JBA Project Code	2020s0744
Contract	Solihull Level 2 SFRA
Client	Faithful & Gould
Date	June 2020
Author	Clare Burnell
Reviewer / Sign-off	Jenni Essex
Subject	Option 1 and 2 Sites – Hydrological Assessment

1 Introduction

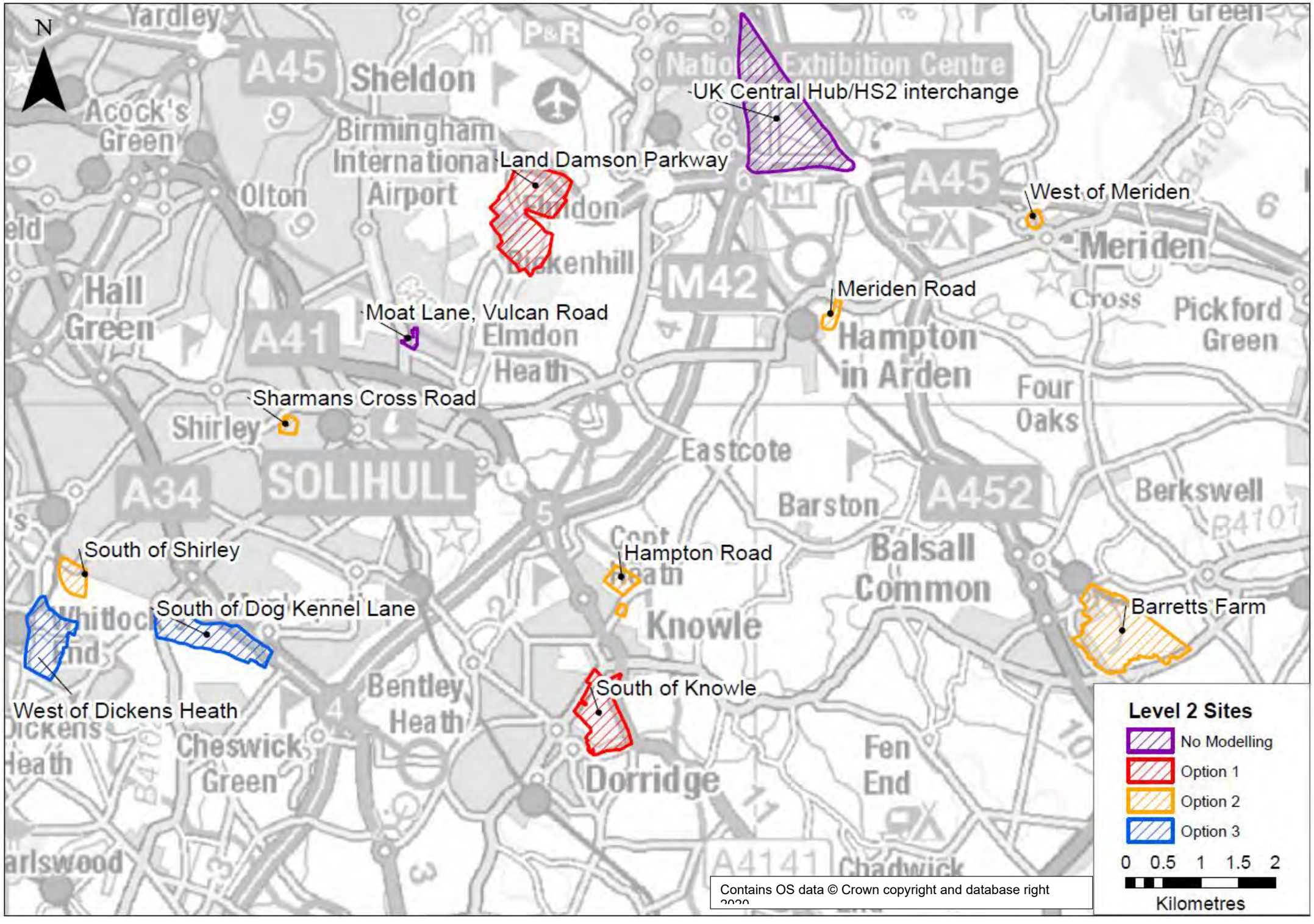
JBA Consulting has been commissioned by Solihull Metropolitan Borough Council (SMBC) to undertake a level 2 strategic flood risk assessment (SFRA) for 12 sites around Solihull, West Midlands. Eight of the sites require broadscale 2D hydraulic modelling of the local watercourses and adjacent area. Two of the sites will be modelled in 2D only (Option 1); the other six sites will be modelled in 2D with key structures added as 1D elements within the model (Option 2). Two further sites require detailed 1D-2D modelling (Option 3) and two do not require any modelling. The sites are detailed in Table 1-1 and shown in Figure 1-1.

Table 1-1: Solihull Level 2 SFRA sites

Option	Site Number	Site Name
No modelling	17	Moat Lane, Vulcan Road
	19	UK Central Hub / HS2 interchange
1	9	South of Knowle
	20	Land Damson Parkway
2	1	Barretts Farm
	6	Meriden Road
	8	Hampton Road
	10	West of Meriden
	18	Sharmans Cross Road
	26	South of Shirley
3	4	West of Dickens Heath
	12	South of Dog Kennel Lane

A hydrological assessment is required to derive model inflows for all Option 1 to 3 sites. This technical note provides a record of the flood flow estimation calculations, and results, for the eight sites where 2D modelling is being carried out (Option 1 and 2 sites). The scope for these sites is constrained to a high-level appraisal and hence a simple hydrological assessment. Due to this only a brief outline of the process taken to derive the inflows is required. Separate detailed calculation records will be generated for the sites where 1D-2D modelling will be undertaken. These require a more comprehensive hydrological analysis, although still constrained by the project scope to a routine assessment.

Figure 1-1: Location of Solihull Level 2 SFRA sites



2 Method statement

2.1 Catchment Characteristics

Solihull is located 11km south east of Birmingham in England with the main watercourses in the area being the River Blythe and Grand Union Canal. The underlying geology in the area has been assessed using the British Geological Survey mapping[1]. The area mainly comprises of Mudstone, Siltstone and Sandstone, with small areas of Limestone. Soils in the area have been assessed using the Cranfield Soil and Agrifood Institutes Soilscapes webservice[2]. The dominant soils in the area are slowly permeable seasonally wet soils and Loamy soils with naturally high ground water.

2.2 Flood History

A brief Internet search was carried out for flood history in Solihull which showed that the area was badly affected by the July 2007[3] as well as the February 2020[4] floods. Specific flood history for each subject site was not available due to the scope of the study.

2.3 Approach for Estimating Flood Flows

Due to the scope of the project a simple approach has been applied for generating design event flood flow estimates and hydrographs:

- Identify if the study watercourse and drainage area to the site is defined by the FEH Web Service. If not, select a local 'representative' catchment for which peak flow estimates and hydrographs can be derived and area-weighted to the study area.
- Brief check of catchment descriptors for each site, focusing predominantly on catchment area.
- FEH Statistical method used to generate design peak flow estimates.
    - Brief search for suitable donor catchment for data transfer. This will generally be the closest gauged catchment to the study area, as per guidance from the latest research on small catchments[5], unless there is good reason to select an alternative donor.
    - Default pooling group accepted without review except to remove any stations with less than eight years record.
- Hydrograph shapes derived using the ReFH2 model and fitted to the Statistical peaks. The recommended storm duration for the location will be used; no storm duration testing will be carried out.

[1] British Geological Survey: http://mapapps.bgs.ac.uk/geologyofbritain/home.html
[2] Cranfield Soil and Agrifood Institutes Soilscapes: http://www.landis.org.uk/soilscapes/
[3] Preliminary Flood Risk Assessment Report (2011) https://www.solihull.gov.uk/Portals/0/CrimeAndEmergencies/PFRA.pdf
[4] Birmingham Live (2020) https://www.birminghammail.co.uk/news/midlands-news/widespread-flooding-across-solihull-storm-17758417
[5] Stewart. L., Faulkner, D., Formetta, G., Griffin, A. Haxton, T., Prosdocimi, I., Vesuviano, G., and Young, A. 2019. Estimating flood peaks and hydrographs for small catchments (Phase 2). Report – SC090031/RO, Environment Agency.

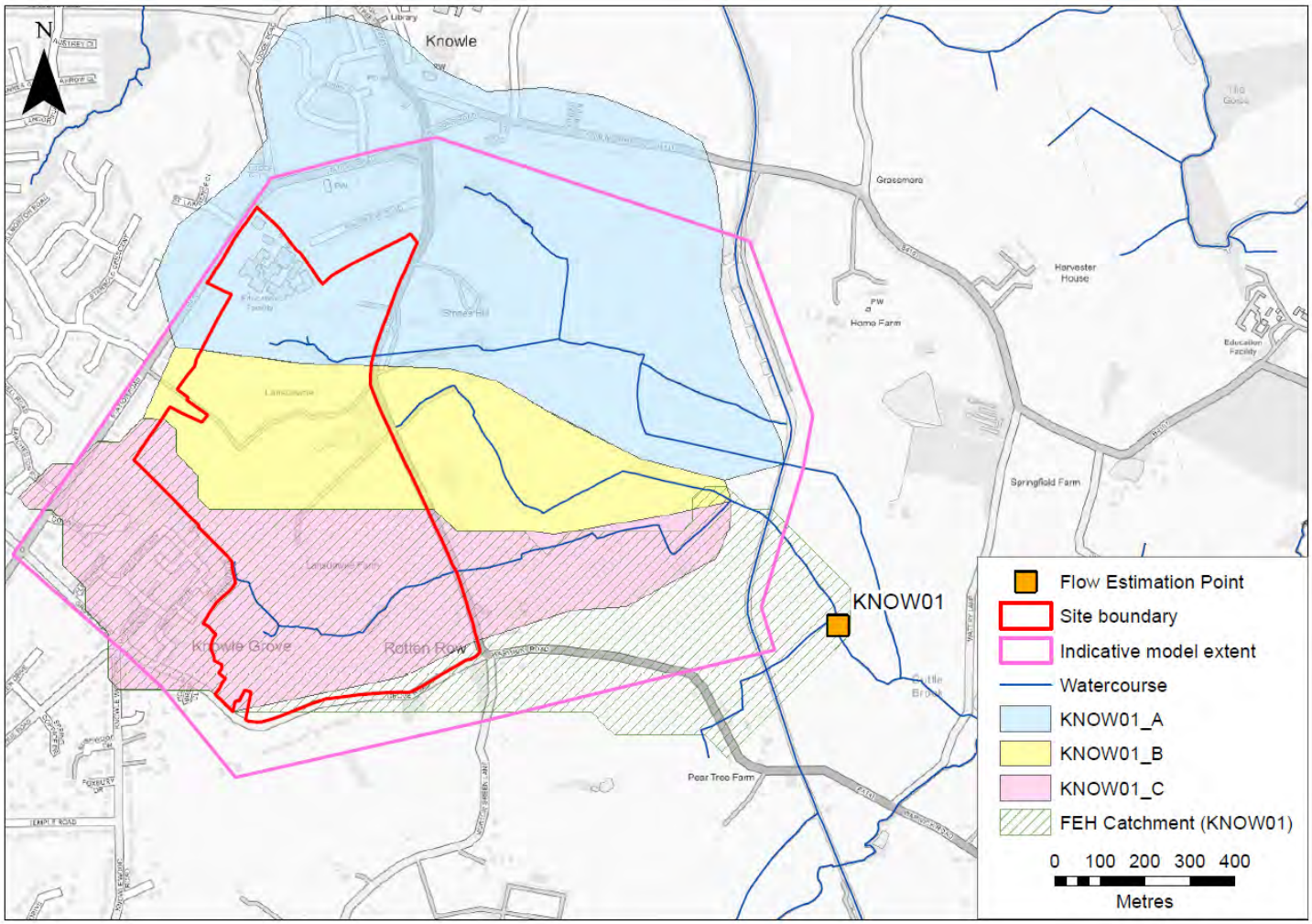
Peak flows have been generated for a range of annual exceedance probability (AEP) events between 50% and 0.1%. However, for the purposes of this study, model inflow hydrographs are only required for the 20%, 1% and 0.1% AEP events. The effects of climate change will be accounted for by applying an increase of 20%, 30% and 50% to the 1% AEP event flow. These increases correlate to the central, higher central and upper end allowances to the 2080s for the Humber River Basin District[6].

Software / data: FEH Web Service[7] / WINFAP-FEH v3.0.003[8]/ ReFH2.3 / NRFA peak flows dataset, Version 8 (September 2019).

[6] Environment Agency. 2016. Flood risk assessments: climate change allowances.
[7] CEH 2015. The Flood Estimation Handbook (FEH) Online Service, Centre for Ecology & Hydrology, Wallingford, Oxon, UK.
[8] WINFAP-FEH v3 © Wallingford HydroSolutions Limited and NERC (CEH) 2009.

3 Flood Estimate Locations & Model Inflows

3.1 Site 9 – South of Knowle



Contains OS data © Crown copyright and database right 2020

Flow estimation point selection & applying model inflows

A flow estimation point (FEP) has been taken as close to the site as possible (KNOW01), on Cuttle Brook, as the drainage area for each tributary was not available on the FEH Web Service. For each of the three tributaries being modelled, the drainage area has been manually derived using two-metre LiDAR data and OS contour mapping[9]. The flow generated at the FEP will be area-weighted to each of the three tributary catchments. The resulting flow will be applied to the upstream extents of the model.

[9] OS Open Data. Terrain50_Contours

Catchment descriptor checks (KNOW01)

Two-metre LiDAR, OS contour mapping and watercourse lines[10] were used to check the FEH Web Service catchment boundary for KNOW01. A very minor inaccuracy was found on the northern boundary of the catchment; this would have minimal impact on the flow estimates. The FEH boundary was deemed to be suitable and no changes were made to the exported shapefile.

The FEH BFIHOST19 value of 0.378 was deemed reasonable based on the soils and geology described in the area (Section 2.1) and was not amended.

The FARL value of 1.00 indicates there is no attenuation in the catchment. The FARL value was considered representative and was not amended.,

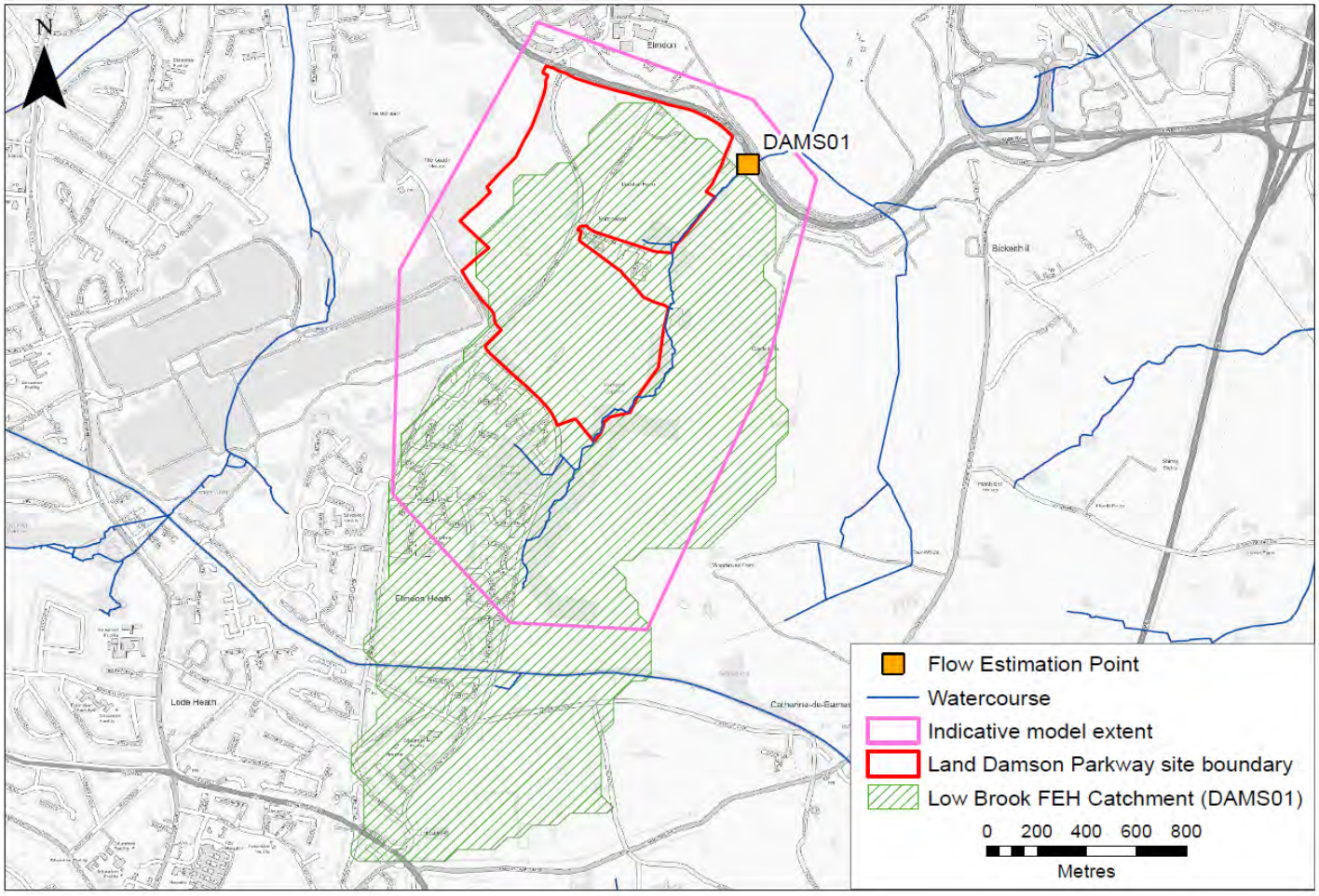
The URBEXT2000 value has been checked against the Urban Extent 2000 layer on the FEH Web Service. It gives an acceptable fit throughout the catchment and was not amended except to update to the current year (2020).

FEP code	Lumped / sub-catchment	Watercourse	Location	Easting	Northing	FEH Web Service AREA (km^2)	Revised AREA (km^2)
KNOW01	L	Cuttle Brook	Representative catchment downstream of the model boundary	419150	275500	0.77	-

FEP code	FARL	PROPWET	BFIHOST19	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	$URBEXT_{2000}$ (updated to 2020[11])	FPEXT
KNOW01	1.00	0.28	0.378	1.15	25.3	712	0.100	0.134

[10] OS Open Data. WatercourseLink_openrivers
[11] CPRE formula from 2006 CEH report on URBEXT2000

3.2 Site 20 – Land at Damson Parkway



Contains OS data © Crown copyright and database right 2020

Flow estimation point selection & applying model inflows

A FEP has been selected at the downstream extent of the model on Low Brook. The upstream area of the model was used to proportion the derived hydrograph, with 32% of the flow being applied to the upstream model extent and 68% being applied slightly downstream of the urban area e.g. on the Low Brook at the southern boundary of the site in the figure above.

Catchment descriptor checks

Two-metre LiDAR, OS contour mapping and watercourse lines were used to check the FEH Web Service catchment boundary. The FEH boundary was deemed to be suitable and no changes were made to the exported shapefile.

The FEH BFIHOST19 value of 0.454 was deemed reasonable based on the soils and geology described in the area (Section 2.1) and was not amended.

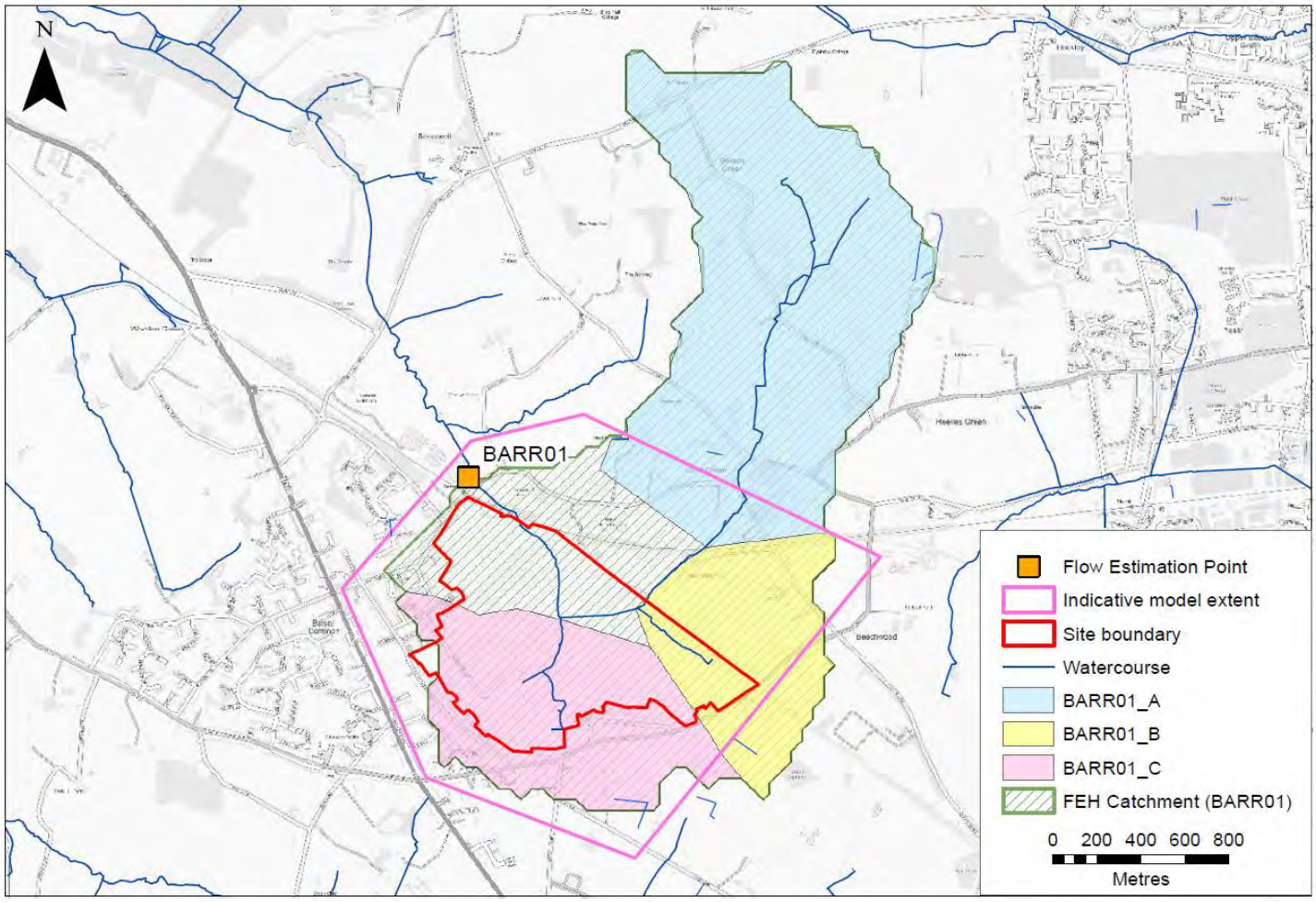
The FARL value of 1.00 indicates there is no attenuation in the catchment. The FARL value was considered representative and was not amended.

The URBEXT2000 value has been checked against the Urban Extent 2000 layer on the FEH Webservice. It gives a poor fit throughout the catchment, with much of the housing development along Damson Parkway not included in the Urban Extent 2000 layer. It is not within the scope of this study to derive a new URBEXT value. Updating the value to the current year (2020) will account for some additional urban area, but it is likely that the URBEXT2000 value is underestimated. It is recommended that a new URBEXT2000 value is derived, and new flow estimates made, for any future detailed studies.

FEP code	Lumped / sub-catchment	Watercourse	Location	Easting	Northing	FEH Web Service AREA (km^2)	Revised AREA (km^2)
DAMS01	Lumped	Low Brook	Downstream boundary	417600	282800	3.36	-

FEP code	FARL	PROPWET	BFIHOST19	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	$URBEXT_{2000}$ (updated to 2020[11])	FPEXT
DAMS01	1.00	0.31	0.454	1.87	34	702	0.087	0.04

3.3 Site 1 – Barretts Farm



Contains OS data © Crown copyright and database right 2020

Flow estimation point selection & applying model inflows

A FEP was selected at the downstream model extent. A coarse representation drainage catchment for each tributary draining to or within the site was manually derived using two-metre LiDAR data and OS contour mapping. These catchments were closely based on the catchments available on the FEH Web Service and as such are likely to be very similar but not identical to the FEH Web Service. This is likely to have little significant impact on flows. The coarse representation drainage areas were used to proportion the flow estimated at the FEP. No intervening area hydrograph is required as all flow estimated at the downstream extent (BARR01) will be applied to the upstream model extents.

Catchment descriptor checks (BARR01)

Two-metre LiDAR, OS contour mapping and watercourse lines were used to check the FEH Web Service catchment boundary. The FEH boundary was deemed to be suitable and no changes were made to the exported shapefile.

The FEH BFIHOST19 value of 0.418 was deemed reasonable based on the soils and geology described in the area (Section 2.1) and was not amended.

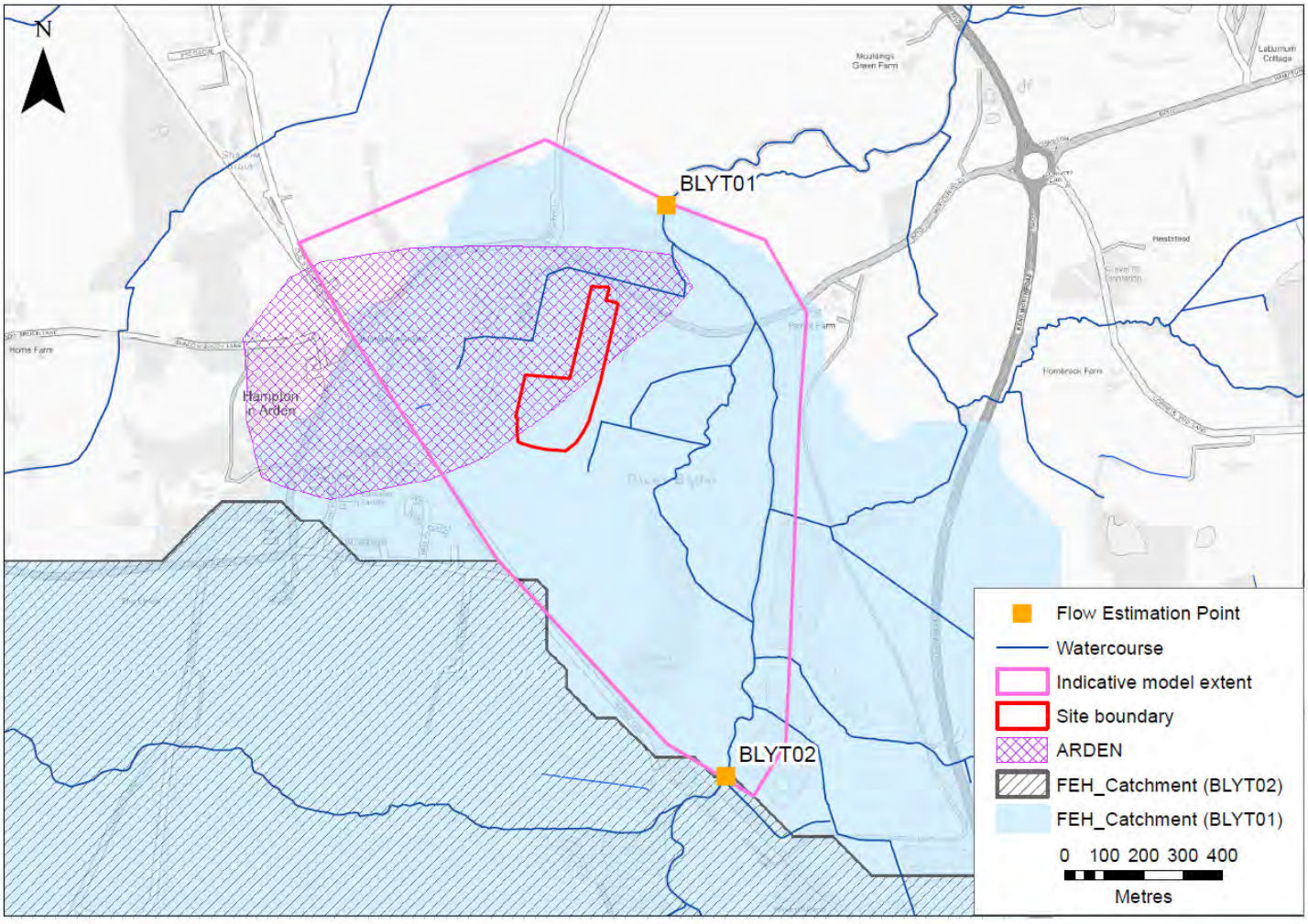
The FARL value of 1.00 indicates there is no attenuation in the catchment. The FARL value is considered representative and was not amended.

The URBEXT2000 value has been checked against the Urban Extent 2000 layer on the FEH Web Service. It gives an acceptable fit throughout the catchment and was not amended except to update to the current year (2020).

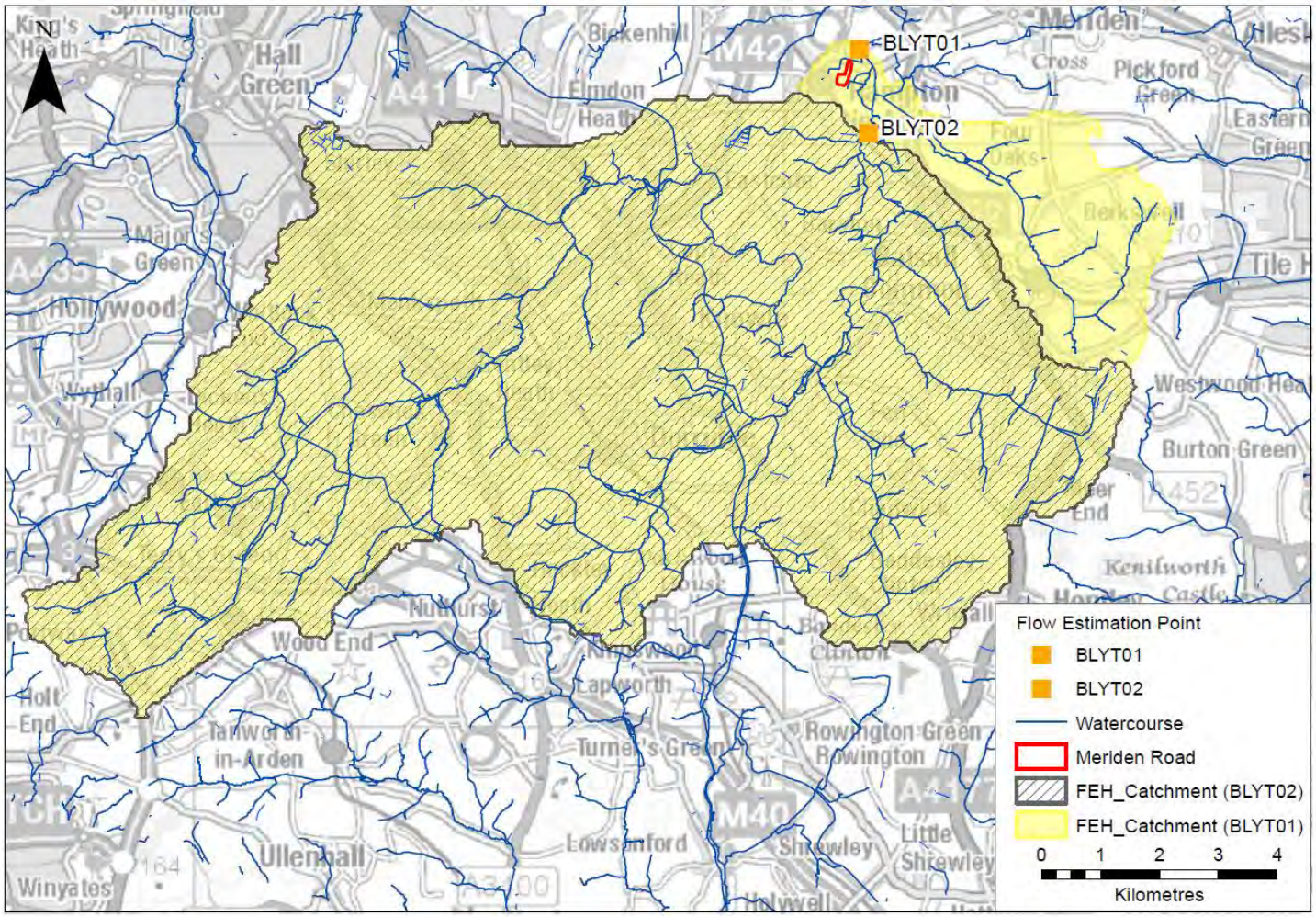
FEP code	Lumped / sub-catchment	Watercourse	Location	Easting	Northing	FEH Web Service AREA (km^2)	Revised AREA (km^2)
BARR01	Lumped	Unnamed	Downstream model extent	424550	277650	4.5	-

FEP code	FARL	PROPWET	BFIHOST19	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	$URBEXT_{2000}$ (updated to 2020[11])	FPEXT
BARR01	1.00	0.3	0.418	2.12	21	702	0.030	0.087

3.4 Site 6 – Meriden Road



Contains OS data © Crown copyright and database right 2020



Contains OS data © Crown copyright and database right 2020

Flow estimation point selection & applying model inflows

Two FEPs were selected, one at the upstream model extent on the River Blythe and one at the downstream extent. The drainage area for the watercourse that flows through Hampton in Arden (ARDEN) is not defined by the FEH Web Service and was manually derived. The intervening area between the two FEPs was calculated, and area-weighted to the manually derived catchment (ARDEN) to provide a model inflow for this watercourse. The remaining flow from the intervening area will be applied as two point inflows along the River Blythe. Flows estimated at the downstream model extent have been area weighted to the upstream catchment and will be applied to the upstream extent of the model on the River Blythe.

Catchment descriptor checks

Two-metre LiDAR, OS contour mapping and watercourse lines were used to check the FEH Web Service catchment boundary. The FEH boundary was deemed to be suitable and no changes were made to the exported shapefile.

The FEH BFIHOST19 values of 0.413 and 0.403 were deemed reasonable based on the soils and geology described in the area (Section 2.1) and were not amended.

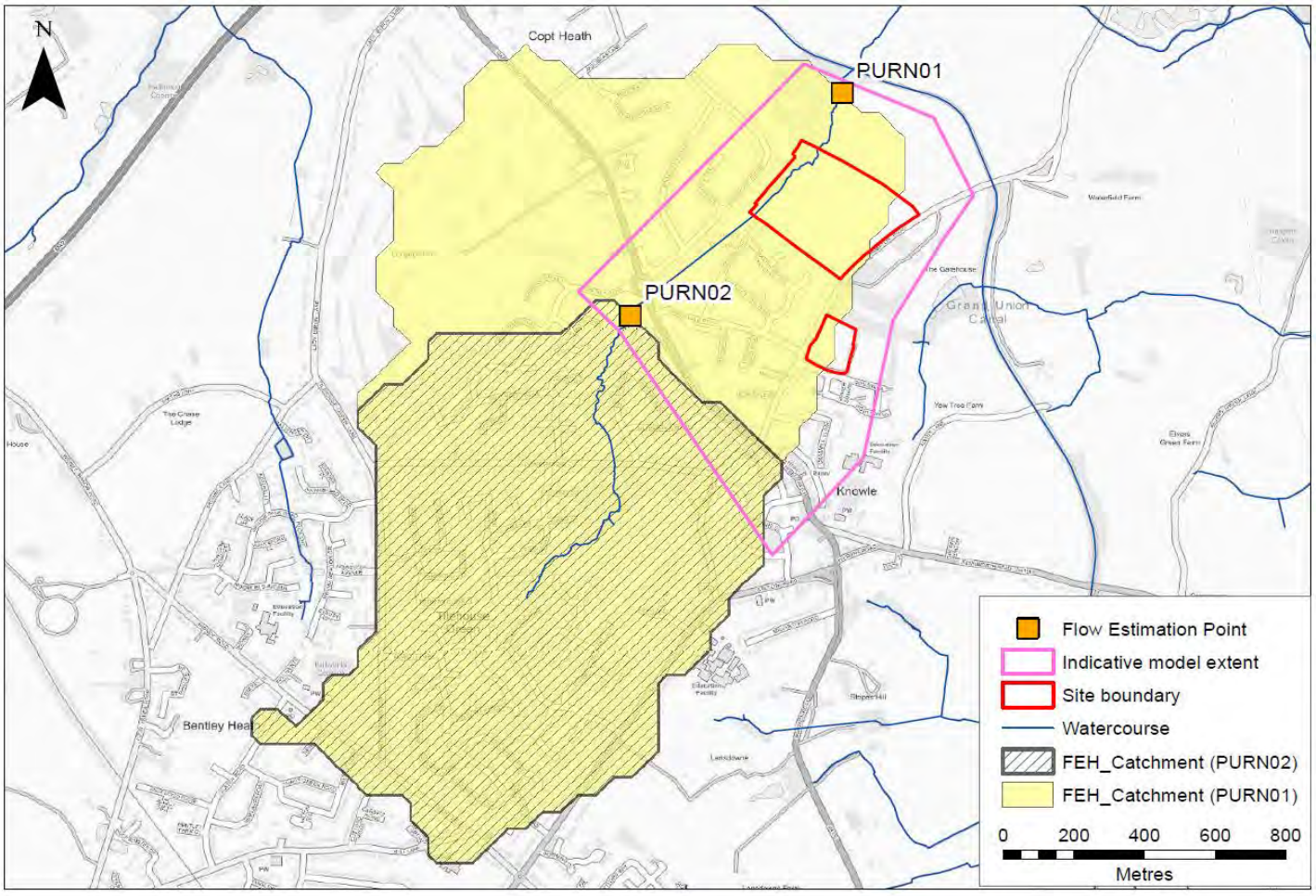
The FARL values of 0.949 and 0.947 indicate there is some attenuation in the catchment. There are several large offline lakes within the model extent. Two of these lakes, just south and just north of the railway line, appear to potentially have a connection to the Blythe. One of the lakes is a fishing lake and the other is part of a nature reserve. Neither of these uses will specifically provide flood flow attenuation and the connection to the river may only be providing an overflow from the lakes. It is not within the scope of the study to investigate this further or to calculate a new FARL value, and the FARL values were not amended.

The URBEXT2000 value was checked against the Urban Extent 2000 layer on the FEH Web Service. It gives a moderate fit throughout the catchment, with only the areas of Dickens Heath and Balsall Common having poor coverage. It is not within the scope of this study to derive new URBEXT values. Updating the values to the current year (2020) will account for some additional urban area, but the URBEXT2000 values may be underestimated. It is recommended that consideration is given to this in any future detailed studies.

FEP code	Lumped / sub-catchment	Watercourse	Location	Easting	Northing	FEH Web Service AREA (km^2)	Revised AREA (km^2)
BLYT01	L	River Blythe	Downstream model extent	421300	281600	130.5	-
BLYT02	L	River Blythe	Upstream model extent	421400	280150	117.1	-

FEP code	FARL	PROPWET	BFIHOST19	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	$URBEXT_{2000}$ (updated to 2020^{11})	FPEXT
BLYT01	0.95	0.29	0.41	15.49	24.2	718	0.085	0.115
BLYT02	0.95	0.29	0.40	14.95	24.1	720	0.092	0.116
BYLTH01_IA	0.95	0.28	0.41	4.16	25.1	718	0.024	0.115

3.5 Site 8 – Hampton Road



Contains OS data © Crown copyright and database right 2020

Flow estimation point selection & applying model inflows

FEPs were selected at the upstream and downstream extents of the model. Flows were produced for the downstream extent of the model only; the catchment area to PURN02 was used to proportion the flow estimated at PURN01, to be applied to the upstream extent of the model. The remaining flow from the hydrograph will be applied as lateral flow between the upstream and downstream extent of the model.

Catchment descriptor checks

Two-metre LiDAR, OS contour mapping and watercourse lines were used to check the FEH Web Service catchment boundaries. The FEH boundaries were deemed to be suitable and no changes were made to the exported shapefiles.

The FEH BFIHOST19 value of 0.505 was deemed reasonable based on the soils and geology described in the area (Section 2.1) and was not amended.

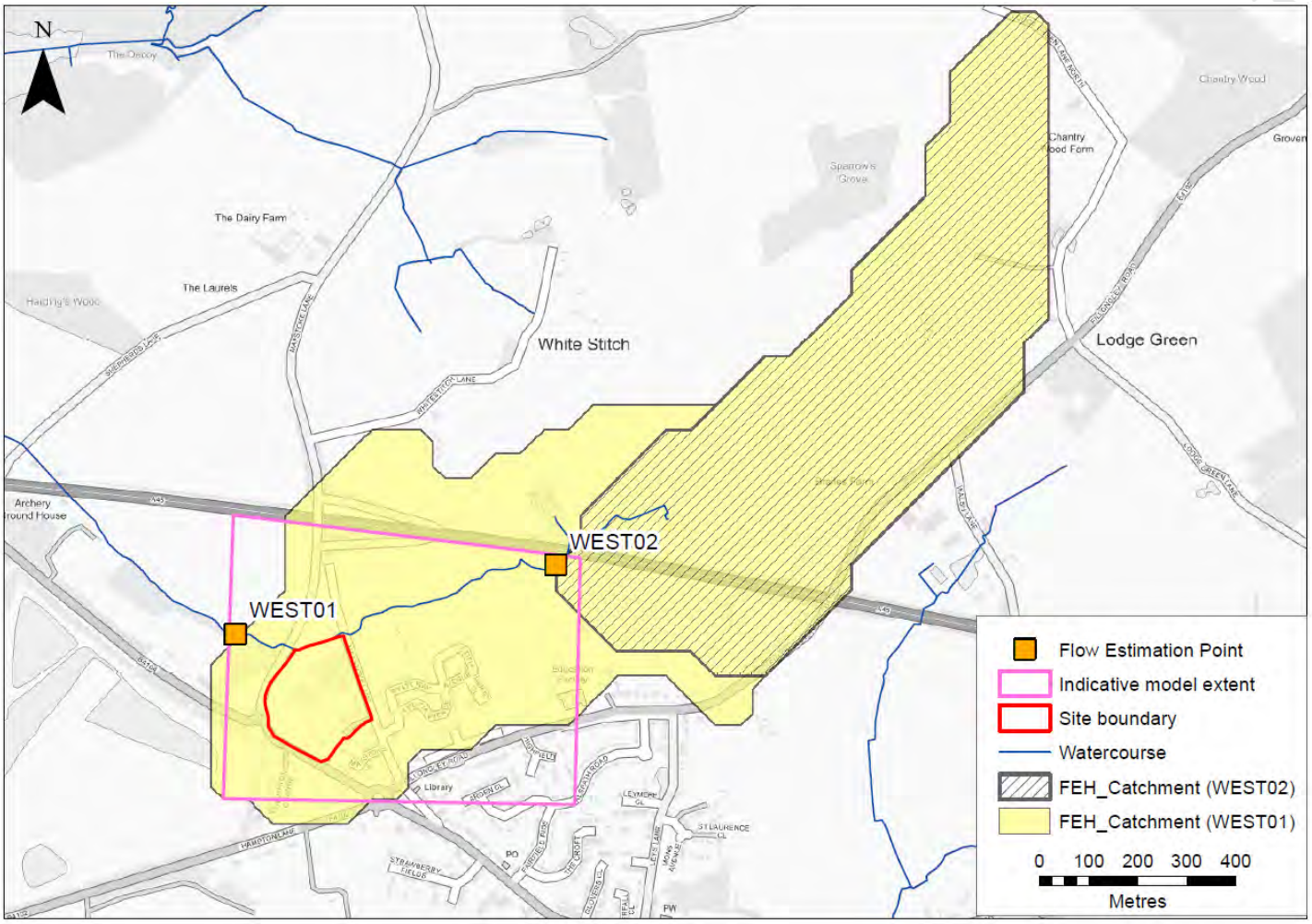
The FARL value of 1.00 indicates there is no attenuation in the catchment. The FARL value was considered representative and was not amended.

The URBEXT2000 value has been checked against the Urban Extent 2000 layer on the FEH Web Service. There are small areas where the coverage is poor, for example, either side of Wychwood Avenue. It is not within the scope of this study to derive a new URBEXT value and, in this case, it is unlikely to make a substantial difference to the results. Updating the value to the current year (2020) will account for some additional urban area, but the URBEXT2000 value may be slightly underestimated. It is recommended that consideration is given to generating an updated URBEXT2000 value for any future detailed studies.

FEP code	Lumped / sub-catchment	Watercourse	Location	Easting	Northing	FEH Web Service AREA (km^2)	Revised AREA (km^2)
PURN01	L	Purnell's Brook	Downstream model extent	418250	277950	2.55	-
PURN02	L	Purnell's Brook	Upstream model extent	417650	277300	1.40	-

FEP code	FARL	PROPWET	BFIHOST19	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	$URBEXT_{2000}$ (updated to 2020^{11})	FPEXT
PURN01	1.00	0.28	0.505	1.59	26.4	710	0.356	0.082

3.6 Site 10 – West of Meriden



Contains OS data © Crown copyright and database right 2020

Flow estimation point selection & applying model inflows

FEPs were selected at the upstream and downstream extents of the model. Flows were produced for the downstream extent of the model only; the catchment area to WEST02 was used to proportion the flow estimated at WEST01, to be applied to the upstream extent of the model. The remaining flow from the hydrograph will be applied as lateral flow between the upstream and downstream extent of the model.

Catchment descriptor checks

Two-metre LiDAR, OS contour mapping and watercourse lines were used to check the FEH Web Service catchment boundaries. The FEH boundaries were deemed to be suitable and no changes were made to the exported shapefiles.

The FEH BFIHOST19 value of 0.516 was deemed reasonable based on the soils and geology described in the area (Section 2.1) and were not amended.

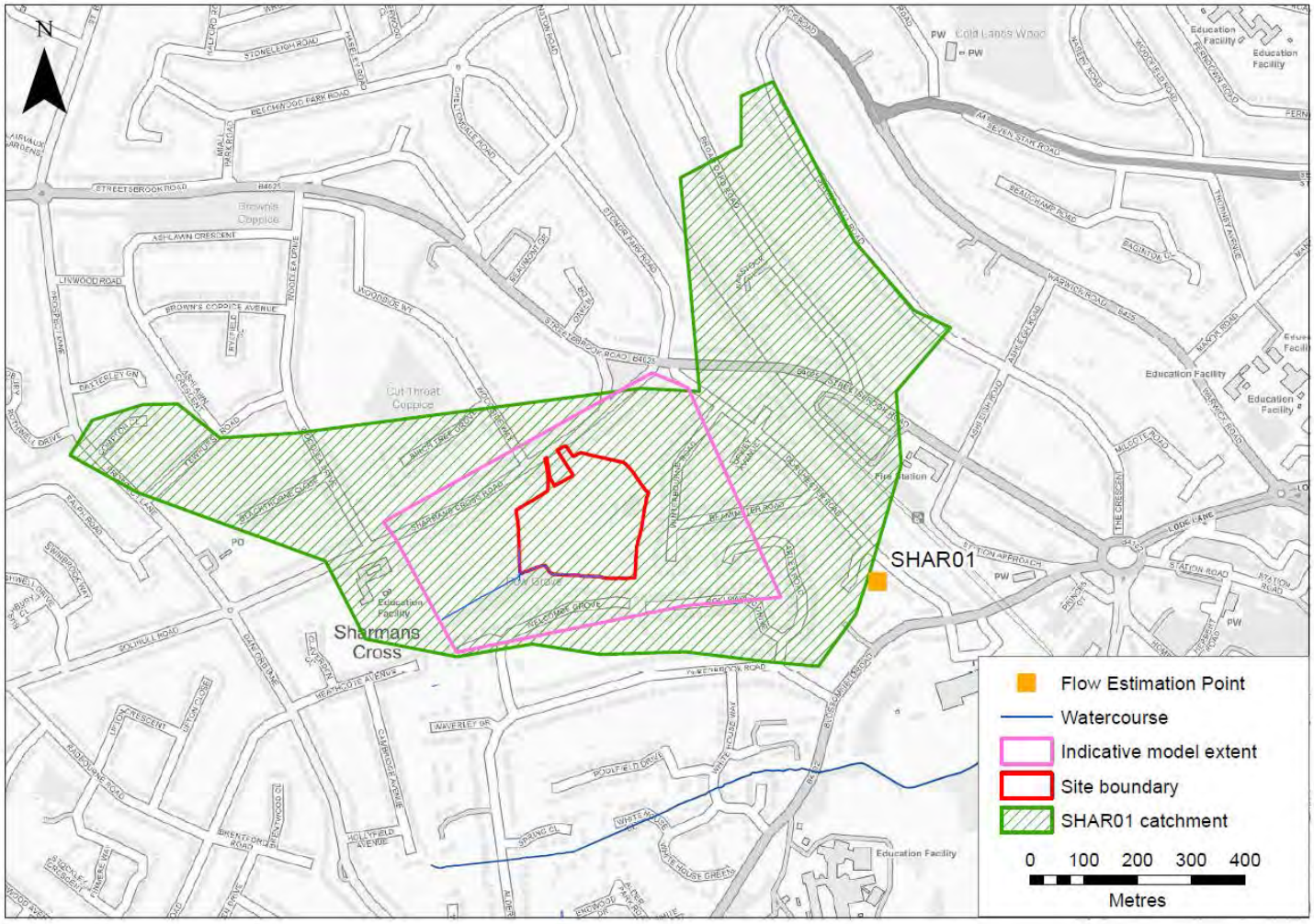
The FARL value of 1.00 indicates there is no attenuation in the catchment. The FARL value is considered representative.

The URBEXT2000 value has been checked against the Urban Extent 2000 layer on the FEH Web Service. It gives an acceptable fit throughout the catchment and was not amended except to update to the current year (2020).

FEP code	Lumped / sub-catchment	Watercourse	Location	Easting	Northing	FEH Web Service AREA (km^2)	Revised AREA (km^2)
WEST01	L	Unnamed	Downstream model extent	423600	282600	1.05	-
WEST02	L	Unnamed	Upstream model extent	424250	282750	0.56	-

FEP code	FARL	PROPWET	BFIHOST19	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	$URBEXT_{2000}$ (updated to 2020)	FPEXT
WEST01	1.00	0.3	0.516	1.03	35.6	703	0.056	0.041

3.7 Site 18 – Sharmans Cross Road



Contains OS data © Crown copyright and database right 2020

Flow estimation point selection & applying model inflows

A FEP was selected at the downstream model extent and the flow applied to the upstream model extent. There is little in the way of open channel shown on OS mapping within this highly urbanised area. The most representative catchment defined by the FEH Web Service has been selected for the purposes of this study, but it is unclear how accurately this defines the drainage area which might affect the site. Catchment descriptors were originally exported for a larger catchment to the west for the purposes of deriving inflows. However, on further investigation, the catchment shown in the figure above was deemed more representative of the area likely to be draining to the site. As the catchment descriptors are likely to be very similar for both FEH catchments, it was decided to use the descriptors exported for the larger catchment and adjust AREA and DPLBAR to represent the smaller catchment, rather than export another set of descriptors.

Catchment descriptor checks

Two-metre LiDAR, OS contour mapping, watercourse lines and the catchment boundary shown on the FEH Web Service were used to define the catchment area for the FEP (as the boundary for this catchment was not exported from the FEH Web Service).

The FEH BFIHOST19 value of 0.345 was deemed reasonable based on the soils and geology described in the area (Section 2.1) and was not amended.

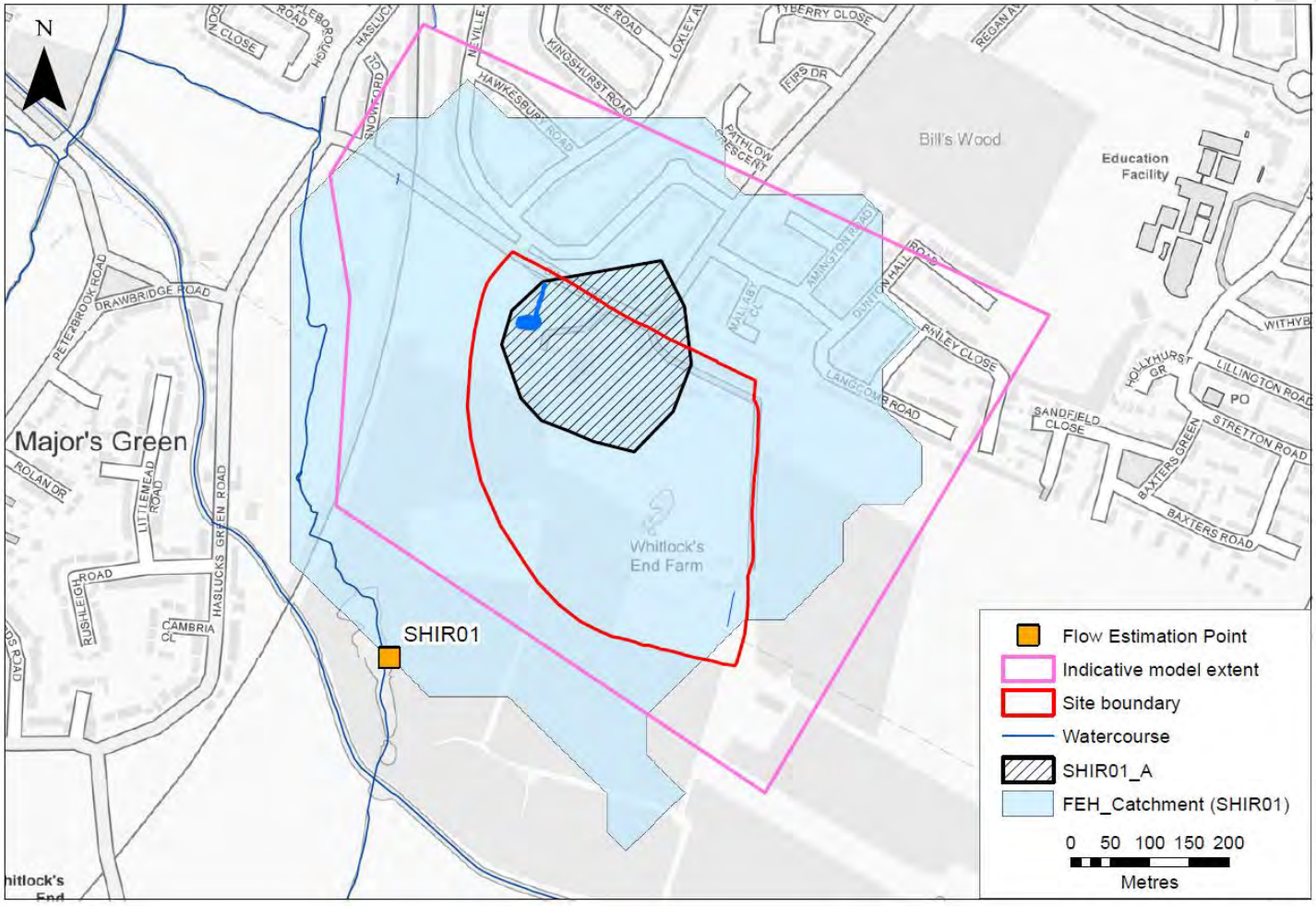
The FARL value of 1.00 indicates there is no attenuation in the catchment which corresponds to mapping of the area. The FARL value is considered representative and was not amended.

The URBEXT2000 values have been checked against the Urban Extent 2000 layer on the FEH Web Service. It gives an acceptable fit throughout the catchments and was not amended except to update to the current year (2020).

FEP code	Lumped / sub-catchment	Watercourse	Location	Easting	Northing	FEH Web Service AREA (km^2)	Revised AREA (km^2)
SHAR01	L	Unnamed	Downstream model extent	413650	279450	0.58	-

FEP code	FARL	PROPWET	BFIHOST19	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	$URBEXT_{2000}$ (updated to 2020[11])	FPEXT
SHAR01	1.00	0.29	0.345	0.74	13.1	741	0.426	0.214

3.8 Site 26 – South of Shirley



Contains OS data © Crown copyright and database right 2020

Flow estimation point selection & applying model inflows

One FEP was selected close to the site to be used as a representative catchment to derive peak flow estimates for the pond that flows into a culvert off site. The drainage area for the pond and culvert were manually derived using two-metre LiDAR data and OS contour mapping. Flows were generated for the FEP and area-weighted to the manually derived catchment, the flows will be applied to the upstream extent of the model.

Catchment descriptor checks (SHIR01)

Two-metre LiDAR, OS contour mapping and watercourse lines were used to check the FEH Web Service catchment boundary. The FEH watercourse definition looks suspect in this location and the catchment area defined by the FEH may not be correct. However, the catchment provided was deemed suitable for the purpose of generating flow estimates to be area-weighted to the site drainage area, and no changes were made to the exported shapefile.

The FEH BFIHOST19 value of 0.33 was deemed reasonable based on the soils and geology described in the area (Section 2.1) and was not amended.

The FARL value of 1.00 indicates there is no attenuation in the catchment. Apart from the pond and culvert in the north west of the site, which flows are being derived for, there are no other ponds/ lakes in the catchment. The FARL value is considered representative and was not amended.

The URBEXT2000 value has been checked against the Urban Extent 2000 layer on the FEH Webservice. It gives an acceptable fit throughout the catchment and was not amended except to update to the current year (2020).

FEP code	Lumped / sub-catchment	Watercourse	Location	Easting	Northing	FEH Web Service AREA (km^2)	Revised AREA (km^2)
SHIR01	L	Unnamed	Donor catchment 0.2km south west of the site	410600	277450	0.52	-

FEP code	FARL	PROPWET	BFIHOST19	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	$URBEXT_{2000}$ (updated to 2020[11])	FPEXT
SHIR01	1.00	0.28	0.33	1.06	16.5	745	0.244	0.425

4 Statistical Method

4.1 Overview of Estimation of QMED at Each Subject Site

Site code	Initial QMED rural (m^3/s)	Final method	Data transfer			Urban adjustment factor (UAF)	Final QMED estimate (m^3/s)
			NRFA numbers for donor sites used (see 3.3)	Distance between centroids d_{ij} (km)	Moderated QMED adjustment factor, $(A/B)^a$		
KNOW01	0.3	DT	54106	39.45	1.058	1.097	0.3
DAMS01	0.8	DT	54034	44.94	1.156	1.096	1.1
PURN01	0.6	DT	54106	41.03	1.056	1.473	0.9
WEST01	0.3	DT	54102	38.18	0.985	1.068	0.3
BLYT02	17.4	DT	54106	39.88	1.057	1.093	20.1
BARR01	1.2	DT	54102	36.94	0.984	1.031	1.2
SHAR01	0.5	DT	54034	40.43	1.172	1.426	0.9
SHIR01	0.3	DT	54034	38.65	1.179	1.229	0.4

Are the values of QMED spatially consistent?	N/A
Method used for urban adjustment for subject and donor sites	WINFAP v4[12]

Parameters used for WINFAP v4 urban adjustment if applicable		
Impervious fraction for built-up areas, IF	Percentage runoff for impervious surfaces, PR_{imp}	Method for calculating fractional urban cover, URBAN
0.3	70%	From updated URBEXT2000

Notes

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

The QMED adjustment factor A/B for each donor site is given in Table 3.2. This is moderated using the power term, a, which is a function of the distance between the centroids of the subject catchment and the donor catchment. The final estimate of QMED is: $(A/B)^a$ x $QMED_{initial}$ x UAF

Important note on urban adjustment

The method used to adjust QMED for urbanisation published in Kjeldsen (2010)[13] in which PRUAF is calculated from BFIHOST is not correctly applied in WINFAP-FEH v3.0.003. Significant differences occur only on urban catchments that are highly permeable.

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

4.2 Search for Donor Sites for QMED

A check was made to identify suitable donor sites.

The geographically closest donor was selected for each FEP unless there was a strong reason not to. This only occurred for the BARR01 FEP, where the closest donor to the site 39026 (Cherwell @ Banbury) was not used due to the NFRA stating that a flood storage area within the catchment affected peak flows. The second closest donor 54102 (Avon @ Lilbourne) was used instead.

This choice is in line with the recommendations of the draft report for Phase 2 of SC090031 (small catchment hydrology) and is appropriate for the scope of this study. It should be noted that for most locations application of the donor increases the catchment descriptor QMED estimate. Station 54102, used for WEST01 and BARR01, reduces the catchment descriptor QMED estimate. However, once the moderation to the adjustment factor is applied (based on distance between catchment centroids), the reduction is only small (<2%).

4.3 Donor Sites Chosen and QMED Adjustment Factors

NRFA no.	FEP	Reasons for choosing	Method (AM or POT)	Adjust-ment for climatic variation?	QMED from flow data (A)	QMED from catchment descriptors (B)	Adjust-ment ratio (A/B)
54034	SHAR01 DAMS01 SHIR01	See Section 4.2	AM	No – more than 30 years of data	9.59	4.34	2.17
54102	WEST01 BARR01				12.4	13.24	0.93
54106	KNOW01 PURN01 BLYT02				30.4	22.97	1.31

4.4 Derivation of Pooling Groups

Name of group	FEP code from whose descriptors group was derived	Subject site treated as gauged?	Changes made to default pooling group	Weighted average L-moments
KNOW01	KNOW01	No	A brief review of the pooling group was performed. One gauge was removed from the default pooling group: 49005 (Bolingey Stream @ Bolingey Cocks Bridge), removed due to having less than 8 years of data. The rest of the gauges were deemed to be suitable.	L-CV: 0.223 L-SKEW: 0.245
DAMS01	DAMS01	No		L-CV: 0.247 L-SKEW: 0.259
PURN01	PURN01	No		L-CV: 0.229 L-SKEW: 0.254
WEST01	WEST01	No		L-CV: 0.223 L-SKEW: 0.245

Name of group	FEP code from whose descriptors group was derived	Subject site treated as gauged?	Changes made to default pooling group	Weighted average L-moments
BARR01	BARR01	No		L-CV: 0.248 L-SKEW: 0.259
SHAR01	SHAR01	No		L-CV: 0.223 L-SKEW: 0.245
SHIR01	SHIR01	No		L-CV: 0.224 L-SKEW: 0.245
BLYT02	BLYT02	No	A brief review of the pooling group was performed. No gauges were removed and the pooling group was deemed to be suitable	L-CV: 0.248 L-SKEW: 0.111
Note: Pooling groups were derived using the procedures from Science Report SC050050 (2008).				

4.5 Derivation of Flood Growth Curves at Subject Sites

FEP code	Method	If P, ESS or J, name of pooling group	Distribution used and reason for choice	Note any urban adjustment or permeable adjustment	Parameters of distribution	Growth factor for 1% AEP event
KNOW01	P	KNOW01	Generalised Logistic gives the best fit	V4 urban adjustment applied to the growth curve Permeable adjustment not applied as most sites in the pooling group have SPRHOST >20%	Location:1.00 Scale: 0.205 Shape:-0.263	2.83
DAMS01	P	DAMS01			Location:1.00 Scale: 0.230 Shape: -0.275	3.12
PURN01	P	PURN01			Location:1.00 Scale: 0.172 Shape:-0.320	2.80
WEST01	P	WEST01			Location:1.00 Scale: 0.212 Shape:-0.255	2.85
BLYT02	p	BLYT01	Generalised Extreme Value gives the best fit		Location:1.00 Scale: 0.381 Shape:0.070	2.36
BARR01	P	BARR01	Generalised Logistic gives the best fit		Location:1.00 Scale: 0.241 Shape:-0.264	3.16

SHAR01	P	SHAR01			Location:1.00 Scale: 0.159 Shape:-0.324	2.68
SHIR01	P	SHIR01			Location:1.00 Scale: 0.185 Shape:-0.289	2.77

4.6 Flood Estimates from The Statistical Method

FEP code	Flood peak (m^3/s) for the following AEP (%) events									
	50	20	10	5	3.33	2	1.33	1	0.5	0.1
KNOW01	0.35	0.47	0.56	0.66	0.73	0.83	0.91	0.98	1.16	1.74
DAMS01	1.1	1.5	1.8	2.2	2.4	2.8	3.1	3.4	4.0	6.2
PURN01	0.9	1.2	1.4	1.7	1.9	2.2	2.4	2.6	3.1	4.9
WEST01	0.3	0.4	0.4	0.5	0.6	0.7	0.7	0.8	0.9	1.4
BLYT02	20.2	28.3	33.3	37.9	40.5	43.6	45.9	47.5	51.3	59.4
BARR01	1.2	1.7	2.1	2.5	2.8	3.2	3.5	3.8	4.5	6.9
SHAR01	0.46	0.59	0.69	0.82	0.91	1.03	1.14	1.23	1.49	2.35
SHIR01	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.3	2.0

5 Revitalised Flood Hydrograph 2 (ReFH2) Method

5.1 Parameters for ReFH2 Model

FEP code	Method	Time to peak (hours)	C_{max} (mm)	PR_{imp}	BL (hours)	BR* (50% AEP to 0.1% AEP)
KNOW01	CD	3.2	310.0	70	31.7	1.40 1.00
DAMS01	CD	3.4	370.0	70	37.6	1.65 2.26
PURN01	CD	3.8	431.1	70	40.6	3.90 2.48
WEST01	CD	2.5	437.2	70	36.2	2.81 2.22
BYLT02	CD	13.4	328.3	70	56.8	1.57 1.08
BLYT01_IA_22	CD	6.4	337.0	70	43.6	1.72 1.21
BARR01	CD	4.4	338.9	70	37.3	1.79 1.26
SHAR01	CD	4.5	282.4	70	31.6	1.40 0.82
SHIR01	CD	3.5	130.6	70	28.8	0.98 0.66
Methods: OPT: Optimisation, BR: Baseflow recession fitting, CD: Catchment descriptors, DT: Data transfer (give details)						

* For impermeable catchments (BFIHOST <0.5) BR is dynamically calculated to close the water balance over an event and that this means that the BR value changes for each design event.

5.2 Design Events f=For ReFH2 Method

FEP code	Urban or rural	Season of design event (summer or winter)	Storm duration (hours)
KNOW01	Rural	Winter	5.5
DAMS01	Rural	Winter	5.5
PURN01	Urban	Summer	6.5
WEST01	Rural	Winter	4.5
BYLT02	Urban	Winter	22.0
BLYT01_IA_22	Rural	Winter	22.0

FEP code	Urban or rural	Season of design event (summer or winter)	Storm duration (hours)
BARR01	Rural	Winter	7.5
SHAR01	Rural	Summer	5.5
SHIR01	Rural	Winter	6.5

6 Assumptions, Limitations, Uncertainty & Checks

6.1 What are the main assumptions made?

The main assumptions in the study are that the chosen donors for each site are reliable and that pooling groups adequately represent the flood frequency relationship for the sites. The ReFH2 model is also assumed to generate representative hydrograph shapes for the watercourses.

For some sites where the FEH Web Service does not define the catchment for the watercourse / drain of interest, the drainage areas have been derived manually. It is assumed that this coarse representation provides an adequate estimate of the area for the purposes of this study and given all other uncertainties associated with the design event peak flow estimates.

Several sites in the study used upstream inflows derived from the following means:

- Applying the downstream FEP flows to the upstream model extent.
- Proportion the flows estimated at the downstream FEP to manually derived catchments at the upstream model extent.
- Deriving an intervening area hydrograph to be applied to the upstream model extent.

Where these situations arose, it has been assumed that model inflows will be no less certain than if estimates were generated specifically for the upstream extents due to the small size of the catchments.

6.2 What are the Limitations?

The main limitation to the study was that for some sites where the FEH Web Service does not define the catchment for the watercourse / drain of interest, drainage areas and catchment descriptors were not available. This meant that representative catchments were required, or hydrographs area-weighted to manually derived catchments.

An additional limitation was the small scope of the study. This has meant that a detailed analysis of flood history, gauge data and pooling groups was not possible.

6.3 Uncertainty in Results

A UK average measure of uncertainty for the FEH Statistical method is presented in a technical guidance report[14] generated by a R&D project into the FEH, local data and uncertainty (Environment Agency funded consortium of JBA, CEH and others). The report presented results for rural and moderately urbanised catchments. The 95% confidence limits for a 1% AEP event flood estimate for a rural and moderately urbanised catchment is:

14 Environment Agency. 2017. Using local data to reduce uncertainty in flood frequency estimation

Catchment Type	URBEXT2000 range	With donor adjustment of QMED (one donor)
Rural	<0.03 URBEXT2000	0.47-2.12 times the best estimate
Moderately urbanised	<0.03 URBEXT2000<0.15	0.34-2.94 times the best estimate

There are no confidence limits for highly urbanised catchments. It can be assumed that the uncertainty will be larger for these catchments.

6.4 Suitability of the Results for Future Studies

The design flow estimates and hydrographs were derived for the purposes of this level 2 SFRA. For these Option 1 and 2 sites the scope of the hydrological assessment is constrained to a simple, high-level analysis. If peak flow estimates and hydrographs are required for a different purpose it is recommended that, at a minimum, a review of the results is undertaken.

6.5 Checks

6.5.1 What is the 1% AEP event growth factor for each site?

The typical range is 2.1-4.0. These values are mostly mid-range with one (BLYT01) towards the lower end of this range.

FEP code	1% AEP event growth factor Statistical
KNOW01	2.83
DAMS01	3.12
PURN01	2.80
WEST01	2.85
BLYT02	2.36
BARR01	3.16
SHAR01	2.68
SHIR01	2.77

6.5.2 What is the 0.1% AEP event flow over 1% AEP event flow ratio for each site?

FEP code	0.1% AEP / 1% AEP flow Statistical
KNOW01	1.77
DAMS01	1.84
PURN01	1.91
WEST01	1.76
BLYT02	1.25
BARR01	1.82
SHAR01	1.90
SHIR01	1.83

6.5.3 Further Checks

Modelled flood levels and extents will be sense-checked to ensure that flow inputs produce realistic outputs.

6.6 Final Results

6.6.1 FEP flows

FEP code	Flood peak (m^3/s) for the following AEP (%) events									
	50	20	10	5	3.33	2	1.33	1	0.5	0.1
KNOW01	0.35	0.47	0.56	0.66	0.73	0.83	0.91	0.98	1.16	1.74
DAMS01	1.1	1.5	1.8	2.2	2.4	2.8	3.1	3.4	4.0	6.2
PURN01	0.9	1.2	1.4	1.7	1.9	2.2	2.4	2.6	3.1	4.9
WEST01	0.3	0.4	0.4	0.5	0.6	0.7	0.7	0.8	0.9	1.4
BLYT02	20.2	28.3	33.3	37.9	40.5	43.6	45.9	47.5	54.4	71.6
BARR01	1.2	1.7	2.1	2.5	2.8	3.2	3.5	3.8	4.5	6.9
SHAR01	0.46	0.59	0.69	0.82	0.91	1.03	1.14	1.23	1.49	2.35
SHIR01	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.3	2.0

6.6.2 Scaling Factors

Site	FEP from which hydrograph flows were derived	Scaling Factor	Comment
Site 1 South of Knowle	KNOW01	KNOW01_A – 109% increase KNOW01_B - 43% decrease KNOW01_C - 64% decrease	Flows from KNOW01 were scaled up or down to the three manually derived catchment areas
Site 20 Land Damson Parkway	DAMS01	DAMS01_A- 32% DAMS01_B- 68%	Flows from DAMS01 were proportioned to DAMS01_A and the remaining proportion applied to DAMS01_B

Site 1 Barrett's Farm	BARR01	BARR01_A -59% BARR01_B -18% BARR01_C -23%	Flows from BARR01 were scaled by the proportion of catchment area covered by the three manually derived catchments
Site 6 Meriden Road	BLYT02 BLYT01_IA	BLYT02 - N/A ARDEN – 4% BLYT01_IA_1 and 2 -96%	Flows from BLYT01_IA were scaled based on the area of ARDEN with the remaining flows used for BLYT01_IA_1 and 2.
Site 8 Hampton Road	PURN01	PURN01_A – 55% PURN01_B – 45%	Flows from PURN01 were proportioned to PURN02 (PURN01_A) and the remaining proportion applied to PURN01_B
Site 10 West of Meriden	WEST01	WEST01_A – 53% WEST01_B – 47%	Flows from WEST01 were proportioned to WEST02 (WEST01_A) and the remaining proportion applied to WEST01_B
Site 18 Sharmans Cross	SHAR01	N/A	No scaling required - all flows generated at SHAR01 applied to the upstream extent of the model
Site 26 South of Shirley	SHIR01	SHIR01_A – 9%	Flows from SHIR01 were scaled to the manually derived catchment SHIR01_A based on catchment area.

If flood hydrographs are needed for the next stage of the study, where are they provided?	DPD-XX-XX-CA-H0-0002-S0-P01.03-Hydrographs.xlsm

7 Annex

7.1 Final pooling groups

7.1.1 Site 9 – South of Knowle

Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
76011 (Coal Burn @ Coalburn)	1.508	41	1.84	0.165	0.315	0.72
27073 (Brompton Beck @ Snainton Ings)	3.485	37	0.82	0.2	0.047	1.342
45816 (Haddeo @ Upton)	3.499	25	3.456	0.306	0.399	0.948
27051 (Crimple @ Burn Bridge)	3.588	46	4.539	0.219	0.148	0.388
28033 (Dove @ Hollinsclough)	3.763	43	4.205	0.231	0.369	0.635
91802 (Allt Leachdach @ Intake)	4.143	34	6.35	0.153	0.257	0.878
71003 (Croasdale Beck @ Croasdale Flume)	4.338	37	10.9	0.212	0.323	0.24
25003 (Trout Beck @ Moor House)	4.349	45	15.12	0.167	0.302	0.587
25019 (Leven @ Easby)	4.365	40	5.384	0.343	0.378	1.733
25011 (Langdon Beck @ Langdon)	4.387	32	15.533	0.235	0.334	1.409
26802 (Gypsey Race @ Kirby Grindalythe)	4.388	19	0.109	0.309	0.183	1.003
54022 (Severn @ Plynlimon Flume)	4.391	38	14.988	0.156	0.171	1.034
47022 (Tory Brook @ Newnham Park)	4.404	25	6.18	0.273	0.149	0.963
206006 (Annalong @ Recorder)	4.606	48	15.33	0.189	0.052	2.119
Total		510				
Weighted means		510		0.223	0.245	

7.1.2 Site 20 - Land Damson Parkway

Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
27051 (Crimple @ Burn Bridge)	1.334	46	4.539	0.219	0.148	0.453
76011 (Coal Burn @ Coalburn)	1.378	41	1.84	0.165	0.315	0.884
45816 (Haddeo @ Upton)	1.476	25	3.456	0.306	0.399	0.577
28033 (Dove @ Hollinsclough)	1.771	43	4.205	0.231	0.369	0.643
25019 (Leven @ Easby)	2.137	40	5.384	0.343	0.378	0.933
26802 (Gypsey Race @ Kirby Grindalythe)	2.176	19	0.109	0.309	0.183	0.581
25011 (Langdon Beck @ Langdon)	2.362	32	15.533	0.235	0.334	1.753
47022 (Tory Brook @ Newnham Park)	2.386	25	6.18	0.273	0.149	0.88
71003 (Croasdale Beck @ Croasdale Flume)	2.506	37	10.9	0.212	0.323	0.311
27010 (Hodge Beck @ Bransdale Weir)	2.52	41	9.42	0.224	0.293	0.131
27073 (Brompton Beck @ Snainton Ings)	2.521	37	0.82	0.2	0.047	1.429
25003 (Trout Beck @ Moor House)	2.566	45	15.12	0.167	0.302	0.706
44008 (South Winterbourne @ Winterbourne Steepleton)	2.619	39	0.448	0.411	0.328	1.923
206006 (Annalong @ Recorder)	2.665	48	15.33	0.189	0.052	2.795

Total		518				
Weighted means		518		0.247	0.259	

7.1.3 Site 1 – Barretts Farm

Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
27051 (Crimple @ Burn Bridge)	1.234	46	4.539	0.219	0.148	0.453
45816 (Haddeo @ Upton)	1.471	25	3.456	0.306	0.399	0.577
76011 (Coal Burn @ Coalburn)	1.672	41	1.84	0.165	0.315	0.884
28033 (Dove @ Hollinsclough)	1.732	43	4.205	0.231	0.369	0.643
27073 (Brompton Beck @ Snainton Ings)	1.872	37	0.82	0.2	0.047	1.429
26802 (Gypsey Race @ Kirby Grindalythe)	1.874	19	0.109	0.309	0.183	0.581
25019 (Leven @ Easby)	1.88	40	5.384	0.343	0.378	0.933
47022 (Tory Brook @ Newnham Park)	2.184	25	6.18	0.273	0.149	0.88
25011 (Langdon Beck @ Langdon)	2.2	32	15.533	0.235	0.334	1.753
27010 (Hodge Beck @ Bransdale Weir)	2.278	41	9.42	0.224	0.293	0.131
44008 (South Winterbourne @ Winterbourne Steepleton)	2.356	39	0.448	0.411	0.328	1.923
25003 (Trout Beck @ Moor House)	2.379	45	15.12	0.167	0.302	0.706
71003 (Croasdale Beck @ Croasdale Flume)	2.389	37	10.9	0.212	0.323	0.311
206006 (Annalong @ Recorder)	2.472	48	15.33	0.189	0.052	2.795
Total		518				
Weighted means		518		0.248	0.259	

7.1.4 Site 6 – Meriden Road

Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
54040 (Meese @ Tibberton)	0.308	45	4.736	0.246	0.29	1.137
33007 (Nar @ Marham)	0.312	36	3.62	0.22	0.004	0.467
39025 (Enborne @ Brimpton)	0.531	51	17	0.198	0.158	1.264
35008 (Gipping @ Stowmarket)	0.534	51	14.298	0.287	0.072	0.525
33011 (Little Ouse @ County Bridge Euston)	0.536	57	3.926	0.306	-0.011	1.389
54041 (Tern @ Eaton Upon Tern)	0.554	42	12.444	0.187	0.109	0.374
15008 (Dean Water @ Cookston)	0.564	53	26.832	0.132	0.059	1.58
42003 (Lymington @ Brockenhurst)	0.6	23	27.4	0.276	0.36	0.864
52010 (Brue @ Lovington)	0.614	54	36.21	0.278	0.338	0.689
25005 (Leven @ Leven Bridge)	0.631	48	43.54	0.241	0.269	0.584
37014 (Roding @ High Ongar)	0.637	54	10.928	0.239	-0.159	2.127

Total		514				
Weighted means				0.237	0.131	

7.1.5 Site 8 - Hampton Road

Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
76011 (Coal Burn @ Coalburn)	1.048	41	1.84	0.165	0.315	0.844
27051 (Crimple @ Burn Bridge)	1.836	46	4.539	0.219	0.148	0.394
45816 (Haddeo @ Upton)	1.887	25	3.456	0.306	0.399	0.924
28033 (Dove @ Hollinsclough)	2.172	43	4.205	0.231	0.369	0.641
27073 (Brompton Beck @ Snainton Ings)	2.373	37	0.82	0.2	0.047	1.36
25019 (Leven @ Easby)	2.6	40	5.384	0.343	0.378	1.692
26802 (Gypsey Race @ Kirby Grindalythe)	2.622	19	0.109	0.309	0.183	0.999
25011 (Langdon Beck @ Langdon)	2.76	32	15.533	0.235	0.334	1.518
47022 (Tory Brook @ Newnham Park)	2.771	25	6.18	0.273	0.149	0.987
71003 (Croasdale Beck @ Croasdale Flume)	2.84	37	10.9	0.212	0.323	0.245
25003 (Trout Beck @ Moor House)	2.861	45	15.12	0.167	0.302	0.619
91802 (Allt Leachdach @ Intake)	2.922	34	6.35	0.153	0.257	0.889
27010 (Hodge Beck @ Bransdale Weir)	2.979	41	9.42	0.224	0.293	0.1
206006 (Annalong @ Recorder)	3.026	48	15.33	0.189	0.052	2.79
Total		513				
Weighted means		513		0.229	0.254	

7.1.6 Site 10 – West of Meriden

Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
76011 (Coal Burn @ Coalburn)	1.125	41	1.84	0.165	0.315	0.72
45816 (Haddeo @ Upton)	2.839	25	3.456	0.306	0.399	0.948
27051 (Crimple @ Burn Bridge)	2.913	46	4.539	0.219	0.148	0.388
28033 (Dove @ Hollinsclough)	3.116	43	4.205	0.231	0.369	0.635
91802 (Allt Leachdach @ Intake)	3.59	34	6.35	0.153	0.257	0.878
27073 (Brompton Beck @ Snainton Ings)	3.602	37	0.82	0.2	0.047	1.342
25019 (Leven @ Easby)	3.75	40	5.384	0.343	0.378	1.733
71003 (Croasdale Beck @ Croasdale Flume)	3.773	37	10.9	0.212	0.323	0.24
25011 (Langdon Beck @ Langdon)	3.786	32	15.533	0.235	0.334	1.409
26802 (Gypsey Race @ Kirby Grindalythe)	3.802	19	0.109	0.309	0.183	1.003
47022 (Tory Brook @ Newnham Park)	3.83	25	6.18	0.273	0.149	0.963
54022 (Severn @ Plynlimon Flume)	3.848	38	14.988	0.156	0.171	1.034
25003 (Trout Beck @ Moor House)	3.85	45	15.12	0.167	0.302	0.587
206006 (Annalong @ Recorder)	4.052	48	15.33	0.189	0.052	2.119
Total		510				

Weighted means		510		0.223	0.245	

7.1.7 Site 18 Sharmans Cross

Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
76011 (Coal Burn @ Coalburn)	1.789	41	1.84	0.165	0.315	0.72
27073 (Brompton Beck @ Snainton Ings)	2.587	37	0.82	0.2	0.047	1.342
45816 (Haddeo @ Upton)	3.399	25	3.456	0.306	0.399	0.948
27051 (Crimple @ Burn Bridge)	3.444	46	4.539	0.219	0.148	0.388
28033 (Dove @ Hollinsclough)	3.636	43	4.205	0.231	0.369	0.635
25003 (Trout Beck @ Moor House)	4.061	45	15.12	0.167	0.302	0.587
91802 (Allt Leachdach @ Intake)	4.067	34	6.35	0.153	0.257	0.878
26802 (Gypsey Race @ Kirby Grindalythe)	4.075	19	0.109	0.309	0.183	1.003
25019 (Leven @ Easby)	4.087	40	5.384	0.343	0.378	1.733
71003 (Croasdale Beck @ Croasdale Flume)	4.126	37	10.9	0.212	0.323	0.24
47022 (Tory Brook @ Newnham Park)	4.133	25	6.18	0.273	0.149	0.963
25011 (Langdon Beck @ Langdon)	4.152	32	15.533	0.235	0.334	1.409
54022 (Severn @ Plynlimon Flume)	4.237	38	14.988	0.156	0.171	1.034
206006 (Annalong @ Recorder)	4.326	48	15.33	0.189	0.052	2.119
Total		510				
Weighted means		510		0.223	0.245	

7.1.8 Site 26 – South of Shirley

Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
76011 (Coal Burn @ Coalburn)	4.309	41	1.84	0.165	0.315	0.72
27073 (Brompton Beck @ Snainton Ings)	4.374	37	0.82	0.2	0.047	1.342
45816 (Haddeo @ Upton)	5.936	25	3.456	0.306	0.399	0.948
27051 (Crimple @ Burn Bridge)	6.012	46	4.539	0.219	0.148	0.388
28033 (Dove @ Hollinsclough)	6.134	43	4.205	0.231	0.369	0.635
25003 (Trout Beck @ Moor House)	6.354	45	15.12	0.167	0.302	0.587
91802 (Allt Leachdach @ Intake)	6.357	34	6.35	0.153	0.257	0.878
71003 (Croasdale Beck @ Croasdale Flume)	6.48	37	10.9	0.212	0.323	0.24
26802 (Gypsey Race @ Kirby Grindalythe)	6.507	19	0.109	0.309	0.183	1.003
54022 (Severn @ Plynlimon Flume)	6.519	38	14.988	0.156	0.171	1.034
47022 (Tory Brook @ Newnham Park)	6.52	25	6.18	0.273	0.149	0.963
25019 (Leven @ Easby)	6.544	40	5.384	0.343	0.378	1.733
25011 (Langdon Beck @ Langdon)	6.562	32	15.533	0.235	0.334	1.409
206006 (Annalong @ Recorder)	6.663	48	15.33	0.189	0.052	2.119
Total		510				
Weighted means		510		0.224	0.245	