

Flood Estimation Report Template

Template: LIT 65087

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Audience: Environment Agency

Description: This report template is a supporting document to the Environment Agency's Flood Estimation Guidelines (LIT 11832). It provides a record of the hydrological context, the method statement, the calculations, the decisions made, and the results of flood estimation. This document can be used for one site or multiple sites.

Guidance notes to help you complete this template are available separately.

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Approval

Revision stage	Analyst:	Approved by:	Amendments	Date
Method statement	R Crabbe N Vaughan	D Barker	-	04/07/2023
Calculations - Revision 1	R Crabbe N Vaughan	D Barker	-	04/07/2023
Calculations - Revision 2				

Abbreviations

Abbreviation	Short for
AEP	annual exceedance probability
AMAX	Annual Maximum
AREA	Catchment area (km ²)
BFI	Base Flow Index
BFIHOST19	Base Flow Index derived using the HOST soil classification, revised in 2019
FARL	FEH index of flood attenuation due to reservoirs and lakes
FEH	Flood Estimation Handbook
GEV	Generalised Extreme Value
GLO	Generalised Logistic
HOST	Hydrology of Soil Types
IF	Impervious Fraction
IRF	Impervious Runoff Factor
LF	Low flow statistics (flow duration curve)
NRFA	National River Flow Archive
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)
Tp	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	Windows Frequency Analysis Package (software that can be used for FEH statistical method)

1. Summary of assessment

1.1 Summary

Catchment location:

There are two watercourses of interest, between Havant and Emsworth, Hampshire. The first is the Nore Farm Stream which discharges into the Nore Rithe at approximate National Grid Reference (NGR) 473,923 (E), 105,391 (N). The second is the West Brook which discharges into the Emsworth Mill Pond at approximate NGR 474,823 (E), 105,277 (N). Both watercourses ultimately outfall to Chichester Harbour. The key areas of interest are where these watercourses pass through the proposed development site to the north of the A27.

Purpose of study and complexity:

The aim of this study is to derive peak flow estimates and hydrographs for the Nore Farm Stream and the West Brook to provide inflows for hydraulic modelling. A hydraulic model of the two watercourses will be developed by Stantec to support the design of a mixed-use development for the Southleigh Road site.

Key catchment features:

Both catchments contain large areas of urbanisation and the selected method should therefore be suitable for use in urbanised catchments.

Flooding mechanisms:

Flooding is likely due to flows exceeding channel capacity. The physical modifications of the watercourses may exacerbate flooding (e.g. backing up of culverts), urbanisation may influence flood flows (response times) and the downstream extent of watercourses may experience tide locking. On both watercourses there are measures to restrict downstream flows. On the Nore Farm Stream, there is a fixed orifice under the A27 to reduce downstream flood risk within the residential areas. On the West Brook the flows are restricted to provide attenuation for additional runoff associated with 'The Haven' development to the east of the site at West Brook View.

Gauged / ungauged:

The National River Flow Archive (NRFA) indicates that there are no flow gauging stations along the Nore Farm Stream or the West Brook within the latest dataset. There is a level only gauge on the West Brook upstream of the St James' Road culvert (approximately 0.4km south of the A27 crossing). The gauge is level only and therefore the West Brook is considered to be ungauged for the purposes of flow estimation calculations.

Final choice of method:

The ReFH2 unadjusted method is used to derive peak flow values and hydrographs. The level gauge is not suitable to directly inform peak flow estimates or hydrograph shape on the West Brook.

Key limitations / uncertainties in results:

The catchment is ungauged, which is the largest source of uncertainty.

1.2 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.
- Return periods are output by the Flood Estimation Handbook (FEH) software and can be expressed more succinctly than AEP. However, AEP can be helpful when presenting results to members of the public who may associate the concept of return period with a regular occurrence rather than an average recurrence interval.
- Results tables in this document contain both return period and AEP titles; both rows can be retained, or the relevant row can be retained and the other removed, depending on the requirement of the study.
- The table below is provided to enable quick conversion between return periods and annual exceedance probabilities.

AEP (%)	50	20	10	5	3.33	2	1.33	1	0.5	0.1
AEP	0.5	0.2	0.1	0.05	0.033	0.02	0.013	0.01	0.005	0.001
Return period (yrs)	2	5	10	20	30	50	75	100	200	1,000

2. Method Statement

2.1 Requirements for flood estimates

Overview and Project Scope:

The aim of this study is to derive peak flow estimates and hydrographs for the Nore Farm Stream and the West Brook catchments, both located in Havant, Hampshire. The peak flow estimates and hydrographs are to inform hydraulic modelling of these watercourses. A hydraulic model of both watercourses will be developed by Stantec to support the design of the Southleigh Road development site.

Peak flow estimates and hydrographs will be derived for the 1 in 2, 5, 10, 20, 30, 50, 75, 100, 200 and 1000-year events.

The purpose of this document is to detail the methods followed, the outcomes and results, and the decision-making process and justification of final accepted flows. Note that it does not include any additional analysis completed using the hydraulic modelling, which is reported and provided separately.

The study is considered to be of moderate complexity due to the urban nature of the catchments. The hydrological assessment makes use of the NRFA v11.1 dataset within WINFAP5. ReFH2.4 with FEH22 rainfall data will be applied as a second suitable method for use to derive peak flow estimates and to define hydrograph shapes. The catchment is ungauged and therefore hydrograph shapes are defined using the latest available rainfall-runoff method.

2.2 The Catchment

Maps:

Figure 1 Overview of catchment areas and site

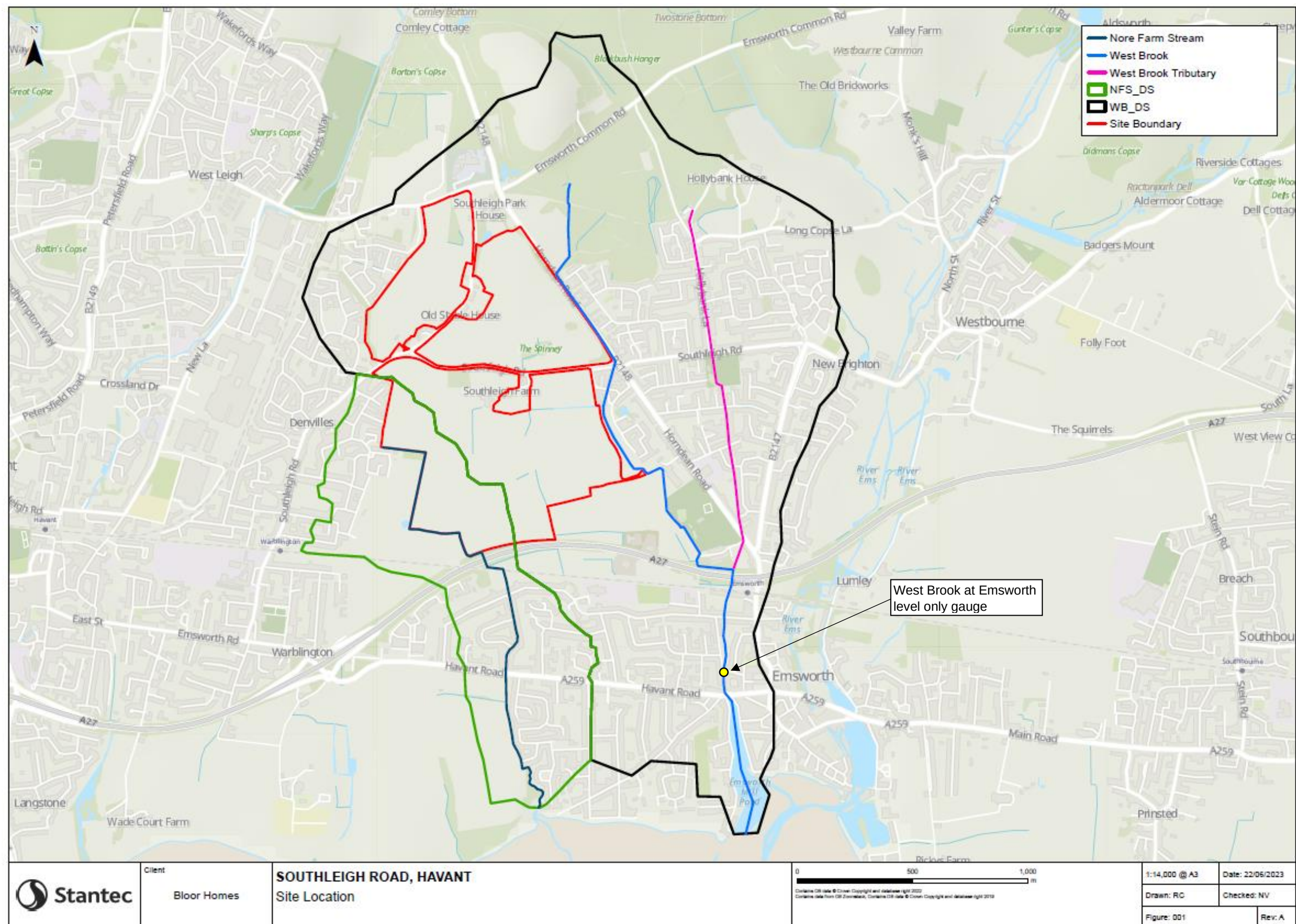
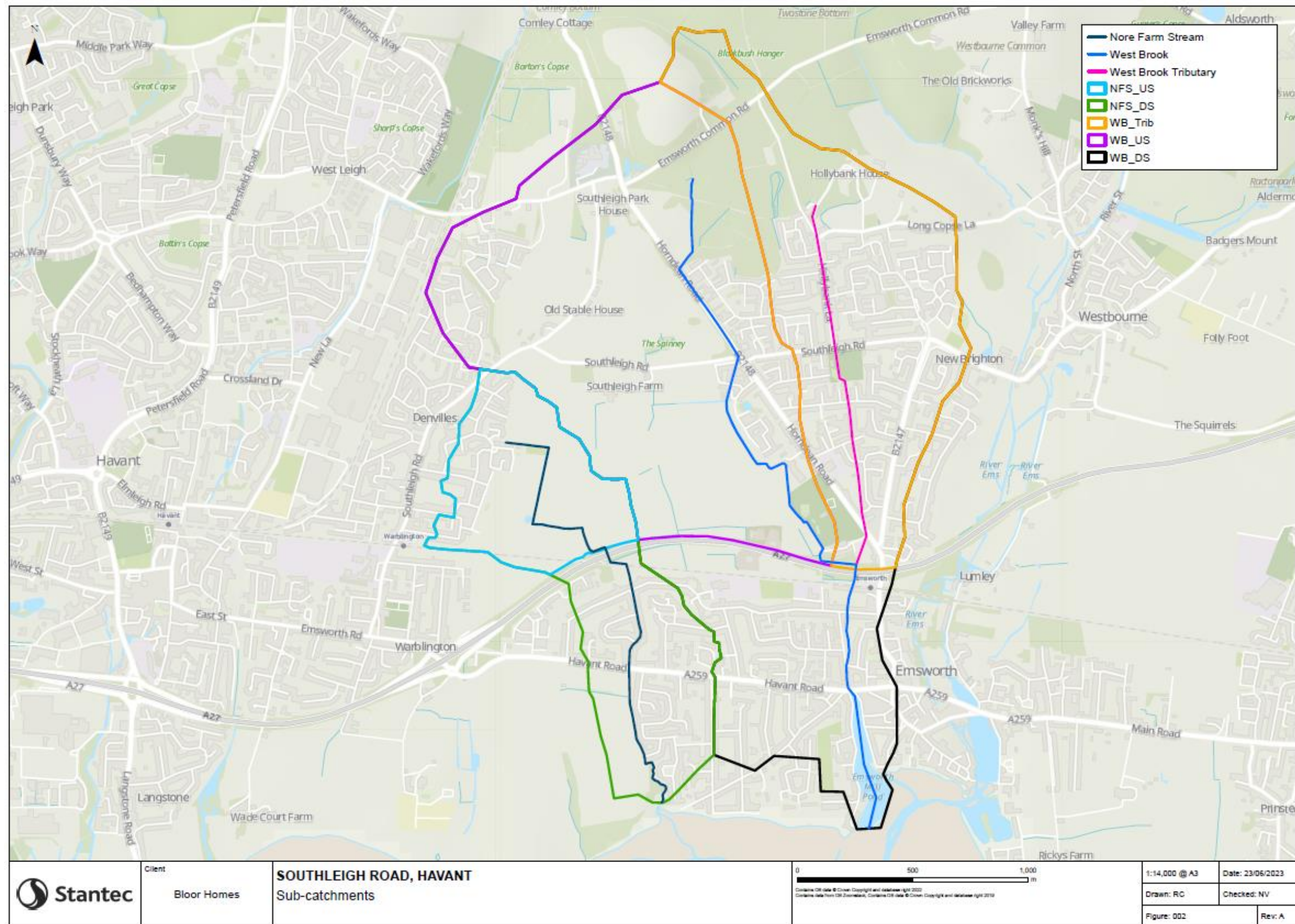


Figure 2 Overview of sub-catchments



Catchment Description:

The Nore Farm Stream flows in a generally southerly direction where it discharges into the Nore Rithe and has a catchment area of approximately 1.0km². The West Brook, which is located approximately 1.6 km east of the Nore Farm Stream, flows in a generally southerly direction until it discharges into the Emsworth Mill Pond and has a catchment area of approximately 4.2 km².

There is some uncertainty over the connectivity and alignment of the West Brook. The West Brook is in open channel to the north-east of Horndean Road where it enters a culvert and flows under Horndean Road to the junction with Southleigh Road. At this point the alignment of the watercourse is not clear, the EA has undertaken a CCTV survey that indicated the watercourse then flows east, and away from the site, along Southleigh Road towards Westbourne Road. Other evidence suggests it turns south-west and flows under Foster Way before discharging into an open channel within the development site. A CCTV survey is being undertaken to confirm the connectivity and alignment of the watercourse.

The Nore Farm Stream catchment ranges in elevation between approximately 15 mAOD in the upper reaches to 3m AOD in the lower reaches where it discharges into the Nore Rithe and is therefore a relatively flat catchment. The West Brook catchment ranges in elevation between approximately 55 mAOD in its upstream reaches to approximately 2 mAOD at its downstream reaches where it discharges into the Emsworth Mill Pond.

The British Geological Survey (BGS) Geology of Britain mapping indicates that the majority of both catchments is underlain by a bedrock geology of clay, classified as the London Clay Formation and the Lambeth Group. This changes to a bedrock geology of chalk in the lower reaches of the catchments just south of the A27 road, i.e. downstream of the site. Both catchments are moderately permeable, with the Nore Farm Stream catchment having a BFIHOST19 value of 0.682 and the West Brook catchment having a BFIHOST19 value of 0.538.

Both catchments are classified as heavily urbanised, particularly in the lower reaches south of the A27, where both watercourses flow through the town of Emsworth. The Nore Farm Stream and the West Brook catchments have URBEXT2000 values of 0.244 and 0.243 to their downstream extents respectively.

Both watercourses exist as largely open channels in their upper reaches, with a number of culverts at road and rail crossings, and at various points in their lower reaches where they flow through Emsworth.

2.3 Hydrometric Data

Source of flood peak data:

NRFA version 11.1 released March 2023 and contains data up to water year 2020-2021 (ends September 2021).

Gauging stations (flow and 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
West Brook	Emsworth	153900005	N/A	2.86	Level only	Feb 2014 to present

Data available at each flow gauging station:

N/A - no flow data available.

Updates or revisions to flood peak data:

No updates made.

Data quality checks carried out:

The available level data for West Brook at Emsworth was reviewed for the 9 calendar years of data. There were no significant periods of missing data within the record and the quality flags indicated that the data was either marked as Good or Estimated, with no occurrences of Suspect data. The data indicates that the West Brook at this location is influenced by the Emsworth Mill Pond, potentially due to a backwater effect from the controlled levels.

Rating Equations:

N/A - not completed.

Rating reviews:

N/A - not completed.

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	-	No	-	No spot flow gauging available
Historical flood data	Yes	Yes	EA open data (DEFRA Spatial Platform)	Recorded Flood Outlines and Historic Flood Map - show recorded flood outline on West Brook downstream of Victoria Road, south of A27/railway and site of interest. No outlines shown for Nore Farm Stream or for West Brook in site of interest.
Flow or river level data for events	Yes	Yes	EA - Hydrology Data Explorer	Level data for West Brook at Emsworth gauge.
Rainfall data for events	Yes	Yes	EA - Hydrology Data Explorer	Rainfall data for the Havant and Walderton gauges.
Potential evaporation data	No	-	-	
Results from previous studies	Yes	Yes	EA Products 5 and 6	Nore Farm Flood Alleviation Scheme (FAS) - September 2015. Reporting details the optioneering modelling completed for the FAS on West Brook, and does not detail the

Type of data	Data relevant to this study?	Data available?	Source of data	Details
				hydrological assessment completed to provide model inflows. No comparison can be made to the previous study in terms of hydrology methods used.
Other data or information				

Conclusions of hydrometric data review:

N/A - no flow data available.

2.4 Hydrological understanding of the catchment

Plots of flood peak data and interpretation:

N/A - no flow data available.

Plots of flow data and interpretation:

N/A - no flow data available.

Plots of stage data and interpretation:

The five highest level events on record were investigated - see **Table 1**.

Table 1 West Brook at Emsworth Observed Events

Event Date	Rank	Observed Level (m)
14 th February 2014	1	3.25
16 th October 2016	2	2.78
16 th November 2022	3	2.76
12 th October 2022	4	2.67
27 th July 2021	=5	2.55
9 th August 2021	=5	2.55

The highest recorded level was approximately 3.25m in February 2014. The event peaked quickly, from approximately 2.00m to 3.25m in an hour. The rainfall for the nearest gauge was obtained (Havant) and it did not show any rainfall

occurring which would result in the peak in level. The next closest rainfall gauge (Walderton) was reviewed and concurred with the Havant rainfall gauge, not showing any rainfall occurring that would result in a level peak. The event was therefore not considered any further due to the lack of correlating rainfall.

The remaining events were reviewed and were found to be similarly fast responding, peaking within approximately 2 hours of the centroid of the contributing rainfall event. The 2nd, 3rd and 4th ranked events were noted to be events occurring in winter months, with the 5th ranked event being summer (July 2021).

The level record for the West Brook catchment generally showed that water levels were elevated in the winter months and the highest recorded events occurred in winter months, indicating that the catchment seasonality is predominantly winter. The 5th and 6th ranked events are summer events, and there were a number of other higher order events occurring within summer months throughout the record. However, these generally appear to be less frequent and lower in magnitude in comparison to winter events. This suggests that the urbanisation in the catchment may be resulting in some sensitivity to summer rainfall events, however, the winter storm profile is likely the most representative for the West Brook catchment.

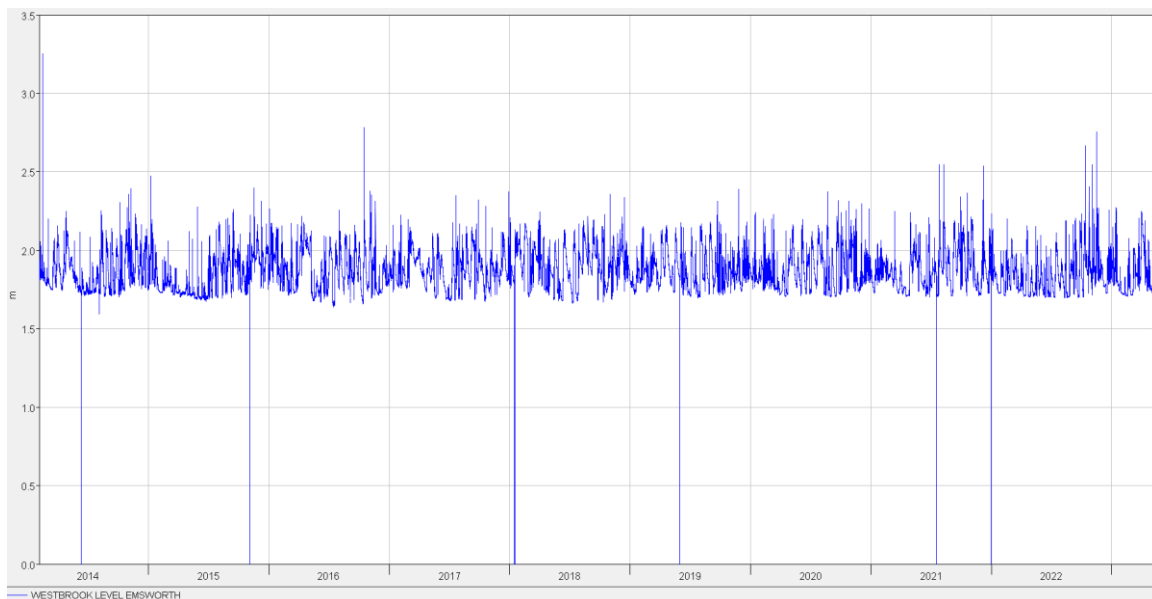


Figure 3: West Brook at Emsworth level record

Conceptual model:

The main sites of interest are the Nore Farm Stream between Southleigh Road and its crossing of the A27, and the West Brook between Horndean Road and its crossing of the A27. These areas coincide with the site boundary of the proposed mixed-use development (**Figure 1**).

The primary source of flooding at these locations are flood flows exceeding channel capacity, but with the potential for some areas of storage where flood volume is important associated with the flood alleviation schemes on both watercourses. The urban areas in the upper reaches of the Nore Farm Stream may increase the proportion of runoff within the catchment in comparison with a rural catchment. The culverts for both watercourses beneath the A27 may cause water to back up into the area of interest. The hydraulic models will represent the existing structures on each watercourse and any constriction to flow that may result.

There are no locations where runoff would be generated on part of the catchment only (e.g. downstream of reservoir) and there is no need to consider temporary debris dams within the hydrological assessment.

Unusual catchment features:

The Nore Farm Stream is just within the classification of groundwater driven (BFIHOST19 exceeds 0.66), based upon the Soil Survey of England and Wales mapping and associated HOST classes. A further review of the geology was completed using the BGS Geology Viewer¹. This indicated that the superficial deposits on the Nore Farm Stream are predominantly formed of clay, sand and silt, and bedrock geology also indicates clay, sand and silt is present (London Clay Formation). This suggests that while the Nore Farm Stream BFIHOST19 value results in a classification of 'groundwater driven', it is not expected that the catchment would respond as a groundwater driven catchment due to the presence of more impermeable superficial and bedrock geology.

The catchments are urban in nature, with parts of the catchments being classified as heavily and very heavily urbanised. The route of the West Brook and West Brook tributary in the upper reaches of the catchment at Horndean Road and Southleigh Road are currently unconfirmed. CCTV survey has been sought to clarify the route of existing culverts and surface water drainage networks, however, the results have not been received at the time of writing. The hydrological assessment therefore assumes that the 'natural' conditions apply, with the watercourse routes following the topographic route (see **Figure 3**). Any adjustments to the watercourse routes will be represented within the hydraulic model and therefore will not impact the final flows or hydrographs of this assessment.

The West Brook has a flood storage area constructed within the area of interest, adjacent to the 'The Haven' development at West Brook View. The Nore Farm Stream has an orifice on the culvert under the A27 to control downstream flow.

¹ British Geological Society, 2023, BGS Geology Viewer [www] Available at: <<https://geologyviewer.bgs.ac.uk/>>

The catchments are not pumped, are not influenced by reservoirs/lakes and do not have historical or operational mining activities.

2.5 Initial choice of approach

Are FEH methods appropriate?

The FEH methods are considered to be suitable for application. Appropriate care and consideration will be given to the urban nature of the catchment.

Initial choice of method(s) and reasons:

The FEH Statistical method will be used to derive QMED values and peak flow estimates at the flow estimation locations. Pooling groups will be derived for the catchments based on the downstream catchment extents.

The ReFH2 method will also be applied to derive peak flow estimates at the flow estimation locations. The ReFH2 method will be applied using the latest available version of the software (ReFH2.4).

How will hydrograph shapes be derived if needed?

The ReFH2 software will be used to derive hydrograph shapes due to the ungauged nature of the catchment.

Will the catchment be split into sub-catchments? If so, how?

Both catchments will be split into sub-catchments, with intervening areas which will be used as inputs to a distributed model (see **Figure 2**). NFS_INT is located between the culverted reach of the Nore Farm Stream under the A27 and the downstream extent, and WB_INT is located between the confluence of the tributary at the A27 and the downstream extent. These sub-catchments are based on the key area of interest, which is found between Southleigh Road and the crossing of the Nore Farm Stream and the West Brook under the A27. Furthermore, these intervening areas are classified as very heavily urbanised due to the URBEXT values exceeding 0.3.

Hydrographs for intervening areas will be derived using ReFH2.

Software to be used:

FEH Web Service² / WINFAP 5³ / ReFH2.4⁴

2 CEH 2015. The Flood Estimation Handbook (FEH) Online Service, Centre for Ecology and Hydrology, Wallingford, UK.

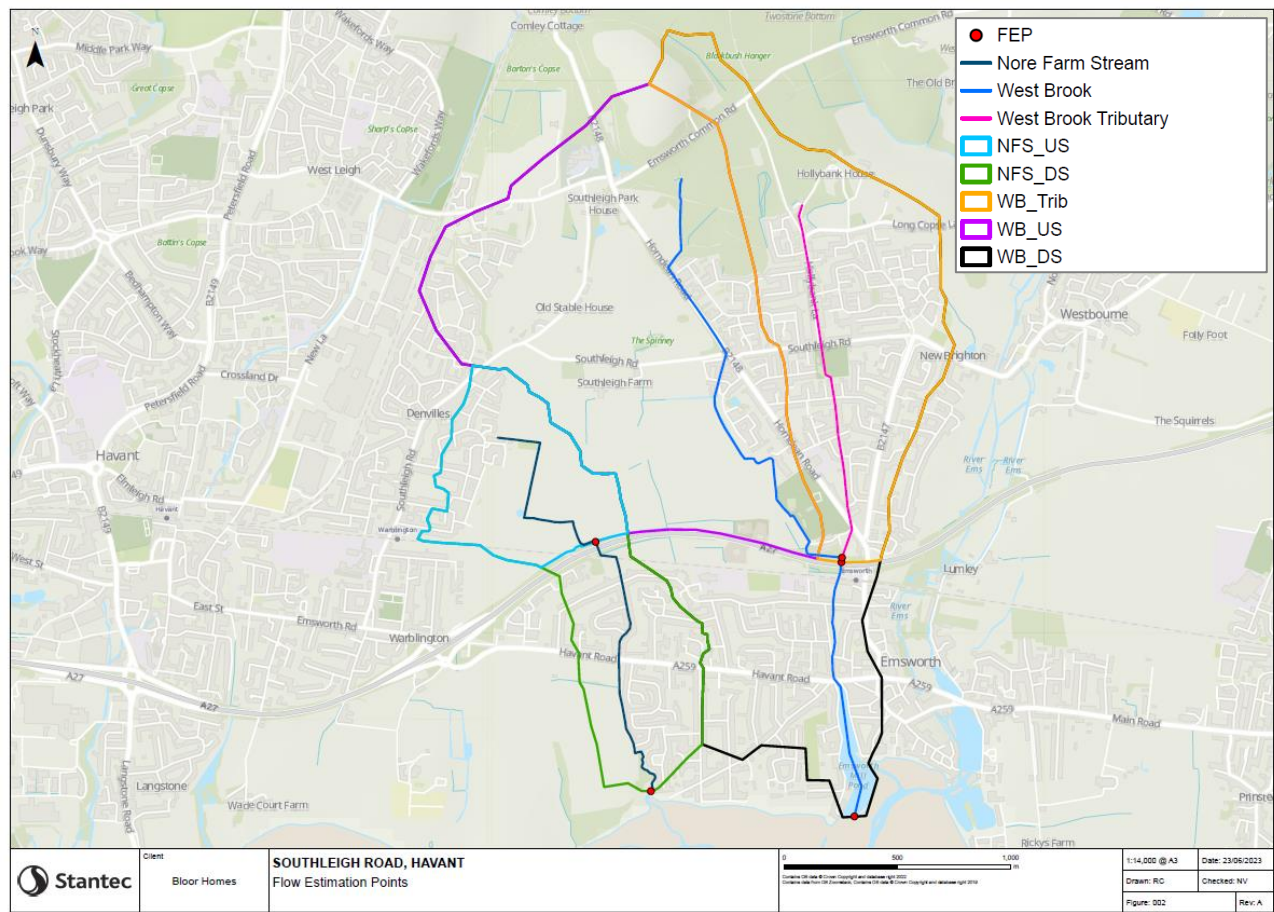
3 WINFAP 5, © Wallingford HydroSolutions Limited 2022.

4 ReFH2.4, © Wallingford HydroSolutions Limited 2023.

3. Locations where flood estimates are required

3.1 Summary of subject sites

Figure 3 Flow Estimation Points



The table below lists the locations of subject sites. The site codes listed below are used in all subsequent tables. Lumped flow estimation points are shown in **Figure 3**.

Site code	Type of estimate: lumped (L) or sub-catchment (S)	Water-course	Site name / description	Easting	Northing	AREA on FEH Web Service (km ²)	Revised AREA (if altered) (km ²)
NFS_US	L	Nore Farm Stream	Catchment upstream of the A27	473620	106479	0.58	0.48
NFS_DS	L	Nore Farm Stream	Total catchment to downstream extent of the model where it discharges into the Nore Rithe	473923	105391	1.27	0.99
NFS_INT	S	Nore Farm Stream	Intervening catchment between the A27 and the downstream model extent	473923	105391	-	0.51
WB_US	L	West Brook	Catchment upstream of the A27	474654	106417	1.49	2.10
WB_TRIB	L	Tributary of West Brook	Downstream extent of tributary at confluence with West Brook at A27	474741	106402	1.06	1.29
WB_DS	L	West Brook	Total catchment to downstream extent of the model where it discharges into the Emsworth Mill Pond	474823	105277	3.17	4.21
WB_INT	S	West Brook	Between confluence of tributary at A27 and downstream model extent	474823	105277	-	0.82

3.2 Catchment Descriptors

Final catchment descriptors at each subject site:

Note: **Red text** denotes catchment descriptors which have been manually calculated changed from the FEH values, with original FEH values shown in brackets where possible. Values for NFS_INT and WB_INT are based on NFS_DS and WB_DS respectively and calculated where possible and appropriate.

Site code	FARL	PROPWET	BFIHOST19	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	URBEXT 1990	URBEXT 2000	FPEXT
NFS_US	1	0.34	0.678 (0.536)	0.88 (1.05)	14.10	754	0.163 (0.017)	0.163 (0.022)	0.183
NFS_DS	1	0.34	0.682 (0.618)	1.13 (1.44)	11.40	742	0.244 (0.103)	0.244 (0.138)	0.179
NFS_INT	1	0.34	0.682	0.69	11.40	742	0.320	0.320	0.179
WB_US	1	0.34	0.483 (0.493)	1.93 (1.37)	20.10	762	0.100 (0.033)	0.100 (0.045)	0.116
WB_TRIB	1	0.34	0.511	1.52 (1.25)	23.40	765	0.310 (0.203)	0.310 (0.308)	0.177
WB_DS	1	0.34	0.538	3.16 (2.38)	19.30	758	0.250 (0.170)	0.243 (0.216)	0.176
WB_INT	1	0.34	0.682	0.90	19.30	758	0.507	0.507	0.176

Catchment boundary checks and revisions:

The overall catchment boundaries for both the Nore Farm Stream and the West Brook were reviewed using available LiDAR data (1m resolution). Discrepancies were found, and therefore LiDAR derived catchments were completed to inform the updates that should be made to make the catchments more representative of the topographic catchment areas. The A27 and railway line to the south of the proposed development are key topographic features which influence flow routes in the catchment.

Figure 4 indicates that the Nore Farm Stream FEH catchment did not include the route of the watercourse and included additional areas in the upper reaches which the LiDAR showed would not topographically drain to the Nore Farm Stream, but rather the adjacent West Brook catchment. This is the flow route shown on the Environment Agency Risk of Flooding from Surface Water maps

that supports this change in catchment area. The catchment is relatively flat between Southleigh Road and the A27, and therefore the FEH catchment is not considered to be representative in this area. The resultant catchment area decreased from 1.27km² to 0.99km².

Figure 4 Comparison of NFS_DS and FEH catchment

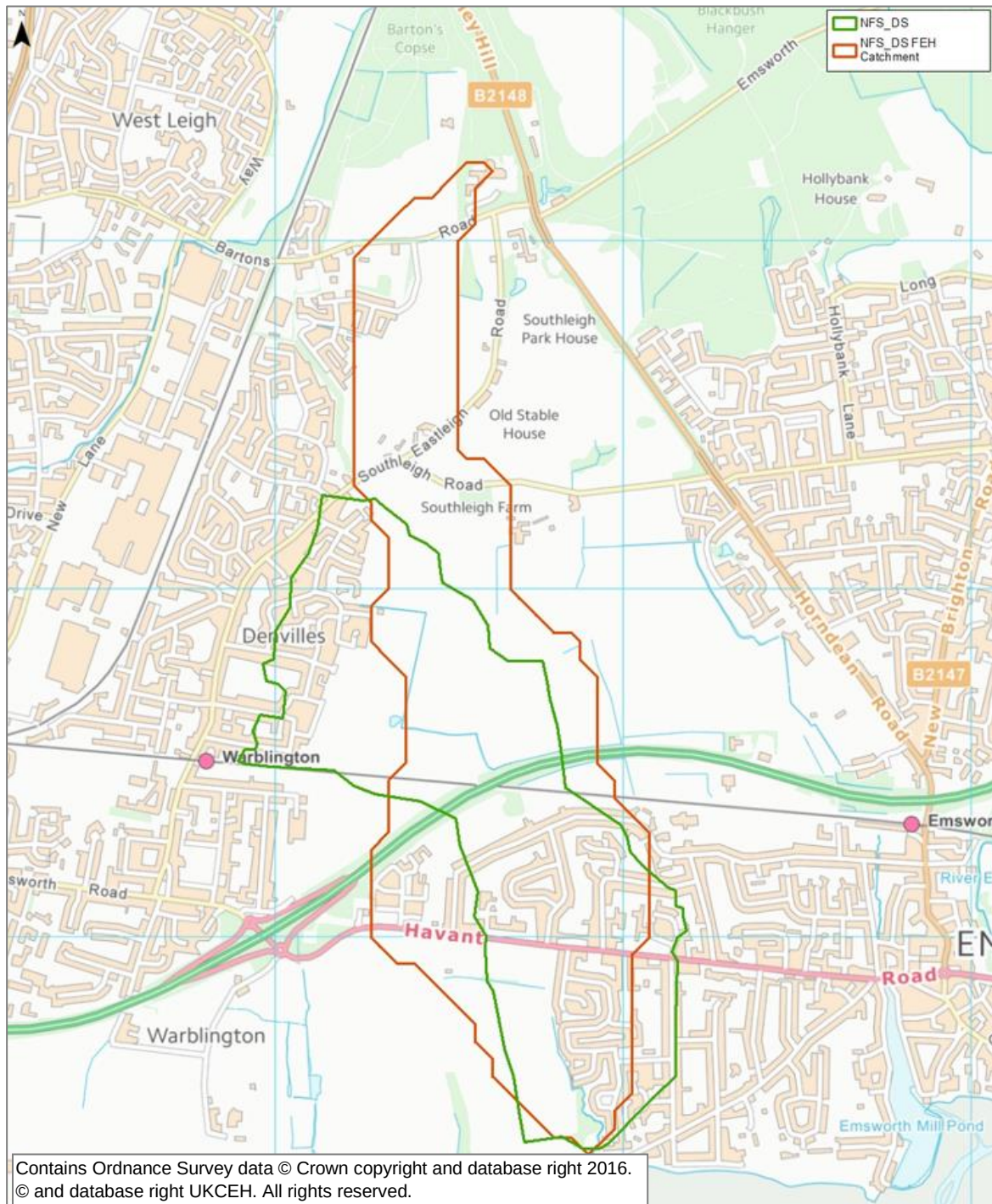


Figure 5 Comparison of WB_DS and FEH catchment

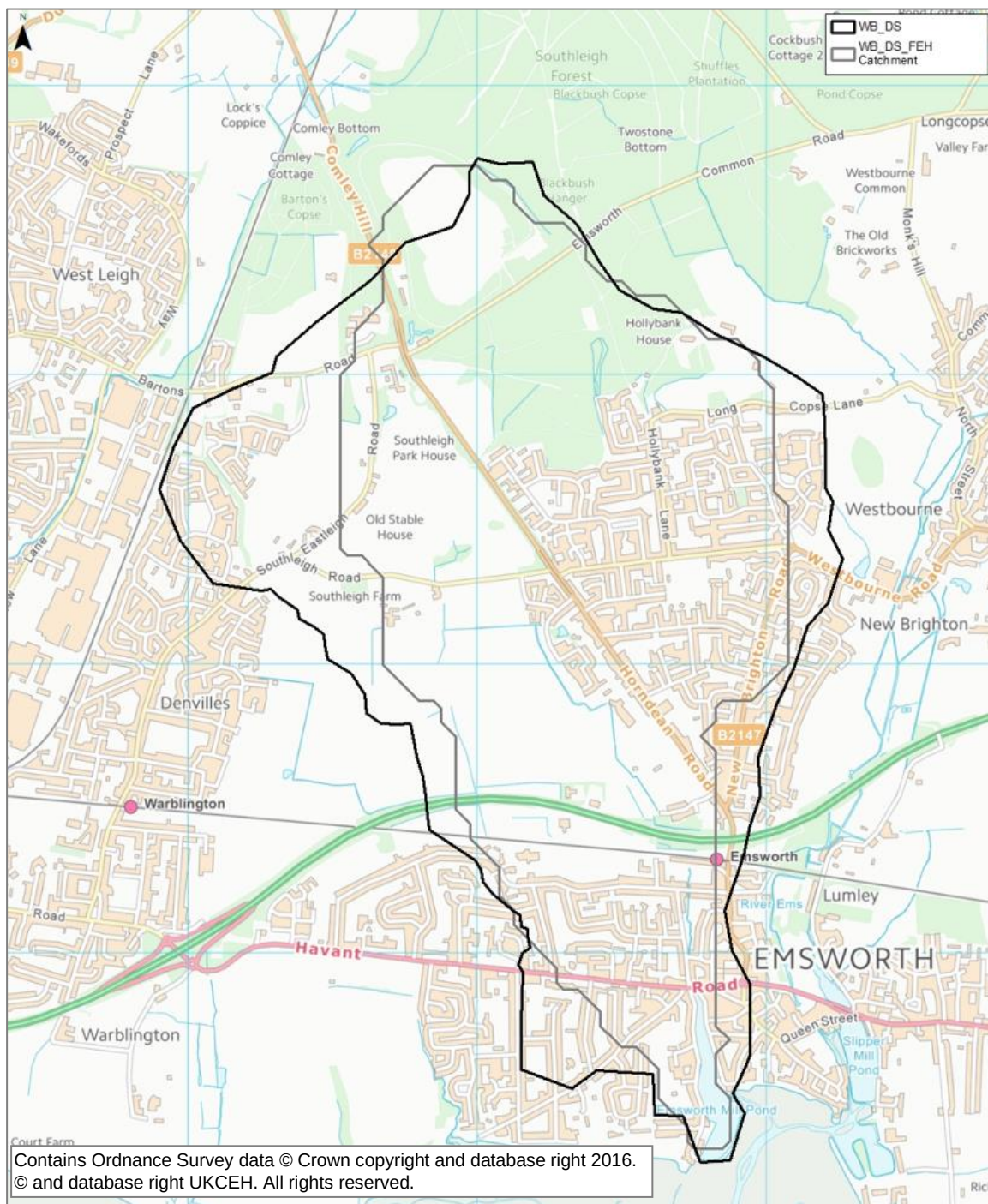


Figure 5 indicates that the FEH catchment for the West Brook was underestimated in comparison to the adjusted catchment. This is largely in the western extent adjacent to the Nore Farm Stream catchment, and is due to the flat nature of the catchment causing issues with the FEH derived catchment. The catchment area increased from 3.17km² to 4.21km².

URBEXT source and method for updating:

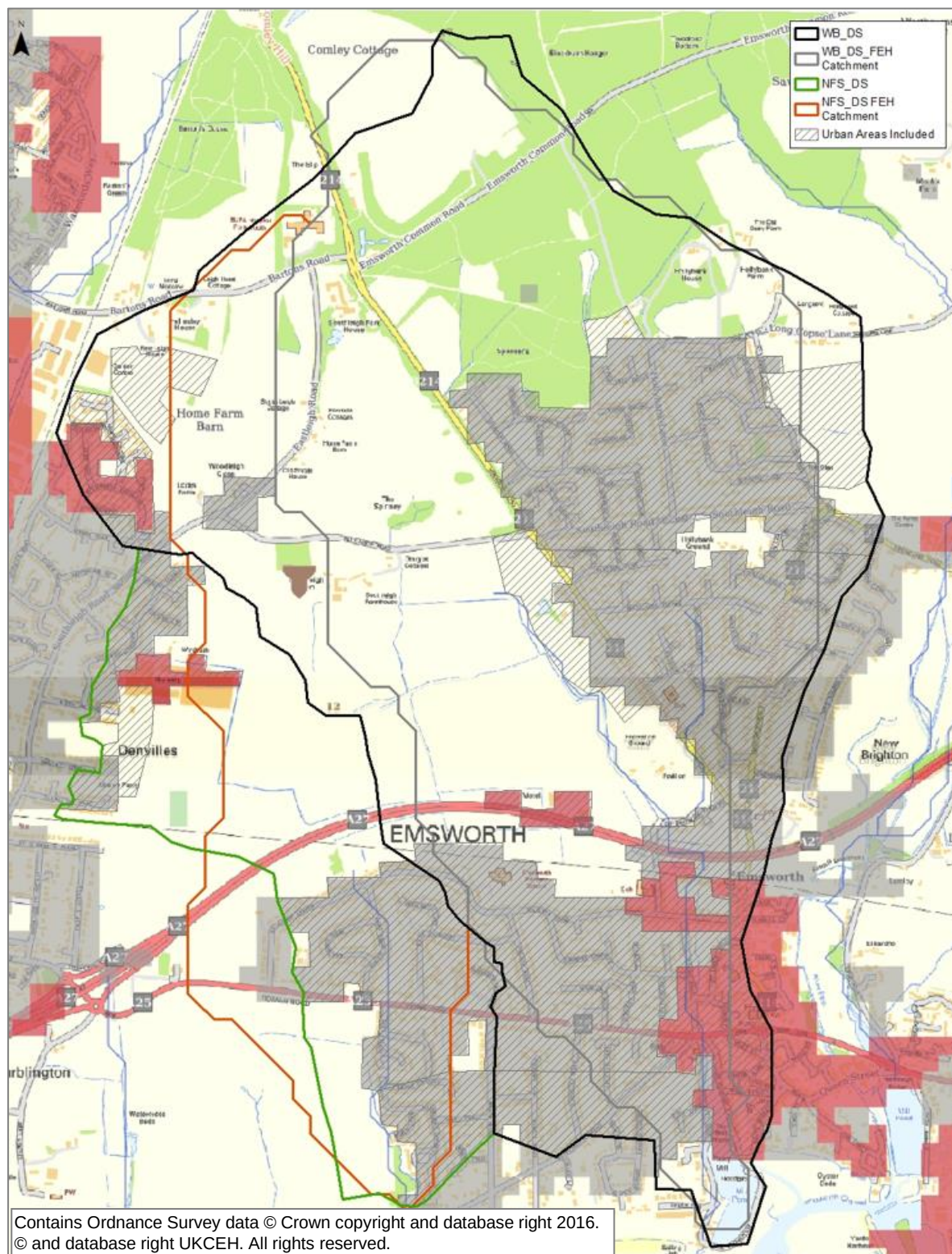
The URBEXT values provided by the FEH Web Service were checked using OS mapping and information provided by the FEH Web Service. Areas of new development were present that were not accounted for in the original URBEXT values provided by the FEH Web Service. This is particularly evident in the upper reaches of the West Brook catchment, where both the towns of Havant in the north-west and Westbourne in the north-east have new areas of development that have not been captured by the FEH Web Service. The catchment area updates also mean additional areas of development have been included within the catchments which need to be represented.

URBEXT1990/URBEXT2000 values provided by the FEH Web Service were therefore manually calculated using FEH Volume 5 Equation 6.2. The updated values differed to the original FEH values, and these were therefore accepted to account for changes in the catchment boundaries and new development not captured on FEH. As the calculations for URBEXT reflected the current conditions in the catchment, the Urban Adjustment Factor was not applied.

The URBEXT values have increased in comparison to the FEH web service, due to a change in catchment areas considered changing the proportion of urban areas, and additional areas of development included.

For NFS_US the increase is significant, increasing from approximately 0.022 to 0.162, going from a classification of rural to one of heavily urbanised. This increase is due to a combination of accepting a smaller catchment area compared to the FEH web service, which contains a higher proportion of urban areas and the inclusion of additional areas of new development. **Figure 6** displays the FEH web service urban areas and catchments in comparison to the updated catchment areas and the urban areas used within the calculations.

Figure 6 NFS_DS and WB_DS Urban Areas Included



BFIHOST source, checks and updates:

The BFIHOST, BFIHOST19 and SPRHOST values were checked using the Soil Survey of England and Wales maps. The values calculated for WB_TRIB and WB_DS were similar to those on the FEH Web Service and were therefore

accepted due to the catchment boundaries remaining broadly similar in these locations. Due to significant changes in the catchment boundaries for the rest of the catchments, the calculated values were accepted over the original FEH values as they are more representative of the soil types included within the updated catchment areas.

The BFIHOST19 values for NFS_US and NFS_DS increased in comparison to the FEH web service, indicating the catchments are more permeable. This is as a result of the change in proportion of soil types included within the altered catchment area, specifically changes in the upper catchment which reduced the proportion of a less permeable soil type (711g) and increased the proportion of a more permeable soil type (841e).

Checks and revisions to other catchment descriptors:

DPLBAR values were adjusted to account for changes in the catchment areas. For NFS_INT and WB_INT it was calculated using the regression equation defined in FEH Volume 5 Equation 7.1. For the remaining sites, it was adjusted using the ratio between the original area and the updated area, with the resultant ratio applied to the FEH DPLBAR value. The calculated values were accepted over the original FEH values.

The OS mapping was reviewed and it was found that there were no online lakes or reservoirs that would contribute to flood storage, and therefore the FARL values of 1 were accepted. It is noted that there is a flood storage area on the West Brook, adjacent to Horndean Road, within the WB_US catchment area. This is within the reach of the watercourse being modelled and therefore the impacts of this will be directly assessed using the hydraulic model rather than considered in the hydrological assessment.

4. Stationary statistical methods

4.1 Method overview

What is the purpose of applying these methods?

The FEH Statistical method is applied to derive QMED and peak flow estimates for the Nore Farm Stream and West Brook catchments.

What methods will be used to estimate QMED and growth curves?

Site code	Methods used for QMED	Methods used for growth curves
NFS_US	Donor adjusted	Pooled analysis
NFS_DS	Donor adjusted	Pooled analysis
NFS_INT	Donor adjusted	Pooled analysis
WB_US	Donor adjusted	Pooled analysis
WB_TRIB	Donor adjusted	Pooled analysis
WB_DS	Donor adjusted	Pooled analysis
WB_INT	Donor adjusted	Pooled analysis

4.2 Estimating QMED

QMED at gauged subject sites:

Site code	Method (AM/ POT/LF)	Initial QMED (m ³ /s)	Number of water years of data used	Adjustment for climatic variation?	Final QMED (m ³ /s)
-	-	-	-	-	-

Methods: AM – Annual maxima; POT – Peaks over threshold; LF – Low flow (flow duration curve) statistics.

Not applicable – no gauged flow data within the catchment.

QMED at ungauged subject sites:

Site code	Method (CD/DT/BCW)	Initial QMED (rural) from CDs (m ³ /s)	Donors used (NRFA numbers)	Donor distances from subject centroid (km)	Donor adjustment factor (rural)	Urban adjustment factor	Final QMED (m ³ /s)
NFS_US	DA	0.09	42017	4.04	1.099	1.304	0.13
NFS_DS	DA	0.16	42017	4.52	1.089	1.479	0.26
NFS_INT	DA	0.09	42017	4.97	1.089	1.652	0.16
WB_US	DA	0.65	42017	4.13	1.094	1.117	0.80
WB_TRIB	DA	0.40	42017	4.74	1.090	1.409	0.61
WB_DS	DA	0.98	42017	4.49	1.099	1.333	1.42
WB_INT	DA	0.14	42017	5.40	1.085	2.123	0.33

Methods: CD - Catchment descriptors alone; DA - catchment descriptors with donor adjustment completed in WINFAP5; DT - catchment descriptors with donor transfer; BCW - catchment descriptors with bankfull channel width.

Urban adjustment of QMED:

WINFAP5 was used for urban adjustment of QMED. The default parameters were used for the urban adjustment, and are as follows:

- Impervious fraction for built-up areas, IF: 0.3
- Percentage runoff for impervious surfaces, PR_{imp}: 70%
- Method for calculating fractional urban cover, URBAN: updated URBEXT 2000

Search for donor sites:

A donor search was completed for each catchment within WINFAP5 to find appropriate donors to inform QMED. Both an urban (URBEXT limit set to 0.3) and non-urban (URBEXT limit set to default 0.03) donor searches were completed for each catchment. Due to the location of the catchments, raising the URBEXT limit to 0.3 allowed for more local stations of similar geology to be included within the donor search.

The urban donor search suggested the 42107 Hermitage Stream @ Havant as an appropriate donor for each catchment, while the non-urban donor search suggested the 41015 Ems @ Westbourne as an appropriate donor for each catchment. A review of both of these donor stations revealed that the Ems @ Westbourne station had a significantly larger catchment area than the Hermitage Stream @ Havant (57 km² vs. 17 km²). Furthermore, the Ems @ Westbourne had a higher SAAR value, a lower FARL value, and is highly groundwater driven (BFHOST19 value of 0.900). The Hermitage Stream @ Havant had a

BFIHOST19 value of 0.273, indicating that it is less permeable than the Nore Farm Stream and West Brook catchments. However, it was more hydrologically similar overall, with similar SAAR, FARL and URBEXT values and more local.

The remainder of the potential donors identified were not considered to be hydrologically similar due to significant differences in either their catchment areas, SAAR, FARL, BFIHOST and SPRHOST values and were not recommended for use by WINFAP5.

The 42017 Hermitage Stream @ Havant was therefore considered to be a suitable donor station to inform QMED values for the Nore Farm Stream and West Brook catchments included within this study. The donor adjusted QMED values were marginally higher in comparison to the catchment descriptor derived QMED values.

Donor sites chosen and QMED adjustment factors:

NRFA no.	Method (AM/POT/LF)	Adjustment for climatic variation?	QMED from flow data (m ³ /s)	De-urbanised QMED from flow data (m ³ /s) (A)	QMED from catchment descriptors (m ³ /s) (B)	Adjustment ratio (A/B)
42017	AM	No	9.61	7.99	6.67	1.20

Methods: AM – Annual maxima; POT – Peaks over threshold; LF – Low flow (flow duration curve) statistics.

4.3 Estimating growth curves

Derivation of growth curves at subject sites:

Site code	Method (SS, P, ESS, H.)	If P or ESS, name of pooling group	Distribution used and reason for choice	Any urban or non-flood years adjustments	Parameters of distribution (location, scale and shape after adjustments)	Growth factor for 100-year return period
NFS_US	P	NFS_DS	K3 - acceptable fit	Urban	Location = 0.94 Scale = 0.261 Shape = -0.237	3.12
NFS_DS						
NFS_INT						
WB_US	P	WB_DS	GL - acceptable fit	Urban	Location = 1 Scale = 0.228 Shape = -0.272	3.09
WB_TRIB						
WB_DS						
WB_INT						

Methods: SS - Single Site; P - Pooled; ESS - Enhanced Single Site; H - Historical. Pooled and ESS growth curves were derived using the procedures

from Science Report SC050050 (2008). Urban adjustments are carried out using the method of Kjeldsen (2010).

Flood frequency curve plots:

Figure 7 FEH Statistical Flood Frequency Curve - NFS_DS

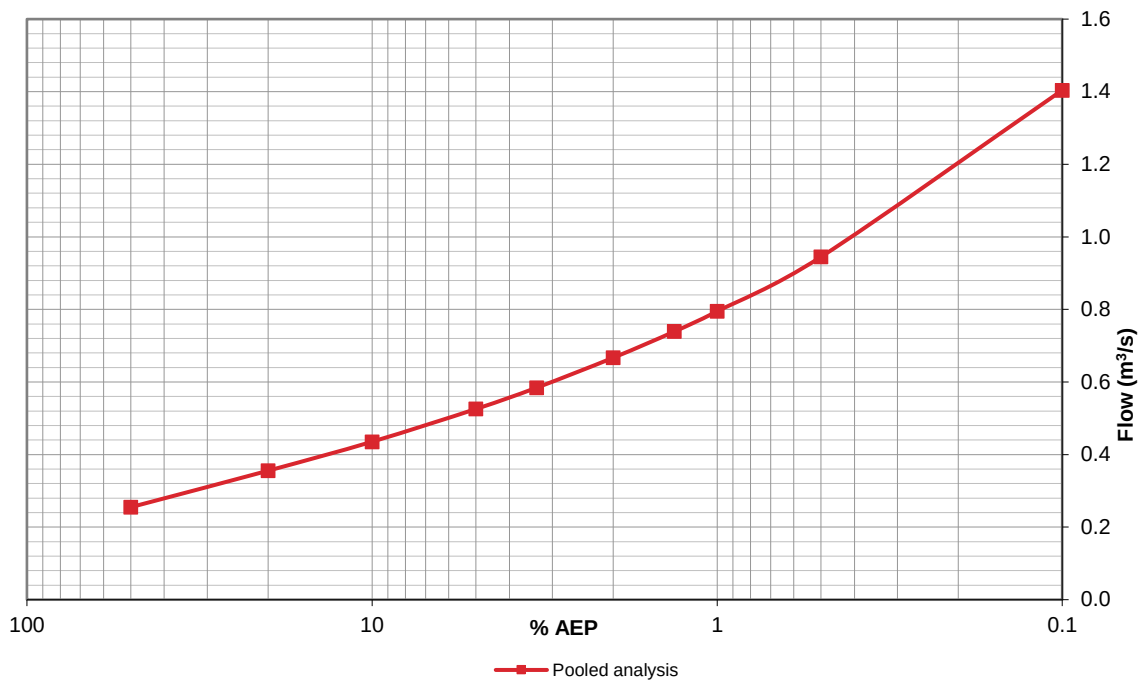
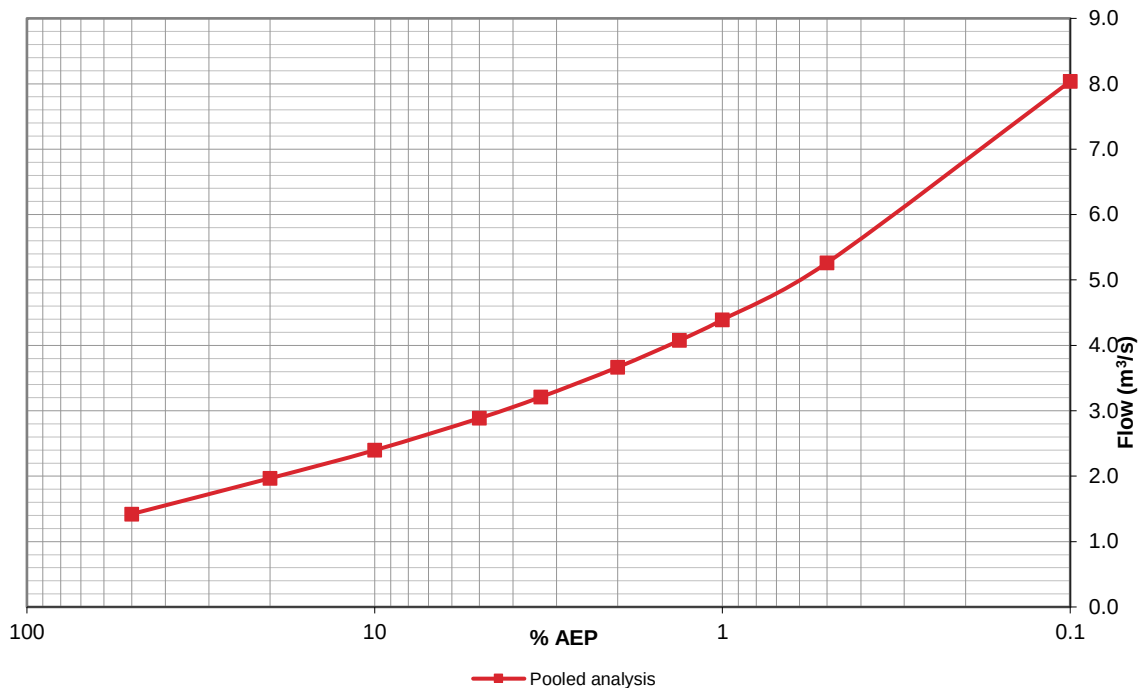


Figure 8 FEH Statistical Flood Frequency Curve - WB_DS



Derivation of pooling groups:

Name of group	Site code from whose descriptors group was derived	Subject site treated as gauged? (ESS)	URBEXT2000 threshold applied to pooling group selection?	L-moments deurbanised (including subject site for ESS)?	Small catchment pooling procedure applied?
NFS_DS	NFS_DS	No	0.03	L-CV: 0.266 L-SKEW: 0.243	No
WB_DS	WB_DS	No	0.03	L-CV: 0.269 L-SKEW: 0.228	No

Methods: Unless otherwise stated, pooling groups were derived using the procedures from Science Report SC050050 (2008). The small catchment pooling procedure is given in the report on Phase 2 of project SC090031 (2021) and implemented in WINFAP v5.

Two pooling groups were created for each watercourse in order to compare their compositions: one for the upstream catchment and one for the downstream catchment. The upstream and downstream catchments for both the Nore Farm Stream pooling groups were identical for NFS_US and NFS_DS, and the West Brook had one differing station in the composition of WB_US and WB_DS pooling groups. Therefore, it was decided that one pooling group would be used for each watercourse based on the pooling group created for the downstream catchment.

The effect of increasing the URBEXT value to 0.3 on pooling group composition was also investigated due to the urban nature of both catchments. There were five changes to the recommended stations for both the NFS_DS and WB_DS pooling groups, with all recommended stations being located a significant distance from the subject catchments (largely northern England), so no additional local gauges included. Both watercourses are ungauged, with no NRFA stations available for use, therefore raising the URBEXT limit would not allow for the inclusion of watercourse-specific or local gauges. Therefore, the default URBEXT limit of 0.03 was retained for both pooling groups.

Pooling group composition:

Name of group	Changes made to default pooling group, with reasons	Weighted average L-moments
NFS_DS	Stations with low years of data (less than 15) were removed and suitable station added to have pooling group with over 500 years of data. <u>Removed:</u> 49005 – removed as only 11 years of data available 7011 – removed as only 9 years of data available	L-CV: 0.266 L-SKEW: 0.243

Name of group	Changes made to default pooling group, with reasons	Weighted average L-moments
	<p><u>Reviewed and retained:</u> 76011 – significantly higher SAAR value and lower BFIHOST19 value, meaning higher proportion of runoff expected on catchment compared to subject catchment 45816 – significantly higher SAAR value and steeper catchment, meaning faster responding catchment than subject catchment 26016 – extremely groundwater driven catchment (BFIHOST19 = 0.927) 28033 – significantly higher SAAR value, much steeper catchment and lower BFIHOST19 value, meaning higher proportion of runoff expected on catchment compared to subject catchment 49005 – significantly higher SAAR value and steeper catchment, meaning faster responding catchment than subject catchment 27010 – significantly higher SAAR value and steeper catchment, meaning faster responding catchment than subject catchment 44008 – significantly higher SAAR value and groundwater driven (BFIHOST19 = 0.848) 47022 – significantly higher SAAR value and steeper catchment, meaning faster responding catchment than subject catchment 26014 – extremely groundwater driven catchment (BFIHOST19 = 0.924) 25011 – significantly higher SAAR value, much steeper catchment and lower BFIHOST19 value, meaning higher proportion of runoff expected on catchment compared to subject catchment</p> <p><u>Added:</u> 41020 – added due to catchment similarity and distance value</p>	
WB_DS	<p>Stations with low years of data (less than 15) removed and suitable station added to have pooling group with over 500 years of data.</p> <p><u>Removed:</u> 49005 – removed as only 11 years of data available 7011 – removed as only 9 years of data available 28058 – removed as only 13 years of data available</p>	L-CV: 0.269 L-SKEW: 0.228

Name of group	Changes made to default pooling group, with reasons	Weighted average L-moments
	<p><u>Reviewed and retained:</u></p> <p>26016 – extremely groundwater driven catchment (BFIHOST19 = 0.927)</p> <p>76011 – significantly higher SAAR value and lower BFIHOST19 value, meaning higher proportion of runoff expected on catchment compared to subject catchment</p> <p>45816 – significantly higher SAAR value and steeper catchment, meaning faster responding catchment than subject catchment</p> <p>27010 – significantly higher SAAR value and steeper catchment, meaning faster responding catchment than subject catchment</p> <p>26014 – extremely groundwater driven catchment (BFIHOST19 = 0.924)</p> <p><u>Added:</u></p> <p>53017 – added due to catchment similarity and distance value</p>	

Weighted L-moments provided above are pre-adjustment values, specifically prior to adjustment for urbanisation.

A review of the stations for each pooling group showed that a large number of years of data were not from stations considered to be hydrologically similar to the subject catchments. These stations are referred to above as 'reviewed and retained'. It was considered preferable to remove these stations due to the anticipated differences in hydrological response, however, this would result in the inclusion of stations with a higher distance value. The distance value is the value derived by WINFAP that is based upon the attributes and catchment descriptors considered to be most important when compiling a pooling group.

Due to the extent of years that would be removed (approximately 200-300) it was considered that those with low years of data and hence of low quality would be removed, and replaced with a station that was relatively hydrologically similar and had a lower distance value. This retained stations that WINFAP considers to be suitable as defined by the lower distance values.

Overall, it is considered that there is low confidence in the FEH Statistical method for deriving peak flows for the Nore Farm Stream and the West Brook. Both catchments are relatively small and the NRFA dataset used to create the pooling groups does not contain many small catchments.

4.4 Final choice of QMED and growth curves

Method choice and reasons:

Site code	Final choice of QMED and reasons	Final choice of flood growth curve method and reasons
NFS_US	Catchment descriptors with donor adjustment (1 donor) using WINFAP5. Local observed data from the Hermitage Stream @ Havant is used to inform QMED adjustment.	Pooled – no gauged data suitable for use within both catchments.
NFS_DS		
NFS_INT		
WB_US		
WB_TRIB		
WB_DS		
WB_INT		

Final flood estimates from stationary statistical methods:

Site code	2 50%	5 20%	10 10%	20 5%	30 3.3 %	50 2%	75 1.3 %	100 1%	200 0.5 %	100 0 0.1 %
NFS_US	0.13	0.18	0.22	0.27	0.30	0.34	0.38	0.41	0.48	0.72
NFS_DS	0.26	0.36	0.44	0.53	0.58	0.67	0.74	0.79	0.94	1.40
NFS_INT	0.10	0.14	0.17	0.20	0.22	0.26	0.28	0.31	0.36	0.54
WB_US	0.80	1.10	1.34	1.62	1.80	2.05	2.28	2.46	2.95	4.50
WB_TRIB	0.61	0.85	1.03	1.24	1.38	1.58	1.76	1.89	2.27	3.46
WB_DS	1.42	1.97	2.40	2.89	3.21	3.67	4.08	4.39	5.26	8.04
WB_INT	0.33	0.45	0.55	0.66	0.73	0.84	0.93	1.00	1.20	1.84

Flood peak in m³/s for the return periods in years or AEP (%) events.

5. Non-stationary statistical methods

Section 4.1 of the latest EA guidance indicates that non-stationary methods should be completed for fluvial flood alleviation projects (short form or outline business case), and flood and coastal erosion risk management strategies if not already submitted to the EA for approval. This study is not being undertaken to support either of these types of projects and therefore isn't considered to be required in this instance.

Due to a lack of reliable, long-term, and suitable quality flow data records in the catchments, non-stationary analysis cannot be completed.

6. Revitalised flood hydrograph (ReFH1) method

Not completed. Method is not suitable for application to the Nore Farm Stream which has a BFIHOST19 values of 0.695, exceeding the upper threshold value of 0.65. The updated ReFH2 method has been applied as presented in **Section 7**.

7. Revitalised flood hydrograph 2 (ReFH2) method

7.1 Method Overview

What is the purpose of applying this method?

The ReFH2.4 method will be used to derive peak flow estimates at the flow estimation locations (**Figure 4**). The ReFH2.4 method will be applied using the latest available version of the software. ReFH2.4 will define the hydrograph shapes for the hydraulic model inflows.

FEH22 rainfall data was released in December 2022, however, the associated ReFH2 software that enables its use in peak flow estimation and hydrograph derivation was not released until June 2023. The EA issued a position statement in December 2022 stating that hydrological assessments completed and submitted prior to 31st August 2023 would not be required to make use of FEH22 and ReFH2.4 due to the release date of ReFH2.4. The updated software was released at the project conception, and hence this assessment was able to make use of the latest available data and software.

Rural and urban catchment sub-divisions:

The ReFH2.4 method was applied with peak flow estimates being derived for lumped catchments to understand how the peak flows change throughout the watercourse catchments. The catchments were not sub-divided.

Version of ReFH2 applied:

ReFH2.4

7.2 Model Parameters

Summary of model parameters:

Site code	Method	Tp (hours) rural	Cmax (mm)	BL (hours)	Area modelled as urban (km ²)	TP urban scaling factor	IF	IRF	DS
NFS_US	CD	2.63	648.6	39.02	0.12	1	0.4	0.7	0.5
NFS_DS	CD	3.25	655.4	41.35	0.80	1	0.4	0.7	0.5
NFS_INT	CD	2.45	655.4	37.13	0.26	0.75	0.4	0.7	0.5
WB_US	CD	3.68	390.8	37.70	0.33	0.75	0.4	0.7	0.5
WB_TRIB	CD	3.06	420.3	37.03	0.63	0.75	0.4	0.7	0.5
WB_DS	CD	4.95	450.8	44.82	1.60	1	0.4	0.7	0.5

Site code	Method	Tp (hours) rural	Cmax (mm)	BL (hours)	Area modelled as urban (km2)	TP urban scaling factor	IF	IRF	DS
WB_INT	CD	2.41	655.4	39.35	0.65	0.75	0.4	0.7	0.5

Methods: OPT: Optimisation from event analysis, BR: Baseflow recession fitting, LAG: TP from lag analysis, CD: Catchment descriptors, DT: Data transfer, CAL: model calibration.

Analysis undertaken to derive model parameters:

No gauged data of sufficient quality is available for the catchment to inform model parameter optimisation or calibration.

7.3 Model inputs for design events

Design events for lumped catchments:

Site code	Rainfall DDF model	Urban or rural	Highly permeable?	Season of design event	Storm duration (hrs)	Initial soil moisture Cini	Initial baseflow BFO
NFS_US	FEH22	Rural	Yes	Summer	4.5	40.76	0.004
NFS_DS	FEH22	Rural	Yes	Summer	7.5	39.96	0.008
WB_US	FEH22	Rural	No	Winter	8.5	101.14	0.062
WB_TRIB	FEH22	Urban	No	Summer	5.5	62.90	0.021
WB_DS	FEH22	Rural	No	Winter	13.5	92.12	0.100

Values above are those calculated for the individual lumped catchment. The season of the design events were selected based on the URBEXT value and BFIHOST value, in accordance with the latest EA guidance (Section 4.3). As noted in **Section 2.4**, a review of the observed level data indicated that the winter storm profile was considered appropriate for the West Brook.

Design events for subcatchments and intervening areas:

Site code(s)	Rainfall DDF model	Season of design event	Storm duration (hrs)	Storm area for ARF	Areal reduction factor ARF	Reason for selecting storm
NFS_US	FEH22	Summer	4.5	0.48	0.982	Critical storm duration for key catchment of interest.
NFS_DS	FEH22					
NFS_INT	FEH22					
WB_US	FEH22	Winter	8.5	2.10	0.977	Critical storm duration for key catchment of interest.
WB_TRIB	FEH22					
WB_DS	FEH22					
WB_INT	FEH22					

Values above are those calculated to provide a consistent storm on the separate watercourses.

Storm duration testing:

The storm duration for each catchment was optimised in ReFH2.4 through iteration.

The storm durations are calculated for each catchment individually and for the overall watercourses based on NFS_US and WB_US as the critical locations. This is to provide a consistent storm duration for all catchments. If ReFH2 is chosen as the final method further consideration will be given to the storm profile and duration used within the hydraulic model.

7.4 Final choice of ReFH2 flow estimates

Method choice and reasons:

Site code	Final choice of design inputs and model parameters
NFS_US	Model parameters derived from catchment descriptors. Critical storm durations and storm profiles are calculated and set based on the area of interest for each watercourse (NFS_US and WB_US).
NFS_DS	
NFS_INT	
WB_US	
WB_TRIB	
WB_DS	
WB_INT	

Final flood estimates from ReFH2 method: Watercourses

Site code	2 50%	5 20%	10 10%	20 5%	30 3.3 %	50 2%	75 1.3 %	100 1%	200 0.5 %	100 0 0.1 %
NFS_US	0.06	0.09	0.11	0.13	0.14	0.16	0.17	0.19	0.22	0.35
NFS_DS	0.10	0.15	0.18	0.21	0.24	0.27	0.29	0.32	0.38	0.60
NFS_INT	0.06	0.09	0.11	0.14	0.15	0.17	0.19	0.20	0.24	0.38
WB_US	0.45	0.60	0.70	0.81	0.87	0.96	1.04	1.10	1.27	1.85
WB_TRIB	0.35	0.46	0.54	0.63	0.68	0.75	0.81	0.86	0.99	1.44
WB_DS	0.78	1.02	1.20	1.38	1.49	1.64	1.78	1.88	2.18	3.22
WB_INT	0.11	0.16	0.19	0.23	0.25	0.28	0.31	0.34	0.41	0.66

Flood peak in m³/s for the return periods in years or AEP (%) events.

Storm profile and duration set by NFS_US for Nore Farm Stream and WB_US for West Brook catchments respectively.

8. Other Rainfall-Runoff or Hydrograph Methods

None applied.

9. Discussion and summary of results

9.1 Comparison of results from different methods

Site code	Ratio of ReFH2 to stationary statistical peak, 50% AEP	Ratio of ReFH2 to stationary statistical peak, 1% AEP
NFS_US	0.46	0.47
NFS_DS	0.39	0.40
NFS_INT	0.61	0.65
WB_US	0.57	0.45
WB_TRIB	0.57	0.45
WB_DS	0.55	0.43
WB_INT	0.34	0.34

9.2 Final choice of method

Choice of method and reasons:

The ReFH2.4 peak flow estimates are selected for use in the hydraulic model. It is suitable for use deriving peak flows and hydrographs for small and urban catchments.

While the FEH Statistical method provides more conservative flow estimates than the ReFH2 method (see **Figure 9** and **Figure 10**), a review of the pooling groups showed that there was low confidence in the hydrological similarity of the pooling group composition. This would result in a large number of years of data being removed and increasing the distance values of those stations added to provide a pooling group with 500 years of data. This is likely due to the small catchment areas of the subject sites and the fact that the NRFA dataset does not contain many small catchments. Hence, the overall confidence level in the pooling groups and their resultant peak flow estimates is low. The ReFH2 method was therefore considered to be the preferred method for deriving peak flow estimates for the subject catchments.

Figure 9 Comparison of FFCs for NFS_DS

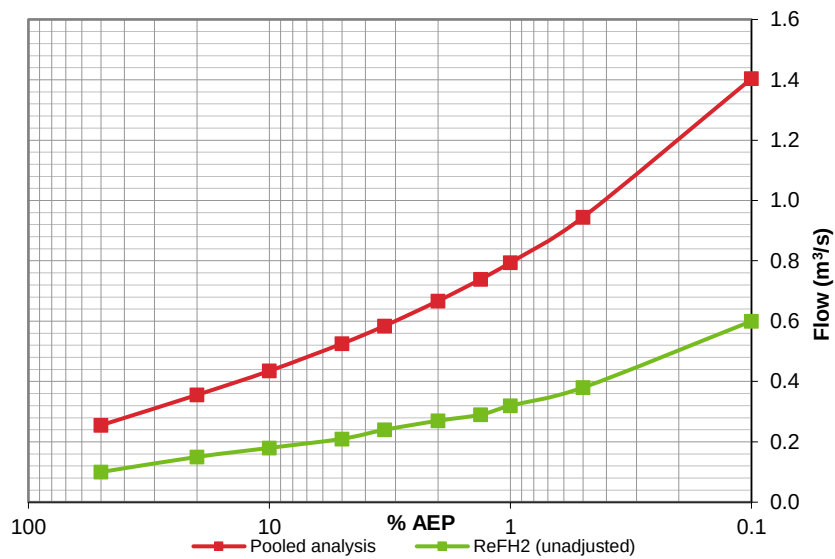
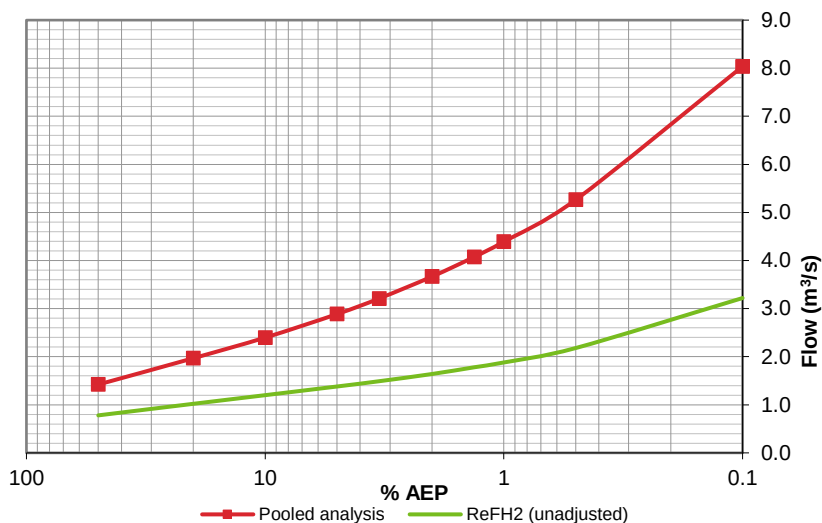


Figure 10 Comparison of FFCs for WB_DS



How will the 0.1% AEP flows be estimated?

ReFH2.4 is suitable for estimating 0.1% AEP flows and will be used to inform the 0.1% AEP flows.

How will the flows be applied to a hydraulic model?

NFS_US will be applied as the upstream inflow to the hydraulic model for the Nore Farm Stream channel, while NFS_INT will be applied as an inflow at the appropriate location along the modelled reach between the culverted reach of the Nore Farm Stream under the A27 and the downstream model extent.

WB_US and WB_TRIB will be applied as the upstream inflows to the hydraulic model to the West Brook main channel and tributary respectively. WB_INT will be applied as an inflow at the appropriate location along the modelled reach

between the confluence of the West Brook (WB_US) and the tributary (WB_TRIB) and the downstream model extent.

9.3 Final results

Site code	2 50%	5 20%	10 10%	20 5%	30 3.3%	50 2%	75 1.3%	100 1%	200 0.5%	1000 0.1%
NFS_US	0.06	0.09	0.11	0.13	0.14	0.16	0.17	0.19	0.22	0.35
NFS_DS	0.10	0.15	0.18	0.21	0.24	0.27	0.29	0.32	0.38	0.60
NFS_INT	0.06	0.09	0.11	0.14	0.15	0.17	0.19	0.20	0.24	0.38
WB_US	0.45	0.60	0.70	0.81	0.87	0.96	1.04	1.10	1.27	1.85
WB_TRIB	0.35	0.46	0.54	0.63	0.68	0.75	0.81	0.86	0.99	1.44
WB_DS	0.78	1.02	1.20	1.38	1.49	1.64	1.78	1.88	2.18	3.22
WB_INT	0.11	0.16	0.19	0.23	0.25	0.28	0.31	0.34	0.41	0.66

Flood peak in m³/s for the return periods in years or AEP (%) events.

Note that the peak flows provided above are those derived for the storm profile and duration considered suitable for the respective watercourses, and not those derived for the individual sub-catchments.

Design storms applied in the hydraulic model:

Site code(s)	Season of design event	Storm duration (hrs)	Storm area for ARF (km ²)	Return period(s)	Reason for selecting storm
NFS_US	Summer	4.5	0.982	30, 100, 1000, 100 +25% allowance for climate change, and 100 +36% allowance for climate change	Summer storm selected based on NFS_US URBEXT value between 0.15 and 0.3 and BFIHOST19 >0.65 – Section 4.3 of EA Guidance.
NFS_DS					
NFS_INT					
WB_US	Winter	8.5	0.977	30, 100, 1000, 100 +25% allowance for climate change, and 100 +36% allowance for climate change	Winter storm selected based on WB_US URBEXT value being between 0.15 and 0.3, and BFIHOST19 <0.65. Analysis of observed data also indicates that the catchment has a
WB_TRIB					
WB_DS					
WB_INT					

Site code(s)	Season of design event	Storm duration (hrs)	Storm area for ARF (km ²)	Return period(s)	Reason for selecting storm
					winter seasonality for higher level events.

Due to the proximity of the two catchments, it is noted that some hydraulic model testing may need to be carried before confirming the final storm duration and seasonality to be used. This will ensure consistency in the model runs and will be confirmed within associated hydraulic modelling reporting.

Climate change allowances:

Based on the latest available guidance⁵, as the site is located within the Arun and Western Streams management catchment, peak river flow allowances of 25% (central) and 36% (higher central) are applicable to this study for the 2080s epoch (2070-2115).

9.4 Checks

Growth factor checks:

Site code	1% AEP growth factor	0.1% AEP / 1% AEP ratio
NFS_US	3.17	1.84
NFS_DS	3.20	1.88
NFS_INT	3.33	1.90
WB_US	2.44	1.68
WB_TRIB	2.46	1.67
WB_DS	2.41	1.71
WB_INT	3.09	1.94

The growth factors provided above are within the anticipated range.

⁵ Environment Agency (2022) Peak river flow climate change allowances by management catchment.

Specific discharge:

Site code	2 50%	5 20%	10 10%	20 5%	30 3.3%	50 2%	75 1.3%	100 1%	200 0.5%	1000 0.1%
NFS_US	1.2	1.9	2.3	2.7	2.9	3.3	3.5	3.9	4.5	7.2
NFS_DS	2.1	3.1	3.7	4.3	5.0	5.6	6.0	6.6	7.9	12.4
NFS_INT	1.2	1.9	2.3	2.9	3.1	3.5	3.9	4.1	5.0	7.9
WB_US	9.3	12.4	14.5	16.7	18.0	19.8	21.5	22.7	26.2	38.2
WB_TRIB	7.2	9.5	11.2	13.0	14.0	15.5	16.7	17.8	20.5	29.8
WB_DS	16.1	21.1	24.8	28.5	30.8	33.9	36.8	38.8	45.0	66.5
WB_INT	2.3	3.3	3.9	4.8	5.2	5.8	6.4	7.0	8.5	13.6

Flood peak in l/s/ha for the return periods in years or AEP (%) events.

Spatial consistency of results:

Peak flow estimates increase downstream at confluences and through lumped catchments.

Return periods for notable historic floods:

NA – no observed flow data.

Compatibility with longer-term flood history:

NA – no gauged data of sufficient quality on either watercourse. The available recorded flood outlines have been reviewed. These show a recorded flood outline on the West Brook downstream of Victoria Road, south of A27/railway and site of interest.

No historic flood outlines are shown for the Nore Farm Stream or for the West Brook in the site of interest. Therefore, no comparisons can be made.

The model outputs will be compared to the Flood Map for Planning as a comparison after the hydraulic modelling has been completed.

Comparisons with previous studies:

No hydrological modelling report is available for the previous flood study carried out by Mott Macdonald in 2015, therefore a comparison is not possible.

Checks on hydraulic model results:

Modelled levels and extents will be sense checked to confirm that flow inputs result in realistic results. This will be reported within the hydraulic modelling report.

9.5 Assumptions, limitations, and uncertainty

Assumptions (specific to this study):

- The catchment descriptors are representative of the catchment
- The method of urban representation is representative
- The ReFH2.4 hydrograph shapes are representative of the catchments to rainfall

Limitations:

The Nore Farm Stream and West Brook catchments do not have reliable gauged data suitable for use deriving peak flow estimates or informing hydrograph shapes. They have therefore been treated as ungauged, which is the most significant limitation to this study.

While a temporary gauge could be installed on the watercourses, the data required to inform a hydrological study is significant and not in line with the timescales of this scheme.

The study has been completed using the available data as far as possible and appropriate, the latest available software and methods, in line with EA guidance. The study is therefore considered to be an appropriate and robust assessment, despite the limitations that exist within the catchment, methods and data available.

Uncertainty:

Note that the uncertainty bounds provided below are based upon the FEH Statistical method, which was not selected for use. They are also based upon the values provided for 'moderately urban' catchments, those with an URBEXT2000 value between 0.03 and 0.15, whereas a number of the catchments used within this study exceed that limit and classification. No uncertainty bound information is provided for more urban catchments. The uncertainty bounds are therefore provided for information only.

Site code	50% AEP Lower 95%	50% AEP Upper 95%	5% AEP Lower 95%	5% AEP Upper 95%	1% AEP Lower 95%	1% AEP Upper 95%	0.1% AEP Lower 95%	0.1% AEP Upper 95%
NFS_US	0.05	0.33	0.10	0.74	0.14	1.19	0.21	2.47
NFS_DS	0.10	0.64	0.19	1.45	0.27	2.34	0.41	4.84
NFS_INT	0.04	0.25	0.07	0.56	0.10	0.90	0.16	1.86
WB_US	0.32	2.00	0.58	4.46	0.84	7.23	1.31	15.53
WB_TRIB	0.24	1.54	0.45	3.43	0.64	5.56	1.00	11.94
WB_DS	0.57	3.57	1.04	7.97	1.49	12.91	2.33	27.73
WB_INT	0.13	0.82	0.24	1.82	0.34	2.95	0.53	6.34

Upper and lower 95% confidence bounds for the flood peak in m³/s for the AEP (%) events.

The ReFH2 peak flow estimates are within the uncertainty bounds outlined above. The exception is the WB_INT 5% AEP event which is 0.01m³/s lower than the lower bound shown. This may be due to difficulties representing intervening catchments when deriving QMED.

Suitability of results for future studies:

The peak flow estimates and hydrographs have been derived for the upstream and downstream extents, tributaries, and intervening areas of the Nore Farm Stream and the West Brook. The hydrology should be reviewed as a minimum for any future studies.

Recommendations for future work:

The main limitation of this study is the lack of gauged flow data for both watercourses. If a flow monitoring station were installed upon the Nore Farm Stream and the West Brook, the observed data could be used to refine the peak flow estimates derived from this study. This was outside the scope of this study.

10. Appendix

10.1 Digital files

File can be provided on request.

10.2 Pooling Group Information

Default pooling group – NFS_DS						
Pooling Group ID	Pooling group stations	Years of AMAX data	Heterogeneity	Goodness of fit		
				GL	GEV	K3
NFS_DS	76011 (Coal Burn @ Coalburn)	44	3.48	1.84	0.32	1.33
	27073 (Brompton Beck @ Snainton Ings)	41				
	27051 (Crimple @ Burn Bridge)	49				
	45816 (Haddeo @ Upton)	28				
	25019 (Leven @ Easby)	43				
	26016 (Gypsey Race @ Kirby Grindalythe)	24				
	28033 (Dove @ Hollinsclough)	46				
	49005 (Bolingey Stream @ Bolingey Cocks Bridge)	11				
	27010 (Hodge Beck @ Bransdale Weir)	41				
	44008 (South Winterbourne @ Winterbourne Steepleton)	30				
	36010 (Bumpstead Brook @ Broad Green)	54				
	47022 (Tory Brook @ Newnham Park)	26				
	26014 (Water Forlornes @ Driffield)	23				
	25011 (Langdon Beck @ Langdon)	35				
	7011 (Black Burn @ Pluscarden Abbey)	9				
TOTAL		504				

Final pooling group – NFS_DS							
Pooling Group ID	Pooling group stations	Years of AMAX data	Heterogeneity	GL	GEV	K3	Final chosen distribution
NFS_DS edit	76011 (Coal Burn @ Coalburn)	44	3.48	1.20	-0.44	0.64	K3
	27073 (Brompton Beck @ Snainton Ings)	41					
	27051 (Crimple @ Burn Bridge)	49					
	45816 (Haddeo @ Upton)	28					
	25019 (Leven @ Easby)	43					
	26016 (Gypsy Race @ Kirby Grindalythe)	24					
	28033 (Dove @ Hollinsclough)	46					
	27010 (Hodge Beck @ Bransdale Weir)	41					
	44008 (South Winterbourne @ Winterbourne Steepleton)	30					
	36010 (Bumpstead Brook @ Broad Green)	54					
	47022 (Tory Brook @ Newnham Park)	26					
	26014 (Water Forlornes @ Driffild)	23					
	25011 (Langdon Beck @ Langdon)	35					
	41020 (Bevern Stream @ Clappers Bridge)	52					
	TOTAL	536					

Default pooling group – WB_DS						
Pooling Group ID	Pooling group stations	Years of AMAX data	Heterogeneity	GL	GEV	K3
WB_DS	27073 (Brompton Beck @ Snainton Ings)	41	3.48	0.98	-0.66	-0.42
	27051 (Crimple @ Burn Bridge)	49				
	25019 (Leven @ Easby)	43				
	26016 (Gypsy Race @ Kirby Grindalythe)	24				
	76011 (Coal Burn @ Coalburn)	44				
	45816 (Haddeo @ Upton)	28				
	49005 (Bolingey Stream @ Bolingey Cocks Bridge)	11				
	27010 (Hodge Beck @ Bransdale Weir)	41				
	44008 (South Winterbourne @ Winterbourne Steepleton)	30				
	26014 (Water Forlornes @ Driffild)	23				
	36010 (Bumpstead Brook @ Broad Green)	54				
	7011 (Black Burn @ Pluscarden Abbey)	9				
	28033 (Dove @ Hollinsclough)	46				
	41020 (Bevern Stream @ Clappers Bridge)	52				
	28058 (Henmore Brook @ Ashbourne)	13				
	TOTAL	508				

Final pooling group – WB_DS							
Pooling Group ID	Pooling group stations	Years of AMAX data	Heterogeneity	GL	Goodness of fit		Final chosen distribution
				GEV	K3		
WB_DS edit	27073 (Brompton Beck @ Snainton Ings)	41	3.70	0.74	-0.97	0.14	GL
	27051 (Crimple @ Burn Bridge)	49					
	25019 (Leven @ Easby)	43					
	26016 (Gypsy Race @ Kirby Grindalythe)	24					
	76011 (Coal Burn @ Coalburn)	44					
	45816 (Haddeo @ Upton)	28					
	27010 (Hodge Beck @ Bransdale Weir)	41					
	44008 (South Winterbourne @ Winterbourne Steepleton)	30					
	26014 (Water Forlornes @ Driffield)	23					
	36010 (Bumpstead Brook @ Broad Green)	54					
	28033 (Dove @ Hollinsclough)	46					
	41020 (Bevern Stream @ Clappers Bridge)	52					
	53017 (Boyd @ Bitton)	48					
	TOTAL	523					