CAPITA

Rother Valley Railway Public Inquiry

Rother Valley Railway Limited

Flood estimation calculation record: Rother Valley

March 2021

Quality Management

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Introduction

This document provides a record of the calculations and decisions made during flood estimation. It is based on the template provided by the Environment Agency in August 2020 (LIT 11833) with the latest version of the Flood Estimation Guidance (LIT 11832).

Contents

Abbreviations

AEP	annual exceedance probability
AM	Annual Maximum
AREA	Catchment area (km^2)
BFI	Base Flow Index
BFIHOST	Base Flow Index derived using the HOST soil classification
CPRE	Council for the Protection of Rural England
FARL	FEH index of flood attenuation due to reservoirs and lakes
FEH	Flood Estimation Handbook
FSR	Flood Studies Report
HOST	Hydrology of Soil Types
NRFA	National River Flow Archive
OS	Ordnance Survey
POT	Peaks Over a Threshold
QMED	Median Annual Flood (with return period 2 years)
ReFH	Revitalised Flood Hydrograph method
ReFH2	Revitalised Flood Hydrograph 2 method
SAAR	Standard Average Annual Rainfall (mm)
SPR	Standard percentage runoff
SPRHOST	Standard percentage runoff derived using the HOST soil classification
Tp(0)	Time to peak of the instantaneous unit hydrograph
URBAN	Flood Studies Report index of fractional urban extent
URBEXT1990	FEH index of fractional urban extent
URBEXT2000	Revised index of urban extent, measured differently from URBEXT1990
WINFAP-FEH	Windows Frequency Analysis Package – used for FEH statistical method

1. Summary of assessment

1.1 Summary

Catchment location	The River Rother is in South East England and flows from west to east through the counties of East Sussex and Kent. The River Rother catchment is largely rural with the river flowing through the villages Etchingham, Robertsbridge and Bodiam.
Purpose of study and scope	This study provides updated flows to be used for hydraulic modelling of the River Rother and its tributaries through Robertsbridge as far downstream as Bodiam. Updated hydrological assessment was requested as part of a public inquiry where the inspector has requested further environmental information including updated flood risk analysis. The inspector requested that the assessment takes into account the most up to date river flow allowances. Due to the age of the existing study it was proposed that the hydrological assessment was updated along with the climate change allowances. The hydraulic model of the River Rother extends from Swife Lane in the upper catchment downstream to Bodiam and includes several key tributaries. The number of tributaries and flow estimation locations make this a complex study.
Key catchment features	The catchment is largely rural with the villages of Etchingham, Robertsbridge and Bodiam providing the main urban coverage. The main feature impacting the hydrology of the catchment is the Darwell Reservoir on the Darwell Stream tributary of the River Rother. Water can be pumped from the River Rother at Robertsbridge and stored in the Darwell Reservoir. Parts of the River Rother floodplain are managed and administered by the Romney Marshes Area IDB.
Flooding mechanisms	The main cause of flooding in the area is fluvial. Overland flow and surface runoff may be encountered within the catchment and to a lesser extent there is risk of flooding from groundwater
Gauged / ungauged	There are two gauges in the study area listed on NRFA. The Rother at Udiam (40004) covers a catchment area of 206k^2 and has been operating since 1958, this gauge is suitable for QMED but is not suitable for pooling. The Udiam gauge is located near the downstream extent of the hydraulic model downstream of Robertsbridge. The Dudwell at Burwash (40017) covers a catchment area of 27.5km^2 and is on one of the River Rothers key tributaries located in the upper catchment. The gauge has been operational since 1967 and is not suitable for QMED or Pooling.
Final choice of method	The FEH Statistical Method is preferred. The estimations of QMED have been improved using the Udiam gauge as a donor station. The peak flow estimates are based on gauged data in the catchment and using pooled data from similar sites.
Key limitations / uncertainties in results	It is assumed that the catchment boundaries and descriptors are correct. It is assumed that the river flow gaugings and data are of good quality and suitable for use. It is assumed that the pooled catchments are similar to the subject sites. Non-stationarity has not been considered.

1.2 Note on flood frequencies

The frequency of a flood can be quoted in terms of a return period, which is defined as the average time between years with at least one larger flood, or as an annual exceedance probability (AEP), which is the inverse of the return period.

The results presented in this document are quoted in terms of return period. The table below provides a quick conversion between return periods and annual exceedance probabilities.

AEP (%)	**50**	**20**	**10**	**5**	**4**	**3.33**	**0**	**1.33**	**1**	**0.5**	**0.2**	**0.1**
Return Period (yrs)	2	5	10	20	25	30	50	75	100	200	500	1000

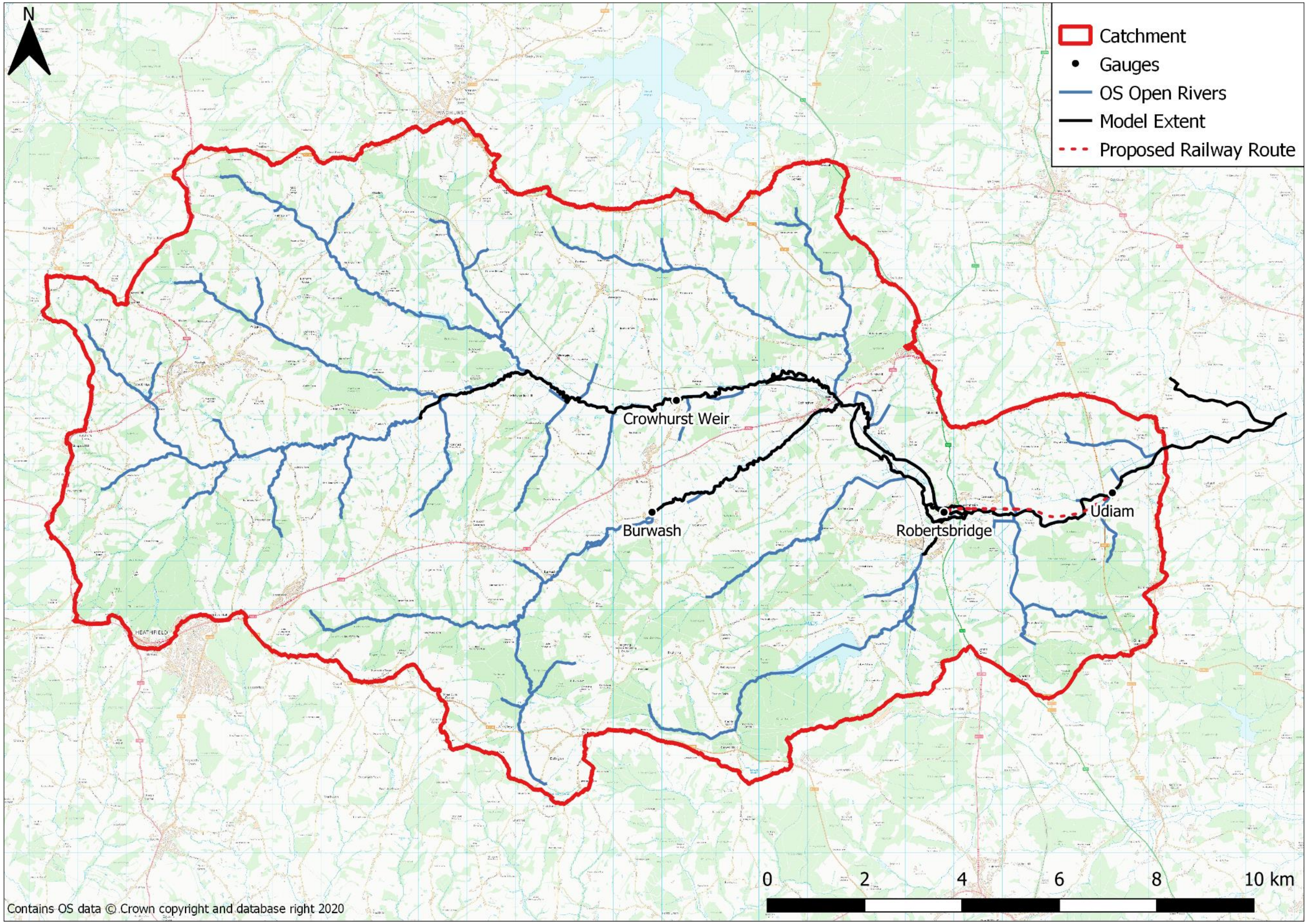
2. Method statement

2.1 Requirements for flood estimates

Overview	This study will provide updated flows to be used for hydraulic modelling of the River Rother and its tributaries through Robertsbridge as far downstream as Bodiam. Updated hydrological assessment was requested as part of a public inquiry where the inspector has requested further environmental information including updated flood risk analysis. The inspector requested that the assessment takes into account the most up to date river flow allowances. Due to the age of the existing study it was proposed that the hydrological assessment was updated along with the climate change allowances. The hydraulic model of the River Rother extends from Swife Lane in the upper catchment downstream to Bodiam and includes several key tributaries. Peak flow estimates will be derived at approximately 14 locations with average hydrograph shapes derived from the Burwash and Udiam gauges. Flows will be estimated for the 2, 5, 10, 20, 50, 75, 100, 200 and 1000 year events. Climate change allowances based on the latest available guidance[1] (first published February 2016 and updated in July 2020) of 45% (2080s Higher Central) and 105% (2080s Upper End) will be applied to the 100 year event. This report summarises the hydrological assessment for the River Rother and its key tributaries.
Project Scope	The FEH Statistical and ReFH2 methods will be used to derive peak flow estimates at the flow estimation locations. For the Statistical method donors will be used to improve the estimation of QMED. Pooling groups will be derived at key locations and for catchments with different catchment characteristics. The latest available NFRA dataset and WINFAP software will be used to undertake the FEH Statistical assessment. The ReFH2 method will be applied using the latest available version of the software. Calibration will be undertaken using the ReFH Calibration Utility to refine parameter estimates. The results of the Statistical and ReFH2 methods will be compared and a set of flows will be selected to complete the hydraulic model simulations. Full hydrographs will be derived from the ReFH2 software. Average hydrograph shape will be derived at the Burwash and Udiam gauges and will support the selection of suitable storm durations. Climate change allowances will be applied to the 1% AEP event flows. No rating reviews at gauged sites will be undertaken.

[1] https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances#exceptions--when-it-might-be-appropriate-to-use-other-data-or-allowances

2.2 The catchment



Description	The River Rother catchment is largely rural with the river flowing through the villages of Etchingham, Robertsbridge and Bodiam. The topography of the study catchment is characterised by well-defined valleys with elevations peaking at approximately 180mAOD, in the upper parts of the catchment to the west, falling to approximately 2mAOD at the catchment outlet in the east. Land use in the catchment is characterised by a mix of woodlands and grasslands in the upper parts of the catchment with arable farming in the river valleys. The catchment has a sedimentary bedrock geology that consists of sandstones, siltstones and mudstones. In the River Rother floodplain, the soils are classified as Soilscape 20, loamy and clayey floodplain soils with high groundwater. Outside of the immediate floodplain of the River Rother the catchment is mostly covered by Soilscape 8 and 18. These are loamy and clayey soil types that either have impeded drainage (Soilscape 8) or are slowly permeable and seasonally wet (Soilscape 18). The South East of England is close to continental Europe and can be subject to continental weather influences that bring cold spells in the winter and hot, humid weather in the summer. It is also far from the path of most Atlantic depressions that are associated with cloud, wind and rain. This is reflected in the SAAR for the catchment which is 856mm. Parts of the River Rother floodplain are managed and administered by the Romney Marshes Area IDB. Water can be pumped from the River Rother at Robertsbridge and stored in Darwell Reservoir. This is located on the Darwell Stream watercourse which is a tributary of the River Rother flowing from the South with its confluence in Robertsbridge.

2.3 Source of flood peak data

Overview	NRFA peak flows dataset, Version 9, released September 2020. This contains data up to the 2018 water year (October 2018 to September 2019).

2.4 Gauging stations (flow or level)

Watercourse	**Station Name**	**Gauging Authority Number**	**NRFA Number**	**Catchment area (km^2)**	**Type (rated / ultrasonic / level…)**	**Start of record and end if station closed**
Dudwell	Burwash	556521001	40017	27.5	Crump weir	02/1967
Rother	Udiam	556505001	40004	206	Flat V/Ultrasonic - Rated to 4.75m^3/s, ultrasonic above this	10/1958

2.5 Data available at each flow gauging station

Station Name	Start and end of NRFA flood peak record	Updated for this study?	Suitable for QMED?	Suitable for Pooling?	Data quality check needed?	Other comments on station and flow data quality
Burwash	06/05/1969/ - 01/10/2019	No	No – Not gauged to within 30% of QMED	No – Few high flow gaugings. Rating cannot be validated beyond QMED.	Current rating has been compared against sample rating from hydraulic model.	Few high flow gaugings. Steep banks contain all but exceptional flows. Wide and flat floodplain. Bypass at stages >1m. One peak flow rating applied across period of record, does not take account of bypassing or drowning. An approximate rating for the gauge has been extracted from the hydraulic model and compared against the NRFA rating (Figure 1). It should be noted that the location of Burwash gauge is only 70m downstream of the model inflow boundary, therefore caution should be applied. However, the rating is vastly different to the rating from NRFA. The NRFA rating produces a QMED value (at roughly bankfull) of 24.5m^3/s for a catchment area of 27.5km^2 which is very high for a catchment which has moderate to low average rainfall, is not highly impermeable and is not very steepsided. At bankfull stage (1.826m) the extracted model rating gives an approximate flow of 12m^3/s. This seems a more feasible value, however the rating curve is a long way from the spot gaugings. There are no spot gaugings above a level of 1.03m. Consequently, there is too much uncertainty around the rating at Burwash for it to be considered as a donor site. Level data since 1990 is classed as 86% Good with 13% Good but Edited.
Udiam	31/07/1968 – 01/10/2019	AMAX updated to add 2019 water year (October 2019 to	Yes – Gauged above QMED	No – Gauged beyond AMAX3 but significant scatter in	Beyond the scope of this study	Well defined channel. Flows confined except in extreme floods when station is bypassed. Stage-discharge relationship affected by downstream conditions following high flows. Difficult to produce fixed rating due to backwater effects and land drainage works.

Station Name	Start and end of NRFA flood peak record	Updated for this study?	Suitable for QMED?	Suitable for Pooling?	Data quality check needed?	Other comments on station and flow data quality
		September 2020)		high flow gaugings		There is a lot of scatter in the high flow gaugings taken at and just below bankfull. Further gaugings at this level may enable better definition of the high flow rating limb. There are very few high flow gaugings in the last 10 years. The ratings from NRFA are shown in Figure 2 along with rating extracted from the hydraulic model and the highest spot gaugings. The modelled rating generally follows the NRFA Historic Winter rating. The existing rating in use (NRFA Weir Rating) is extrapolated beyond a level of 1.29m, which is low compared to bankfull (3.175m). Confidence in the rating above QMED is limited. Gathering additional high flow gaugings may support extension of the weir rating. Level data since 1990 is 43% unchecked and 54% good with 3% of the data missing. The majority of the unchecked data is the record prior to April 2004.
Link to any updated or revised data sets or further data quality checks				The CD3 file for Udiam (40004) was updated to add an additional year of AMAX data for the 2019 water year. This was extracted from the gauged record provided by the Environment Agency. The additional AMAX record was a gauged flow of 111.0m^3/s on 20/12/2019 at 19:30.		

Figure 1 Burwash gauge ratings

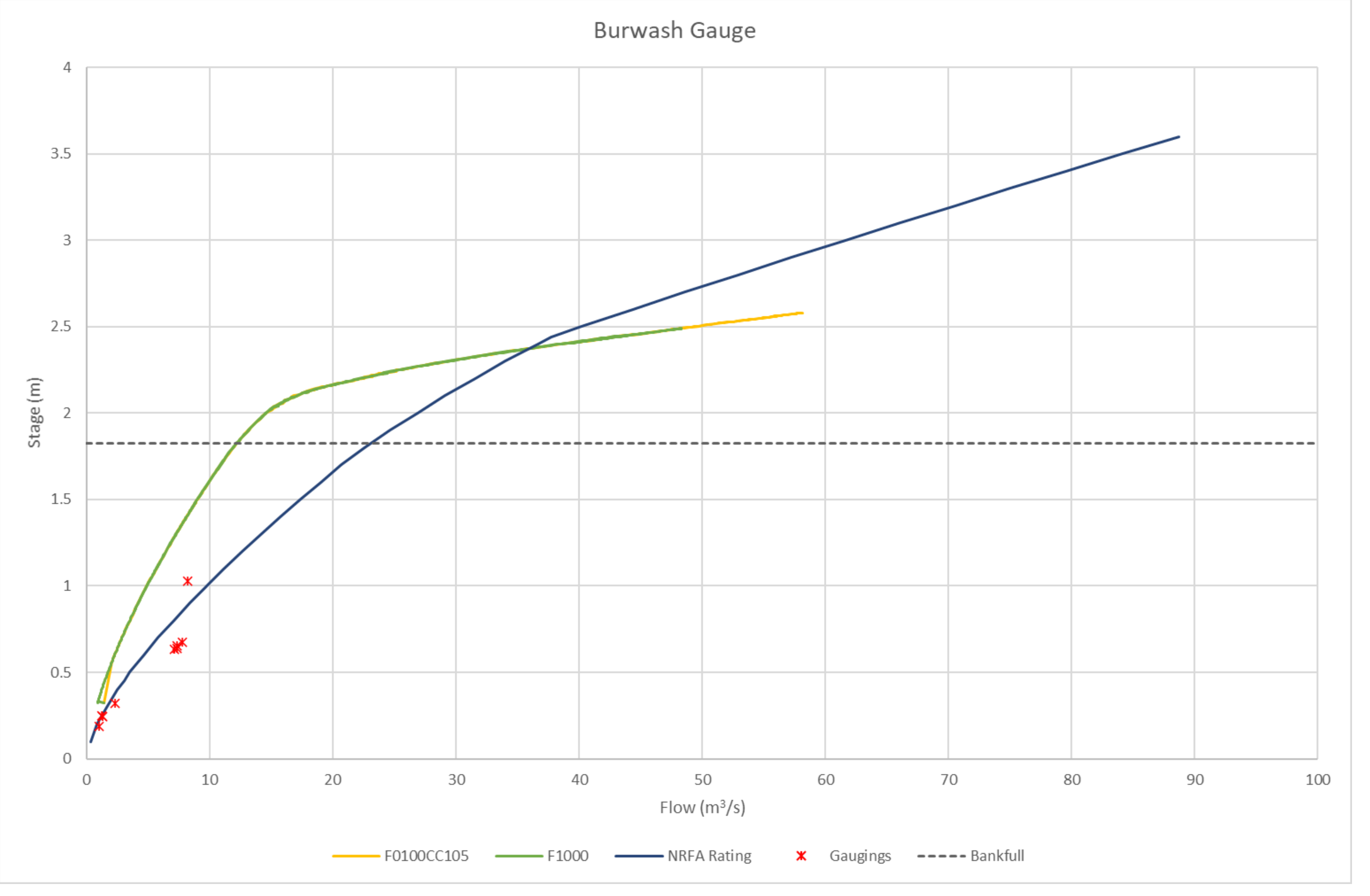
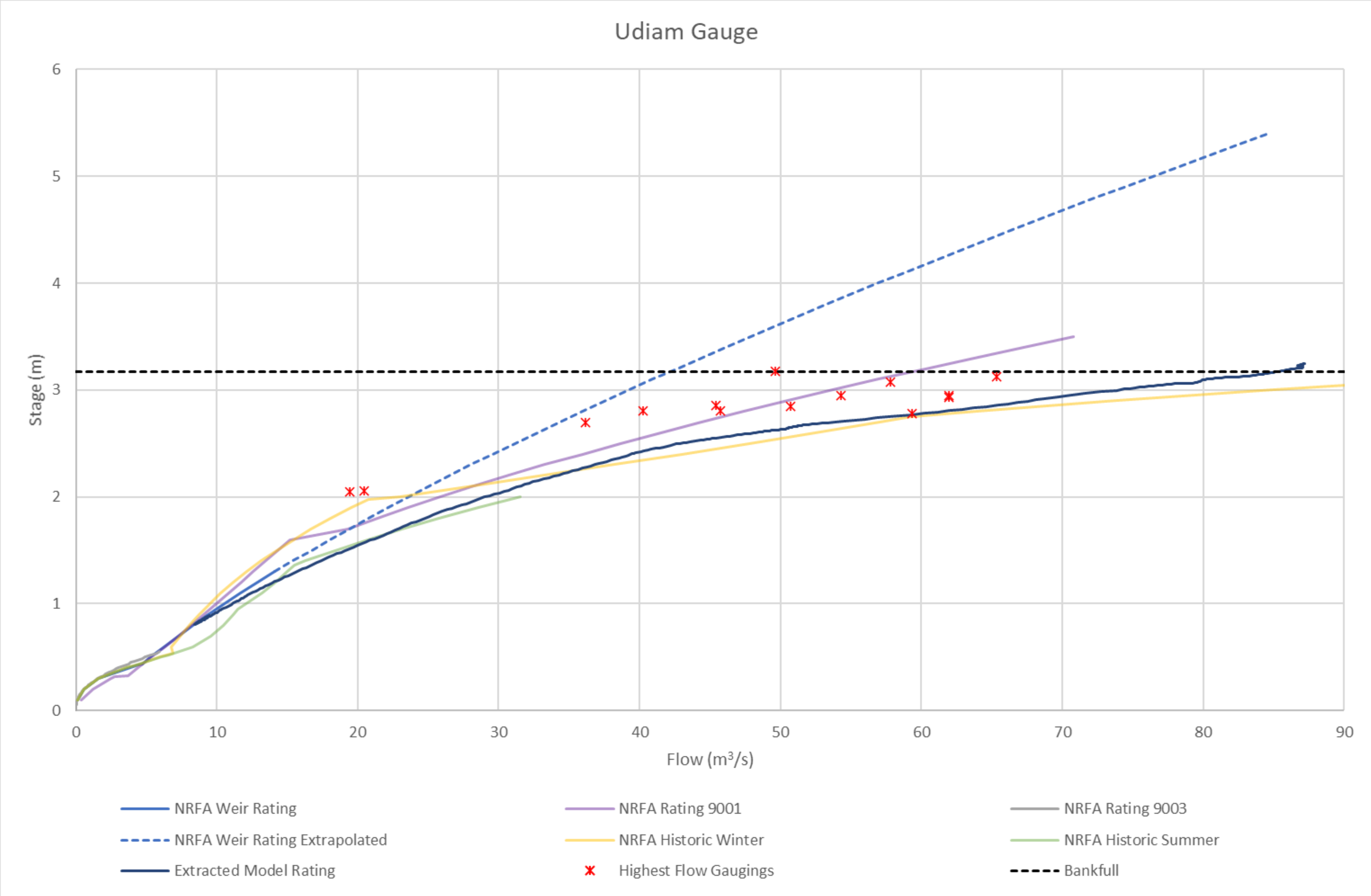


Figure 2 Udiam gauge ratings

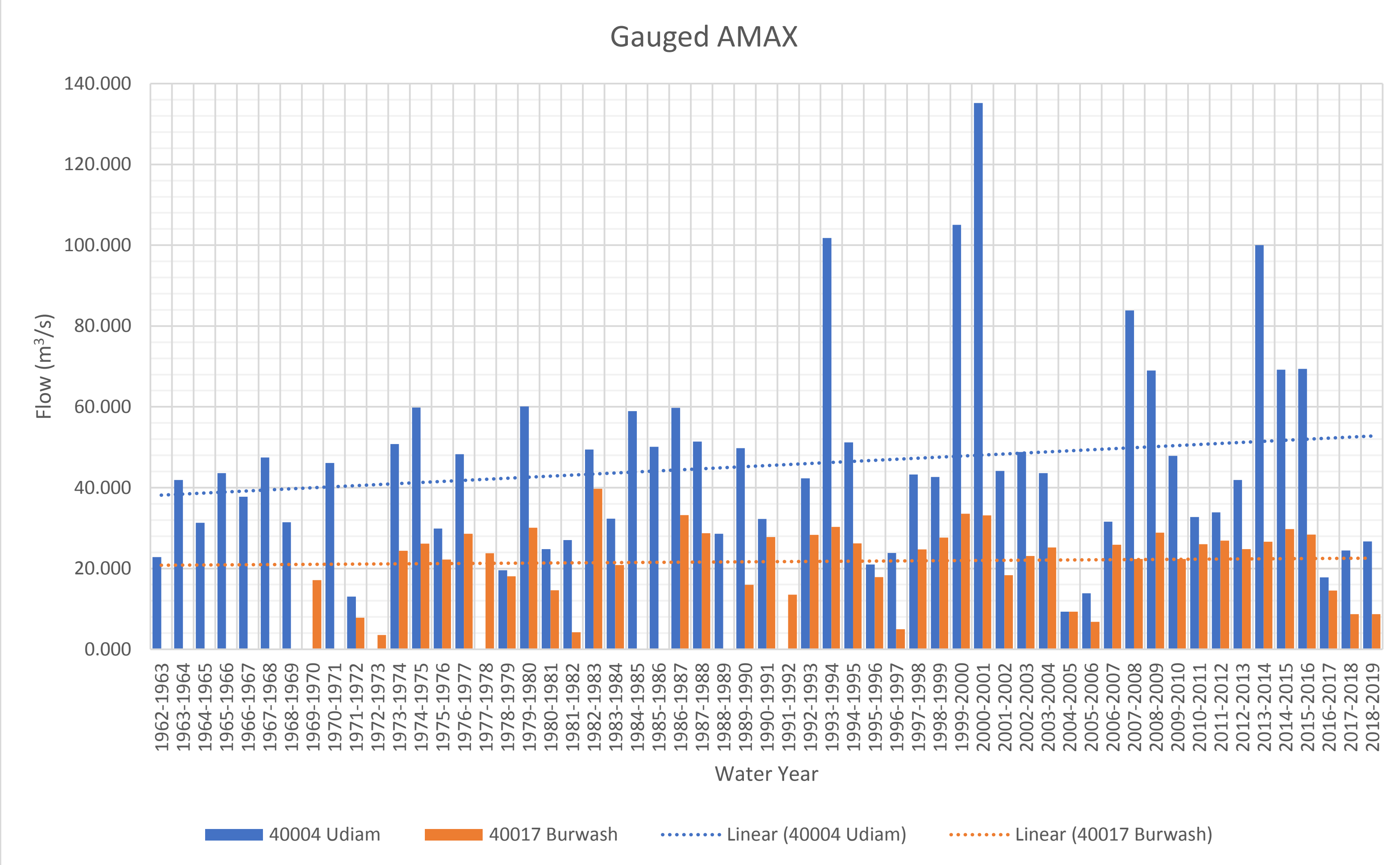


2.6 Other data available and how it has been obtained

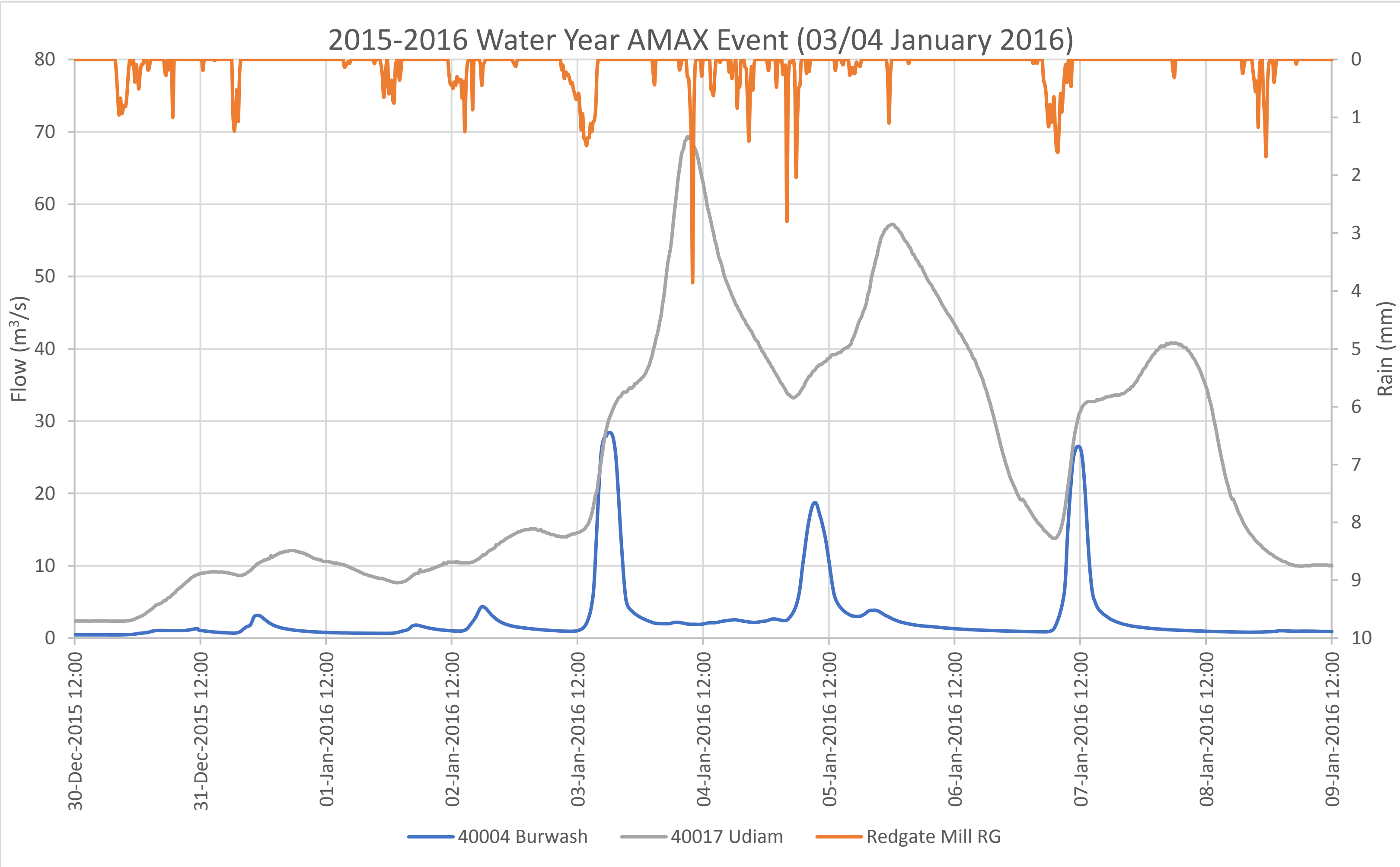
Type of data	Data relevant to this study?	Data available?	Source of data	Details
Check flow gaugings (if planned to review ratings)	No	NA	NA	NA
Historical flood data	Yes	Yes	Rother Valley Railway Limited	Historical flood information for the River Rother. See Annex section 7.2.
Flow or river level data for events	Yes	Yes	Environment Agency	Data for the Burwash and Udiam gauges for the period covering 01/01/1990 to 07/09/2020.
Rainfall data for events	Yes	Yes	Environment Agency	Data for the Hartfield gauge for the period covering 20/01/2016 to 07/09/2020 and the Redgate Mill gauge for the period covering 23/02/2015 to 07/09/2020.
Potential evaporation data	Yes	No	NA	NA
Results from previous studies	Yes	Yes	Environment Agency	Hyder - Hydraulic Modelling, ABD and Hazard Mapping Report (2011)
Other data or information	No	NA	NA	NA

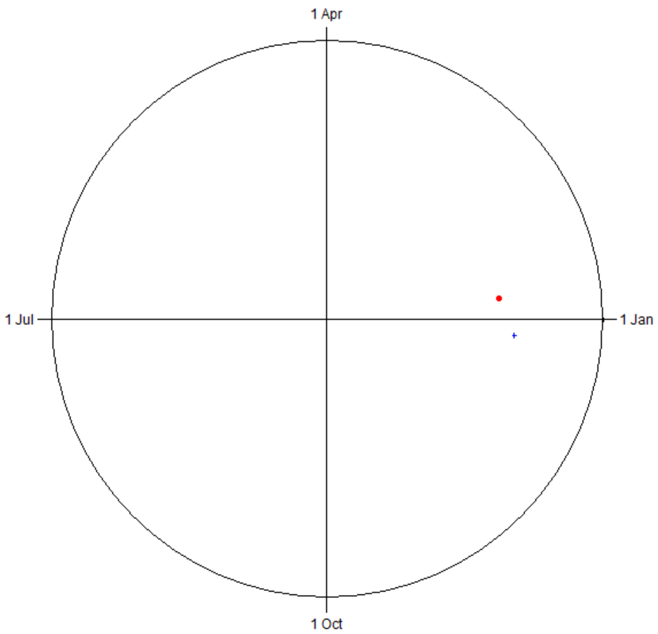
2.7 Hydrological understanding of catchment

AMAX	The AMAX flow record for the Udiam and Burwash gauges shows a positive correlation of 0.65. The AMAX records are indicated in the plot with the linear trend over the gauged record. This indicates a general increase in the peak flow for events over time for the Udiam gauge, but this trend is not replicated to the same extent in the Burwash gauge.



In the AMAX record of the Udiam and Burwash gauge approximately 20 of the overlapping records are from the same event. Analysis of these 20 events indicates that the Burwash gauge in the upper catchment peaks several hours before the downstream Udiam gauge. One event (26/03/1979) indicates that both gauges are peaking at the same time, this has been discarded from analysis as it is likely there is two peaks in the catchment. The average lag between the peak at the two gauges for the remaining 19 events is 13.37 hours (13:22) ranging from a maximum of 20.25 hours to 2.75 hours. This minimum value may again be two separate events.

Event Comparison	Comparison of flows at the gauges for the January 2016 event (2015-2016 water year) indicates that the Burwash gauge has a quicker response to heavy rainfall with a quick rise and fall in the gauged flows. The Udiam gauge has more drawn out rising and falling limbs with higher volumes of water flowing though the site. This difference in rate of rise and fall is a factor of the difference in catchment area and the time of travel as water reaches the gauged site at different rates from the upstream subcatchments. 

Flood Seasonality	For both Udiam and Burwash gauges January is the most frequent (mode) month for the AMAX flood. Flood seasonality plots for both gauges indicate a similar seasonality as indicated in the plot where Udiam is indicated in red and Burwash in black. Flood seasonality: 40004 & 40017 

Conceptual model	The main area of interest is the proposed reinstated railway on the route of the former Rother Valley Railway between Bodiam and Robertsbridge. The railway runs parallel to the River Rother for approximately 3.5km. Flow estimation is required for several points on the River Rother and its key tributaries to enable hydraulic modelling of the catchment to assess the impact of the proposal. The main cause of flooding in the area is fluvial. Overland flow and surface runoff may be encountered within the catchment and to a lesser extent there is risk of flooding from groundwater.
Unusual catchment features	The catchment is not permeable nor is it heavily urbanised. There is little attenuation by reservoirs or lakes except for the Darwell Reservoir. Water can be pumped from the River Rother at Robertsbridge and stored in Darwell Reservoir. The Darwell Stream catchment has a FARL value of 0.866.

2.8 Initial choice of approach

Is FEH appropriate?	FEH statistical and ReFH2 methods are appropriate.
Initial choice of method(s) and reasons **How will hydrograph shapes be derived if needed?** **Will the catchment be split into subcatchments? If so, how?**	The FEH Statistical and ReFH2 methods will be applied to derive peak flow estimates in the study area. For the FEH Statistical method donors will be sought to improve the estimation of QMED. Pooling groups will be based on the gauging stations and compiled using WINFAP 4 and the NRFA version 9 dataset. Additional pooling groups may be constructed for catchments with different characteristics such as Darwell Stream that is significantly influenced by a reservoir. ReFH 2.3 will be used to derive catchment descriptor estimates of flow. Data at the Burwash and Udiam gauges will be used in the ReFH2 calibration utility to refine the parameter estimates for a maximum of eight peak flow events. If calibration is successful, the ReFH parameter will be adjusted throughout the catchment using these gauges as donors. Full hydrographs will be derived from the ReFH2 software. Hydrograph shape will also be derived from the average shape at the Burwash and Udiam gauges for comparison.

	The flow estimations will be distributed in the hydraulic model. Flow estimation points are located at the confluences with each key tributary and at key locations on the modelled watercourse. Lumped estimates will be inserted at the upstream modelled extents with subcatchment flows applied via lateral inflows.
Software to be used (with version numbers)	FEH Web Service[2] / WINFAP 4[3] / ReFH2.3 / ReFH 2 Calibration Utility

[2] CEH 2015. The Flood Estimation Handbook (FEH) Online Service, Centre for Ecology & Hydrology, Wallingford, UK.
[3] WINFAP 4 © Wallingford HydroSolutions Limited 2016.

3. Locations where flood estimates required

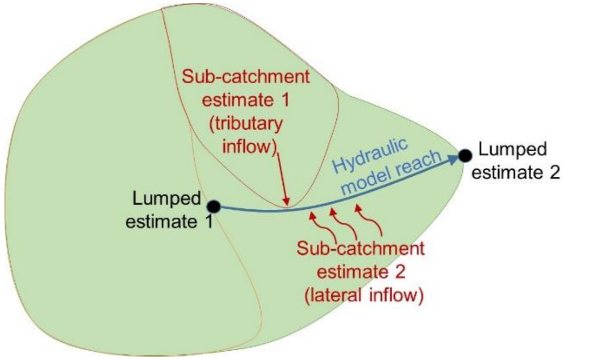
3.1 Summary of subject sites

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

Site code	Type of estimate L: Lumped catchment S: Sub-catchment	Watercourse	Description of site	Easting	Northing	AREA on FEH Webservice (km^2)	Revised AREA if altered
RO_06	L	River Rother	River Rother at upstream model extent at Swife Lane	563050	125950	36.06	NA
RO_05	L*	River Rother	River Rother at Crowhurst Weir	568350	126300	92.77	NA
RO_04	L*	River Rother	River Rother at confluence with River Dudwell	571600	126300	117.83	NA
RO_03	L*	River Rother	River Rother downstream of River Dudwell confluence	571650	126250	150.98	NA
RO_02	L*	River Rother	River Rother downstream of Robertsbridge	574700	124000	188.29	NA
RO_01	L*	River Rother	River Rother at Udiam	577250	124400	204.64	NA
RO_DS	L*	River Rother	River Rother downstream model extent at Bodiam	578400	125300	209.81	NA
DU_02	L	River Dudwell	River Dudwell at Burwash	567850	123950	26.13	NA
DU_01	L*	River Dudwell	River Dudwell at confluence with River Rother	571600	126200	33.14	NA
WH_01	L	Unnamed Tributary	Unnamed Willards Hill tributary	572950	124650	10.01	NA

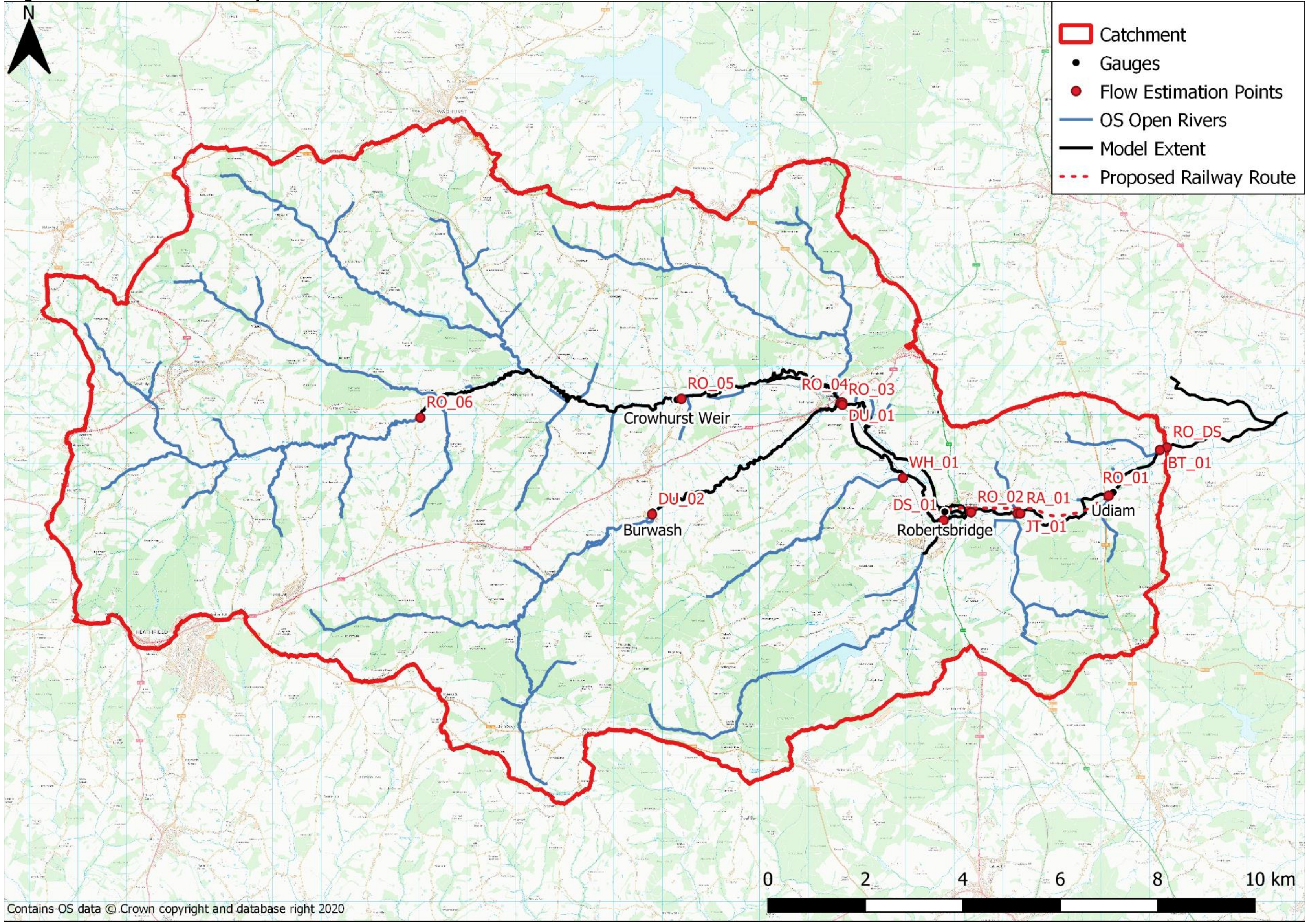
Site code	Type of estimate L: Lumped catchment S: Sub-catchment	Watercourse	Description of site	Easting	Northing	AREA on FEH Webservice (km^2)	Revised AREA if altered
DS_01	L	Darwell Stream	Darwell stream at confluence with River Rother	573700	123750	19.89	NA
RA_01	L	Unnamed Tributary	Northern Robertsbridge tributary (Jarretts Cottages) at confluence with River Rother	575250	123900	8.34	NA
JT_01	L	Unnamed Tributary	Southern Robertsbridge tributary (Robertsbridge Abbey) at confluence with River Rother	575250	124000	1.26	NA
BT_01	L	Unnamed Tributary	Bodiam tributary at confluence with River Rother	578150	125200	3.15	NA

Note: Lumped catchments (L) are complete catchments draining to points at which design flows are required. Sub-catchments (S) are catchments or intervening areas that are being used as inputs to a semi-distributed model of the river system. There is no need to report any design flows for sub-catchments, as they are not relevant: the relevant result is the hydrograph that the sub-catchment is expected to contribute to a design flood event at a point further downstream in the river system. This will be recorded within the hydraulic model output files. However, catchment descriptors and ReFH model parameters should be recorded for sub-catchments so that the results can be reproduced.
The schematic diagram illustrates the distinction between lumped and sub-catchment estimates.



*All sites estimated as lumped. For the purposes of hydraulic modelling these sites have lumped estimates upstream of them and will be split down to the intervening catchment area.

Figure 3 Flow estimation points



3.2 Important catchment descriptors at each subject site

Site code	FARL	PROPWET	BFIHOST19	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	URBEXT1990*	URBEXT2000*	FPEXT
RO_06	0.994	0.36	0.357	7.58	95.3	874	0.011814	0.017477	0.0389
RO_05	0.982	0.36	0.333	10.98	95.8	867	0.008237	0.012692	0.0403
RO_04	0.984	0.36	0.337	13.28	93.8	858	0.007587	0.011859	0.0422
RO_03	0.986	0.35	0.343	12.63	94.6	863	0.007045	0.011235	0.0428
RO_02	0.972	0.35	0.353	15.43	93.5	860	0.008454	0.011859	0.0491
RO_01	0.975	0.35	0.358	17.75	92.7	857	0.008454	0.011547	0.0573
RO_DS	0.975	0.35	0.357	18.93	92.0	856	0.008237	0.011443	0.0612
DU_02	0.994	0.35	0.390	6.49	104.9	888	0.005419	0.009883	0.0283
DU_01	0.994	0.35	0.365	10.01	97.3	877	0.005203	0.009155	0.0444
WH_01	0.966	0.36	0.358	4.33	96.0	855	0.002818	0.006138	0.0454
DS_01	0.866	0.35	0.407	5.41	89.5	864	0.015499	0.012484	0.0434
RA_01	1.000	0.36	0.407	3.27	88.9	833	0.010080	0.007282	0.0717
JT_01	1.000	0.36	0.330	1.46	106.0	807	0.008563	0.020182	0.0754
BT_01	1.000	0.36	0.280	2.25	76.9	803	0.000434	0.002081	0.1136

*Updated to 2020

3.3 Checking catchment descriptors

Record how catchment boundary was checked and describe any changes	Catchment boundaries were checked using OS mapping and through GIS watershed analysis on a 1m resolution DTM. The catchment is generally well defined and there is good correlation between the DTM derived catchments and the FEH catchments. OS mapping was used to confirm flow pathways and catchment boundaries in the lower lying areas of farmland in the valley bottom downstream of Robertsbridge where there are multiple flow pathways.
Record how other catchment descriptors were checked and describe any changes.	SAAR is consistent with the catchment topography and geographical location. FARL was checked visually using mapping and satellite imagery, the values are representative for each flow node.

	Soils were checked using Soilscapes mapping. The SPR, BRIHOST19 and PROPWET are representative of the catchment. URBEXT was checked using mapping the values are reasonable.
Source of URBEXT	URBEXT2000
Method for updating of URBEXT	URBEXT2000 was updated to 2020 using the updated CPRE formula from DEFRA R&D Technical Report FD1919/TR.

4. Statistical method

4.1 Application of Statistical method

What is the purpose of applying this method?	The Statistical method is applied here to estimate peak flows at the subject sites. Flows will be used in hydraulic modelling. Lumped flows will be inserted at the upstream extents of the model with incremental flows added laterally in the intervening areas at key locations. The statistical method relies on observed data from donor sites with similar characteristics to improve the confidence in estimate.

4.2 Overview of estimation of QMED at each subject site

Site code	QMED (rural) from CDs (m^3/s)	Final method	Data transfer					Urban Adjustment Factor, UAF	Final estimate of QMED (m^3/s)
			NRFA numbers for donor sites (see 4.3)	Distance between centroids, d_{sg} (km)	Moderated QMED adjustment factor, (A/B)[a]	If more than one donor			
						Weight	Weighted ave. adjustment		
RO_06	13.62	DT	40004	7.27	0.49			1.016	12.50
RO_05	30.18	DT	40004	4.88	0.54			1.011	27.39
RO_04	36.12	DT	40004	3.47	0.60			1.011	32.36
RO_03	44.92	DT	40004	2.49	0.66			1.010	39.67
RO_02	50.13	DT	40004	0.88	0.84			1.011	42.43
RO_01	53.39	DT	40004	0.00	1.00			1.011	43.41
RO_DS	54.51	DT	40004	0.27	0.94			1.011	45.95
DU_02	9.93	DT	40004	3.82	0.58			1.010	8.93
DU_01	12.54	DT	40004	2.92	0.63			1.009	11.15
WH_01	3.95	DT	40004	4.48	0.55			1.006	3.57
DS_01	4.43	DT	40004	6.34	0.50			1.012	4.05
RA_01	3.20	DT	40004	10.24	0.45			1.007	2.96
JT_01	0.71	DT	40004	8.77	0.47			1.018	0.65

BT_01	1.68	DT	40004	10.48	0.45			1.002	1.55
Are the values of QMED spatially consistent?						Yes			
Method used for urban adjustment for subject and donor sites						WINFAP v4[4]			
Parameters used for WINFAP v4 urban adjustment (if applicable)									

Impervious fraction for built-up areas, IF	**Percentage runoff for impervious surfaces, PR_{imp}**	**Method for calculating fractional urban cover, URBAN**
0.3	70%	From updated URBEXT2000

Notes

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

The QMED adjustment factor A/B for each donor site is moderated using the power term, a, which is a function of the distance between the centroids of the subject catchment and the donor catchment. The final estimate of QMED is $(A/B)^a$ times the initial (rural) estimate from catchment descriptors.

Important note on urban adjustment

The method used to adjust QMED for urbanisation published in Kjeldsen (2010)[5] in which PRUAF is calculated from BFIHOST is not correctly applied in WINFAP-FEH v3.0.003. Significant differences occur only on urban catchments that are highly permeable. This is discussed in Wallingford HydroSolutions (2016)[4].

4.3 Search for donor sites for QMED (if applicable)

Comment on potential donor sites	There is one gauge within the catchment, Rother at Udiam (40004), that is suitable as a donor transfer for QMED. Burwash (40017) was considered as a potential donor site for the Rother tributaries, including site on the River Dudwell, as it is within the study catchment. However, the site is unsuitable as a QMED donor as it is not gauged to within 30% QMED. Cowbeech (41016) and Stonebridge (40009) are located in adjacent catchments and were considered and rejected as potential donors as the Udiam gauge is a suitable donor and is located within the study catchment.

[4] Wallingford HydroSolutions (2016). WINFAP 4 Urban adjustment procedures.
[5] Kjeldsen, T. R. (2010). Modelling the impact of urbanization on flood frequency relationships in the UK. Hydrol. Res. **41**. 391-405.

4.4 Donor sites chosen and QMED adjustment factors

NRFA no.	Method (AM or POT)	Adjustment for climatic variation?	QMED from flow data (A)	QMED from catchment descriptors (B)	Adjustment ratio (A/B)
40004	AM	No	43.41	53.39	0.81

4.5 Derivation of pooling groups

Name of group	Site code from whose descriptors group was derived	Subject site treated as gauged? (enhanced single site analysis)	Changes made to default pooling group, with reasons	Weighted average L-moments L-CV and L-skew (before urban adjustment)
Udiam	RO_01	ESS	No changes.	L-CV: 0.278 L-skew: 0.211
Darwell Stream	DS_01	No	49005, 7011, 28058 were all removed as they have a short record length. 44013 has a much steeper growth curve and a significant number of flood free years was removed. 28041 was added to the group. Changes reduce 100 year growth factor from 3.532 to 3.356.	L-CV: 0.274 L-skew: 0.245
Small Tributaries	WH_01	No	206006 (NI station),49005 (short record length), 47022 (low FARL), 25011, 25003, 71003 (high SAAR) all removed. 73015, 26014, 41020 and 72007 added to the group. Limited impact on growth curve. Changes reduce 100 year growth factor from 3.346 to 3.353.	L-CV: 0.264 L-skew: 0.263
Note: Pooling groups were derived using the procedures from Science Report SC050050 (2008)				

4.6 Derivation of flood growth curves at subject sites

Site code	Method (SS, P, ESS, J)	If P, ESS or J, name of pooling group	Distribution used and reason for choice	Note any urban adjustment or permeable adjustment	Parameters for distribution (location, scale and shape after adjustments)	Growth factor for 100-year return period
RO_06 RO_05 RO_04 RO_03 RO_02 RO_01 RO_DS DU_02 DU_01	ESS	Udiam	General Logistic gives the lowest absolute Z value	NA	Location: 1 Scale: 0.284 Shape: -0.211 Bound: -0.351	3.211
DS_01	P	Darwell Stream	General Logistic gives the lowest absolute Z value	NA	Location: 1 Scale: 0.277 Shape: -0.245 Bound: -0.13	3.359
WH_01 RA_01 JT_01 BT_01	P	Small Tributaries	General Logistic gives the lowest absolute Z value	NA	Location: 1 Scale: 0.264 Shape: -0.263 Bound: -0.002	3.353

Notes:
Methods: SS – Single site; P – Pooled; ESS – Enhanced single site; J – Joint analysis
Urban adjustments are all carried out using the method of Kjeldsen (2010).
Growth curves were derived using the procedures from Science Report SC050050 (2008).

4.7 Flood estimates from the Statistical method

Site code	Flood peak (m^3/s) for the following return periods (in years)								
	2	**5**	**10**	**20**	**50**	**75**	**100**	**200**	**1000**
RO_06	12.50	18.24	22.46	27.04	33.99	37.48	40.13	47.20	68.12
RO_05	27.39	39.96	49.21	59.26	74.49	82.14	87.95	103.43	149.27
RO_04	32.36	47.21	58.14	70.01	88.01	97.04	103.91	122.20	176.36
RO_03	39.67	57.87	71.27	85.82	107.88	118.95	127.37	149.79	216.18
RO_02	42.43	61.90	76.23	91.79	115.39	127.23	136.23	160.21	231.23
RO_01	43.41	63.33	77.99	93.91	118.06	130.17	139.38	163.92	236.57
RO_DS	44.95	65.58	80.76	97.25	122.26	134.80	144.33	169.75	244.98
DU_02	8.93	13.02	16.04	19.31	24.28	26.77	28.66	33.71	48.65
DU_01	11.15	16.27	20.04	24.13	30.33	33.45	35.81	42.12	60.78
WH_01	3.57	5.14	6.37	7.75	9.95	11.09	11.97	14.39	22.00
DS_01	4.05	5.90	7.32	8.90	11.36	12.63	13.60	16.24	24.37
RA_01	2.96	4.26	5.28	6.42	8.24	9.18	9.91	11.92	18.22
JT_01	0.65	0.94	1.17	1.42	1.82	2.03	2.19	2.64	4.03
BT_01	1.55	2.24	2.77	3.37	4.33	4.83	5.21	6.26	9.57

5. Revitalised Flood Hydrograph 2 (ReFH2) method

5.1 Application of the ReFH2 method

What is the purpose of applying this method?	The ReFH2 method is applied here to estimate peak flows at the subject sites. ReFH2 flows will be compared to Statistical estimates for extreme events. ReFH2 is used to estimate peak flows using catchment descriptors and with calibrated parameters. Calibration of parameters at the gauged sites from observed events is undertaken to refine the ReFH model parameters using events at the Burwash and Udiam gauges. The ratio between the catchment descriptor and observed values of Tp, Cmax and BL is used to adjust the parameters at the subject sites.

5.2 Parameters for ReFH2 model

Site code	Method	Tp_{rural} (hours)	Tp_{urban} (hours)	Cmax (mm)	PR_{imp} % runoff for impermeable surfaces	BL (hours)	BR*
RO_06	OPT / BR		5.99	235.174	70	166.571	0.819
RO_05	OPT / BR		7.40	220.960	70	173.130	0.654
RO_04	OPT / BR		8.30	223.268	70	181.071	0.667
RO_03	OPT / BR		8.31	228.125	70	184.071	0.711
RO_02	OPT / BR		9.35	234.129	70	195.670	0.767
RO_01	OPT / BR		10.16	237.190	70	203.466	0.796
RO_DS	OPT / BR		10.57	236.575	70	205.992	0.790
DU_02	OPT / BR		3.50	226.336	70	98.752	1.077
DU_01	OPT / BR		4.59	212.107	70	104.265	0.857
WH_01	OPT / BR		2.77	207.052	70	84.744	0.85
DS_01	OPT / BR		5.21	269.386	70	169.719	1.424
RA_01	OPT / BR		2.41	235.157	70	86.156	1.281
JT_01	OPT / BR		1.44	192.527	70	63.634	0.570

Site code	Method	Tp_{rural} (hours)	Tp_{urban} (hours)	Cmax (mm)	PR_{imp} % runoff for impermeable surfaces	BL (hours)	BR*
BT_01	OPT / BR		2.04	169.078	70	63.298	0.413
Brief description of any flood event analysis carried out (further details should be given in the annex)			The ReFH2 parameters were optimised using the ReFH 2 Calibration Utility. The Redgate Mill rain gauge was used. Only data from 2016 to 2020 was available, therefore only a small number of events were used in the analysis (7 at each gauge). SM and Tp were optimised in the model. BL and BR were adjusted through recession fitting. A good calibration has not been achieved. A list of events and model vs observed plots are shown in Section 7.3.				
Methods: OPT: Optimisation, BR: Baseflow recession fitting, CD: Catchment descriptors, DT: Data transfer (give details)							

* For the 100 year scenario

5.3 Design events for ReFH2 method: Lumped catchments

Site code	Urban or rural	Season of design event (summer or winter)	Storm duration (hours)	Calibrated Storm duration (hours)
RO_06	Rural	Winter	8.60	11.20
RO_05	Rural	Winter	10.60	13.80
RO_04	Rural	Winter	11.90	15.40
RO_03	Rural	Winter	11.90	15.50
RO_02	Rural	Winter	13.40	17.40
RO_01	Rural	Winter	14.50	18.90
RO_DS	Rural	Winter	15.10	19.60
DU_02	Rural	Winter	8.00	6.60
DU_01	Rural	Winter	10.40	8.60
WH_01	Rural	Winter	6.20	5.10
DS_01	Rural	Winter	7.50	9.70
RA_01	Rural	Winter	5.30	4.40
JT_01	Rural	Winter	3.10	2.60
BT_01	Rural	Winter	4.40	3.70

5.4 Flood estimates from the ReFH2 method (uncalibrated)

Site code	Flood peak (m^3/s) for the following return periods (in years)								
	2	**5**	**10**	**20**	**50**	**75**	**100**	**200**	**1000**
RO_06	13.84	18.48	21.81	25.28	30.36	32.89	34.85	40.39	60.26
RO_05	33.31	44.07	51.77	59.79	71.61	77.61	82.30	95.79	143.62
RO_04	38.40	50.73	59.40	68.69	82.18	89.15	94.66	110.42	165.98
RO_03	48.25	63.50	74.33	85.72	102.43	111.03	117.81	137.50	207.28
RO_02	54.77	71.35	83.18	95.54	114.03	123.72	131.43	154.37	234.23
RO_01	56.15	72.77	84.56	96.98	115.69	125.63	133.63	157.75	240.42
RO_DS	56.33	72.92	84.70	97.02	115.77	125.71	133.74	157.91	240.33
DU_02	9.56	12.72	14.95	17.25	20.60	22.29	23.61	27.39	41.51
DU_01	11.36	14.89	17.37	19.96	23.81	25.80	27.40	32.13	49.16
WH_01	4.69	6.28	7.42	8.57	10.29	11.17	11.86	13.83	21.11
DS_01	7.09	9.38	10.98	12.60	15.01	16.26	17.26	20.22	31.43
RA_01	3.46	4.65	5.48	6.31	7.53	8.18	8.71	10.28	16.25
JT_01	0.86	1.21	1.45	1.70	2.06	2.24	2.37	2.78	4.23
BT_01	2.20	3.00	3.57	4.16	5.01	5.44	5.79	6.85	10.59

5.5 Flood estimates from the calibrated ReFH2 method

Site code	Flood peak (m^3/s) for the following return periods (in years)								
	2	**5**	**10**	**20**	**50**	**75**	**100**	**200**	**1000**
RO_06	11.20	14.90	17.58	20.40	24.62	26.77	28.46	33.34	51.32
RO_05	27.10	35.81	42.13	48.76	58.74	63.89	67.96	79.91	122.68
RO_04	31.64	41.51	48.64	56.27	67.75	73.83	78.73	93.12	143.65
RO_03	39.68	51.89	60.77	70.12	84.32	91.83	97.85	115.84	179.13
RO_02	44.56	57.90	67.40	77.50	93.09	101.48	108.30	128.73	199.92

Site code	Flood peak (m^3/s) for the following return periods (in years)								
	2	**5**	**10**	**20**	**50**	**75**	**100**	**200**	**1000**
RO_01	44.90	58.00	67.41	77.37	92.77	101.12	107.95	128.74	200.02
RO_DS	44.84	57.94	67.36	77.35	92.81	101.20	108.08	129.16	201.14
DU_02	9.99	13.64	16.27	18.99	22.98	25.00	26.58	31.07	48.23
DU_01	11.85	15.98	18.89	22.01	26.60	28.96	30.82	36.33	56.95
WH_01	4.94	6.78	8.12	9.47	11.51	12.56	13.38	15.72	24.51
DS_01	5.58	7.37	8.63	9.92	11.88	12.93	13.78	16.34	26.12
RA_01	3.52	4.86	5.80	6.75	8.16	8.90	9.49	11.25	18.23
JT_01	0.91	1.31	1.60	1.89	2.31	2.52	2.68	3.15	4.87
BT_01	2.29	3.20	3.86	4.54	5.52	6.02	6.40	7.59	11.87

6. Discussion and summary of results

6.1 Comparison of results from different methods

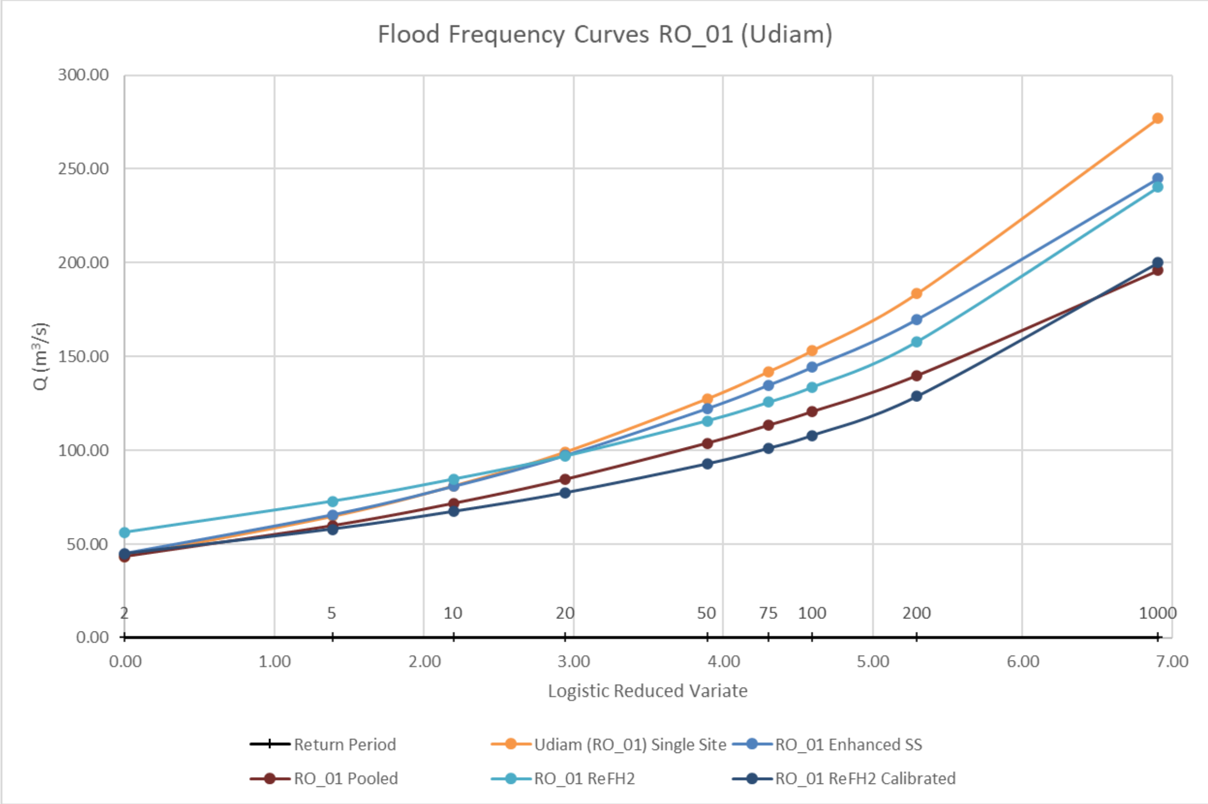
Site code	2 year			100 year		
	Statistical peak flow (m^3/s)	ReFH2 peak flow (m^3/s)	Ratio	Statistical peak flow (m^3/s)	ReFH2 peak flow (m^3/s)	Ratio
RO_06	12.50	11.20	0.90	40.13	28.46	0.71
RO_05	27.39	27.10	0.99	87.95	67.96	0.77
RO_04	32.36	31.64	0.98	103.91	78.73	0.76
RO_03	39.67	39.68	1.00	127.37	97.85	0.77
RO_02	42.43	44.56	1.05	136.23	108.30	0.79
RO_01	43.41	44.90	1.03	139.38	107.95	0.77
RO_DS	44.95	44.84	1.00	144.33	108.08	0.75
DU_02	8.93	9.99	1.12	28.66	26.58	0.93
DU_01	11.15	11.85	1.06	35.81	30.82	0.86
WH_01	3.57	4.94	1.38	11.97	13.38	1.12
DS_01	4.05	5.58	1.38	13.60	13.78	1.01
RA_01	2.96	3.52	1.19	9.91	9.49	0.96
JT_01	0.65	0.91	1.40	2.19	2.68	1.22
BT_01	1.55	2.29	1.47	5.21	6.40	1.23

6.2 Final choice of method

Choice of method and reasons	The Statistical estimates have been used for this study. The Statistical method uses observed data from similar catchments to increase the observed record length through pooled analysis. Enhanced Single Site Analysis has been undertaken applying gauged data from the Udiam gauge for the Udiam pooling group. The estimations of QMED have been improved using the local Udiam gauge as a donor station. The Statistical estimates are preferred as it

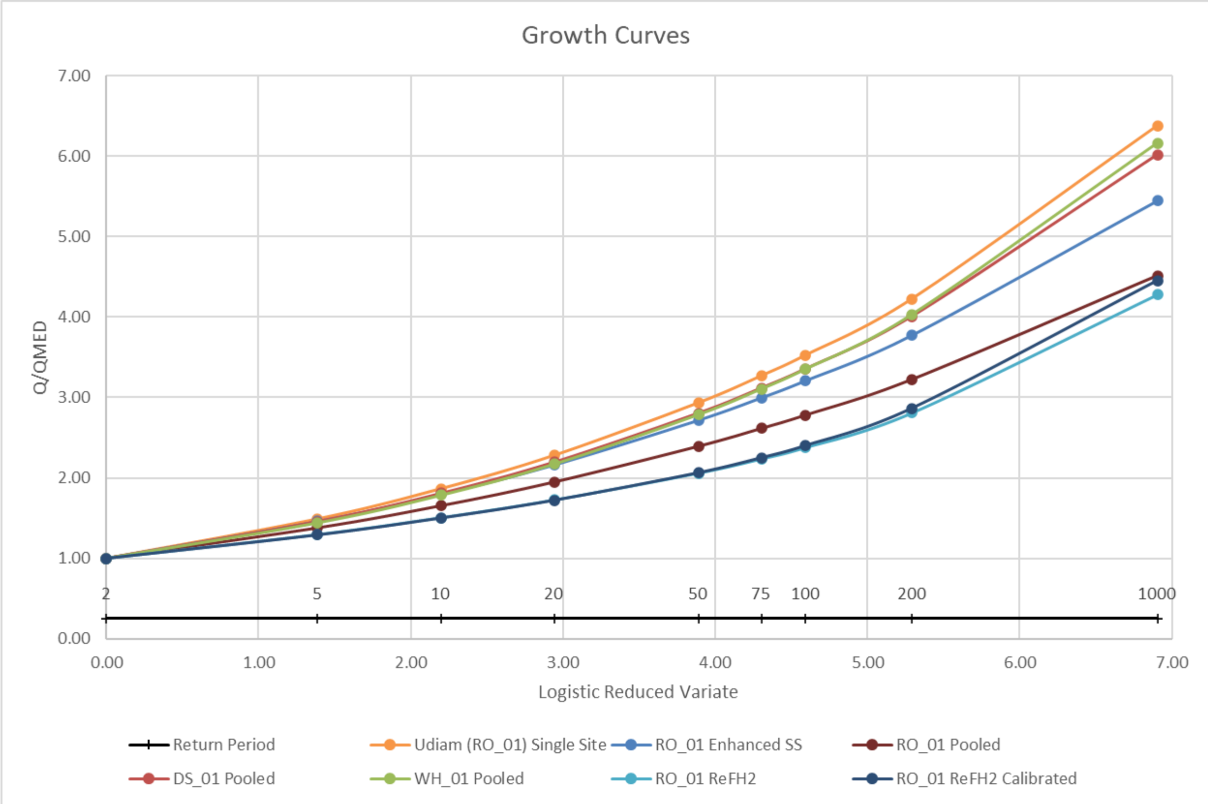
	has been improved with the use of local data from the study catchment including updated the AMAX record at the Udiam gauge with the data for the 2019-2020 water year. The use of the Udiam gauge as a donor site within the catchment decreased the estimate of QMED by an average of 11% across all sites compared to QMED estimated solely by catchment descriptors. There is uncertainty in the Statistical method due to the quality of the stage discharge rating at Udiam gauging station. The station is gauged to approximately QMED and there is reasonable confidence in the estimates, but scatter in the gaugings and changes to the station over time mean there is some uncertainty in higher flows and the station is indicated as not suitable for pooling. However, it is recommended that flood estimates are improved by using real data where possible, and as the station is within the subject catchment and close to the site of the proposed railway, it has been taken forward into Enhanced Single Site to make use of the AMAX data. Using Enhanced Single Site produces larger flows than using the pooled method alone without Udiam gauge included in the pooling group. ReFH2 flows were estimated using catchment descriptors and with parameters calibrated at the Burwash and Udiam gauged sites. On the River Rother the ReFH2 method based on catchment descriptors gives lower peak flow estimates than the Statistical Method. The ReFH calibration reduces the peak flow estimates further but introduces an increased uncertainty. Calibration was only undertaken on events between 23/02/2015 and 07/09/2020 due to a short period of data available at the Redgate Mill rain gauge. Some events were discarded as a result of missing suspect data quality at gauges and the performance of the modelled data compared to observed. There is also an increased level of uncertainty associated with the subjectivity involved in the calibration process. The peak flow estimates for the 2 year are within 10% of each other and for the 100 year event are within 29% of each other on the River Rother. The estimates from the ReFH2 method are consistently lower than the Statistical Method on the River Rother for the higher return period, more extreme events (greater than 50 years). Figure 4 shows the range of Flood Frequency curves for RO_01 from each method. The Enhanced Single Site and uncalibrated ReFH2 are within a similar range. The pooled analysis and calibrated ReFH2 have similar 1000 year flows, but ReFH2 calibrated has generally lower flows. Single Site gives much higher flows for the higher return periods.

Figure 4 Flood Frequency Curves for RO_01



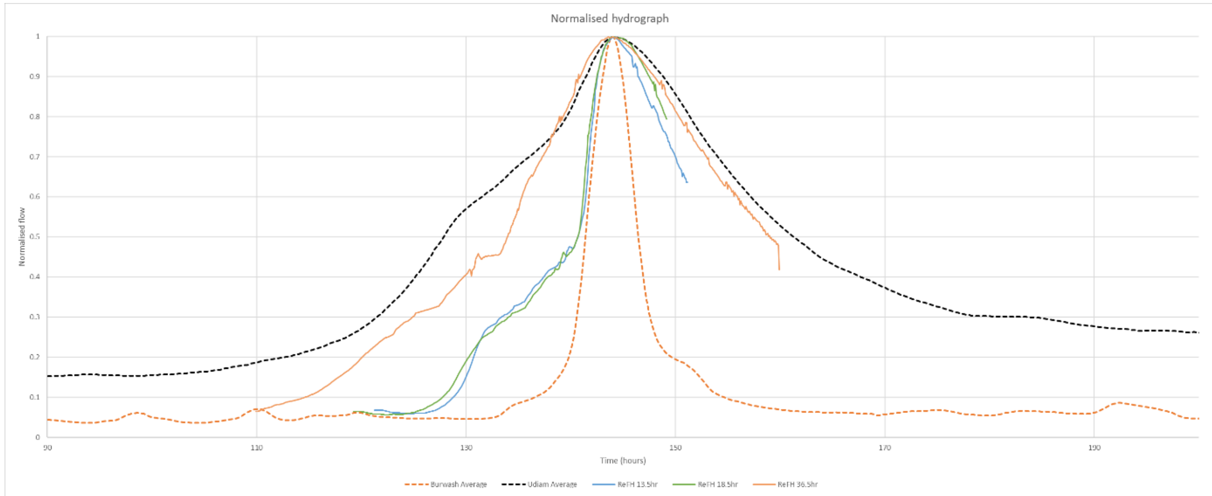
The growth curves are shown for each method in Figure 5 below. The Enhanced Single Site growth curve sits slightly above the central range of the curves, with the ReFH2 growth factors being generally lower than the statistical method. The pooled growth curve for Udiam without enhancement is quite flat. The ReFH2 growth curves, although lower growth factors, show a kick in the curve from 100 year up to 1000 year.

Figure 5 Growth curves for each method



Full hydrographs are required for the hydraulic modelling. Testing has been undertaken in the hydraulic model using the gauged average shapes (based on AMAX events since 1990) and the ReFH2 hydrographs fitted to the Statistical peak flows. Modelled results were compared to the average shape hydrograph at the Udiam gauge. The average hydrograph was derived from 28 gauged AMAX events dating back to 1990. From the testing undertaken the ReFH hydrograph with a duration of 36.5 hours proved to be the best fit at Udiam (Figure 6). A full plot of all events is shown in Section 7.4.

<table>
<tr><td></td><td>Figure 6 Modelled and observed hydrograph shapes and Udiam


</td></tr>
<tr><td>How will the flows be applied to a hydraulic model?</td><td>The 36.5 hour storm duration ReFH hydrograph will be scaled to the Statistical Method peak flow estimates. Although not a storm duration identified within the calculations, this duration gives the best fit to the average observed hydrograph shape at Udiam gauge. The peak flow estimates will be applied to the hydraulic model at the upstream lumped catchments (RO_06, DU_02, DS_01, WH_01). The flow estimates at intervening sites (RO_05, RO_04, DU_01) will be adjusted by applying the minus method and applied as lateral inflows to the hydraulic model. The smaller tributaries of the River Rother that are not modelled (JT_01, RA_01, BT_01) will be applied as lateral inflows to the hydraulic model. Flow reconciliation has been undertaken and tributary hydrograph timings have been checked to ensure modelled peak flows at Udiam are within 5% of the peak flow estimate. Following testing, flows for RO_DS, RO_01, RO_02 and RO_03 have not been applied as the estimated peak flow at Udiam reaches the lumped estimate without any lateral flow requirement.

Peak flows for each node to be applied in the model are shown in the table below the final results. The model inflow hydrographs for the 100 year event are shown in section 7.5.</td></tr>
</table>

6.3 Assumptions, limitations and uncertainty

List the main assumptions made (specific to this study)	It is assumed that the FEH catchment boundaries and descriptors are correct for this study. It was not possible to check the catchment boundaries on the ground therefore is it assumed that the check using

	mapping and GIS watershed analysis is suitable. It is assumed that the desk-based checks undertaken on the catchment descriptors is suitable. It is assumed that the river flow gauging ratings and data are good and suitable for use. The FEH Statistical analysis used flow gauge data as a donor to generate flows for similar sites within the catchment. The assumption has been made that the characteristics of the subject and donor catchments are similar. It is assumed the default ReFH2 parameters are suitable for the catchment descriptor only flow estimates. And that the calibration undertaken on the ReFH2 parameters is suitable. It is assumed the ReFH2 recommended storm duration represents the study site and that a uniform storm duration with a winter profile is appropriate. Non-stationarity has not been considered.
Discuss any particular limitations	The Statistical method has been applied beyond the recommended limit of the 0.5% AEP event The ReFH2 method has been applied beyond the calibrated limit of 0.67% AEP event.
Provide information on the uncertainty in the design peak flow estimates and the methodology used	There is always uncertainty surrounding the design flood estimation for hydrological and hydraulic modelling. The selected FEH statistical approach follows the most up to date Flood Estimation methods and uses available observed local and pooled gauged data. Based on the Environment Agency 2020 Flood Estimation Guidelines (LIT 11832), the confidence bounds for a Statistical method with one donor site are indicated in section 6.6.
Comment on the suitability of the results for future studies	The flood estimates are based on the available data at the time of the study. The results can be replicated and/or updated for future studies at the study sites. The results should be considered within the context of the needs of this study and it is cautioned that the estimated design flows may not be appropriate for wider purposes, for example site specific flood risk studies. Future users of this assessment should satisfy themselves that the flows are suitable for use in their work. Additionally, when new hydrometric data becomes available or the methods are updated, the estimates should be revisited.
Give any other comments on the study	More local gauged flow data on the main rivers and small tributary watercourses is recommended. This would be useful for future hydrology studies and would improve confidence in the gauge ratings, peak flow estimates and hydrograph volume/shape.

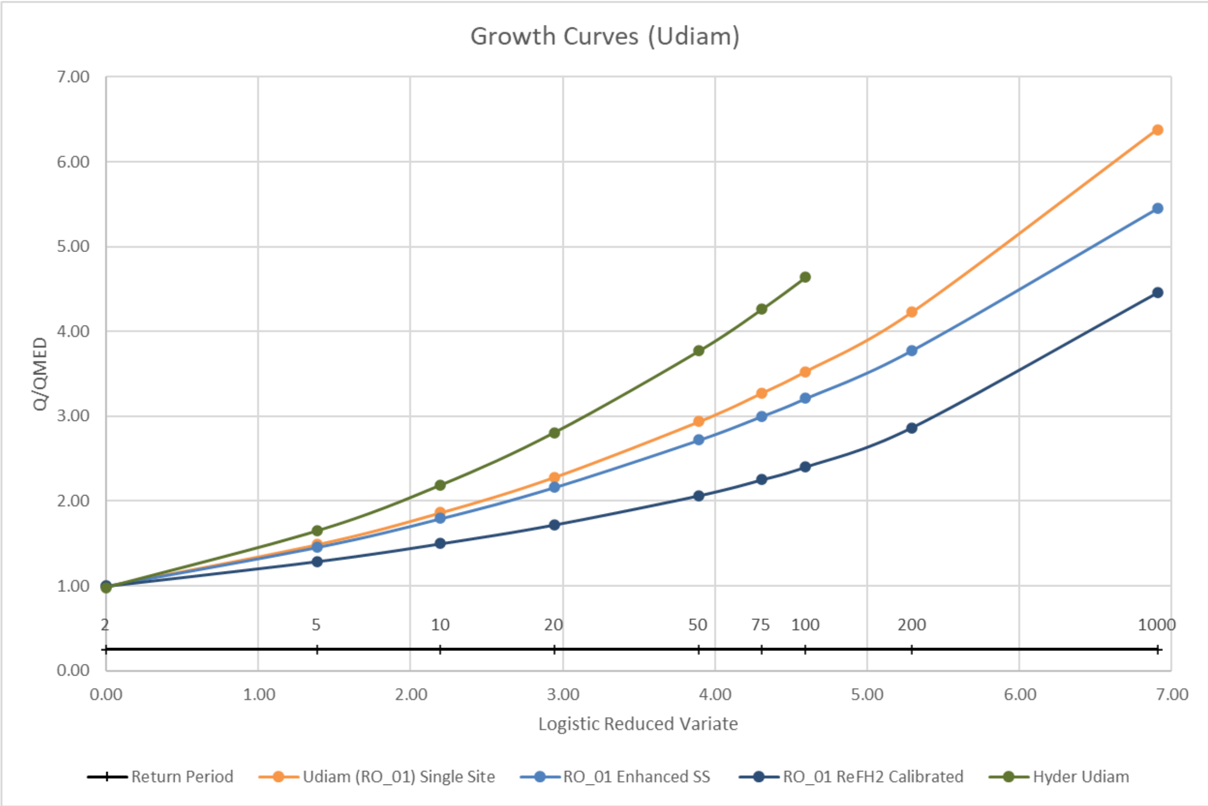
6.4 Checks

<table>
<tr><td>Are the results consistent, for example at confluences?</td><td>Peak flows are consistent with increasing catchment area.</td></tr>
<tr><td>What do the results imply regarding the return periods / frequency of floods during the period of record?</td><td>The highest AMAX value recorded at Udiam gauge is recorded as 135.2m3/s for October 2000. Based on the statistical method peak flows at RO_01 (the location of the gauge), this would indicate that the AMAX 1 event could be attributed an AEP of between 75 year and 100 year.
Due to the poor quality of rating at Burwash, and lack of data to improve it, the return period of AMAX1 has not been estimated.</td></tr>
<tr><td>What is the range of 100-year growth factors? Is this realistic?</td><td>The Statistical method (ESS, GL distribution) the 100 year growth factors range from 3.21 to 3.36.
The ReFH2 method growth factors range from 2.37 to 2.75 based on catchment descriptors and 2.40 to 2.93 for the calibrated model parameters.</td></tr>
<tr><td>If 1000-year flows have been derived, what is the range of ratios for 1000-year flow over 100-year flow?</td><td>The Statistical method has ratios ranging from 1.70 to 1.84.
The ReFH2 method has ratios ranging from 1.73 to 1.87 based on catchment descriptors and 1.80 to 1.92 for the calibrated model parameters.</td></tr>
<tr><td>How do the results compare with those of other studies? Explain any differences and conclude which results should be preferred.</td><td>Hyder undertook an assessment of flows for the River Rother ABD and Hazard Mapping study in 2009/2010.

The estimates from their study (5001-WX58005-WX-00 Hydrology Report addendum.pdf) are shown in the table below along with the same estimates from this latest study. The Hyder estimates are consistently higher than the estimates from this latest study, other than QMED at Udiam.
<table>
<tr><th>Return Period (in years)</th><th>2</th><th>5</th><th>10</th><th>20</th><th>50</th><th>75</th><th>100</th></tr>
<tr><td colspan="8">Udiam</td></tr>
<tr><td>Hyder</td><td>38.6</td><td>64.7</td><td>86.1</td><td>110.3</td><td>148.2</td><td>167.6</td><td>182.4</td></tr>
<tr><td>Capita</td><td>43.4</td><td>63.3</td><td>78.0</td><td>93.9</td><td>118.1</td><td>130.2</td><td>139.4</td></tr>
<tr><td>Difference</td><td>4.8</td><td>-1.4</td><td>-8.1</td><td>-16.4</td><td>-30.1</td><td>-37.4</td><td>-43.0</td></tr>
<tr><td colspan="8">Burwash</td></tr>
<tr><td>Hyder</td><td>13.4</td><td>19.7</td><td>24.1</td><td>28.4</td><td>34.1</td><td>36.7</td><td>38.5</td></tr>
<tr><td>Capita</td><td>8.9</td><td>13.0</td><td>16.0</td><td>19.3</td><td>24.3</td><td>26.8</td><td>28.7</td></tr>
<tr><td>Difference</td><td>-4.5</td><td>-6.7</td><td>-8.1</td><td>-9.1</td><td>-9.8</td><td>-9.9</td><td>-9.8</td></tr>
</table>

Hyder used the single site GEV growth curve from Udiam and Burwash to derive the flow estimates. They established a new rating at Burwash, but do not include the rating parameters within the report to replicate.</td></tr>
</table>

	The growth curve for Udiam is shown in Figure 7 compared to the growth curves derived from this new study for Udiam (RO_01). The Hyder growth curve is very steep, with a 100 year growth factor of 4.64 which we would suggest is very high and outside of the typical range. Hyder's reasoning for using the single site growth curve was that within the pooling group they derived, Udiam had a much steeper growth curve than any other station in the group, thus effectively making it an outlier in its own pooling group. Within the Enhanced Single Site pooling group using more up to date station data for this study, stations 2 to 5 in the group all have a similar growth curve to Udiam (though station 3 is much steeper). Using Hyder's results for Udiam, this would indicate that the October 2000 event (AMAX1) would be within a 20 and 50 year return period which seems very low compare to the 75-100 year return period estimated by the latest results. Justifying the flows at Burwash is difficult due to the significant uncertainty in the rating at the site. Area weighting the Capita derived Udiam flow to Burwash would give a QMED value of 5.7m3/s. Therefore, the derived estimate of 8.9m3/s seems reasonable without causing a significant step in flows through the catchment. We would have greater confidence in the latest estimates as the catchment does not have suitably unusual features to warrant such a high 100 year growth factor at Udiam and produces a more indicative return period for the observed flood record. The Capita estimates make use of the latest methods and data.

	Figure 7 Comparison of Hyder and new growth curves 
Are the results compatible with the longer-term flood history?	The Statistical flow estimates use local gauged data which dates back to the 1960s. The results of this study incorporate changes over time as these will be inherent in the gauged record.
Describe any other checks on the results,	Sense checks on modelled results will be undertaken.

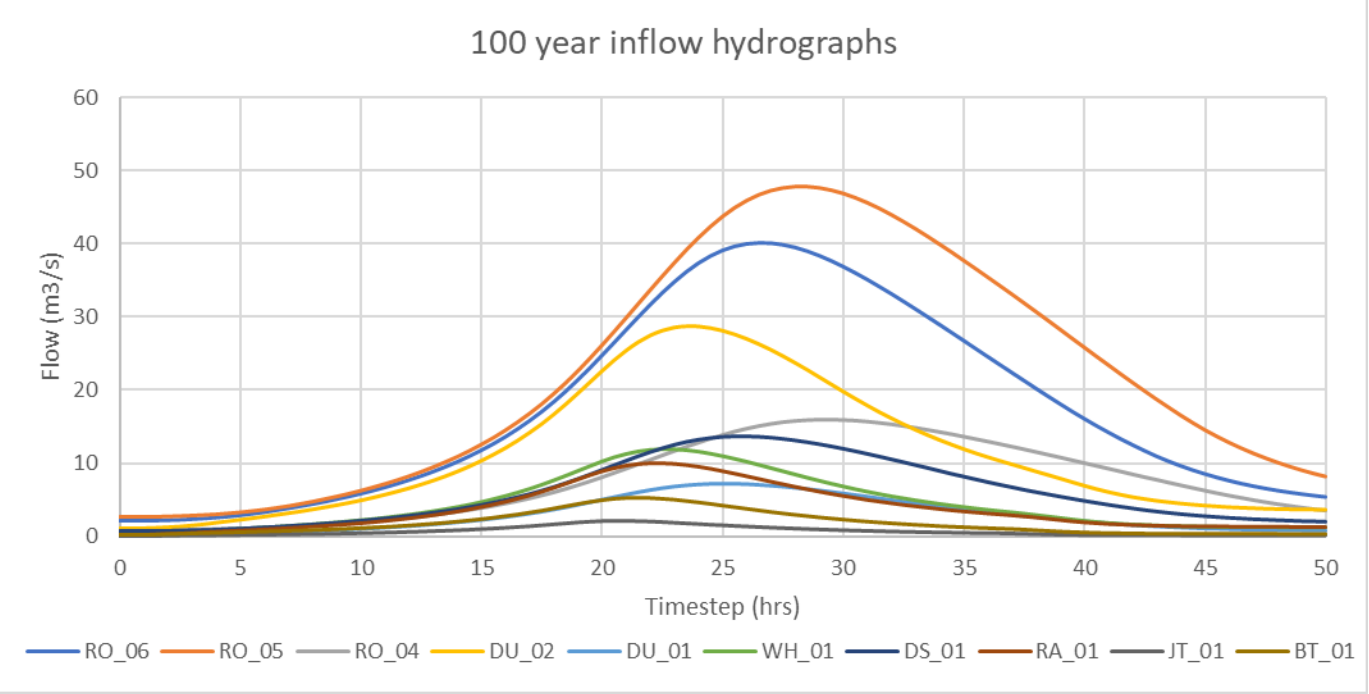
6.5 Final results

Site code	Flood peak (m^3/s) for the following return periods (in years)								
	2	5	10	20	50	75	100	200	1000
RO_06	12.50	18.24	22.46	27.04	33.99	37.48	40.13	47.20	68.12
RO_05	27.39	39.96	49.21	59.26	74.49	82.14	87.95	103.43	149.27
RO_04	32.36	47.21	58.14	70.01	88.01	97.04	103.91	122.20	176.36
RO_03	39.67	57.87	71.27	85.82	107.88	118.95	127.37	149.79	216.18
RO_02	42.43	61.90	76.23	91.79	115.39	127.23	136.23	160.21	231.23
RO_01	43.41	63.33	77.99	93.91	118.06	130.17	139.38	163.92	236.57
RO_DS	44.95	65.58	80.76	97.25	122.26	134.80	144.33	169.75	244.98
DU_02	8.93	13.02	16.04	19.31	24.28	26.77	28.66	33.71	48.65
DU_01	11.15	16.27	20.04	24.13	30.33	33.45	35.81	42.12	60.78
WH_01	3.57	5.14	6.37	7.75	9.95	11.09	11.97	14.39	22.00
DS_01	4.05	5.90	7.32	8.90	11.36	12.63	13.60	16.24	24.37
RA_01	2.96	4.26	5.28	6.42	8.24	9.18	9.91	11.92	18.22
JT_01	0.65	0.94	1.17	1.42	1.82	2.03	2.19	2.64	4.03
BT_01	1.55	2.24	2.77	3.37	4.33	4.83	5.21	6.26	9.57

Incremental peak flow estimates for model inflows

Site code	Type	Flood peak (m^3/s) for the following return periods (in years)								
		2	5	10	20	50	75	100	200	1000
RO_06	S	4.97	7.25	8.93	10.75	13.52	14.91	15.96	18.77	27.09
RO_05	S	14.89	21.72	26.75	32.21	40.50	44.65	47.81	56.23	81.15
RO_04	L	12.50	18.24	22.46	27.04	33.99	37.48	40.13	47.20	68.12
RO_03	S	2.23	3.25	4.00	4.82	6.05	6.68	7.15	8.41	12.13
RO_02	L	11.15	16.27	20.04	24.13	30.33	33.45	35.81	42.12	60.78
RO_01	L	8.93	13.02	16.04	19.31	24.28	26.77	28.66	33.71	48.65
RO_DS	L	3.57	5.14	6.37	7.75	9.95	11.09	11.97	14.39	22.00
DU_02	L	4.05	5.90	7.32	8.90	11.36	12.63	13.60	16.24	24.37
DU_01	L	2.96	4.26	5.28	6.42	8.24	9.18	9.91	11.92	18.22
WH_01	L	0.65	0.94	1.17	1.42	1.82	2.03	2.19	2.64	4.03

DS_01	S	4.97	7.25	8.93	10.75	13.52	14.91	15.96	18.77	27.09
RA_01	S	14.89	21.72	26.75	32.21	40.50	44.65	47.81	56.23	81.15
JT_01	L	12.50	18.24	22.46	27.04	33.99	37.48	40.13	47.20	68.12
BT_01	S	2.23	3.25	4.00	4.82	6.05	6.68	7.15	8.41	12.13



6.6 Uncertainty bounds

This table reports the flows derived from the uncertainty analysis detailed in Section 6.3. The ‘true’ value is more likely to be near the estimate reported in Section 6.5 than the bounds. However, it is possible that the ‘true’ value could still lie outside these bounds.

Site code	Flood peak (m^3/s) for the following return periods (in years)											
	2				100				1000			
	68%		95%		68%		95%		68%		95%	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
RO_06	31.47	63.83	22.48	90.81	99.59	210.73	67.84	305.99	164.14	365.02	110.24	546.31
RO_05	30.39	61.64	21.71	87.69	96.17	203.50	65.51	295.49	158.50	352.49	106.46	527.56
RO_04	29.70	60.25	21.21	85.71	94.00	198.90	64.03	288.81	154.92	344.53	104.05	515.63
RO_03	27.77	56.33	19.83	80.13	87.88	185.95	59.86	270.02	144.84	322.11	97.28	482.08
RO_02	22.65	45.95	16.18	65.37	71.69	151.70	48.84	220.28	118.16	262.77	79.36	393.28
RO_01	19.17	38.90	13.70	55.33	60.68	128.40	41.33	186.44	100.01	222.41	67.17	332.87
RO_DS	8.75	17.75	6.25	25.25	27.69	58.60	18.86	85.08	45.64	101.50	30.65	151.91
DU_02	7.81	15.84	5.58	22.53	24.71	52.28	16.83	75.92	40.72	90.57	27.35	135.55
DU_01	6.25	12.68	4.46	18.03	19.78	41.85	13.47	60.77	32.60	72.49	21.89	108.49
WH_01	2.50	5.07	1.79	7.21	8.26	17.48	5.63	25.38	14.74	32.77	9.90	49.05
DS_01	2.83	5.75	2.02	8.18	9.39	19.86	6.39	28.84	16.33	36.32	10.97	54.35
RA_01	2.07	4.20	1.48	5.97	6.84	14.48	4.66	21.02	12.21	27.14	8.20	40.63
JT_01	0.46	0.93	0.33	1.32	1.51	3.20	1.03	4.65	2.70	6.00	1.81	8.99
BT_01	1.09	2.21	0.78	3.14	3.59	7.60	2.45	11.04	6.41	14.26	4.31	21.34

If flood hydrographs are needed for the next stage of the study, where are they provided?	Capita updated River Rother Flood Modeller – TUFLOW hydraulic model, ied version 865

7. Annex

7.1 Pooling group composition

WINFAP v4 Default pooling group Udiam

Station	Distance	Years of Data	QMED AM	L-CV	L-SKEW	Discordancy
40004 (Rother @ Udiam)	0	54	43.411	0.291	0.245	0.755
43006 (Nadder @ Wilton)	0.141	52	14.808	0.224	0.29	0.92
11004 (Urie @ Pitcaple)	0.198	18	21.42	0.306	0.268	0.989
7003 (Lossie @ Sheriffmills)	0.213	61	44.353	0.287	0.228	0.446
21032 (Glen @ Kirknewton)	0.225	44	44.45	0.267	0.236	0.173
52005 (Tone @ Bishops Hull)	0.229	58	44.312	0.191	0.034	1.699
67008 (Alyn @ Pont-y-capel)	0.235	54	21.635	0.153	0.293	2.63
43018 (Allen @ Walford Mill)	0.277	45	6.912	0.243	0.133	1.365
9003 (Isla @ Grange)	0.304	60	53.547	0.237	0.159	0.916
45003 (Culm @ Woodmill)	0.319	57	70.6	0.23	0.17	0.327
21025 (Ale Water @ Ancrum)	0.323	33	51.665	0.214	0.097	1.547
21013 (Gala Water @ Galashiels)	0.333	52	51.252	0.24	0.25	0.234
Total		588				
Weighted Means				0.278	0.211	
H2 Value	0.3666					
Goodness of Fit	**Generalised Logistic**		**Generalised Extreme Value**		**Pearson Type 3**	
	-0.0061		-1.8138		-3.073	

Amended pooling group Udiam – No Changes

WINFAP v4 Default pooling group Darwell Stream

Station	Distance	Years of Data	QMED AM	L-CV	L-SKEW	Discordancy
48007 (Kennal @ Ponsanooth)	0.901	51	4.179	0.193	0.23	0.634
49005 (Bolingey Stream @ Bolingey Cocks Bridge)	0.947	9	5.777	0.271	0.151	3.371
26016 (Gypsey Race @ Kirby Grindalythe)	0.951	22	0.1	0.321	0.266	0.099
44008 (South Winterbourne @ Winterbourne Steepleton)	0.954	40	0.434	0.411	0.337	0.353
27010 (Hodge Beck @ Bransdale Weir)	0.966	41	9.42	0.224	0.293	0.676
25019 (Leven @ Easby)	0.972	41	5.09	0.342	0.386	0.471

7011 (Black Burn @ Pluscarden Abbey)	1.118	7	5.205	0.544	0.571	2.253
73015 (Keer @ High Keer Weir)	1.118	28	12.375	0.204	0.26	0.653
72014 (Conder @ Galgate)	1.141	51	16.646	0.231	0.16	0.186
28058 (Henmore Brook @ Ashbourne)	1.171	13	8.838	0.188	-0.109	2.634
26014 (Water Forlornes @ Driffield)	1.183	21	0.424	0.306	0.147	0.343
41020 (Bevern Stream @ Clappers Bridge)	1.197	50	13.575	0.207	0.182	0.613
47022 (Tory Brook @ Newnham Park)	1.201	25	6.176	0.257	0.191	0.56
36010 (Bumpstead Brook @ Broad Green)	1.207	52	7.395	0.382	0.181	1.16
44013 (Piddle @ Little Puddle)	1.209	27	0.857	0.501	0.295	1.606
48004 (Warleggan @ Trengoffe)	1.26	50	9.957	0.257	0.258	0.387
Total		528				
Weighted Means				0.298	0.235	
H2 Value	2.3424					
Goodness of Fit	**Generalised Logistic**		**Generalised Extreme Value**		**Pearson Type 3**	
	1.9845		0.2717		-1.6809	

Amended pooling group Darwell Stream

Station	Distance	Years of Data	QMED AM	L-CV	L-SKEW	Discordancy
48007 (Kennal @ Ponsanooth)	0.901	51	4.179	0.193	0.23	0.732
26016 (Gypsey Race @ Kirby Grindalythe)	0.951	22	0.1	0.321	0.266	0.186
44008 (South Winterbourne @ Winterbourne Steepleton)	0.954	40	0.434	0.411	0.337	1.638
27010 (Hodge Beck @ Bransdale Weir)	0.966	41	9.42	0.224	0.293	0.475
25019 (Leven @ Easby)	0.972	41	5.09	0.342	0.386	1.533
73015 (Keer @ High Keer Weir)	1.118	28	12.375	0.204	0.26	0.46
72014 (Conder @ Galgate)	1.141	51	16.646	0.231	0.16	0.535
26014 (Water Forlornes @ Driffield)	1.183	21	0.424	0.306	0.147	1.187
41020 (Bevern Stream @ Clappers Bridge)	1.197	50	13.575	0.207	0.182	0.86
47022 (Tory Brook @ Newnham Park)	1.201	25	6.176	0.257	0.191	1.627
36010 (Bumpstead Brook @ Broad Green)	1.207	52	7.395	0.382	0.181	2.192
48004 (Warleggan @ Trengoffe)	1.26	50	9.957	0.257	0.258	0.208
28041 (Hamps @ Waterhouses)	1.295	34	26.313	0.219	0.288	1.368
Total		506				
Weighted Means				0.274	0.245	
H2 Value	0.5326					
Goodness of Fit	**Generalised Logistic**		**Generalised Extreme Value**		**Pearson Type 3**	

	0.5271	-0.9199	-2.6866

WINFAP v4 Default pooling group Small Tributaries

Station	Distance	Years of Data	QMED AM	L-CV	L-SKEW	Discordancy
27051 (Crimple @ Burn Bridge)	0.506	47	4.524	0.218	0.156	0.458
25019 (Leven @ Easby)	0.68	41	5.09	0.342	0.386	0.83
26016 (Gypsey Race @ Kirby Grindalythe)	0.735	22	0.1	0.321	0.266	0.584
49005 (Bolingey Stream @ Bolingey Cocks Bridge)	0.82	9	5.777	0.271	0.151	2.761
45816 (Haddeo @ Upton)	0.96	26	3.456	0.3	0.406	0.641
27010 (Hodge Beck @ Bransdale Weir)	1.031	41	9.42	0.224	0.293	0.165
28033 (Dove @ Hollinsclough)	1.042	44	4.177	0.228	0.371	0.684
47022 (Tory Brook @ Newnham Park)	1.072	25	6.176	0.257	0.191	0.547
44008 (South Winterbourne @ Winterbourne Steepleton)	1.107	40	0.434	0.411	0.337	2.051
25011 (Langdon Beck @ Langdon)	1.163	33	15.647	0.232	0.328	0.764
206006 (Annalong @ Recorder)	1.439	48	15.33	0.189	0.052	2.832
27032 (Hebden Beck @ Hebden)	1.528	53	4.052	0.204	0.237	0.404
25003 (Trout Beck @ Moor House)	1.558	46	15.142	0.168	0.29	0.866
71003 (Croasdale Beck @ Croasdale Flume)	1.56	37	10.9	0.212	0.323	0.413
Total		512				
Weighted Means				0.257	0.273	
H2 Value	1.2798					
Goodness of Fit	**Generalised Logistic**		**Generalised Extreme Value**		**Pearson Type 3**	
	0.3425		-0.8416		-2.7658	

Amended pooling group Small Tributaries

Station	Distance	Years of Data	QMED AM	L-CV	L-SKEW	Discordancy
27051 (Crimple @ Burn Bridge)	0.506	47	4.524	0.218	0.156	0.656
25019 (Leven @ Easby)	0.68	41	5.09	0.342	0.386	0.911
26016 (Gypsey Race @ Kirby Grindalythe)	0.735	22	0.1	0.321	0.266	0.57
45816 (Haddeo @ Upton)	0.96	26	3.456	0.3	0.406	0.9
27010 (Hodge Beck @ Bransdale Weir)	1.031	41	9.42	0.224	0.293	0.249
28033 (Dove @ Hollinsclough)	1.042	44	4.177	0.228	0.371	1.12
44008 (South Winterbourne @ Winterbourne Steepleton)	1.107	40	0.434	0.411	0.337	1.953
27032 (Hebden Beck @ Hebden)	1.528	53	4.052	0.204	0.237	0.882
72014 (Conder @ Galgate)	1.663	51	16.646	0.231	0.16	0.556

73015 (Keer @ High Keer Weir)	1.675	28	12.375	0.204	0.26	0.283
26014 (Water Forlornes @ Driffield)	1.72	21	0.424	0.306	0.147	1.713
41020 (Bevern Stream @ Clappers Bridge)	1.81	50	13.575	0.207	0.182	1.051
72007 (Brock @ Upstream of a6)	1.847	41	28.011	0.198	0.229	0.924
Total		505				
Weighted Means				0.264	0.263	
H2 Value	0.9971					
Goodness of Fit	**Generalised Logistic**		**Generalised Extreme Value**		**Pearson Type 3**	
	0.4474		-0.7811		-2.5536	

7.2 Flood History

Date	**Description and Source**
1946, 1960, 1979,1985, 1999, 2001	Fluvial - Insufficient storage capacity. Very intense rainfall on an already wet soil leading to rapid runoff. Recent development in the floodplains, debris in the river channel.
1993	Fluvial - Intense rainfall, properties flooded by sewage contaminated water.
12th October 2000 (greater than 1% event) 31st October 2000 5th November 2000	Fluvial - Very intense rainfall on an already wet soil leading to rapid runoff. Recent development in the floodplains, debris in the river channel, backing up from road drains and surcharging of combined sewerage system (indirect source), backing up behind culverts and bridges, overtopping of low flood embankment, back up of floodwater from the floodplains, reduced storage capacity due to repeat events.
20th December 2019	Fluvial – heavy rainfall caused the River Rother to burst its banks.
February 2020	Fluvial – heavy rainfall caused the River Rother to burst its banks.

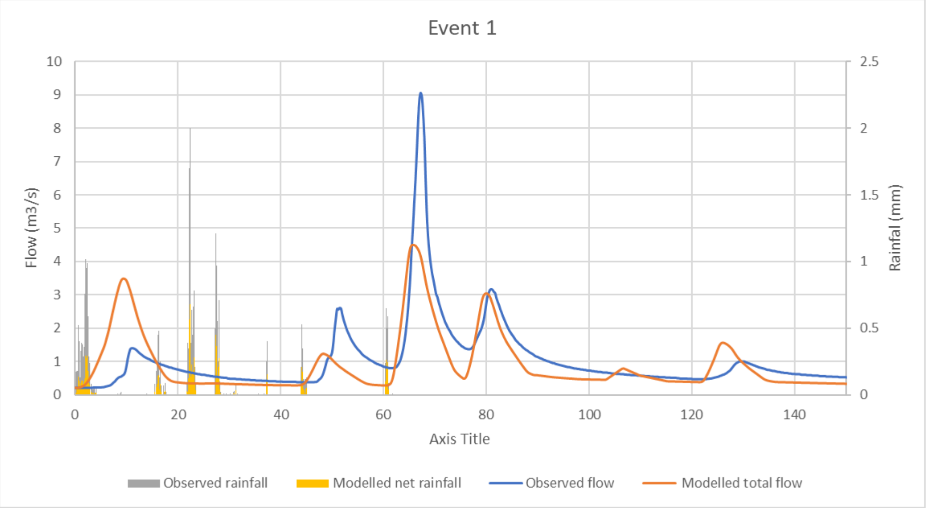
7.3 ReFH2 Calibration Events List

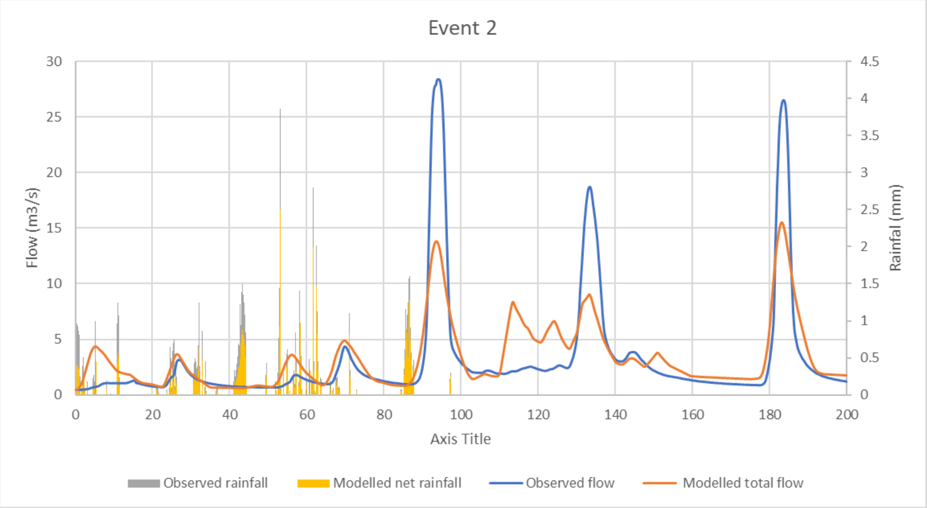
Burwash Events

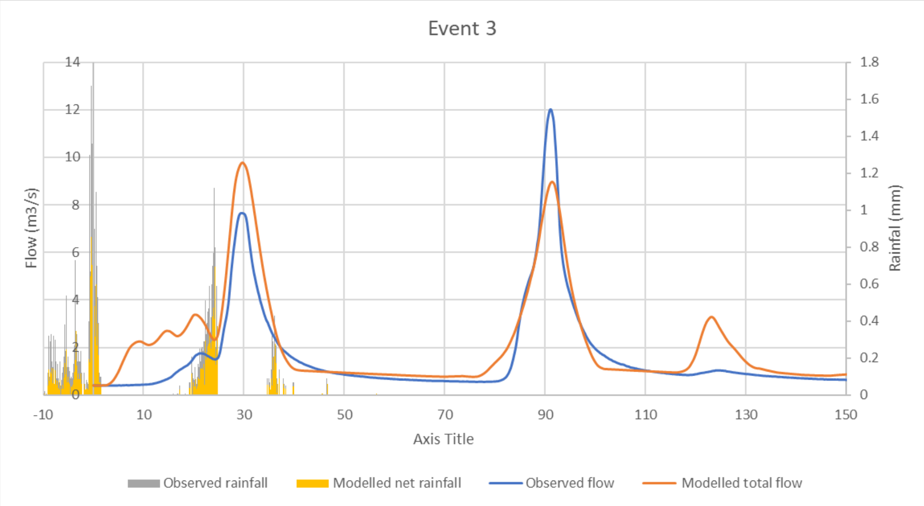
Event Number	**Time stamp**	**Flow (m^3/s)**	**Type**	**Comments**
1	17/11/2015 04:45	9.056	POT	
2	03/01/2016 17:45	28.404	AMAX	
3	30/01/2016 06:45	12.005	POT	
4	09/03/2016 08:45	17.027	POT	

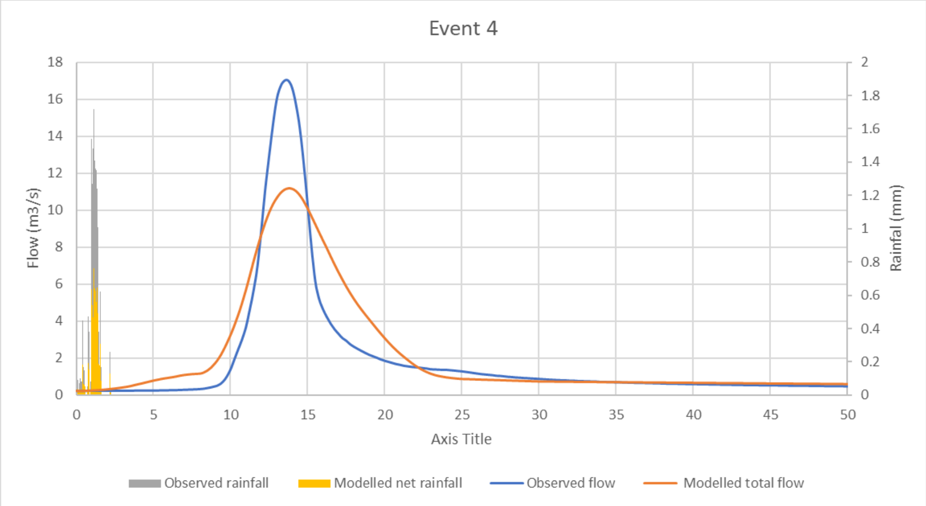
-	28/03/2016 03:15	6.884	POT	Not used – significant missing rainfall
5	12/01/2017 21:30	14.505	AMAX	
6	02/12/2018 05:30	7.647	POT	
7	20/12/2018 01:00	8.728	AMAX	

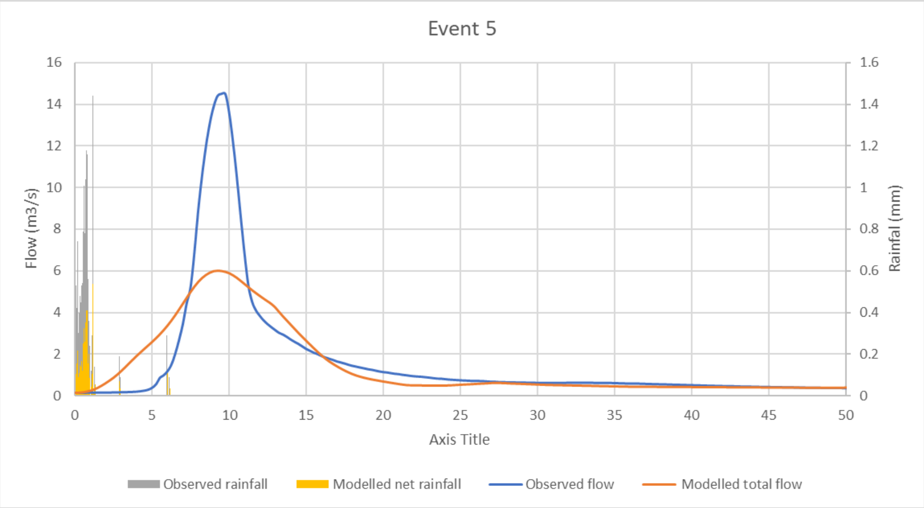
Burwash ReFH2 Calibration Plots

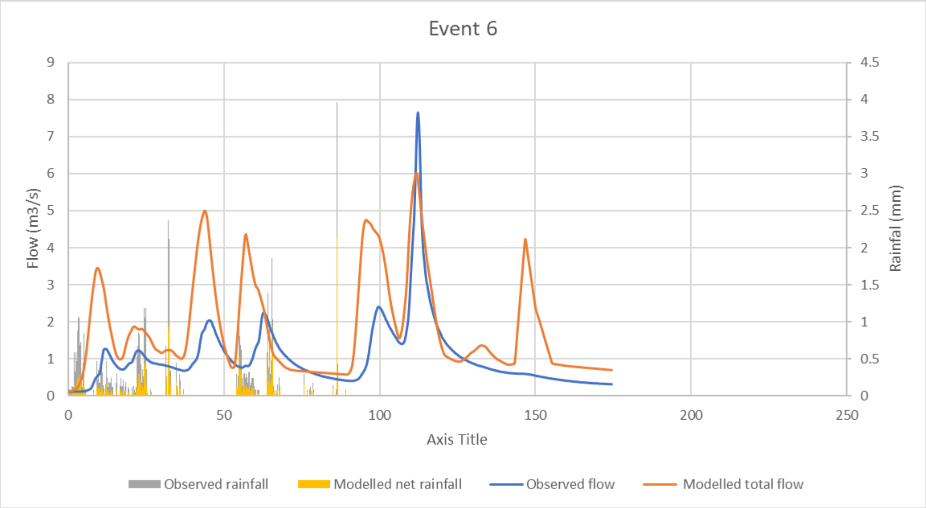


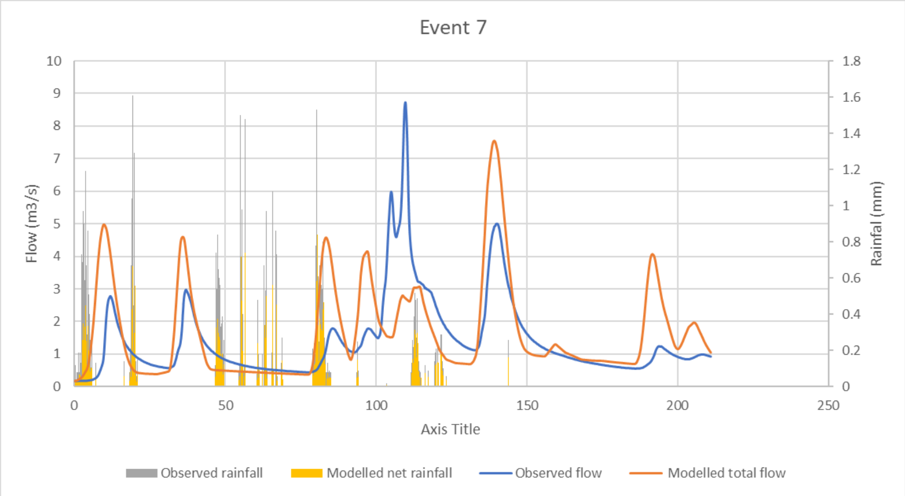



Event 3
Flow (m3/s)
Rainfall (mm)
Axis Title
Observed rainfall
Modelled net rainfall
Observed flow
Modelled total flow


Event 4
Flow (m3/s)
Rainfall (mm)
Axis Title
Observed rainfall
Modelled net rainfall
Observed flow
Modelled total flow


Event 5
Flow (m3/s)
Rainfall (mm)
Axis Title
Observed rainfall
Modelled net rainfall
Observed flow
Modelled total flow

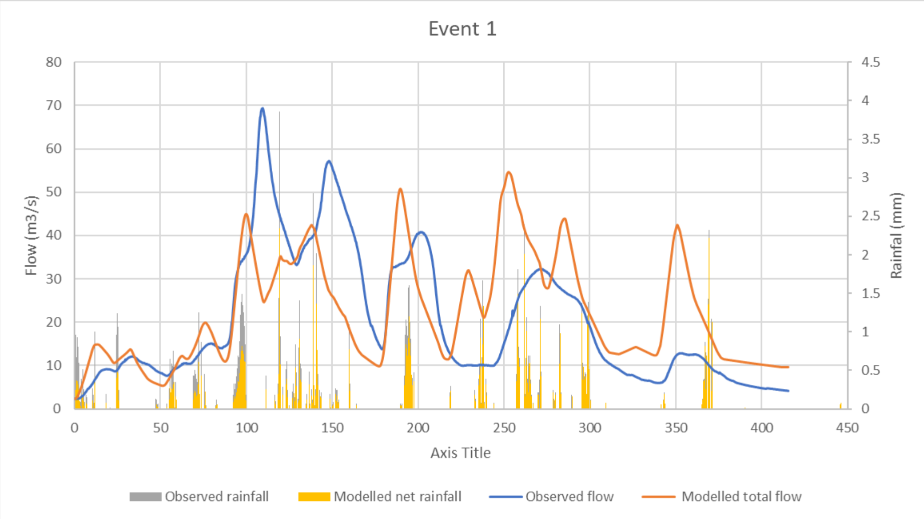

Event 6
Flow (m3/s)
Rainfall (mm)
Axis Title
Observed rainfall
Modelled net rainfall
Observed flow
Modelled total flow

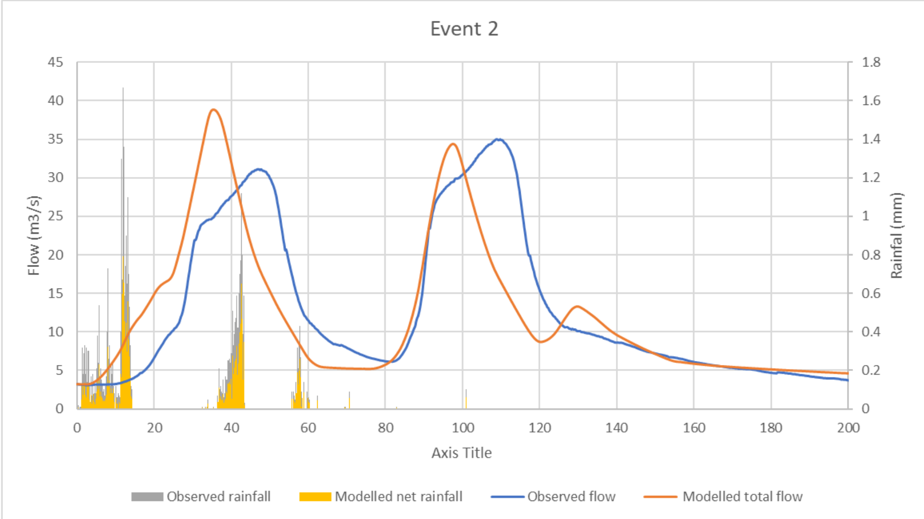


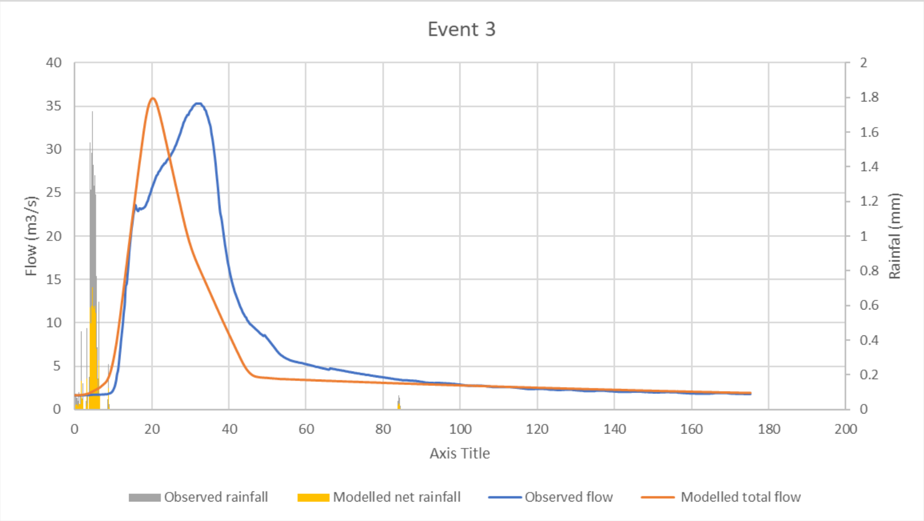
Udiam Events

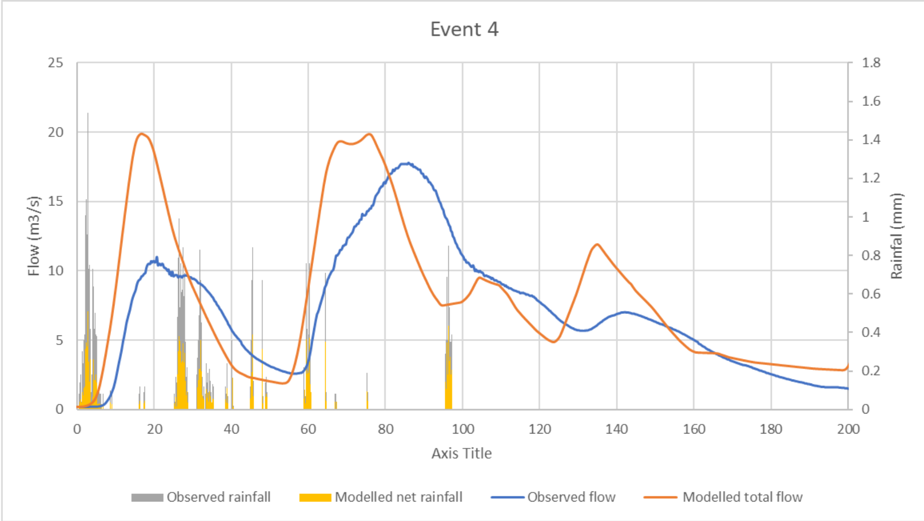
Event Number	Time stamp	Flow (m^3/s)	Type	Comments
1	04/01/2016 09:15	69.385	AMAX	
2	31/01/2016 01:15	34.988	POT	
3	10/03/2016 02:45	35.346	POT	
-	28/03/2016 17:15	25.007	POT	Not used – significant missing rainfall
4	02/02/2017 03:30	17.768	AMAX	suspect rainfall
-	01/01/2018 12:00	24.427	AMAX	Suspect rainfall data unchecked for quality
5	31/03/2018 09:15	22.138	POT	
6	20/12/2018 21:15	26.718	AMAX	
7	20/12/2019 19:30	111.000	AMAX	

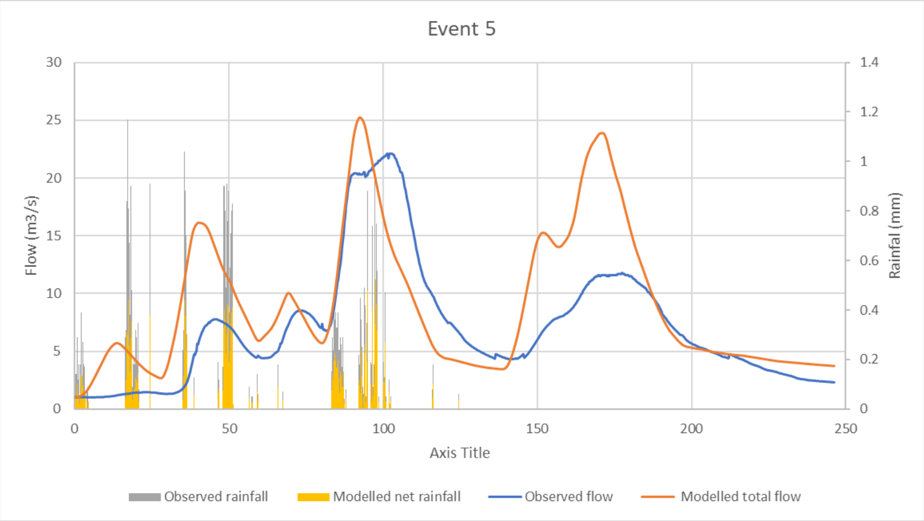
Udiam ReFH2 Calibration Plots

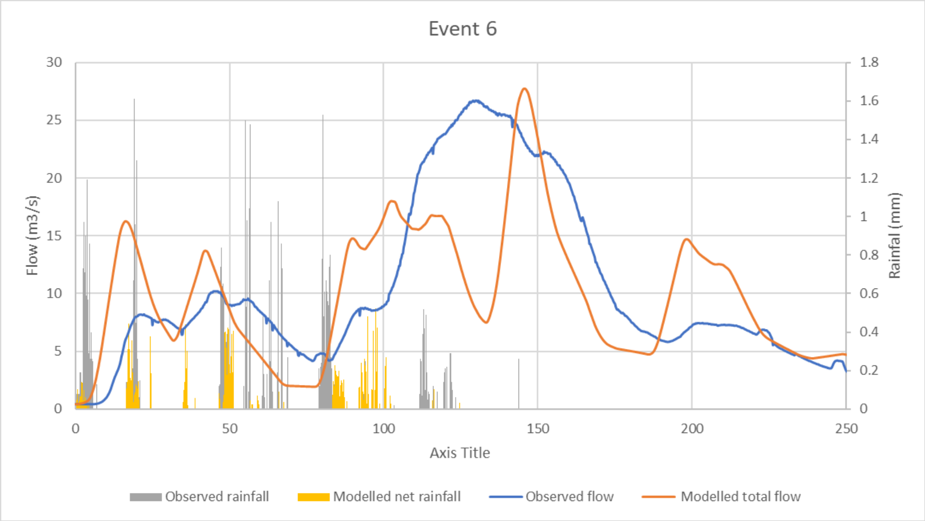

Event 1
Flow (m3/s)
Rainfall (mm)
Axis Title
Observed rainfall
Modelled net rainfall
Observed flow
Modelled total flow

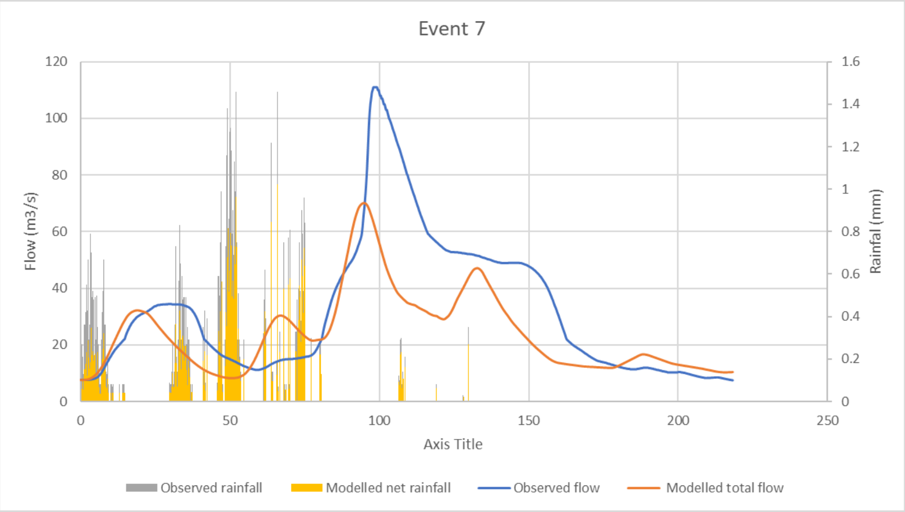

Event 2
Flow (m3/s)
Rainfall (mm)
Axis Title
Observed rainfall
Modelled net rainfall
Observed flow
Modelled total flow


Event 3
Flow (m3/s)
Rainfall (mm)
Axis Title
Observed rainfall
Modelled net rainfall
Observed flow
Modelled total flow

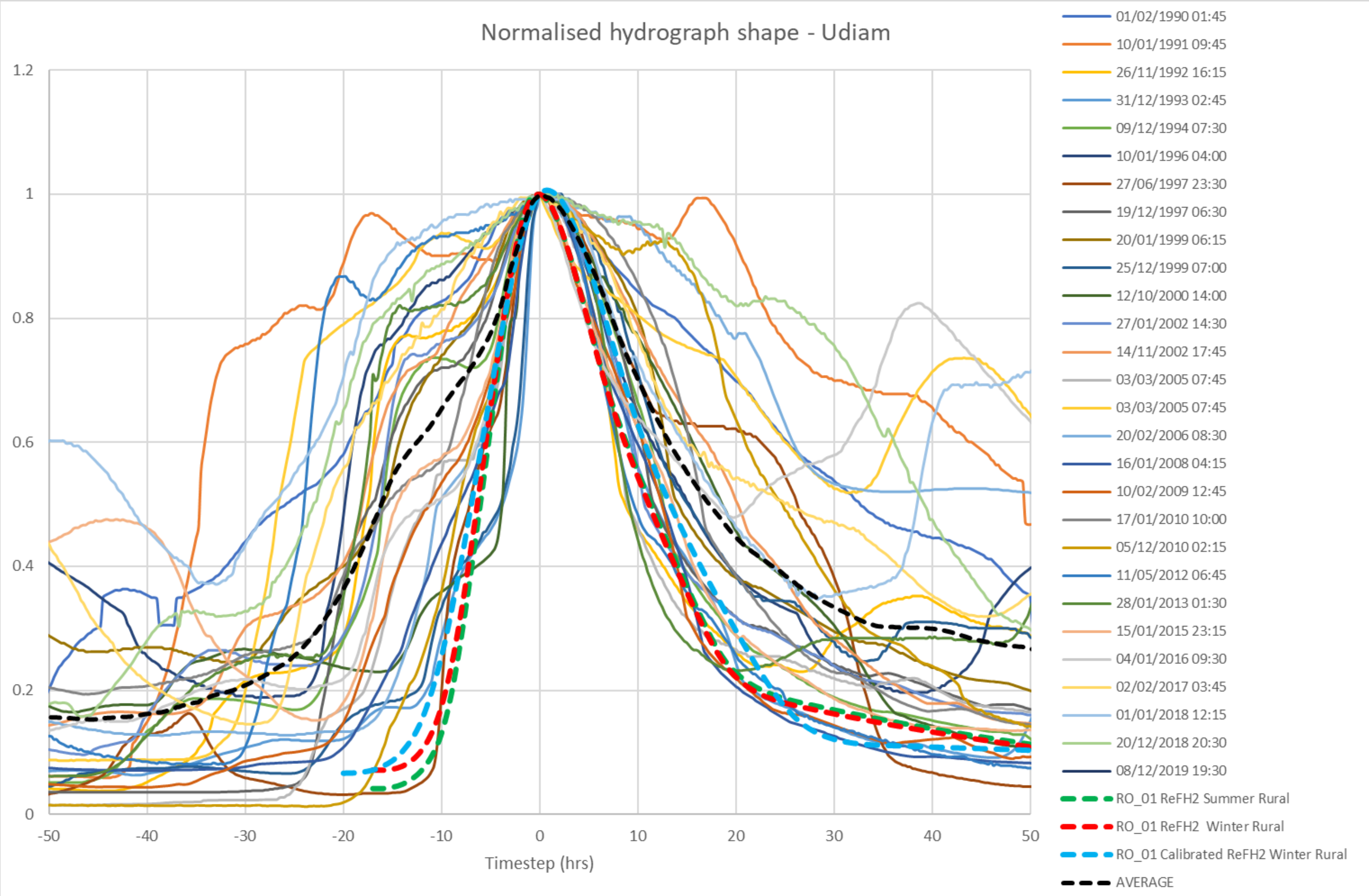

Event 4
Flow (m3/s)
Rainfall (mm)
Axis Title
Observed rainfall
Modelled net rainfall
Observed flow
Modelled total flow


Event 5
Flow (m3/s)
Rainfall (mm)
Axis Title
Observed rainfall
Modelled net rainfall
Observed flow
Modelled total flow


Event 6
Flow (m3/s)
Rainfall (mm)
Axis Title
Observed rainfall
Modelled net rainfall
Observed flow
Modelled total flow


Event 7
Flow (m3/s)
Rainfall (mm)
Axis Title
Observed rainfall
Modelled net rainfall
Observed flow
Modelled total flow

7.4 Averaged hydrograph shape plot



7.5 100 year inflow hydrographs

Timestep	RO_06	RO_05	RO_04	DU_02	DU_01	WH_01	DS_01	RA_01	JT_01	BT_01
0.00	2.05	2.64	0.93	1.02	0.26	0.37	0.71	0.29	0.06	0.14
0.50	2.05	2.64	0.93	1.03	0.26	0.38	0.71	0.30	0.06	0.15
1.00	2.06	2.65	0.93	1.06	0.27	0.40	0.72	0.32	0.07	0.16
1.50	2.09	2.67	0.94	1.11	0.28	0.43	0.73	0.36	0.10	0.19
2.00	2.13	2.71	0.95	1.19	0.29	0.49	0.75	0.41	0.12	0.24
2.50	2.19	2.76	0.96	1.30	0.30	0.56	0.78	0.48	0.15	0.29
3.00	2.27	2.83	0.98	1.44	0.33	0.65	0.81	0.57	0.17	0.34
3.50	2.37	2.91	1.00	1.61	0.35	0.74	0.85	0.65	0.19	0.39
4.00	2.49	3.01	1.03	1.81	0.39	0.84	0.90	0.72	0.20	0.43
4.50	2.64	3.14	1.06	2.01	0.43	0.93	0.97	0.80	0.22	0.47
5.00	2.81	3.28	1.10	2.22	0.47	1.03	1.04	0.88	0.24	0.52
5.50	3.01	3.45	1.15	2.43	0.52	1.12	1.12	0.96	0.25	0.56
6.00	3.24	3.65	1.21	2.65	0.57	1.22	1.21	1.04	0.27	0.61
6.50	3.50	3.88	1.27	2.88	0.62	1.32	1.30	1.13	0.29	0.65
7.00	3.76	4.13	1.34	3.12	0.68	1.43	1.40	1.22	0.31	0.70
7.50	4.05	4.43	1.42	3.36	0.73	1.55	1.50	1.31	0.33	0.75
8.00	4.35	4.74	1.51	3.63	0.79	1.66	1.61	1.41	0.36	0.80
8.50	4.67	5.08	1.61	3.91	0.86	1.79	1.73	1.51	0.38	0.86
9.00	5.02	5.44	1.72	4.21	0.93	1.92	1.85	1.62	0.41	0.92
9.50	5.38	5.82	1.84	4.53	1.00	2.07	1.98	1.74	0.44	0.99
10.00	5.77	6.24	1.97	4.87	1.08	2.22	2.12	1.87	0.48	1.07
10.50	6.19	6.68	2.10	5.24	1.16	2.38	2.27	2.01	0.51	1.15
11.00	6.64	7.16	2.25	5.64	1.25	2.56	2.43	2.17	0.55	1.23
11.50	7.12	7.67	2.40	6.07	1.35	2.76	2.60	2.34	0.60	1.33
12.00	7.64	8.22	2.57	6.53	1.45	2.97	2.79	2.52	0.65	1.44
12.50	8.19	8.81	2.75	7.03	1.56	3.20	2.99	2.72	0.70	1.55

13.00	8.79	9.45	2.95	7.57	1.68	3.45	3.21	2.94	0.76	1.67
13.50	9.44	10.14	3.16	8.16	1.82	3.73	3.44	3.18	0.82	1.81
14.00	10.14	10.88	3.39	8.81	1.96	4.03	3.69	3.44	0.89	1.96
14.50	10.90	11.68	3.64	9.51	2.12	4.35	3.97	3.73	0.96	2.12
15.00	11.72	12.55	3.91	10.28	2.28	4.71	4.27	4.04	1.05	2.30
15.50	12.61	13.48	4.20	11.12	2.47	5.11	4.59	4.38	1.13	2.49
16.00	13.58	14.50	4.52	12.03	2.67	5.54	4.95	4.75	1.23	2.71
16.50	14.63	15.60	4.86	13.03	2.89	6.01	5.33	5.16	1.34	2.93
17.00	15.77	16.79	5.22	14.12	3.13	6.52	5.75	5.60	1.45	3.19
17.50	17.01	18.08	5.62	15.31	3.39	7.08	6.21	6.09	1.58	3.46
18.00	18.35	19.48	6.05	16.61	3.68	7.69	6.70	6.62	1.71	3.75
18.50	19.80	20.99	6.52	18.01	3.98	8.33	7.24	7.18	1.85	4.06
19.00	21.36	22.61	7.02	19.49	4.31	8.99	7.81	7.75	1.98	4.36
19.50	23.00	24.33	7.55	21.02	4.65	9.65	8.41	8.32	2.08	4.65
20.00	24.71	26.12	8.10	22.54	5.00	10.28	9.03	8.83	2.16	4.89
20.50	26.46	27.97	8.68	24.00	5.34	10.85	9.66	9.27	2.19	5.07
21.00	28.22	29.86	9.27	25.33	5.68	11.31	10.28	9.60	2.19	5.18
21.50	29.96	31.77	9.88	26.48	6.00	11.66	10.89	9.81	2.15	5.21
22.00	31.66	33.68	10.48	27.40	6.29	11.88	11.46	9.91	2.10	5.17
22.50	33.29	35.56	11.09	28.07	6.55	11.97	11.98	9.91	2.02	5.08
23.00	34.80	37.40	11.69	28.49	6.77	11.95	12.45	9.83	1.94	4.95
23.50	36.17	39.16	12.27	28.66	6.93	11.83	12.84	9.67	1.85	4.77
24.00	37.36	40.82	12.83	28.63	7.05	11.63	13.15	9.45	1.76	4.58
24.50	38.34	42.36	13.37	28.42	7.12	11.35	13.38	9.18	1.66	4.37
25.00	39.11	43.73	13.87	28.05	7.15	11.02	13.53	8.86	1.58	4.15
25.50	39.66	44.92	14.33	27.55	7.13	10.65	13.60	8.52	1.49	3.93
26.00	40.00	45.91	14.74	26.94	7.09	10.25	13.60	8.17	1.41	3.71
26.50	40.13	46.69	15.09	26.23	7.00	9.82	13.54	7.81	1.33	3.49
27.00	40.09	47.26	15.39	25.45	6.89	9.38	13.43	7.45	1.26	3.27

27.50	39.88	47.63	15.62	24.59	6.76	8.94	13.26	7.10	1.19	3.07
28.00	39.51	47.81	15.79	23.67	6.61	8.50	13.05	6.76	1.12	2.89
28.50	39.01	47.81	15.90	22.72	6.44	8.06	12.81	6.43	1.06	2.71
29.00	38.39	47.65	15.96	21.73	6.25	7.64	12.54	6.11	1.00	2.54
29.50	37.68	47.33	15.96	20.73	6.05	7.24	12.24	5.81	0.94	2.39
30.00	36.88	46.88	15.91	19.74	5.84	6.85	11.92	5.53	0.89	2.23
30.50	36.02	46.30	15.83	18.77	5.63	6.48	11.58	5.26	0.84	2.09
31.00	35.10	45.61	15.70	17.83	5.41	6.14	11.22	5.00	0.80	1.96
31.50	34.14	44.83	15.53	16.93	5.18	5.81	10.85	4.77	0.75	1.84
32.00	33.15	43.96	15.33	16.08	4.95	5.50	10.47	4.54	0.71	1.73
32.50	32.12	43.03	15.10	15.27	4.73	5.22	10.09	4.33	0.68	1.62
33.00	31.07	42.04	14.85	14.51	4.51	4.95	9.69	4.13	0.64	1.52
33.50	30.00	41.00	14.57	13.80	4.29	4.70	9.30	3.95	0.61	1.43
34.00	28.92	39.93	14.28	13.12	4.07	4.46	8.90	3.77	0.58	1.34
34.50	27.83	38.83	13.97	12.48	3.87	4.24	8.50	3.60	0.55	1.26
35.00	26.73	37.71	13.65	11.87	3.67	4.03	8.12	3.45	0.52	1.19
35.50	25.62	36.57	13.31	11.30	3.48	3.83	7.74	3.31	0.50	1.12
36.00	24.52	35.42	12.98	10.77	3.30	3.64	7.37	3.17	0.48	1.06
36.50	23.43	34.26	12.63	10.27	3.13	3.47	7.01	3.05	0.46	1.00
37.00	22.34	33.09	12.28	9.78	2.97	3.30	6.67	2.92	0.43	0.94
37.50	21.25	31.90	11.92	9.30	2.81	3.12	6.33	2.78	0.39	0.87
38.00	20.17	30.70	11.55	8.81	2.66	2.93	6.01	2.63	0.35	0.78
38.50	19.10	29.49	11.18	8.33	2.51	2.73	5.70	2.46	0.30	0.69
39.00	18.05	28.27	10.80	7.84	2.36	2.53	5.40	2.28	0.27	0.60
39.50	17.02	27.04	10.42	7.35	2.22	2.32	5.11	2.11	0.25	0.53
40.00	16.03	25.82	10.04	6.87	2.09	2.14	4.82	1.97	0.23	0.47
40.50	15.08	24.60	9.66	6.41	1.95	1.98	4.55	1.86	0.22	0.42
41.00	14.16	23.40	9.27	6.00	1.83	1.84	4.29	1.76	0.21	0.39
41.50	13.28	22.20	8.89	5.64	1.70	1.73	4.04	1.69	0.20	0.36

42.00	12.44	21.02	8.50	5.32	1.59	1.63	3.80	1.62	0.20	0.33
42.50	11.64	19.86	8.12	5.05	1.49	1.56	3.57	1.57	0.20	0.32
43.00	10.89	18.72	7.75	4.81	1.41	1.49	3.37	1.52	0.20	0.31
43.50	10.20	17.61	7.37	4.61	1.33	1.43	3.19	1.49	0.20	0.30
44.00	9.57	16.53	7.00	4.44	1.25	1.39	3.02	1.46	0.20	0.29
44.50	8.99	15.50	6.64	4.29	1.19	1.35	2.87	1.44	0.19	0.29
45.00	8.47	14.54	6.28	4.16	1.13	1.32	2.74	1.43	0.19	0.29
45.50	7.99	13.65	5.93	4.04	1.09	1.30	2.62	1.42	0.19	0.29
46.00	7.55	12.82	5.60	3.94	1.04	1.28	2.51	1.41	0.19	0.29
46.50	7.16	12.06	5.29	3.86	1.00	1.27	2.42	1.40	0.19	0.28
47.00	6.81	11.35	4.99	3.79	0.97	1.26	2.33	1.39	0.19	0.28
47.50	6.49	10.70	4.71	3.73	0.94	1.26	2.26	1.38	0.18	0.28
48.00	6.20	10.10	4.44	3.68	0.91	1.25	2.19	1.38	0.18	0.28
48.50	5.95	9.55	4.20	3.65	0.89	1.24	2.13	1.37	0.18	0.27
49.00	5.72	9.05	3.97	3.62	0.87	1.23	2.07	1.36	0.18	0.27
49.50	5.51	8.59	3.75	3.61	0.85	1.23	2.03	1.35	0.18	0.27
50.00	5.32	8.17	3.56	3.59	0.83	1.22	1.98	1.34	0.18	0.27

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