Coal Burn @ Coalburn)	0.81	39	1.84	0.164	0.316	0.878
45816 (Haddeo @ Upton)	2.014	23	3.456	0.307	0.418	1.050
27051 (Crimple @ Burn Bridge)	2.038	44	4.539	0.223	0.156	0.180
28033 (Dove @ Hollinsclough)	2.295	37	4.2	0.237	0.418	0.551
27073 (Brompton Beck @ Snainton Ings)	2.574	35	0.82	0.2	0.049	0.539
25019 (Leven @ Easby)	2.828	38	5.333	0.338	0.391	1.985
49006 (Camel @ Camelford)	2.86	10	11.35	0.12	-0.269	2.893
26802 (Gypsey Race @ Kirby Grindalythe)	2.863	17	0.116	0.274	0.240	0.389
25011 (Langdon Beck @ Langdon)	2.912	28	15.878	0.238	0.318	0.746
47022 (Tory Brook @ Newnham Park)	2.932	23	7.123	0.262	0.115	0.587
91802 (Allt Leachdach @ Intake)	2.943	34	6.35	0.153	0.257	1.161
71003 (Croasdale Beck @ Croasdale Flum	2.947	37	10.9	0.212	0.323	0.249
49005 (Bollingey Stream @ Bolingey Cocks	2.968	6	6.511	0.265	0.063	2.188
25003 (Trout Beck @ Moor House)	2.977	43	15.164	0.17	0.288	0.648
54022 (Severn @ Plynlimon Flume)	3.119	38	14.988	0.156	0.171	0.752
206006 (Annalong @ Recorder)	3.168	48	15.33	0.189	0.052	1.204
Total		500				
Weighted means				0.218	0.226	

Default Pooling Group Catchment Descriptors

Station	Distance SDM	AREA	SAAR	FPEXT	FARL	URBEXT 2000
76011 (Coal Burn @ Coalburn)	0.81	1.63	1096	0.074	1.000	0.000
45816 (Haddeo @ Upton)	2.014	6.81	1210	0.011	1.000	0.005
27051 (Crimple @ Burn Bridge)	2.038	8.17	855	0.013	1.000	0.006
28033 (Dove @ Hollinsclough)	2.295	7.92	1346	0.007	1.000	0.000
27073 (Brompton Beck @ Snainton Ings)	2.574	8.06	721	0.237	1.000	0.008
25019 (Leven @ Easby)	2.828	15.09	830	0.02	1.000	0.004
49006 (Camel @ Camelford)	2.86	12.52	1418	0.013	1.000	0.003
26802 (Gypsey Race @ Kirby Grindalythe)	2.863	15.85	757	0.03	1.000	0.000
25011 (Langdon Beck @ Langdon)	2.912	12.79	1463	0.012	1.000	0.001
47022 (Tory Brook @ Newnham Park)	2.932	13.43	1403	0.023	0.942	0.014
91802 (Allt Leachdach @ Intake)	2.943	6.54	2554	0.003	0.992	0.000
71003 (Croasdale Beck @ Croasdale Flu	2.947	10.71	1882	0.016	1.000	0.000
49005 (Bollingey Stream @ Bolingey Cocl	2.968	16.08	1044	0.023	0.991	0.006
25003 (Trout Beck @ Moor House)	2.977	11.4	1905	0.041	1.000	0.000
54022 (Severn @ Plynlimon Flume)	3.119	8.75	2481	0.01	1.000	0.000
206006 (Annalong @ Recorder)	3.168	14.44	1704	0.023	0.981	0.000

Final Pooling Group Catchment Descriptors

Station name	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
76011 (Coal Burn @ Coalburn)	0.81	39	1.84	0.164	0.316	1.212
45816 (Haddeo @ Upton)	2.014	23	3.456	0.307	0.418	1.136
27051 (Crimple @ Burn Bridge)	2.038	44	4.539	0.223	0.156	1.135
28033 (Dove @ Hollinsclough)	2.295	37	4.2	0.237	0.418	0.933
25019 (Leven @ Easby)	2.828	38	5.333	0.338	0.391	1.997
25011 (Langdon Beck @ Langdon)	2.912	28	15.878	0.238	0.318	0.960
91802 (Allt Leachdach @ Intake)	2.943	34	6.35	0.153	0.257	1.255
71003 (Croasdale Beck @ Croasdale Flum	2.947	37	10.9	0.212	0.323	0.245
54022 (Severn @ Plynlimon Flume)	3.119	38	14.988	0.156	0.171	0.858
206006 (Annalong @ Recorder)	3.168	48	15.33	0.189	0.052	2.079
22003 (Usway Burn @ Shillmoor)	3.424	13	16.17	0.282	0.311	1.220
49003 (de Lank @ de Lank)	3.569	50	13.985	0.225	0.217	0.370
27032 (Hebden Beck @ Hebden)	3.569	50	3.923	0.207	0.253	0.172
41020 (Bevern Stream @ Clappers Bridge	3.951	47	13.9	0.205	0.170	0.428
Total		526				
Weighted means				0.222	0.264	

Station	Distance SDM	AREA	SAAR	FPEXT	FARL	URBEXT 2000
76011 (Coal Burn @ Coalburn)	0.81	1.63	1096	0.074	1.000	0.000
45816 (Haddeo @ Upton)	2.014	6.81	1210	0.011	1.000	0.005
27051 (Crimple @ Burn Bridge)	2.038	8.17	855	0.013	1.000	0.006
28033 (Dove @ Hollinsclough)	2.295	7.92	1346	0.007	1.000	0.000
25019 (Leven @ Easby)	2.828	15.09	830	0.02	1.000	0.004
25011 (Langdon Beck @ Langdon)	2.912	12.79	1463	0.012	1.000	0.001
91802 (Allt Leachdach @ Intake)	2.943	6.54	2554	0.003	0.992	0.000
71003 (Croasdale Beck @ Croasdale Flu	2.947	10.71	1882	0.016	1.000	0.000
54022 (Severn @ Plynlimon Flume)	3.119	8.75	2481	0.01	1.000	0.000
206006 (Annalong @ Recorder)	3.168	14.44	1704	0.023	0.981	0.000
22003 (Usway Burn @ Shillmoor)	3.424	21.88	1056	0.006	1.000	0.000
49003 (de Lank @ de Lank)	3.569	21.61	1628	0.064	0.998	0.000
27032 (Hebden Beck @ Hebden)	3.569	22.25	1433	0.021	0.997	0.000
41020 (Bevern Stream @ Clappers Bridge	3.951	35.48	886	0.076	0.993	0.013

DERIVING A POOLED GROWTH CURVE			
Site	Fortree Burn	√	Ungauged site
NGR	NJ 94848 29353		Gauged site
Attached Printouts			
	WINFAP-FEH station details		
	WINFAP-FEH summary information if gauged site		

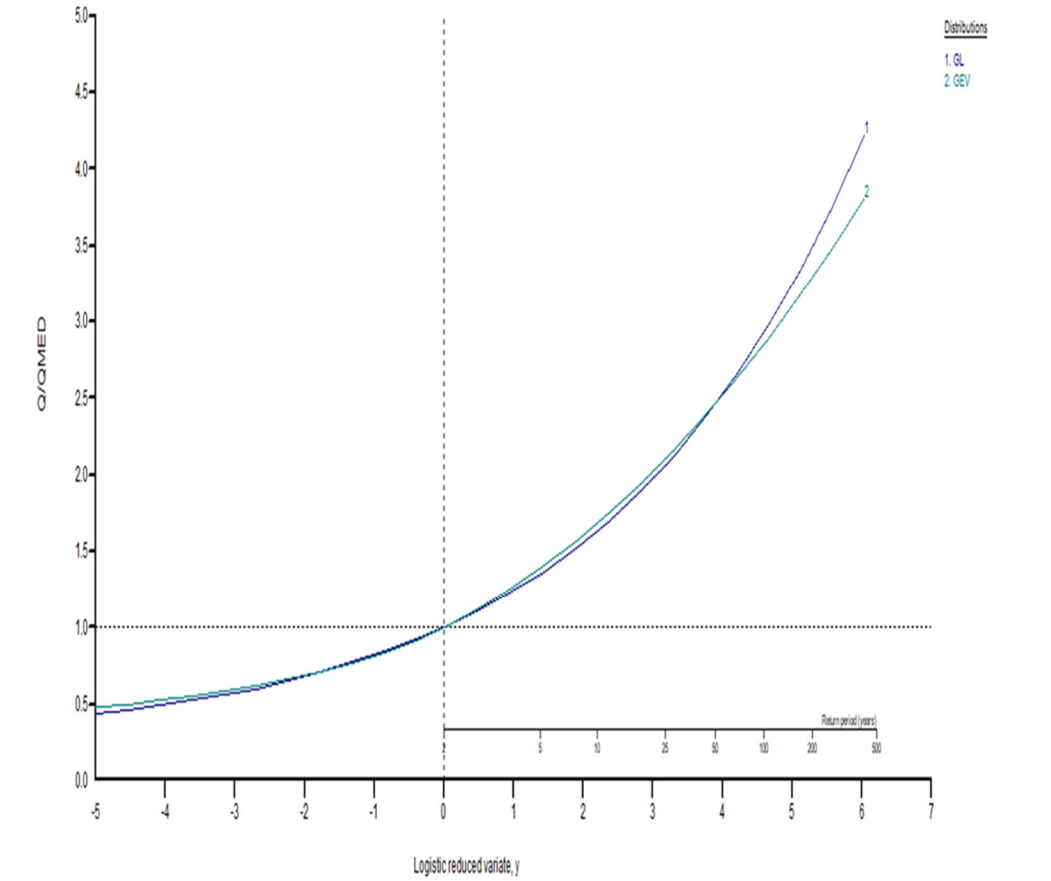
Initial Pooling Group Details	
Name	Fortree Burn
Site of interest	FortreeBurn@Ythan
Return period of interest	200 years
Other information	
Version of WIN-FAP FEH	Version 3.0
Data Files	G:\FEH\WINFAP-FEH files - Hiflows UK Dec 2004 version\Pooling
If 'Other' chosen in Data Files enter file path here	

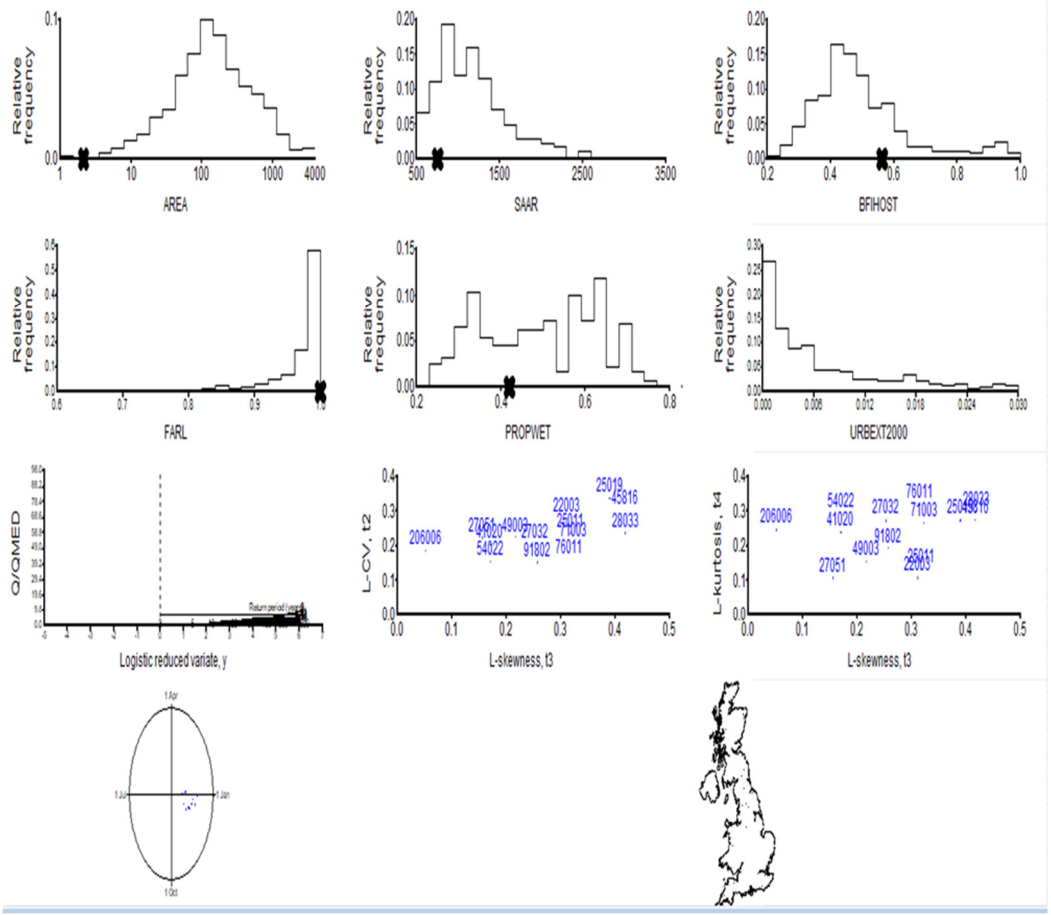
Adjustment/ Changes made to Default Pooling Group.
Also note sites that were investigated but retained in the group (i.e. for discordancy)

Station number	Name	Addition/ Deletion/ Move/ Investigate	Reason
27073	Brompton Beck @ Snainton ings	D	BFI 0.887
49006	Camel@Camleford	D	Outlier on Lmoments
26802	Gypsey Race @Kirkby Grindalythe	D	BFI 0.959
47022	Tory Brook @ Hewham Park	D	FARL 0.942
49005	ilingley Stream@Boilingey Cock Brid	D	5 years data only
25003	Trout Beck@ Moor House	D	SAAR 1905
27032	Hebden Beck @Hebden	A	Increase record length
49003	De Lank @ De Lank	A	Increase record length
22003	Ursway Burn @Shilmoor	A	Increase record length
41020	Bevern Stream@Clappers Bridge	A	Increase record length

Final Pooling Group Details	
Heterogeneity Measure	
H1	Heterogeneous
H2	Acceptably Homogeneous
Goodness of Fit	
Acceptable Fit	**Distribution**
√	Generalised Logistic
√	Generalised Extreme Value
	Pearson Type iii
	Generalised Pareto

Growth Curve Fittings		
Attached print outs		WINFAP-FEH growth curve fittings
		WINFAP-FEH growth curve
Name of Final Pooling Group		Fortree Default


Distributions
1. GL
2. GEV
Q/QMED
Logistic reduced variate, y
Return period (years)


Relative frequency
AREA
SAAR
BFIHOST
FARL
PROPWET
URBEXT2000
Q/QMED
Logistic reduced variate, y
L-CV, t2
L-skewness, t3
L-kurtosis, t4
L-skewness, t3

6.1.2 Hillhead Burn

FEH STATISTICAL FLOOD ESTIMATION SUMMARY SHEET			
Site	Hillhead Burn		
NGR	NJ 95729 29846		
Type of problem/objective of	Peak flows for model		
	30, 100, 200, 200cc, 500, 1000		
Type of catchment	Rural		
QMED site cd	0.2	m^3/s	
Donor/ Analogue Sites Considered			
Site name	Ythan@Ardlethen		
Station number	10001		
NGR	NJ924309		
Proximity (km)	16.88	0.00	
Adjustment	1.011	0.00	
Site Chosen	Y		
QMED site adjusted by data transfer (m^3/s)	0.2	**Specific Q (l/s/ha)**	2.8
Q_{100} growth curve factor	2.95	**Q100/ area (l/s/ha)**	8.3
Q_{100} (m^3/s)	**0.6**		
Summary Data			
FEH catchment area	2.15	km^2	
Adjusted catchment area	0.71	km^2	
URBEXT 1990	0.057		
URBEXT 2010	0.061		
URBEXT Adjustment Method	Urbext2000		
SAAR	752		
Method Used	FEH Statistical Method		
Variation from Chosen Method			
Index Used	BFI		
QMED	0.20	m^3/s	
5	0.29	m^3/s	
10	0.36	m^3/s	
25	0.45	m^3/s	
50	0.54	m^3/s	
100	0.64	m^3/s	
200	0.76	m^3/s	
500	0.96	m^3/s	
1000	1.15	m^3/s	
Climate Change Region	Eastern Scotland		
Climate change adjustment	24.0%		
200 + cc	0.9	m^3/s	
Donor/ Analogues Used			
Calcs by:	Grace Thompson	Date:	28/02/2018
Checked by:	David Cameron	Date:	21/03/2018

POOLING GROUP DETAILS

Original Default Pooling Group

Station name	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
76011 (Coal Burn @ Coalburn)	0.81	39	1.84	0.164	0.316	0.878
45816 (Haddeo @ Upton)	2.014	23	3.456	0.307	0.418	1.050
27051 (Crimple @ Burn Bridge)	2.038	44	4.539	0.223	0.156	0.180
28033 (Dove @ Hollinsclough)	2.295	37	4.2	0.237	0.418	0.551
27073 (Brompton Beck @ Snainton Ings)	2.574	35	0.82	0.2	0.049	0.539
25019 (Leven @ Easby)	2.828	38	5.333	0.338	0.391	1.985
49006 (Camel @ Camelford)	2.86	10	11.35	0.12	-0.269	2.893
26802 (Gypsey Race @ Kirby Grindalythe)	2.863	17	0.116	0.274	0.240	0.389
25011 (Langdon Beck @ Langdon)	2.912	28	15.878	0.238	0.318	0.746
47022 (Tory Brook @ Newnham Park)	2.932	23	7.123	0.262	0.115	0.587
91802 (Allt Leachdach @ Intake)	2.943	34	6.35	0.153	0.257	1.161
71003 (Croasdale Beck @ Croasdale Flum	2.947	37	10.9	0.212	0.323	0.249
49005 (Bollingey Stream @ Bolingey Cocks	2.968	6	6.511	0.265	0.063	2.188
25003 (Trout Beck @ Moor House)	2.977	43	15.164	0.17	0.288	0.648
54022 (Severn @ Plynlimon Flume)	3.119	38	14.988	0.156	0.171	0.752
206006 (Annalong @ Recorder)	3.168	48	15.33	0.189	0.052	1.204
Total		500				
Weighted means				0.218	0.226	

Default Pooling Group Catchment Descriptors

Station	Distance SDM	AREA	SAAR	FPEXT	FARL	URBEXT 2000
76011 (Coal Burn @ Coalburn)	0.81	1.63	1096	0.074	1.000	0.000
45816 (Haddeo @ Upton)	2.014	6.81	1210	0.011	1.000	0.005
27051 (Crimple @ Burn Bridge)	2.038	8.17	855	0.013	1.000	0.006
28033 (Dove @ Hollinsclough)	2.295	7.92	1346	0.007	1.000	0.000
27073 (Brompton Beck @ Snainton Ings)	2.574	8.06	721	0.237	1.000	0.008
25019 (Leven @ Easby)	2.828	15.09	830	0.020	1.000	0.004
49006 (Camel @ Camelford)	2.86	12.52	1418	0.013	1.000	0.003
26802 (Gypsey Race @ Kirby Grindalythe)	2.863	15.85	757	0.030	1.000	0.000
25011 (Langdon Beck @ Langdon)	2.912	12.79	1463	0.012	1.000	0.001
47022 (Tory Brook @ Newnham Park)	2.932	13.43	1403	0.023	0.942	0.014
91802 (Allt Leachdach @ Intake)	2.943	6.54	2554	0.003	0.992	0.000
71003 (Croasdale Beck @ Croasdale Flu	2.947	10.71	1882	0.016	1.000	0.000
49005 (Bollingey Stream @ Bolingey Cocl	2.968	16.08	1044	0.023	0.991	0.006
25003 (Trout Beck @ Moor House)	2.977	11.4	1905	0.041	1.000	0.000
54022 (Severn @ Plynlimon Flume)	3.119	8.75	2481	0.010	1.000	0.000
206006 (Annalong @ Recorder)	3.168	14.44	1704	0.023	0.981	0.000

Final Pooling Group Catchment Descriptors

Station name	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
76011 (Coal Burn @ Coalburn)	0.821	38	1.84	0.165	0.331	1.28
45816 (Haddeo @ Upton)	2.003	22	3.489	0.314	0.415	1.018
27051 (Crimple @ Burn Bridge)	2.025	43	4.514	0.219	0.154	0.36
28033 (Dove @ Hollinsclough)	2.284	36	4.225	0.24	0.415	0.78
27073 (Brompton Beck @ Snainton Ings)	2.551	34	0.816	0.198	0.056	1.209
25019 (Leven @ Easby)	2.813	37	4.989	0.342	0.39	1.904
26802 (Gypsey Race @ Kirby Grindalythe)	2.846	16	0.112	0.274	0.274	0.885
25011 (Langdon Beck @ Langdon)	2.898	28	15.878	0.238	0.318	1.442
47022 (Tory Brook @ Newnham Park)	2.918	22	7.227	0.262	0.093	1.553
71003 (Croasdale Beck @ Croasdale Flum	2.936	37	10.9	0.212	0.323	0.275
25003 (Trout Beck @ Moor House)	2.964	42	15.142	0.172	0.293	0.732
54022 (Severn @ Plynlimon Flume)	3.11	38	14.988	0.156	0.171	1.998
27010 (Hodge Beck @ Bransdale Weir)	3.176	41	9.42	0.224	0.293	0.092
22003 (Usway Burn @ Shillmoor)	3.408	13	16.17	0.282	0.311	1.295
49003 (de Lank @ de Lank)	3.552	49	14.324	0.227	0.214	0.117
24006 (Rookhope Burn @ Eastgate)	4.096	20	24.62	0.152	0.117	1.061
Total		516				
Weighted means				0.228	0.261	

Station	Distance SDM	AREA	SAAR	FPEXT	FARL	URBEXT 2000
76011 (Coal Burn @ Coalburn)	0.821	1.63	1096	0.074	1	0
45816 (Haddeo @ Upton)	2.003	6.81	1210	0.011	1	0.005
27051 (Crimple @ Burn Bridge)	2.025	8.17	855	0.013	1	0.006
28033 (Dove @ Hollinsclough)	2.284	7.92	1346	0.007	1	0
27073 (Brompton Beck @ Snainton Ings)	2.551	8.06	721	0.237	1	0.008
25019 (Leven @ Easby)	2.813	15.09	830	0.02	1	0.004
26802 (Gypsey Race @ Kirby Grindalythe)	2.846	15.85	757	0.03	1	0
25011 (Langdon Beck @ Langdon)	2.898	12.79	1463	0.012	1	0.001
47022 (Tory Brook @ Newnham Park)	2.918	13.43	1403	0.023	0.942	0.014
71003 (Croasdale Beck @ Croasdale Flu	2.936	10.71	1882	0.016	1	0
25003 (Trout Beck @ Moor House)	2.964	11.4	1905	0.041	1	0
54022 (Severn @ Plynlimon Flume)	3.11	8.75	2481	0.01	1	0
27010 (Hodge Beck @ Bransdale Weir)	3.176	18.82	987	0.009	1	0.001
22003 (Usway Burn @ Shillmoor)	3.408	21.88	1056	0.006	1	0
49003 (de Lank @ de Lank)	3.552	21.61	1628	0.064	0.998	0
24006 (Rookhope Burn @ Eastgate)	4.096	36.6	1126	0.018	0.994	0

DERIVING A POOLED GROWTH CURVE			
Site	Hillhead Burn @ Ythan	√	Ungauged site
NGR	NJ 95729 29846		Gauged site
Attached Printouts			
	WINFAP-FEH station details		
	WINFAP-FEH summary information if gauged site		

Initial Pooling Group Details	
Name	Hillhead Burn@Ythan
Site of interest	Hillhead Burn
Return period of interest	200 years
Other information	
Version of WIN-FAP FEH	Version 3.0
Data Files	Other
If 'Other' chosen in Data Files enter file path here	

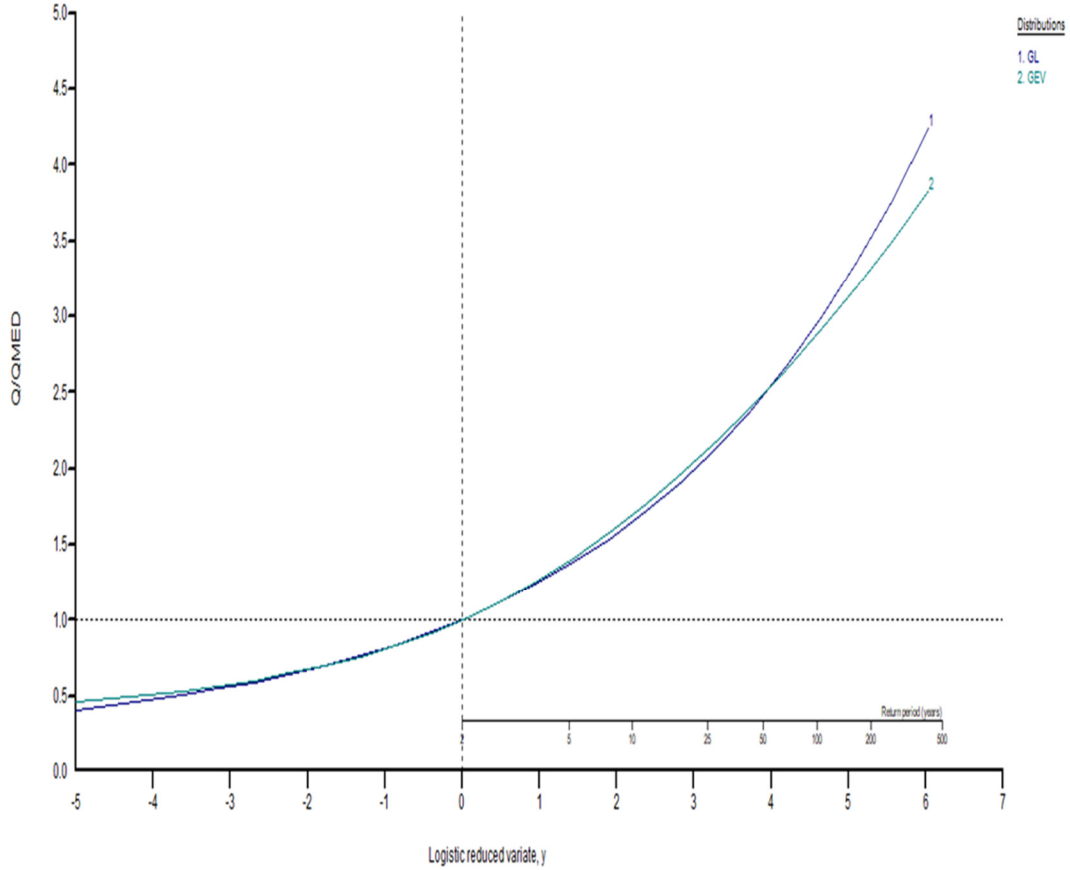
Adjustment/ Changes made to Default Pooling Group.
Also note sites that were investigated but retained in the group (i.e. for discordancy)

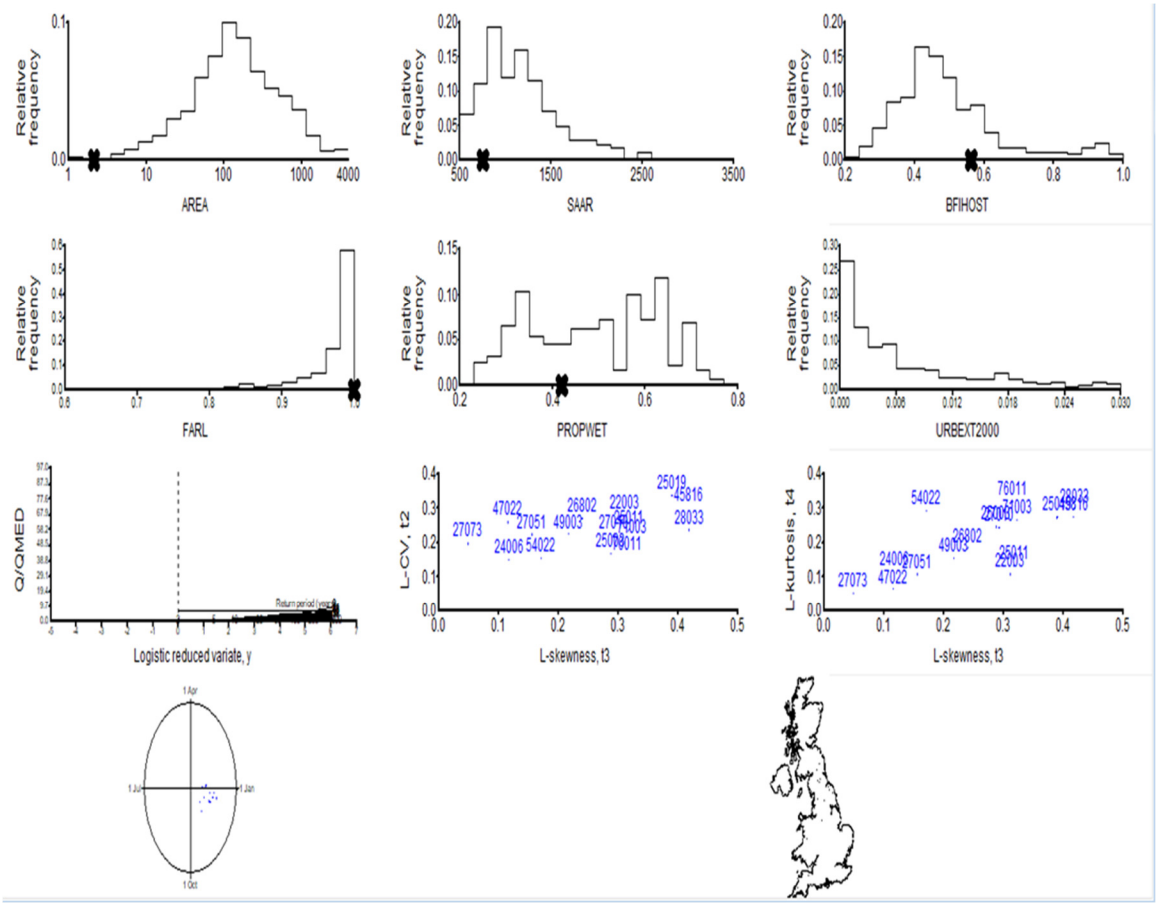
Station number	Name	Addition/ Deletion/ Move/ Investigate	Reason
49005	Boilngey Stream @Boilingey Cock Beridge	D	Only 5 years of data
26006	Annalong@Recorder	D	Thoeretical discharge values
49006	Camel@Camelford	D	Outlier on Lmoments
49003	De Lank @ De Lank	A	Increase record length
22003	Usway Burn @Shilmoor	A	Increase record length
24006	Rookhope Burn @Eastgate	A	Increase record length
27010	Hodge Beck @Bransdale	A	Increase record length
91802	Allt Leachdach @ Intake	D	SAAR 2554

Final Pooling Group Details	
Heterogeneity Measure	
H1	Heterogeneous
H2	Acceptably Homogeneous

Goodness of Fit	
Acceptable Fit	**Distribution**
√	Generalised Logistic
√	Generalised Extreme Value
	Pearson Type iii
	Generalised Pareto

Growth Curve Fittings		
Attached print outs		WINFAP-FEH growth curve fittings
		WINFAP-FEH growth curve
Name of Final Pooling Group		Hillhead Burn


Distributions
1. GL
2. GEV
Q/QMED
Logistic reduced variate, y
Return period (years)


Relative frequency
AREA
SAAR
BFIHOST
FARL
PROPWET
URBEXT2000
Q/QMED
Logistic reduced variate, y
L-CV, t2
L-skewness, t3
L-kurtosis, t4
L-skewness, t3

B ReFH2 Additional Outputs

B.1 Broomies Burn

UK Design Flood Estimation

Generated on 22 November 2017 15:35:37 by jflownw
Printed from the ReFH Flood Modelling software package, version 2.2.6029.28099

Summary of estimate using the Flood Estimation Handbook revitalised flood hydrograph method (ReFH)

Site details Checksum: 7DB6-FA59

Site name: BroomiesBurn
Easting: 397200
Northing: 830400
Country: Scotland
Catchment Area (km²): 6.13 [5.78]*
Using plot scale calculations: No
Site description: None

Model run: 200 year

Summary of results

Rainfall - FEH 2013 (mm):	66.66	Total runoff (ML):	87.81
Total Rainfall (mm):	46.48	Total flow (ML):	173.19
		Peak flow (m³/s):	3.78
Peak Rainfall (mm):	9.06		

Parameters

Where the user has overriden a system-generated value, this original value is shown in square brackets after the value used.
** Indicates that the user locked the duration/timestep*

Rainfall parameters (Rainfall - FEH 2013 model)

Name	Value	User-defined?
Duration (hh:mm:ss)	06:30:00	No
Timestep (hh:mm:ss)	00:30:00	No
SCF (Seasonal correction factor)	0.72	No
ARF (Areal reduction factor)	0.96	No
Seasonality	Winter	n/a

Loss model parameters

Name	Value	User-defined?
Cini (mm)	111.85	No
Cmax (mm)	438.53	No
Use alpha correction factor	No	No
Alpha correction factor	n/a	No

Routing model parameters

Name	Value	User-defined?
Tp (hr)	3.74	No
Up	0.65	No
Uk	0.8	No

Baseflow model parameters

Name	Value	User-defined?
BF0 (m³/s)	0.16	No
BL (hr)	34.99	No
BR	0.97	No

Urbanisation parameters

Name	Value	User-defined?
Urban area (km²)	0.01	No
Urbext 2000	0	No
Impervious runoff factor	0.7	No
Imperviousness factor	0.3	No
Tp scaling factor	0.5	No
Sewered area (km²)	0.00	Yes
Sewer capacity (m³/s)	0.00	Yes

B.2 Modley Burn

UK Design Flood Estimation

Generated on 22 November 2017 15:43:13 by jflownw
Printed from the ReFH Flood Modelling software package, version 2.2.6029.28099

Summary of estimate using the Flood Estimation Handbook revitalised flood hydrograph method (ReFH)

Site details Checksum: E5EF-400A

Site name: Modleysburns
Easting: 394850
Northing: 830400
Country: Scotland
Catchment Area (km²): 3.62 [3.75]*
Using plot scale calculations: No
Site description: None

Model run: 200 year

Summary of results

Rainfall - FEH 2013 (mm):	66.99	Total runoff (ML):	47.09
Total Rainfall (mm):	46.96	Total flow (ML):	92.70
		Peak flow (m³/s):	2.06
Peak Rainfall (mm):	9.16		

Parameters

Where the user has overriden a system-generated value, this original value is shown in square brackets after the value used.
** Indicates that the user locked the duration/timestep*

Rainfall parameters (Rainfall - FEH 2013 model)

Name	Value	User-defined?
Duration (hh:mm:ss)	06:30:00	No
Timestep (hh:mm:ss)	00:30:00	No
SCF (Seasonal correction factor)	0.72	No
ARF (Areal reduction factor)	0.97	No
Seasonality	Winter	n/a

Loss model parameters

Name	Value	User-defined?
Cini (mm)	104.12	No
Cmax (mm)	470.27	No
Use alpha correction factor	No	No
Alpha correction factor	n/a	No

Routing model parameters

Name	Value	User-defined?
Tp (hr)	3.65	No
Up	0.65	No
Uk	0.8	No

Baseflow model parameters

Name	Value	User-defined?
BF0 (m³/s)	0.08	No
BL (hr)	33.09	No
BR	1.03	No

Urbanisation parameters

Name	Value	User-defined?
Urban area (km²)	0.15	No
Urbext 2000	0.03	No
Impervious runoff factor	0.7	No
Imperviousness factor	0.3	No
Tp scaling factor	0.5	No
Sewered area (km²)	0.00	Yes
Sewer capacity (m³/s)	0.00	Yes

B.3 Hillhead Burn

UK Design Flood Estimation

Generated on 29 January 2018 12:04:53 by jflownw
Printed from the ReFH Flood Modelling software package, version 2.2.6029.28099

Summary of estimate using the Flood Estimation Handbook revitalised flood hydrograph method (ReFH)

Site details Checksum: 2C2A-C56B

Site name: Hillhead Burn
Easting: 395050
Northing: 830050
Country: Scotland
Catchment Area (km²): 0.71 [2.12]*
Using plot scale calculations: No
Site description: None

Model run: 200 year

Summary of results

Rainfall - FEH 2013 (mm):	64.14	Total runoff (ML):	8.44
Total Rainfall (mm):	44.64	Total flow (ML):	16.26
		Peak flow (m³/s):	0.45
Peak Rainfall (mm):	10.14		

Parameters

Where the user has overriden a system-generated value, this original value is shown in square brackets after the value used.
** Indicates that the user locked the duration/timestep*

Rainfall parameters (Rainfall - FEH 2013 model)

Name	Value	User-defined?
Duration (hh:mm:ss)	05:30:00	No
Timestep (hh:mm:ss)	00:30:00	No
SCF (Seasonal correction factor)	0.71	No
ARF (Areal reduction factor)	0.98	No
Seasonality	Winter	n/a

Loss model parameters

Name	Value	User-defined?
Cini (mm)	100.78	No
Cmax (mm)	485.45	No
Use alpha correction factor	No	No
Alpha correction factor	n/a	No

Routing model parameters

Name	Value	User-defined?
Tp (hr)	2.91	No
Up	0.65	No
Uk	0.8	No

Baseflow model parameters

Name	Value	User-defined?
BF0 (m³/s)	0.01	No
BL (hr)	28.64	No
BR	1.06	No

Urbanisation parameters

Name	Value	User-defined?
Urban area (km²)	0.06	No
Urbext 2000	0.05	No
Impervious runoff factor	0.7	No
Imperviousness factor	0.3	No
Tp scaling factor	0.5	No
Sewered area (km²)	0.00	Yes
Sewer capacity (m³/s)	0.00	Yes

B.4 Fortree Burn

UK Design Flood Estimation

Generated on 29 January 2018 11:57:35 by jflownw

Printed from the ReFH Flood Modelling software package, version 2.2.6029.28099

Summary of estimate using the Flood Estimation Handbook revitalised flood hydrograph method (ReFH)

Site details Checksum: 9422-FA00

Site name: Fortree Burn

Easting: 395050

Northing: 830050

Country: Scotland

Catchment Area (km²): 2.07 [2.12]*

Using plot scale calculations: No

Site description: None

Model run: 200 year

Summary of results

Rainfall - FEH 2013 (mm):	64.14	Total runoff (ML):	24.21
Total Rainfall (mm):	44.25	Total flow (ML):	46.61
		Peak flow (m³/s):	1.29
Peak Rainfall (mm):	10.06		

Parameters

Where the user has overriden a system-generated value, this original value is shown in square brackets after the value used.

** Indicates that the user locked the duration/timestep*

Rainfall parameters (Rainfall - FEH 2013 model)

Name	Value	User-defined?
Duration (hh:mm:ss)	05:30:00	No
Timestep (hh:mm:ss)	00:30:00	No
SCF (Seasonal correction factor)	0.71	No
ARF (Areal reduction factor)	0.97	No
Seasonality	Winter	n/a

Loss model parameters

Name	Value	User-defined?
Cini (mm)	100.78	No
Cmax (mm)	485.45	No
Use alpha correction factor	No	No
Alpha correction factor	n/a	No

Routing model parameters

Name	Value	User-defined?
Tp (hr)	2.91	No
Up	0.65	No
Uk	0.8	No

Baseflow model parameters

Name	Value	User-defined?
BF0 (m³/s)	0.04	No
BL (hr)	28.64	No
BR	1.06	No

Urbanisation parameters

Name	Value	User-defined?
Urban area (km²)	0.18	No
Urbext 2000	0.05	No
Impervious runoff factor	0.7	No
Imperviousness factor	0.3	No
Tp scaling factor	0.5	No
Sewered area (km²)	0.00	Yes
Sewer capacity (m³/s)	0.00	Yes

C Ellon AMAX

Below is a table comparing the original AMAX data series for Ellon and the new AMAX series used in this study following the rating review.

Date	Stage (m)	Original AMAX (m^3/s)	Current AMAX (m^3/s)	Difference	Comment
29/01/1984	2.474	57.13	57.13	0.00%	Keep SEPA Q
04/11/1984	3.023	93.63	93.63	0.00%	Keep SEPA Q
01/12/1985	2.870	82.32	82.32	0.00%	Keep SEPA Q
11/04/1987	2.463	56.51	56.51	0.00%	Keep SEPA Q
25/01/1988	2.895	84.10	84.10	0.00%	Keep SEPA Q
20/10/1988	2.685	69.84	69.84	0.00%	Keep SEPA Q
17/12/1989	1.348	14.01	14.01	0.00%	Keep SEPA Q
05/03/1991	2.158	40.98	40.98	0.00%	Keep SEPA Q
04/11/1991	1.967	32.40	32.40	0.00%	Keep SEPA Q
01/10/1992	1.955	31.90	31.90	0.00%	Keep SEPA Q
01/03/1994	2.791	77.69	77.69	0.00%	Keep SEPA Q
12/09/1995	3.011	89.69	97.25	8.43%	JBA Rating
10/02/1996	3.256	103.78	117.61	13.33%	JBA Rating
04/12/1996	1.995	39.86	39.86	0.00%	ORIGINAL SEPA RATING
05/04/1998	2.367	56.40	56.40	0.00%	ORIGINAL SEPA RATING
15/11/1998	2.198	48.63	48.62	0.00%	ORIGINAL SEPA RATING
27/04/2000	2.848	80.74	80.74	0.00%	ORIGINAL SEPA RATING
12/03/2001	2.594	67.49	67.49	0.00%	ORIGINAL SEPA RATING
20/07/2002	2.109	44.70	44.70	0.00%	ORIGINAL SEPA RATING
23/10/2002	3.189	99.85	111.59	11.76%	JBA Rating
19/01/2004	2.038	41.66	41.66	0.00%	ORIGINAL SEPA RATING
08/01/2005	1.906	36.44	36.22	-0.62%	ORIGINAL SEPA RATING
25/03/2006	2.324	54.38	54.38	0.00%	ORIGINAL SEPA RATING
12/02/2007	2.481	61.88	61.88	0.00%	ORIGINAL SEPA RATING
22/11/2007	2.464	61.05	61.05	0.00%	ORIGINAL SEPA RATING
04/09/2009	2.784	77.32	77.32	0.00%	ORIGINAL SEPA RATING
02/11/2009	3.320	107.60	123.53	14.80%	JBA Rating
11/12/2010	2.922	84.76	84.76	0.00%	ORIGINAL SEPA RATING
14/08/2012	1.707	28.55	28.55	0.00%	ORIGINAL SEPA RATING
23/12/2012	3.344	109.02	125.80	15.39%	JBA Rating
06/02/2014	2.211	49.21	49.21	0.00%	ORIGINAL SEPA RATING
07/10/2014	2.362	56.16	56.16	0.00%	ORIGINAL SEPA RATING
08/01/2016	4.460	183.25	260.30	42.04%	JBA Rating
08/02/2017	2.137	45.92	45.92	0.00%	ORIGINAL SEPA RATING

D Technical Review Certificate

Technical Review Certificate

Project Name	Ellon, Inverurie and Insch FPS
Project Number	2017s6743
Project Manager	Caroline Anderton
Work Carried Out by	Grace Thompson and Briony McIntosh
Reviewer	David Cameron
Subject of Review	Peak flow estimates for the Ythan and 4 tributaries
Date	20 March 2018
Revision	1.0
Documents used in Review	..\AIZ-JBAU-EL-00-CA-HM-0001-Flood-estimate-method-comparison-Ellon-S0-P01.01.xlsx ..\5.Statistical\Broomies_Stat_Pooling.xlsm ..\5.Statistical\Fortree_stat_pooling.xlsm ..\5.Statistical\Hillhead_Stat_Pooling.xlsm ..\5.Statistical\Modley_Stat_Pooling.xlsm ..\6.FEH RR ..\8.ReFH2 N:\2017\Projects\2017s6743 - Dougall Baillie Associates - Ellon, Inverurie, & Insch FPS\AIZ-JBAU-HM\EL\Calcs\AIZ-JBAU-EL-00-CA-HM-0002-Hydrology\5.Statistical\2017s5526 FEH_Spreadsheet_v3.2.6 SCO Ythan_v3.xlsm N:\2017\Projects\2017s6743 - Dougall Baillie Associates - Ellon, Inverurie, & Insch FPS\AIZ-JBAU-HM\EL\Calcs\AIZ-JBAU-EL-00-CA-HM-0002-Hydrology\AIZ-JBAU-EL-00-CA-HM-0001-Flood-estimate-method-comparison-Ellon-S0-P01.02.xlsx
Applicable Standards or Guidance	

Use the following colour scheme to record recommendations:

Green – suggestion for improved / good practice but which is unlikely to change the project outcomes.

Amber – non-standard method or method not following guidance but unlikely to have impacted on results

Red – omission that could make the findings subject to challenge and which requires correction/further work.

SCOPE OF REVIEW:

Review FEH estimates (FEH RR, ReFH2 with FEH13 and FEH Statistical) for the Ythan and the Broomies, Modley, Hillhead and Fortree Burns (which are tributaries of the Ythan).

DETAILED REVIEW COMMENTS:

Suitable approach comparing 3 FEH methods.

RECOMMENDATIONS:

The recommended approaches (enhanced single site on the Ythan and FEH RR on the Burns) are suitable but ideally this should be agreed with SEPA before proceeding with further work such as hydraulic modelling design runs.

The naming of the sites on the FEH Statistical sheets for the Burns only needs to be corrected before they are included in a report. (This will not affect the flow values though).

PRELIMINARY CERTIFICATE (only required when comments are raised). In respect of the project design described above, I have carried out a Review and consider the technical output sound, subject to the comments and recommendations listed above. Please inform me when you have considered these comments so that I may complete the Final Certificate.	
Signature of Reviewer	
Name of Reviewer	
Date	

	Aspect	Y/N	Comments
General	Has the appropriate calculation record been completed?	Y	FEH calculation records produced for all statistical results. The naming of the sites on the FEH Statistical sheets for the Burns only needs to be corrected before they are included in a report (e.g,. Ythan@Broomies Burn should be Broomies Burn@Ythan).
	Has a method statement been produced?	N	Included as text in report
	Does the analysis (or an accompanying report) include a description of the catchment and its flooding processes?	Y	Included as text in report
	Are there any unusual features of the catchment and how they will be taken into account?	N	No unusual features.
	Aspect	**Revision required? (Y,N,N/A)**	**Comments**
Data Review & Choice of Method	Has a review of existing data been carried out?	N	Rating review undertaken for Ellon gauging station. Tp estimated at Mill of Keithfield as check on rainfall runoff estimates.
	Are flow and level stations present, and closed stations as well as current ones?	N	Ellon AMAX data extended using regression with closed Ardlethen station per 2005s1059.
	Have stations outside the HiFlows-UK dataset been considered, e.g. temporary loggers?	N	Temporary logger for tidal data considered per 2005s1059.
	Is it appropriate to update the flood peak series from those in HiFlows-UK, if so has this been done?	N	SEPA data updated and HiFlows v6 used.
	Is there a potential donor site? Within / outside the reach?	N	Ythan gauged at Ellon. Ardlethen used as donor for burns as smaller catchment area than Ellon.
	Is the data quality reviewed – at a minimum HiFlows-UK classification	N	Rating review undertaken at Ellon. HiFlows stations used otherwise.
	Is more detailed review of data and ratings appropriate for this study, has this been carried out?	N	Rating review undertaken at Ellon.
	Has a historical review of data been carried out?	N	Included as text in report
	Does the report include plots and interpretation of flood peak time series and flood event data?	N	Include in report.
	Appropriate choice of flow calculation point?	N	Yes. At gauging stations and at downstream points on each burn.
	Has catchment boundary been checked and area revised?	N	Yes. FEH boundaries adjusted from default.
	What other catchment descriptors have been checked - is this appropriate?	N	URBEXT updated using national growth.
	What method has been chosen?	N	Statistical for Ythan; FEH RR for Burns
	Is chosen method appropriate?	N	Yes: statistical for large rural catchment and RR for

			small catchments.
Statistical Method	Has the standard methodology been adjusted?	N	No adjusted.
	QMED checked? Has the revised QMED equation been used (CEH, 2008)?	N	Revised method used.
	Has the revised method of data transfer (CEH, 2008) been used?	N	Revised method used.
	Choice of donor appropriate?	N	Yes. The combined series for Ellon could also potentially have been used, but FEH Statistical is being used as check only for the burns so unlikely to change the final outcome.
	Choice of adjustment factor appropriate?	N	Appropriate: 1.053 Ellon 1.011 Broomies, Fortree, Hillhead, Modley.
	Have QMED estimates been checked for consistency with upstream and downstream gauges?	N	Ardlethen and Ellon considered.
	Local data being used to full potential?	N	Yes
	Choice of adjustment factor appropriate?	N	As above
	Estimation of growth factor appropriate?	N	Appropriate: Ellon: 2.99 Broomies: 2.94 Fortree: 2.92 Hillhead: 2.95 Modely: 2.92
	Growth factor Q2-Q100 is 1.8-3.0	N	Yes (as above)
	Pooling group reviewed and details given?	N	Yes. Burns final pooling group essentially the same which is acceptable given similar sizes and location.
	Has the removal and retention of sites in the pooling group been justified?	N	Yes.
	Are there any flood peak records suitable for the derivation of single site growth curves?	N	Yes. Ellon and merged Ellon series.
	Has enhanced single site analysis been carried out? (rural sites)	N	Yes at Ellon.
	Has a comparison of the pooled, single site and enhanced growth curves been undertaken?	N	SS and ESS compared at Ellon.
	Climate change considered?	N	Yes
Rainfall Runoff	Has the standard methodology been adjusted?	N	Standard methods used.
	Has FEH rainfall runoff method been used or ReFH?	N	FEH RR and ReFH2 with FEH13 rainfall applied to Burns.
	Have any parameters been adjusted?	N	Parameters not adjusted, but comparison of Tp made at Mill of Keithfield level only site. Tp at this site was v. similar between FEH RR with catchment descriptors and observed Tp. FEH RR with catchment descriptors therefore retained.
	Has lag analysis been undertaken?	N	See previous comment.
	Climate change considered?	N	Yes
Small Catchments	Have non FEH methods been used for small catchment estimates? If so have these been justified and limitations acknowledged?	N	N/A
	If the catchment is heavily urbanised ($URBEXT_{2000}$>0.150)	N	N/A
	If there is a significant reservoir influence	N	N/A

	(FARL<0.9, with reservoirs not kept permanently full), and there is inadequate flood peak data available downstream of the reservoirs		
	If the catchment is permeable (SPRHOST<20%), has the statistical method been used, with growth curves adjusted to remove non-flood annual maximum flows?	N	N/A
	Is the catchment is pumped?	N	N/A
Final Checks	Have results for all methods been summarised for comparison?	N	Yes on spreadsheet and in report.
	Is choice of method justified?	N	Yes.
	Have the design flows been checked for spatial consistency, e.g. at confluences and along reaches?	N	At Ardlethen and Ellon only.
	Have they been checked against flood peaks in the gauged record, and any longer-term flood history?	N	Flood history considered in report.
	Have the specific runoff rates been checked for spatial consistency?	N	Broomies and Modley similar and Hillhead and Fortree similar. To be expected given similar drainage patterns.
	Have the results been compared with any from other studies	N	Ythan results compared with 2005 and 2010 studies.
	Does the report comment on uncertainty in the design flows?	N	To be included in report.
	Are the assumptions and limitations of the methods acknowledged?	N	To be included in report.

RESPONSE (only required when a Preliminary Certificate is raised)

I have addressed the comments raised under the Preliminary Certificate.

Signature	
Name	Briony McIntosh
Date	22 March 2018

FINAL CERTIFICATE

In respect of the project design described above, I have carried out a Review and consider the technical output sound, and any comments raised under a Preliminary Certificate have been satisfactorily addressed.

Signature of Reviewer	
Name of Reviewer	David Cameron
Date	21 March 2018

E Ellon Gauging Station and 2016 Flooding

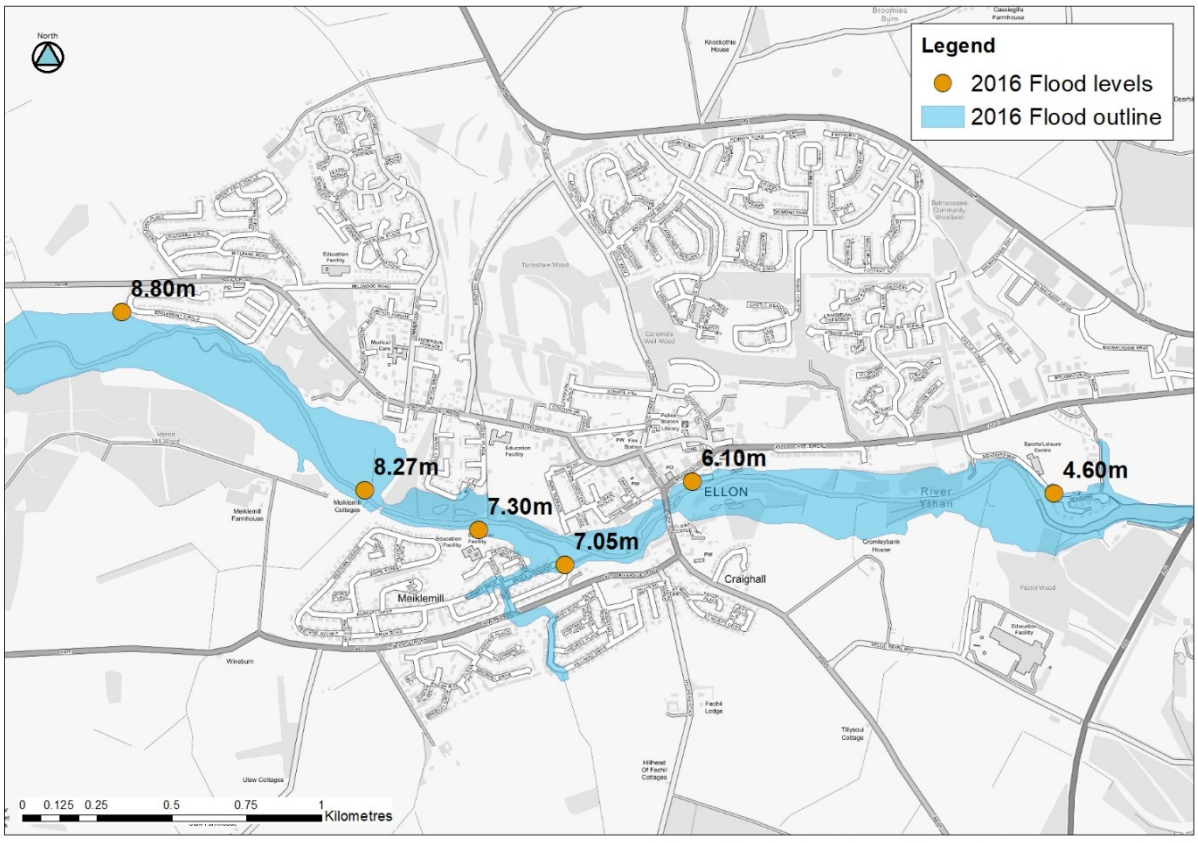
Photos of the Ellon gauging station provided by Aberdeenshire Council 19 December 2017, originally supplied to the council via Huddle (Iris Krammer, SEPA). Photos believed to have been taken on 11 January 2016.

A: Left bank bypassing and debris accumulation by the RB gauging station

B: Wrack mark and debris accumulation by Ellon gauging station

C: View from footbridge by Ellon gauging station

D: SEPA Flood levels and extents at Ellon



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