Flood estimation report

(FEH Calculation Record)

Introduction

This report template is based on a supporting document to the Environment Agency's flood estimation guidelines (Version 5, 2015). It provides a record of the hydrological context, the method statement, the calculations and decisions made during flood estimation and the results.

Contents

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Abbreviations

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

1 Method statement

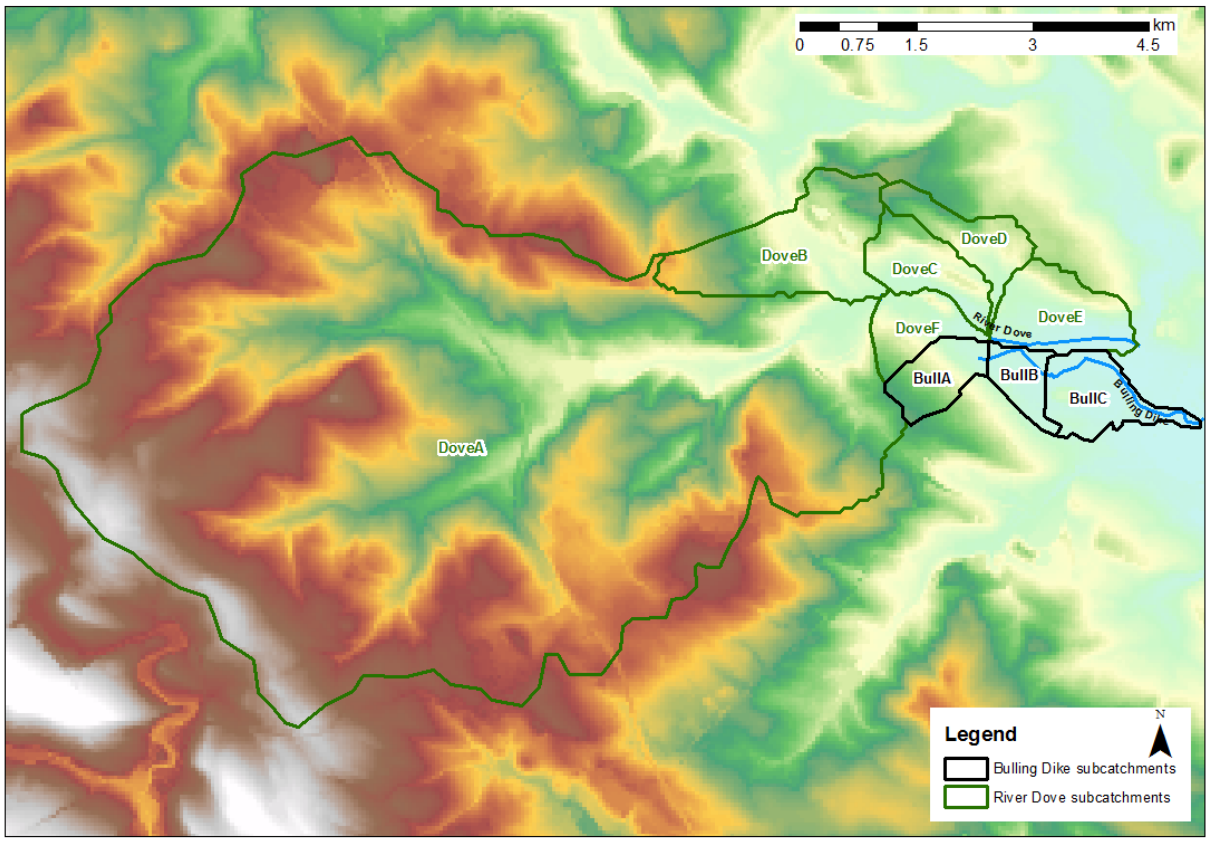
1.1 Requirements for flood estimates

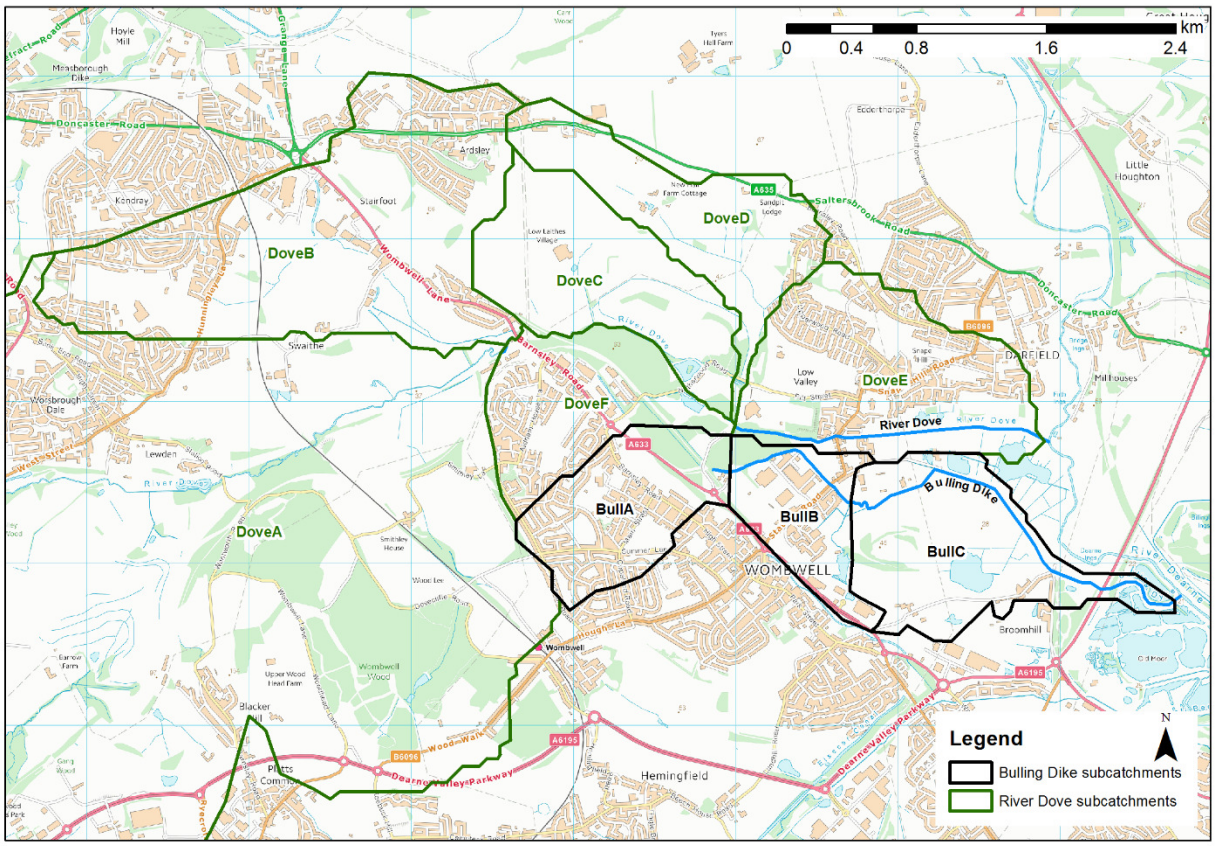
Item	Comments
Overview • Purpose of study • Peak flows or hydrographs? • Range of return periods and locations	This study is a reanalysis of the Bulling Dike hydrological estimates for the Wombwell Wetlands Extension Scheme. In 2015, hydrological estimates calculated during earlier studies were updated using the FEH Statistical Method, applying revised technical procedures in accordance with standard practice adopted in the industry. An independent review of the updated estimates made recommendations for revision of the estimates to more specifically address the influence of urban areas within the study catchment. This study implements those recommendations with calculations based on the Urban ReFH Method only. It includes the following elements: • Re-conceptualisation of the system including natural and artificial storage capacities and urban drainage issues. • Subcatchment schematisation with consideration of the Yorkshire Water sewer network data. • Application of the Urban ReFH Method to the River Dove and Bulling Dike. • Review of ReFH results, comparison of design event magnitudes across different estimation points. • Calculation of design flow hydrographs for each subcatchment • Calculation of design flows for multiple storm durations. In the next stage of the Wetlands Extension Scheme, revised design flow hydrographs will be incorporated into the hydraulic model. Various model simulations will be completed to determine the critical storm duration for the study catchments and comparisons will be made at various points along the watercourse and with results from previous studies. The hydraulic model will then be used to demonstrate absolute risk and benefit of the proposed wetlands extension. Design flow hydrographs have been calculated for a range of return periods; 2yr, 5yr, 10yr, 25yr, 50yr, 75yr, 100yr, 100yr plus a climate change allowance (100yr+cc), 200yr & 1000yr.
	The study area has been divided into subcatchments following careful consideration of the Yorkshire Water sewer network data, in conjunction with defined subcatchment boundaries on the FEH CD-ROM v3.0[1]. It was decided that a series of point inflows would be used to represent lateral catchments rather than treating lateral inflows as differences between up and downstream points. Flood estimates have therefore been derived for each of these point inflows, summarised below. There is an upstream inflow on each of the study watercourses, located where the hydraulic model begins; on the River Dove, DoveA and on the Bulling Dike, BullA. On the River Dove a further five point inflows have been calculated corresponding to each subcatchment (DoveB to DoveF). On the Bulling Dike there are a further two estimates (BullB and BullC). The location of the model inflows will be considered in the modelling phase of the study, but it is envisaged that these will be located either where the surface water component of the sewer network joins the watercourse or at tributary inflow points, depending on the nature of the subcatchment.

[1] FEH CD-ROM v3.0 © NERC (CEH). © Crown copyright. © AA. 2009. All rights reserved.

1.2 The catchment

Item	Comments
Map	





Description Include topography, climate, geology, soils, land use and any unusual features that may affect the flood hydrology.	The following gives an overview of the study catchments. The River Dove is a relatively small (56.46km^2), ungauged catchment. It is not particularly permeable (BFIHOST 0.543), and is partially urbanised (URBEXT$_{2000}$ 0.083). Bulling Dike is a very small (2.69km^2), highly urbanised (0.2374), ungauged catchment, with a slightly lower permeability than the River Dove, (BFIHOST 0.421). The bedrock geology of these two catchments is primarily carboniferous coal measures. The catchments have a relatively dry climate, indicated by SAAR values ranging from 640 to 725 and are relatively shallow, indicated by the DPSBAR range (28.4 to 74.6). There are significant artificial influences on the study watercourses. The Wombwell Ings washlands are located at the downstream end of the study catchments near to where the rivers discharge into the River Dearne. The washlands have been artificially created to provide flood storage when the River Dearne water levels are too high to accept further inflows. There are also a number of lakes in the vicinity of the model extent. The artificial influences in these catchments make flood estimation uncertain, and careful consideration of the appropriate method is required.

1.3 Other data available

Hydrological estimates have been calculated using various alternative methods during several previous studies looking at this catchment. Due to the differences in the approach taken to estimating flows on the study watercourses it is not straightforward to make comparisons between this and previous studies. This study calculates flow hydrographs for subcatchments along the watercourse rather than lumped estimates at successive points along the watercourse. In addition to this critical duration has not yet been determined. In the next stage of the study, model results will be compared at points across the catchment and with previous studies.

1.4 Hydrological understanding of catchment

All catchments	
Outline the conceptual model, addressing questions such as: • Where are the main sites of interest? • What is likely to cause flooding at those locations? (peak flows, flood volumes, combinations of peaks, groundwater, snowmelt, tides…) • Might those locations flood from runoff generated on part of the catchment only, e.g. downstream of a reservoir? • Is there a need to consider temporary debris dams that could collapse?	The area of interest for this study is the site of the proposed wetland extension in the Wombwell Ings washland, located near the downstream end of the River Dove and Bulling Dike close to the River Dearne confluences. The aim of the study is to demonstrate absolute risk and benefit for the proposed wetland extension scheme. The likely cause of flooding along these rivers is a combination of peak flows and flood volumes once the volume of the washlands is exceeded during a flood event.
Any unusual catchment features to take into account? e.g. • highly permeable – avoid ReFH if BFIHOST>0.65, consider permeable catchment adjustment for statistical method if SPRHOST<20% • highly urbanised – seek local flow data; consider method that can account for differing sewer and topographic catchments • pumped watercourse – consider lowland catchment version of rainfall-runoff method • major reservoir influence (FARL<0.90) – consider flood routing, extensive floodplain storage – consider choice of method carefully	The study catchments are urbanised. There is significant reservoir influence, with a number of lakes in the catchments of the modelled reaches. The modelled reaches have significant artificial influences.

1.5 Initial choice of approach

Is FEH appropriate? (it may not be for extremely heavily urbanised or complex catchments) If not, describe other methods to be used.	Yes.
Initial choice of method(s) and reasons How will hydrograph shapes be derived if needed? Will the catchment be split into sub-catchments? If so, how?	The Urban ReFH Method is the only method considered for this study as previous calculations have looked at alternatives. The Urban ReFH Method is deemed most suitable for reflecting the urban influence in the study catchments. The catchment has been split into subcatchments with consideration of the sewer network and FEH subcatchments.
Software to be used (with version numbers)	FEH CD-ROM v3.0[1] ISIS v3.7 (for implementation of the Urban ReFH Method)

2 Locations where flood estimates required

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

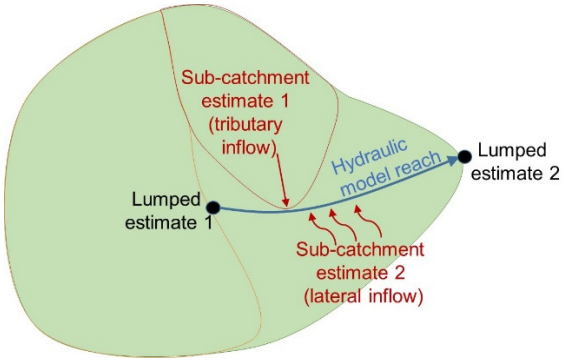
2.1 Summary of subject sites

Site code	Type of estimate L: lumped catchment S: Sub-catchment	Watercourse	Name or description of site	Easting	Northing	AREA on FEH CD-ROM (km^2)	Revised AREA if altered
BullA	S	Bulling Dike	Littlefield Lane, Wombwell	440100	403600	0.88	-
BullB	S	Bulling Dike	D/s of Cotterdale Gardens off B6096 Station Road, Wombwell	440100	403600	0.88	0.61
BullC	S	Bulling Dike	River Dearne confluence	442800	402650	2.69	1.24
DoveA	S	River Dove	Aldham Bridge, u/s of A633 Wombwell Lane.	438550	404300	48.78	50.51
DoveB	S	River Dove	Tributary joining River Dove at Aldham Bridge	438550	404400	2.75	2.98
DoveC	S	River Dove	Rural area north-east of A633 including Low Laithes	439900	404100	1.10	1.26
DoveD	S	River Dove	Tributary draining rural area west of Darfield north to A635	439900	404100	1.10	-
DoveE	S	River Dove	Urban area of Darfield to R.Dearne confluence	439900	404100	1.10	1.60
DoveF	S	River Dove	North-western part of Wombwell, off A633 Barnsley Road	438550	404400	2.75	0.96

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.



2.2 Important catchment descriptors at each subject site (incorporating any changes made)

Site code	FARL	PROPWET	BFIHOST	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	URBEXT 1990	FPEXT
BullA	1.000	0.32	0.321	0.95	49.7	622	0.386	0.0886
BullB	1.000	0.32	0.321	0.95	49.7	622	0.386	0.0886
BullC	0.904	0.32	0.421	3.00	28.4	614	0.204	0.2551
DoveA	0.927	0.32	0.537	7.46	75.7	724	0.059	0.0247
DoveB	1.000	0.32	0.526	1.90	55.6	637	0.198	0.0373
DoveC	1.000	0.32	0.769	1.52	55.8	622	0.054	0.0567
DoveD	1.000	0.32	0.769	1.52	55.8	622	0.054	0.0567
DoveE	1.000	0.32	0.769	1.52	55.8	622	0.054	0.0567
DoveF	1.000	0.32	0.526	1.90	55.6	637	0.198	0.0373

2.3 Checking catchment descriptors

Record how catchment boundary was checked and describe any changes (add maps if needed)	The FEH CD-ROM boundaries of the study catchments were checked against a 50m resolution digital terrain model as part of the 2015 hydrological estimates update. During that study a site visit confirmed the unusual shape of the Bulling Dike boundary. No irregularities were found with the River Dove catchment boundary.
Record how other catchment descriptors were checked and describe any changes. Include before/after table if necessary.	Catchment descriptors were checked for the main study catchments as part of the hydrological estimate update in 2015. For this study, catchment descriptors for the required subcatchments were extracted from the FEH CD-ROM where available. These descriptors have been transferred for other required subcatchments based on the nature of the subcatchment. Where descriptors have been transferred from another subcatchment, catchment AREA has been adjusted according to digitised subcatchments in a GIS package. DPLBAR has been calculated based on the assigned AREA for each subdivision of the subcatchment (undeveloped, paved draining away, paved draining towards).
Source of URBEXT	URBEXT1990
Method for updating of URBEXT	CPRE formula from FEH Volume 4

3 Revitalised flood hydrograph (ReFH) method

3.1 Catchment sub-divisions for urban ReFH model

Site code	Area (km^2)			
			Only relevant if significant transfers of water via sewers crossing catchment boundaries…	
	Rural or undeveloped	Paved	Paved with sewers draining out of topographic catchment	Paved outside topographic catchment with sewers draining into catchment
BullA	0.640	0.002	0.241	N/A. The ISIS application of Urban ReFH has been used for this study, which does not have provision for representing these areas.
BullB	0.495	0.088	0.027	
BullC	1.190	0.003	0.051	
DoveA	47.727	2.235	0.546	
DoveB	2.400	0.352	0.229	
DoveC	1.250	0.008	0.000	
DoveD	1.038	0.037	0.030	
DoveE	1.267	0.196	0.132	
DoveF	0.743	0.143	0.074	
Sources of information for creating sub-divisions	Yorkshire Water sewer network information and FEH CD-ROM.		**Sewer capacity** (return period / rainfall intensity / flow rate) and source of information	10-year (to allow for older aspects of sewer network and account for blockage potential)
Link to map or shapefile of subdivisions	2015s2285_Sewer catchments_v3.shp			
DPLBAR has been calculated for each part of the subcatchment (undeveloped, paved etc), based on area. DPLBAR=AREA$^{0.548}$ (FEH volume 5). The exception to this was subcatchment DoveA for which DPLBAR was set for paved areas to the FEH CD-ROM descriptor value, as the subcatchment is large with paved areas located some distance from the watercourse. URBEXT for undeveloped parts of the subcatchment has been set to 0. For paved areas URBEXT has been set to 0.25 in order to maintain a ratio of Tp_{urban} to Tp_{rural} of 0.5, for identical values of the other descriptors.				

3.2 Parameters for ReFH model (urban or mixed urban & rural catchments)

Site code	Method	Tp_{rural} (hours)*	Tp_{urban} (hours)**	C_{max} (mm)	PR_{imp} % runoff for impermeable surfaces	BL (hours)***	BR
BullA	CD	1.565	0.111	266.5	70	25.945	0.730
BullB	CD	1.438	0.387	266.5	70	25.187	0.730
BullC	CD	2.245	0.312	344.8	70	31.652	0.978
DoveA	CD	5.744	2.554	434.5	70	54.273	1.272
DoveB	CD	2.342	0.591	426.0	70	38.096	1.244
DoveC	CD	1.889	0.166	611.2	70	42.250	1.874
DoveD	CD	1.777	0.698	611.2	70	41.360	1.874
DoveE	CD	1.897	0.488	611.2	70	42.313	1.874
DoveF	CD	1.594	0.440	426.0	70	33.292	1.244
*Tp_{rural} is for the undeveloped part of the subcatchment.							

Site code	Method	Tp_{rural} (hours)*	Tp_{urban} (hours)**	C_{max} (mm)	PR_{imp} % runoff for impermeable surfaces	BL (hours)***	BR
**Tp_{urban} is for the paved area of the subcatchment draining towards the watercourse. It is generally much smaller than Tp_{rural} due to the smaller DPLBAR values for the paved areas, as well as the increase in URBEXT. ***BL stated is for the undeveloped part of the subcatchment.							

3.3 Design events for Urban ReFH method

Site code	Season of design event (summer or winter)	Storm duration (hours)	Storm area for ARF (if not catchment area)
BullA	Summer	2.2	2.02
BullB	Summer	2.2	2.02
BullC	Summer	2.2	2.02
DoveA	Summer	8.8	56.46
DoveB	Summer	8.8	56.46
DoveC	Summer	8.8	56.46
DoveD	Summer	8.8	56.46
DoveE	Summer	8.8	56.46
DoveF	Summer	8.8	56.46
Are the storm durations likely to be changed in the next stage of the study, e.g. by optimisation within a hydraulic model?		The hydraulic model will be updated to include these revised estimates and used to determine critical storm duration for the study catchments.	
A provisional value for storm duration has been set for each study catchment based on that recommended in the ReFH method. These were set independently as the two catchments are not linked, both flow into the River Dearne separately. The River Dove storm duration was set for the whole catchment near the River Dearne confluence and the Bulling Dike for the catchment to the site of interest, the proposed wetland extension. The storm area is then set for the catchment to this point. This was in order to represent a catchment wide storm.			

3.4 Flood hydrographs from the Urban ReFH method

The parameters shown in the tables above have been entered into ISIS Urban ReFH units, with a unit for each subcatchment. This results in a flow hydrograph for each subcatchment which reflects inflows from the different components of the subcatchment; undeveloped, paved draining away and paved draining towards. The magnitude and timing of the inflows from each component will vary and this influences the resulting hydrograph. The ISIS Urban ReFH units will form the inflows to the hydraulic model.

4 Discussion and summary of results

4.1 Comparison of results from different methods

Due to differences in the way the estimates have been derived using the Statistical Method and Urban ReFH it is not straightforward to compare estimates from the two methods. The Statistical Method estimates used a lumped catchment approach, whereas the Urban ReFH Method estimates used independent subcatchments. In light of this, in order to make some comparison between the methods, hydraulic model results from the current scenario have been compared at key locations.

Model Location	Modelled Flow (m^3/s) or Level (mAOD)		
	Parameter	Model output for 100 year return period simulation	
		Statistical	ReFH*
River Dove, between Dove valley Way and Stonyford Road,B6096 (model node DOVE01_1799).	Flow	25.98	24.73
	Level	27.57	27.52
Bulling Dike, downstream of Station Road, B6096 (model node BUL01_2630).	Flow	9.19	8.13
	Level	24.45	24.35
Bulling Dike, adjacent to caravan park (model node BUL01_1941).	Level	22.60	22.61

*Results shown from ReFH are with design storm durations on each modelled watercourse (River Dove 8.9hrs, Bulling Dike 2.1hrs)

4.2 Final choice of method

Choice of method and reasons Include reference to type of study, nature of catchment and type of data available.	As the study catchments are ungauged it is difficult to say with certainty which method produces most realistic flow estimates. The Statistical Method has the benefit of using a donor catchment to refine estimates from catchment descriptors, whereas the Urban ReFH allows for urbanisation within the study catchments to be accounted for more specifically. The Urban ReFH method has been chosen due to the ability to represent the urban influence in these catchments. The gauging of study catchment flows and/or levels would allow model calibration and greatly improve the uncertainty associated with flow estimates.

5 Annex

5.1 Discussion of recommendations from the Wombwell Wetlands Modelling Review

Recommendation/Action from review	JBA Response
Urbanisation of the study catchments not directly considered in the ReFH method. Review recommended using Urban ReFH where applicable.	All estimates for the study catchments have been calculated applying the Urban ReFH Method. This included careful consideration of the Yorkshire Water sewer network in order to delineate subcatchments in accordance with the urban drainage influences.
The design storm should be a catchment wide storm with the same profile and duration. Critical duration analysis is recommended as volumes could be critical. Each storm scenario should be catchment wide and consider multiple scenarios where necessary. Storm scenario should also consider the impacts with the River Dearne.	A single storm has been applied to each of the study watercourses. For the River Dove this is based on the whole catchment to the confluence with the River Dearne. For the Bulling Dike this takes a target site located at the downstream end of the proposed Wetland scheme. Model simulations will be used to determine the critical storm duration once hydrological estimates are approved by the EA.
Mixture of tributary inflows and main river FEPs, although close together so justification not required. Derivation of lateral/intervening area CDs should be explained.	Rather than use lateral/intervening areas, all subcatchments are assumed to have a single discharge point to the main river, and are treated as tributary inflows. This may not be realistic for rural areas but is more representative of the real system in urban areas.
Advise on the Update of URBEXT values within the FEH Statistical Method.	Not applicable here as the FEH Statistical method has not been used for this study.
Outline the extent to which the River Dearne is likely to interact/influence flood mechanisms.	The next stage of the Wombwell Wetlands Extension Scheme will test the sensitivity of the modelled water levels to changes in the River Dearne levels.
Volumes are potentially significant. Interactions with the River Dearne may also be significant. Methodology should be enhanced to consider alternative flooding mechanisms/sources, i.e. volumes & River Dearne.	In the next stage of the Wombwell Wetlands Extension Scheme study, the impact of volumes will be assessed during the critical duration analysis and testing of sensitivity to River Dearne water levels.
Useful to provide HiFlows Uk version number and amendments made to data.	Not applicable with the Urban ReFH Method used here.
How does urbanisation influence hydrology, for example the sewer network? Is this influence critical? Comments should be provided to state how urbanisation, particularly on Bulling Dike, is expected to influence hydrology, particularly assumptions made now and recommendations for future studies.	The urban influence on the two study catchments has been directly addressed by applying the Urban ReFH Method for obtaining flow estimates, with consideration of the sewer network
Bulling Dike catchment is small and highly urbanised. Is the Statistical method representative for such a catchment? Consideration should be given to peak flows	Urban ReFH Method used to incorporate the influence of the urbanised nature of the catchment.

from rainfall-runoff modelling as well as Statistical. Consideration should be given to role of volumes in defining flood risk.	The hydraulic model will be used to assess critical storm duration in the next stage of the project.

5.2 Derivation of subcatchments for Urban ReFH Method

5.2.1 Overview

The study catchments have been split into sub-catchments based on available FEH CD-ROM sub-catchments and careful consideration of the Yorkshire Water sewer network and corresponding discharge points to the study watercourses. Each subcatchment represents inflows from the contributing urban parts of the catchment.

Catchment descriptors have been extracted for sub-catchments from the FEH CD-ROM where available. Any sub-catchments not delineated on the FEH CD-ROM have catchment descriptors adopted from nearby FEH subcatchments. The catchment descriptors AREA and DPLBAR have been adjusted in these cases. URBEXT has been set in order to achieve a reasonable ratio of urban to rural time to peak (Tp). An URBEXT value of 0.25 has been used for paved areas. For undeveloped areas URBEXT has been set to 0. If all other catchment descriptors were consistent between the rural and urban parts this would yield a ratio of 0.5. Once the revised inflows are applied to the model, hydrograph shapes will be reviewed. The inflows have generally been applied to the model at the mid-point of the subcatchment, the exceptions being the subcatchments representing the upstream ends of the modelled watercourses. Minimal information regarding sewer network inflow points was available and the subcatchments also represent inflows from undeveloped areas with the subcatchments. Hence it was deemed appropriate to input the inflows for each subcatchment in this way.

General assumptions

The sewer network has been used to determine parts of the urban areas which drain towards and away from the study watercourses. This was done mainly in the larger urban areas, particularly near the boundary separating the topographic catchments of the adjacent study watercourses. For other parts of the catchment away from the boundaries, any paved areas falling within the study catchments have been assumed to drain towards the watercourse. Terrain data has been used to inform decisions where sewer network data was not available.

Where no sewers were shown in the Yorkshire Water network (for example where private sewers exist or for farms) paved areas are assumed to drain towards the watercourse, unless along the topographic catchment boundary and terrain data suggests otherwise.

Paved areas which are beyond the topographic catchment for the study watercourses, which drain into the study catchment via the sewers have been ignored, as the application of the Urban ReFH method in the ISIS software makes no provision for inclusion of areas such as this. These areas were not deemed to be significant.

Where paved areas drain into combined sewers and on to sewage treatment works, the paved area is deemed to drain away from the study watercourse, as the combined sewers and treatment works effectively act as storage of the flows. It is assumed that these flows are unlikely to be discharged into the watercourses during the design event and so will not contribute to flood flows. Without further information on sewer network discharges and discharge locations it is difficult to quantify discharges from the combined sewers and so this assumption was deemed reasonable for the current study.

For paved areas where the sewer network pipe system crosses topographic catchments, the paved area has been split by the topographic sub-catchment boundary. This is in order to represent the areas within the limits of the ISIS Urban ReFH unit.

For digitised paved areas, it has been assumed that 40% of the area is developed, with 60% contributing to the undeveloped part of the catchment. This is based on the assumption that not all of the urban area will be paved surfaces, the urban area also encompasses gardens and green spaces. For this study when defining urban areas, large green spaces (approximately greater than

100m by 100m) were excluded from the paved area. Hence a value of 40% has been used for the developed proportion of the urban area, rather than the 30% value often used.

The percentage runoff value has been set to the default value of 70% as per guidance on this.

The sewer capacity is assumed such that it can accept the 10yr storm runoff to account for older sewer network components and the potential for blockage.

5.2.2 River Dove

Dove A – The Upper Reaches

This subcatchment comprises the upper reaches of the catchment, upstream of the modelled reach. This area is largely rural, but includes the urban areas of Dodworth, Worsbrough and Birdwell. Catchment descriptors have been taken from the FEH CD-ROM v3.0. There are some small areas which lie to the north of the topographic catchment boundary in the area of Worsborough Common where the sewers drain towards the Dove. However these cannot be accounted for with the ISIS Urban ReFH unit subdivisions. These areas are small so are not deemed critical.

Dove B – Stairfoot and Ardsley

This subcatchment includes parts of the urban areas of Kendray, Stairfoot and Ardsley, plus rural areas to the River Dove. This is based on topographic boundaries and catchment descriptors have been taken from the FEH CD-ROM v3.0 for this subcatchment. As with subcatchment Dove A, there are some small areas which lie to the north of the topographic catchment boundary where the sewers drain towards the Dove (from parts of Kendray). However these cannot be accounted for with the ISIS Urban ReFH unit subdivisions. These do not constitute a significant area and so would be unlikely to impact the flow estimates significantly.

Dove C – Between Stairfoot and Darfield, north of the River Dove

This subcatchment represents the rural area to the north of the River Dove, between Albany Close off the A633 Wombwell Lane and Netherwood. Catchment descriptors have been transferred from the nearby FEH CD-ROM tributary catchment (DoveD). The area descriptor has been adjusted based on the digitised subcatchment in GIS software, with DPLBAR calculated from the FEH Volume 5 equation based on area (DPLBAR=AREA^0.548).

Dove D – West of Darfield

This subcatchment is based on the FEH tributary catchment covering part of the rural area to the west of Darfield, south of the A635. Catchment descriptors are taken from the FEH CD-ROM v3.0. A small part of the urban area at Upperwood Road is thought to drain into the study watercourse which cannot be represented in ISIS. This is however not deemed significant.

Dove E – Darfield urban area

Part of the urban area of Darfield is included in this subcatchment, from Barnsley Road in the north to the River Dove plus small parts of Stonyford Road and Station Road to the south. Catchment descriptors from the nearby FEH tributary catchment (DoveD) have been used here. Area has been adjusted based on the subcatchment drawn in GIS software, with DPLBAR calculated based on the adjusted area.

Dove F – Barnsley Road south of River Dove

This subcatchment covers the north-western area of Wombwell off the A633 Barnsley Road between Aldham Bridge and White Rose roundabout, plus the wooded areas north-east of Barnsley Road to the River Dove south bank. Catchment descriptors from the neighbouring FEH tributary catchment covering Stairfoot and Ardsley (DoveB) have been used. Area has been adjusted as per the drawn subcatchment in GIS software, with DPLBAR calculated based on this.

5.2.3 Bulling Dike

Bull A – Upper reaches

This subcatchment covers the central part of Wombwell north of the B6096 to Wilson Street further north, from Windmill Road in the west to the A633 Mitchells Way in the east then onto Bulling Dike further east. The catchment descriptors were obtained from the FEH CD-ROM.

A small part of the south-west of this subcatchment (9700m^2) is thought to drain into the River Dove catchment via the sewer network. This area is classed as draining away from Bulling Dike. There is however no provision in the ISIS Urban ReFH unit to include it in the neighbouring River Dove catchment coming in from outside the topographic catchment.

Bull B – Urban area off the B6096 Station Road, Wombwell

This subcatchment includes the majority of the developed area either side of the B6096 Station Road, situated north-east of the A6333 Mitchells Way between Netherwood roundabout and Waterside Park, to Stonyford Road in the north-east. Catchment descriptors for the upstream part of the Bulling Dike have been used with area adjusted and DPLBAR set based on the altered area.

Bull C – Lower reaches of Bulling Dike including part of Wombwell Ings

The Town Lands sewage treatment works, the caravan site near Wombwell Ings and the urban areas along Everill Gate Lane are included in this subcatchment, which also covers the area of the proposed wetland for the Wombwell Wetland Extension Scheme. Catchment descriptors from the downstream Bulling Dike catchment have been used with area and DPLBAR adjusted accordingly.

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