Department for Environment Food & Rural Affairs

Environment Agency

Cyfoeth Naturiol Cymru Natural Resources Wales

Llywodraeth Cymru Welsh Government

Estimating flood peaks and hydrographs for small catchments: data collection

FCERM Research & Development Programme research report

Date: March 2024

Version: SC090031/R1

We are the Environment Agency. We protect and improve the environment.

We help people and wildlife adapt to climate change and reduce its impacts, including flooding, drought, sea level rise and coastal erosion.

We improve the quality of our water, land and air by tackling pollution. We work with businesses to help them comply with environmental regulations. A healthy and diverse environment enhances people's lives and contributes to economic growth.

We can't do this alone. We work as part of the Defra group (Department for Environment, Food & Rural Affairs), with the rest of government, local councils, businesses, civil society groups and local communities to create a better place for people and wildlife.

Published by:

Environment Agency
Horizon House, Deanery Road,
Bristol BS1 5AH

www.gov.uk/environment-agency

Further copies of this report are available from our publications catalogue: Flood and Coastal Erosion Risk Management Research and Development Programme or our National Customer Contact Centre: 03708 506 506

Email: fcerm.evidence@environment-agency.gov.uk.

Author(s):
Maxine Zaidman, Duncan Faulkner, Katie Burnham, Harriett Twohig-Howell and Lara Bentley

Keywords:
Flood frequency, United Kingdom, rural, urban, plot-scale, QMED, pooling, DDF, ReFH2, local data

Research contractor:
JBA Consulting, South Barn, Broughton Hall Skipton, BD23 3AE

Environment Agency's Project Manager:
Mark Whitling

Project number:
SC090031

Contents

Acknowledgements

Particular thanks are due to the Environment Agency's Project Board, members of which were responsible for developing the vision and scope of this research. The board has continued to advise and support the project team, providing valuable feedback, practical suggestions and lively discussions. The project team is also grateful to staff from the Environment Agency, Natural Resources Wales, the Scottish Environment Agency (SEPA) and the Rivers Agency for supplying data and advice on data quality, and to those who have acted as external reviewers.

Project Board

Anita Asadullah (Project Sponsor, Environment Agency)

Donna Wilson (Project Executive, Environment Agency)

Mark Whitling (Project Manager, Environment Agency)

Andy Eden (Environment Agency)

Tim Hunt (Environment Agency)

Sean Longfield (Environment Agency)

Peter Spencer (Environment Agency)

Rob Stroud (Environment Agency)

Glenda Tudor-Ward (Natural Resources Wales)

External reviewers

Thomas Kjeldsen (University of Bath)

Claire Samuel (Jacobs)

Project Team

Centre for Ecology & Hydrology (CEH)

Lisa Stewart (Project Manager),

Giuseppe Formetta

Adam Griffin

Ilaria Prosdocimi

Gianni Vesuviano

Independent consultant

David MacDonald

JBA Consulting

Duncan Faulkner

Harriett Twohig-Howell

Maxine Zaidman

Lara Bentley

Alexander Siddaway

Wallingford HydroSolutions

Andy Young

Tracey Haxton

This project follows on from phase 1, which was jointly funded by the Environment Agency, the Centre for Ecology & Hydrology and JBA Consulting.

Executive summary

The overall aim of this project is to develop improved flood estimation procedures for small UK catchments. The research relies on good quality flood peak data being sourced for as many small catchments across the UK as possible. JBA Consulting has identified and collated a suitable flood peak data set for England, Wales, Scotland and Northern Ireland.

This report sets out the following:

1. the procedure used to identify good quality gauging stations able to reliably capture peak flood discharges from small catchments
2. the catchment characteristics sampled by the 154 gauging stations identified by the procedure outlined in step 1
3. the geographical distribution of all gauging stations located in small catchments, including stations that were deemed not to be able to provide high flow data of suitable quality as well as the 154 that were flagged as reliably measuring flood flows

The resulting list of stations providing flood peak data is provided digitally in a supporting appendix. A summary of conclusions and recommendations arising from the review is provided in the final section.

The work described in this report was carried out towards the beginning of the project, which spanned a period of several years. Some small changes in the composition of the data set were made as the research progressed, and these are described in the final project report (SC090031/R0).

Important Note:

Work on Project SC090031 ‘Estimating flood peaks and hydrographs in small catchments (Phase 2)’ began in December 2013. Tasks carried out in the early stages of the project have already been documented in several project notes and reports, so it is possible that there may be inconsistencies, particularly in the various data sets and methods that have been applied at different points in time. This report provides a summary of the research carried out throughout the project, and we have detailed the data sets and methods used in each of the stages and tasks.

1. Introduction

1.1 Purpose of this report

This report forms a record of the work carried out by JBA Consulting to identify and collate a data set of flood peaks on small catchments across the UK. The need for an expanded data set was identified in the report in stage 1 of the 'Estimating flood peaks and hydrographs for small catchments' project.

The data set was used by the Centre for Ecology & Hydrology (CEH) as the basis for testing and developing flood estimation methods for small catchments as described in the other project reports.

1.2 Definition of a small catchment

In this study, a small catchment was defined as having an area that did not exceed 40 km^2. Perhaps surprisingly, there are in fact around 600 stations within the UK's river flow measurement network that meet this criterion. Not all these stations are able to provide data that would be reliable during periods of high flow; those that traditionally have been considered as providing flood peak data of acceptable quality are included in the HiFlows-UK database. This amounts to just over 120 stations in all.

HiFlows-UK was a joint initiative between UK measuring authorities that aimed to update and extend the flood peak data sets given in appendix to Volume 3 of the Flood Estimation Handbook, as published in 1999. The resulting database was made freely available to all UK flood practitioners via a link on the Environment Agency website. In 2014, HiFlows-UK became integrated into the National River Flow Archive and referred to as the UK peak flow data set (see http://www.ceh.ac.uk/data/nrfa/peakflow_overview.html). The version of the HiFlows-UK database that is referred to in this report is v3.3.2, which was issued in 2014.

1.3 Disclaimer

This report was written in 2014 to 2015 and refers to data sets that were available at that time; the data collection was carried out in 2014. It refers to the HiFlows-UK data set, which is now known as the National River Flow Archive (NRFA) peak flows data set.

The stations and records identified in this report represent the shortlist of stations proposed to CEH to use in subsequent stages of the project. Some small changes in the composition of the data set were made as the research progressed, and these are described in the final project report (SC090031/R0).

1.4 Approach to seeking data

HiFlows-UK has been regularly reviewed and updated. For these reasons, there are reasonably few stations providing exceptionally good quality flood peak data that are not currently included in the database. However, the criteria applied in HiFlows-UK are reasonably strict; and this implies other stations might also be useful for this study. HiFlows-UK may also not reflect recent improvements in data quality - for example, as a result of a new stage-discharge rating becoming available for a particular station. Furthermore, HiFlows-UK is considered slightly out of date for Scotland, where the Scottish Environment Protection Agency (SEPA) often use different ratings in-house than applied in HiFlows-UK and sometimes have different views on data quality than assumed for HiFlows-UK.

The approach taken in this study was therefore to assume that the 122 stations on HiFlows-UK should be automatically shortlisted for this study. However, measuring authority staff were asked to flag any stations that might not be suitable or where updates were needed; for these, a more detailed investigation was carried out.

There was a considerable amount of time and effort in identifying which of the 480 non-HiFlows-UK stations in small catchments potentially might have high flow data of reasonable quality. Not all the 480 stations could be reviewed in detail. However, based on the catchment characteristics the most ‘representative’ stations were identified and investigated on a site-by-site basis. As well as reviewing the flood peak data available for these sites, the opinions of measuring authority staff were sought. This process identified 32 stations that could have data suitable to be used in the study. As these sites are not currently on HiFlows-UK it would be beneficial if the measuring authorities could prioritise them for further consideration.

Given the total number of records identified, it was not necessary to use level-only data (to be converted to flow by applying a modelled rating) to extend/enhance the shortlist.

A full set of flood peak data was developed for each of the 154 sites included in the final shortlist. This involved extending, or in some cases revising, data already presented in HiFlows-UK, or for stations not in HiFlows-UK, extracting

the annual maximum (AMAX) and peaks over threshold series from available 15-minute stage or flow records.

2. Methodology

A slightly different approach was used to identify potential sites in Scotland and Northern Ireland compared to that used in England and Wales.

2.1 Identifying sites in England and Wales

The following steps were taken to reach the final shortlist of sites:

1) The Environment Agency's data and information acquisition plan (DIAP) database was used to identify all gauging stations within England and Wales, even if currently closed. Any non-Environment Agency sites that were identified as being potentially useful in phase 1 of this study were added to the list.
2) This list was cross referenced with HiFlows-UK listings and NRFA listings to ensure an appropriate NRFA number was attributed to each site where appropriate.
3) With help from CEH, a full set of FEH catchment descriptors was produced for each site.
4) Stations with a catchment area of more than 40 km^2 were excluded. This left a sample of around 520 sites.
5) The remaining sites were reviewed manually. Any stations with records of less than five years, located in non-natural watercourses or where flows were obviously strongly impacted (for example, by artificial influences) were removed from the list.
6) The likely quality of flood peak data was identified using known data flags, including HiFlows-UK suitability flags. All stations where the data quality could not be established definitively (a significant number of sites) were noted for further investigation (data quality review).
7) Given the number of stations potentially needing a data quality review at this stage, a prioritisation procedure was used to identify which stations might offer ‘best value’ given the project objectives and on which the data quality investigations should be focused. This gave priority to more urbanised catchments and to smaller catchments as well as to any catchments that filled a geographical gap. This process identified 104 stations that are widely accepted as providing good quality flood peak data (as per HiFlows-UK quality flags), and a further 127 stations to be prioritised in a data quality review.
8) Feedback on ‘priority’ sites was sought from the Environment Agency and Natural Resources Wales. In addition, a data quality review was carried out on each gauge; this examined flood hydrographs, flood peak data, rating curves, station type, catchment influences and measuring

authority feedback on each site. The criteria used to assess suitability at high flows in HiFlows-UK were also considered. The data quality review identified 26 stations providing good quality flood peak data. Together with those stations already on HiFlows-UK, this brought the total number of flood peak data sets in England and Wales that could be used in the small catchments project to 130.

2.2 Identifying sites in Scotland

Broadly, the following steps were taken:

1) All continuously gauged river flow sites in Scotland below 40 km^2 were identified from the NRFA database (70 sites).
2) This list was cross referenced with HiFlows-UK listings and note taken of suitability flags.
3) The station details and catchment characteristics of all 70 sites (except for closed sites) were investigated. Stations sampling urban catchments were identified. Artificial influences on catchment behaviour were noted.
4) The data was reviewed manually, with any stations with records of less than five years, relating to non-natural watercourses, or where flows were obviously strongly impacted being removed from the list. This left 21 sites.
5) The likely quality of flood peak data was identified using known data flags, including HiFlows-UK suitability. All stations where the data quality could not be established definitively (a significant number of sites) were flagged for further investigation (data quality review).
6) Feedback on the shortlisted sites was sought from SEPA, along with relevant data sets. Following a review of the comments provided, several stations were removed from the shortlist, leaving a total of 19 sites in Scotland that provided data suitable to be included in the small catchments project. Of these, 12 were already in HiFlows-UK.

2.3 Identifying sites in Northern Ireland

Broadly, the following steps were taken:

1) All continuously gauged river flow sites in Northern Ireland below 40 km^2 were identified from the NRFA database (10 sites).
2) The likely quality of flood peak data was identified using known data flags, including HiFlows-UK suitability (6 of the 10 sites feature in HiFlows-UK). The Rivers Agency in Northern Ireland was asked to

provide a comment on all 10 sites and to suggest any additional flood peak data sets that might be considered.

3) Following a review of comments and updated data provided by the Rivers Agency, four stations were removed from the shortlist, leaving a total of six sites in Northern Ireland that provided data suitable to be included in the project. All of these were already in HiFlows-UK.

3. Catchment characteristics sampled

3.1 Overview

In terms of catchment descriptors, it is important that the final sample set is as representative as possible of the small catchment gauging network. At the same time, it is acknowledged that the gauging network in the UK is biased towards certain catchment types.

A review of catchment descriptors captured within the final sample set was therefore carried out. This focused on the following catchment descriptors:

- Area (AREA)
- Urban extent ($URBEXT_{2000}$)
- Standard-period average annual rainfall (SAAR)
- Base flow index hydrology of soil types (BFIHOST)
- Drainage path slope (DSPBAR)
- Flood attenuation by reservoirs and lakes (FARL)

The catchment descriptors captured in the sample set have been compared with those for all small catchments (defined as a catchment area of 40 km^2 or less) within the gauging station network as a whole (England, Scotland, Wales and Northern Ireland).

3.2 AREA

The definition of 'small' within the context of this study was a catchment area no larger than 40 km^2. Figure 1 presents a histogram of the catchment area of the final shortlist compared to all small catchments.

Of the 600 stations nationally with upstream catchment areas less than the 40 km^2 threshold, around a sixth had catchments smaller in size than 5 km^2. However, very few of these were found to provide flood peak data good enough to include in the study, therefore, 13 of the shortlisted stations had areas under 5 km^2. The average catchment size across all sites in the final shortlist sites is 20.5 km^2. However, as shown in Figure 1 there is good representation of all catchment sizes and no strong bias within the final data set. The Darwen at Ewood has the largest catchment size (AREA = 39.5 km^2) of the shortlisted sites, whilst the Sike (Tees tributary) has the smallest (AREA = 0.04 km^2).

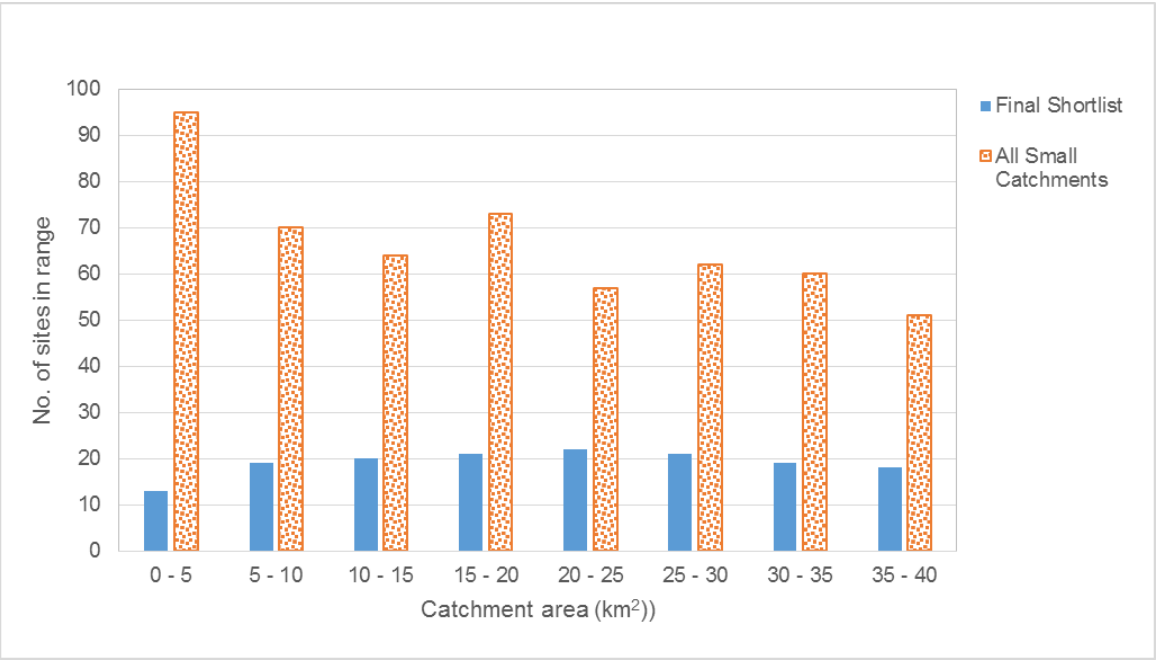

Figure 1 - Histogram showing distribution of catchment area within the final shortlist compared to all 'small' catchments

The histogram in Figure 1 shows the number of sites in range from 0 to 100 (on the y-axis) against the catchment area in km^2 (from 0-5 to 35-40 km^2) on the x-axis. Results are shown for the final shortlist (blue bars) and all small catchments (orange bars).

3.3 $URBEXT_{2000}$

As outlined in the methodology, an aim of this study was to capture a greater proportion of urban catchments in the sample data set. This is because most studies requiring flood estimates for small catchments tend to be in urban areas.

Figure 2 shows the distribution of $URBEXT_{2000}$ across the final shortlist compared to the distribution within the national data set of gauged small catchments. The bins used are not equal in size. Note that no information on $URBEXT_{2000}$ was available for about 100 of the latter data sets (the catchments being too small to identify on the FEH CD-ROM). It can be assumed that $URBEXT_{2000} < 0.03$ implies the catchment is rural, an $URBEXT_{2000}$ of between 0.03 and 0.15 is moderately built up and $URBEXT_{2000} > 0.15$ implies the catchment is highly urban.

Most of the sites in the shortlist are predominantly or completely rural. The shortlist did include some very urban catchments; however, the catchment with the greatest urban proportion being the Graveney catchment at Longley Road

($URBEXT_{2000}$ = 0.811). The mean across the final sample was 0.063, although this is weighted upwards by the few high values. These trends are generally reflected across all UK catchments of less than 40 km^2, as shown by Figure 2. Although, the mean average for the national data set was somewhat lower, at 0.036, a result of a larger proportion of completely rural catchments.

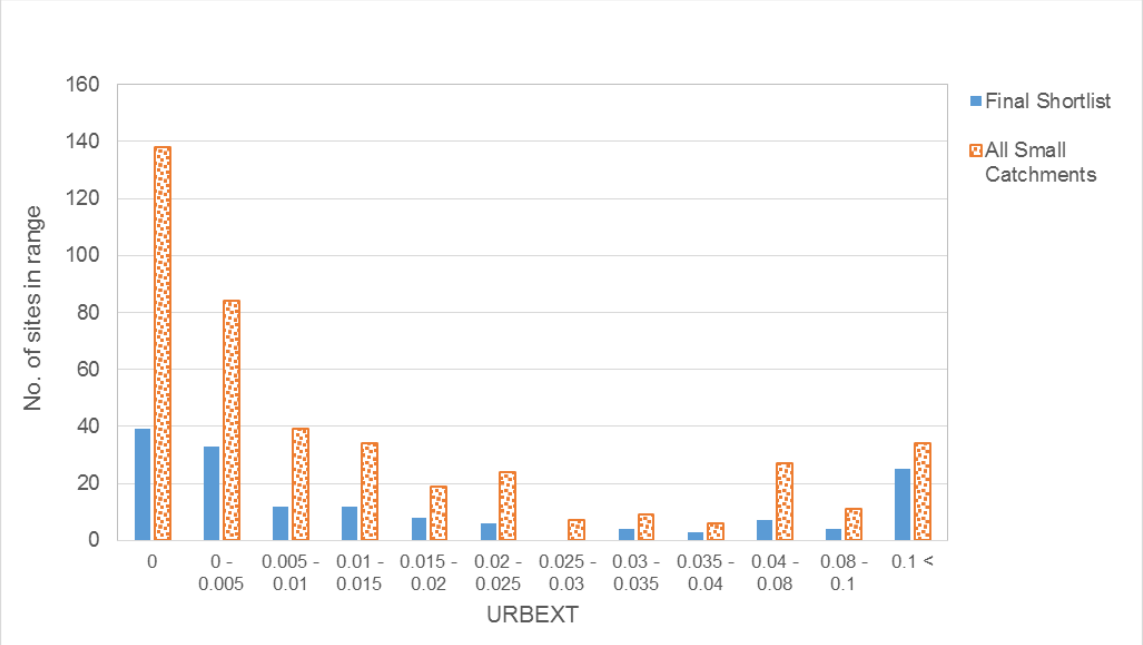

Figure 1 - Histogram showing distribution of $URBEXT_{2000}$ within the final shortlist compared to all 'small' catchments

Figure 2 is a histogram plotting the number of sites in range from 0 to 160 (on the y-axis) against the distribution of $URBEXT_{2000}$ (from 0 to 0.1<) on the x-axis. Results are shown for the final shortlist (blue bars) and all small catchments (orange bars).

3.4 SAAR

The standard-period average annual rainfall (SAAR) represents the mean annual rainfall over a catchment in mm. Values around 700 to 900 mm are typical of the drier South-East, whereas average annual rainfall can easily reach 3,000 mm in upland areas of Wales and Scotland.

Figure 3 shows the distribution of SAAR within the final shortlist and for all small catchment gauges. The average figure for the final shortlist is 1,170 mm, while the highest and lowest values are 2,766 mm and 555 mm respectively. The average for all small catchments nationally was 1,127 mm, with maximum and minimum values of 3,130 mm and 531 mm respectively. Therefore, in terms of SAAR, the final site list is considered to be an acceptable representation of all

small catchments across the UK. The histogram indicates that about 45% of the shortlisted catchments have SAAR values below 1,000 mm, and this is reflective of a good number of lowland catchments being captured in the sample set.

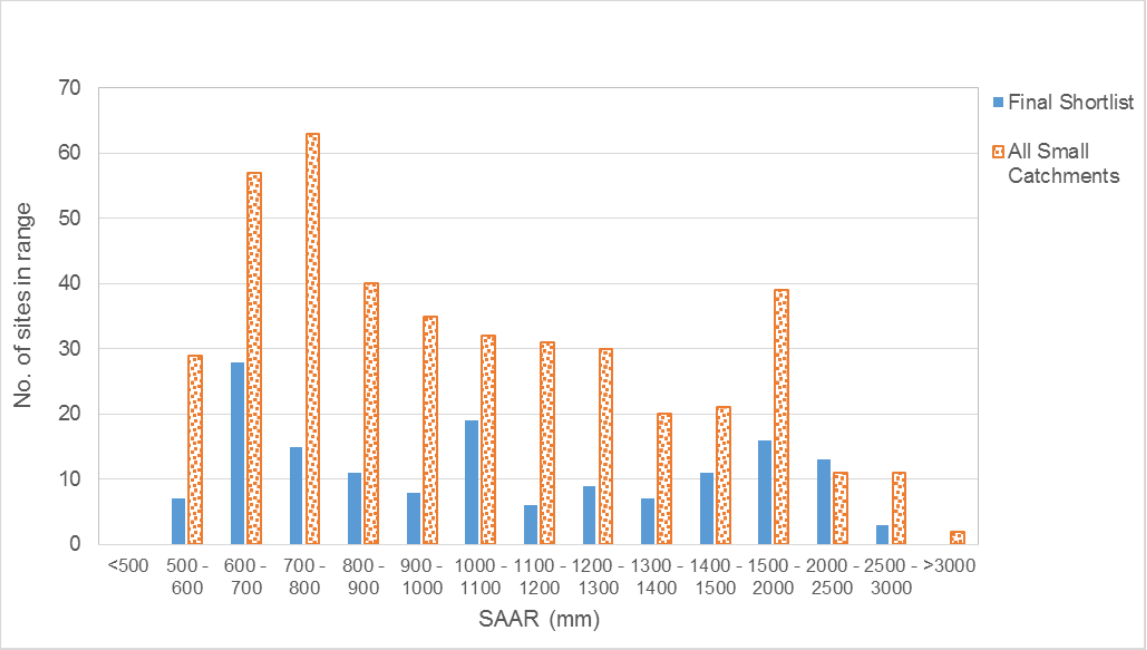

Figure 3 - Histogram showing distribution of SAAR within the final shortlist compared to all 'small' catchments

The histogram in Figure 3 shows the number of sites in range from 0 to 70 (on the y-axis) against the distribution of SAAR (from <500 to >3000 mm) on the x-axis. Results are shown for the final shortlist (blue bars) and all small catchments (orange bars).

3.5 BFIHOST

The base flow index (BFI) is a measure of the proportion of river runoff that is derived from the stored sources such as groundwater. The BFIHOST is an estimate of BFI derived from knowledge of catchment soil types as represented in the hydrology of soil types (HOST) classification. A high BFIHOST indicates a more permeable underlying rock, superficial deposit or soil in a catchment and therefore, the potential for more sustained river flow during periods of dry weather. Larger catchments are more likely to cross a range of geologies and have BFI values that reflect this (that is, neither extremely high nor extremely low values). Small catchments are more likely to be composed of a single geological type and a larger proportion of small catchments will have BFI values in excess of 0.8 and below 0.4.

Of the 600 small catchments in the network, as shown in Figure 4, the largest proportion have BFIHOST values between 0.3 and 0.6, but there are also a good number of sites that have BFI in excess of 0.8 and can be considered highly permeable. Some very impermeable (for example, Yeading Brook West, BFIHOST = 0.172) as well as permeable (for example, Ings Beck at South Newbald, BFIHOST = 0.98) catchments are captured in the final shortlist. However, permeable catchments are less susceptible to flash floods, and historically less attention has been placed on measuring flood flows at gauging stations in permeable catchments. For this reason, less than 10% of stations making the final list are representative of these catchments. On the other hand, a greater number of the stations on the final shortlist demonstrate more responsive behaviour (BFI between 0.3 and 0.5) as they are small upland catchments.

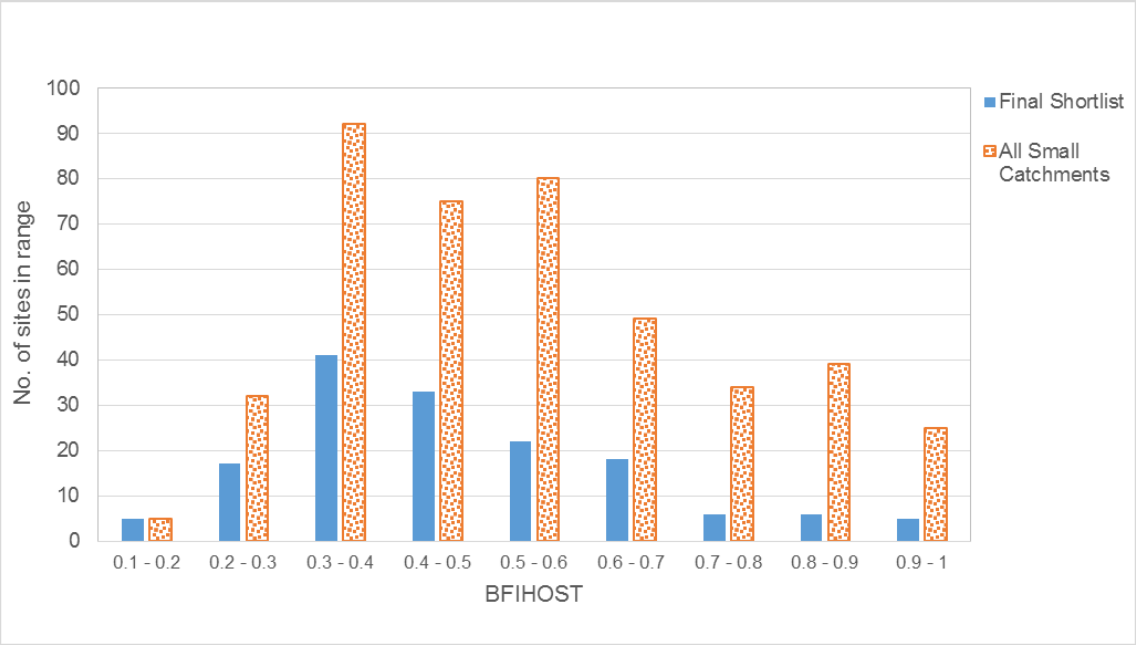

Figure 2 - Histogram showing distribution of BFIHOST within the final shortlist and all 'small' catchments

Figure 4 is a histogram plotting the number of sites in range from 0 to 100 (on the y-axis) against the distribution of BFIHOST (from 0.1 to 1) on the x-axis. Results are shown for the final shortlist (blue bars) and all small catchments (orange bars).

3.6 DPSBAR

DPSBAR provides an index of overall catchment steepness by calculating the mean of all inter-nodal slopes. Generally, values range from >300 m/km in mountainous terrain to <25 m/km in the flattest parts of the country. Gradients

of greater than 100 m/km may be considered steep. Figure 5 suggests that, in the UK, the majority of the 'small catchment' gauges are in lowland catchments, with the mean steepness across the data set being 94.2 m/km. Only 4% of the sites analysed were in areas with DPSBAR values >250 m/km.

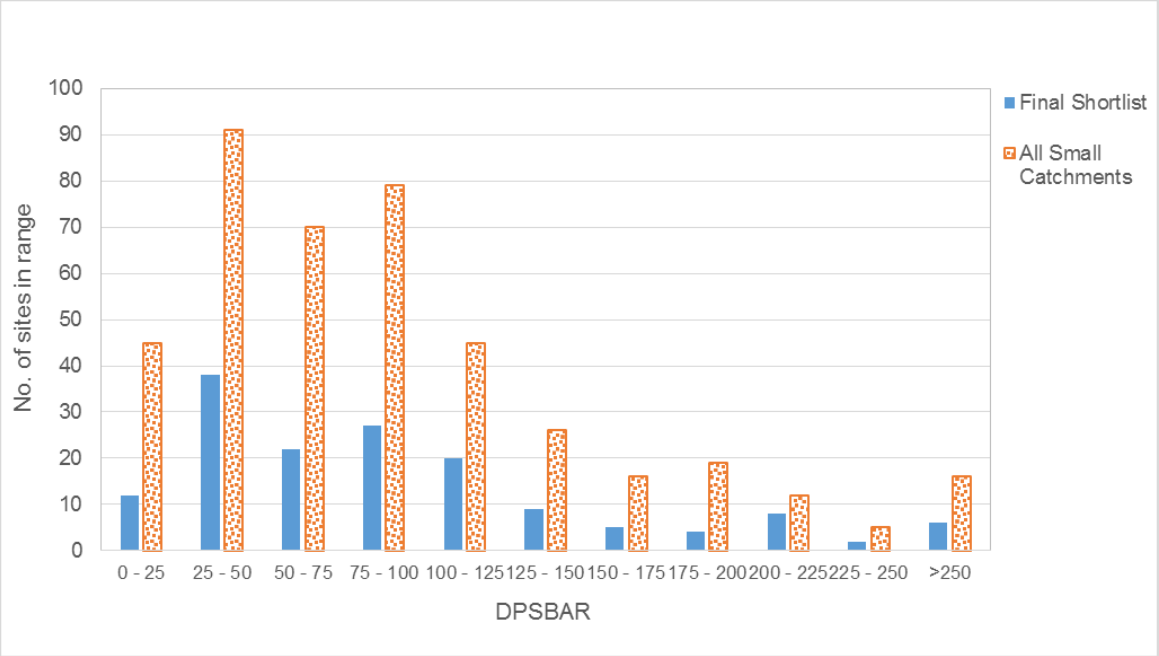

Figure 3 - Histogram showing distribution of DPSBAR within the final shortlist and all 'small' catchments

The histogram in Figure 5 shows the number of sites in range from 0 to 100 (on the y-axis) against the distribution of DPSBAR (from 0 to >250) on the x-axis. Results are shown for the final shortlist (blue bars) and all small catchments (orange bars).

A similar distribution is seen in the final shortlist. The lowest value recorded in the shortlist (8.8 m/km) was for the Larling Brook gauged at Stonebridge. Three catchments in the final shortlist had drainage path slopes in excess of 300 m/km. Two of these were in Scotland: Dargall Lane at Loch Dee (307.5 m/km) and Strae at Glen Strae (324.4 m/km), and one was in Wales: Cerist at Llawr Cae (433.3 m/km).

3.7 FARL

Generally, reservoirs or lakes within a river catchment will have an impact on the flood response. Those which are directly linked to a stream network are the most likely to produce an attenuation effect. The flood attenuation by reservoirs and lakes (FARL) index provides a guideline to the extent of the flood attenuation that can be attributed to the presence of reservoirs and lakes above

a catchment gauging station. A value close or equal to one indicates that there is an absence of attenuation due to lakes and reservoirs, therefore no impact on the flood response.

Most small catchments have FARL values that are close or equal to one, although a handful have FARL values lower than 0.9 and are likely to be substantially influenced by the presence of lakes or reservoirs. This position is reflected in the final shortlist, however fewer of the impacted stations were deemed suitable for the purposes of the study.

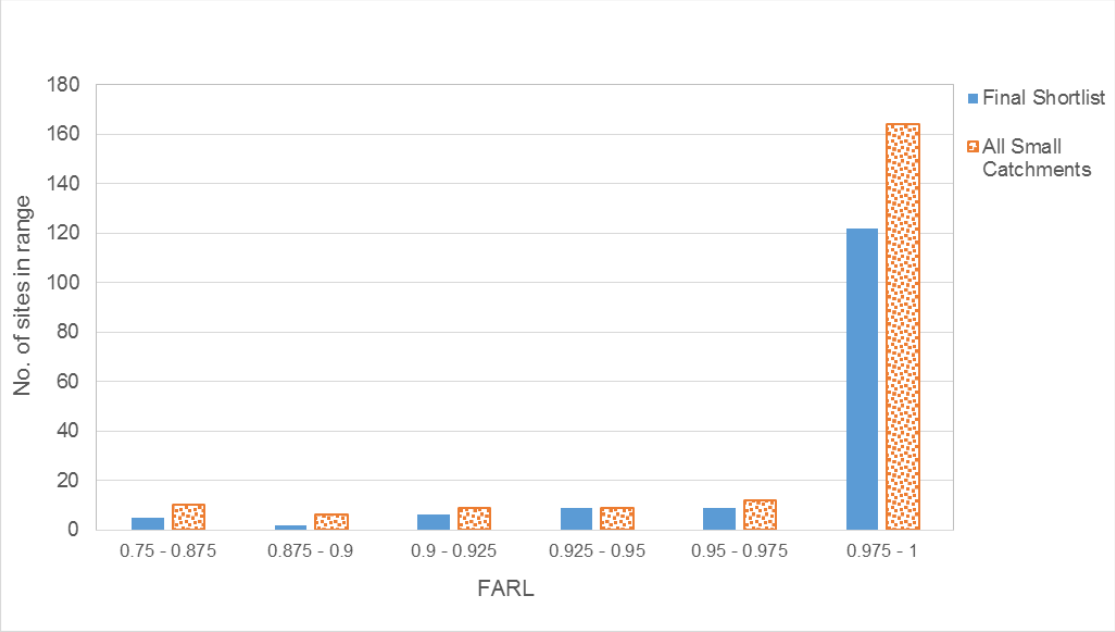

Figure 4 - Histogram showing distribution of FARL within the final shortlist and all 'small' catchments

Figure 6 is a histogram plotting the number of sites in range from 0 to 180 (on the y-axis) against the distribution of FARL (from 0.75 to 1) on the x-axis. Results are shown for the final shortlist (blue bars) and all small catchments (orange bars).

4. Spatial distribution

4.1 Regional breakdown

The following chart shows the regional breakdown of the shortlisted sites (English sites are taken from the six former Environment Agency water management regions), compared to that for all gauging stations having an upstream area of 40 km^2 or less.

Around 40% of all small catchment gauges are in the former South-West and South-East regions, and a similar proportion of stations in the final shortlist are also located in these regions. However, while around 20% of small catchment gauges are in Scotland, only 10% of the final shortlisted stations are Scottish. This may reflect the difficulty in measuring high flows in energetic upland/highland streams.

On average, 30% of the small catchment gauges considered in each region were accepted to the final shortlist. Northern Ireland has the greatest proportion of sites making the shortlist in relation to the number of sites considered, but this is reflective of the fact that there are very few small catchment sites available in this region to begin with. In the North-East region a disproportionately large number of the gauges considered made it to the final shortlist. The reasons for this are not clear, but they could include, for example, better local knowledge on gauging station performance, more of the stations being better suited to high flow measurement, and a greater focus on high flow measurement within hydrometric teams.

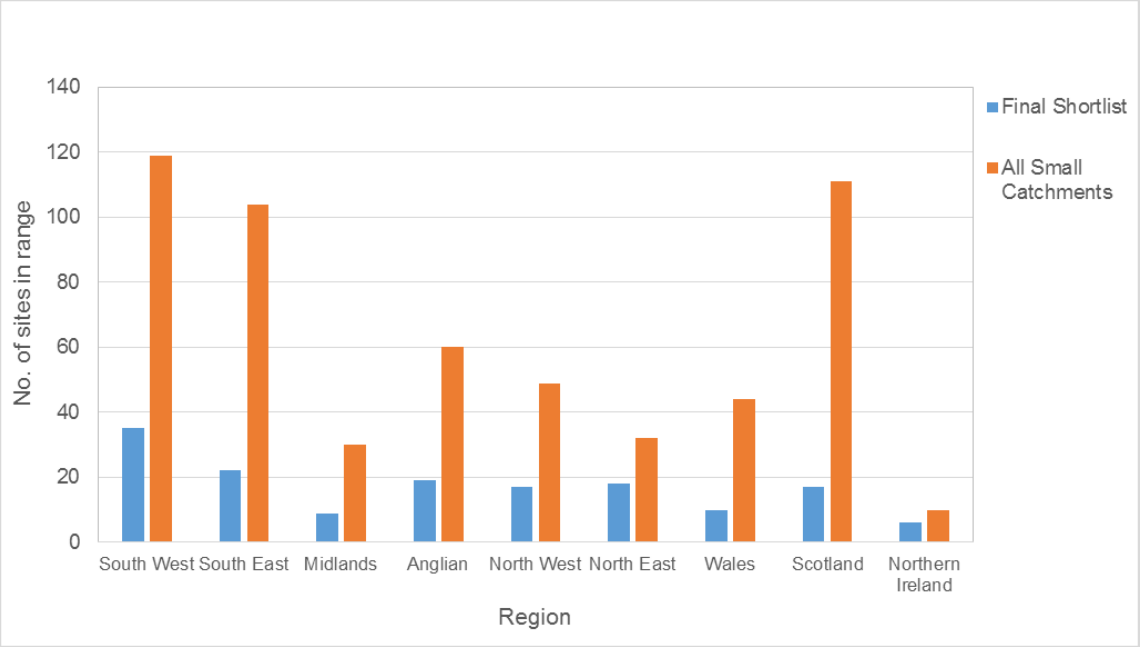

Figure 7 - Histogram showing distribution of the number of the final chosen sites compared to the total number of sites for each region

Figure 7 is a histogram plotting the number of sites in range from 0 to 140 (on the y-axis) against the regions (South-West, South-East, Midlands, Anglian, North-West, North-East, Wales, Scotland and Northern Ireland), which are shown on the x-axis. Results are shown for the final shortlist (blue bars) and all small catchments (orange bars).

4.2 Geographical distribution

National map

The map in Figure 8 shows the spatial distribution of the stations making the final shortlist across all of the regions. Sites identified through the data quality review are shown in red, while sites deemed suitable based on their HiFlows-UK designations are shown in green. The size of the symbol reflects the size of the catchment - the bigger the catchment the larger the symbol. The map also shows the locations of those small catchment gauges whose flood peak data was not considered robust enough to inform the study (black dots). The spatial distribution of sites is good, but there are some gaps.

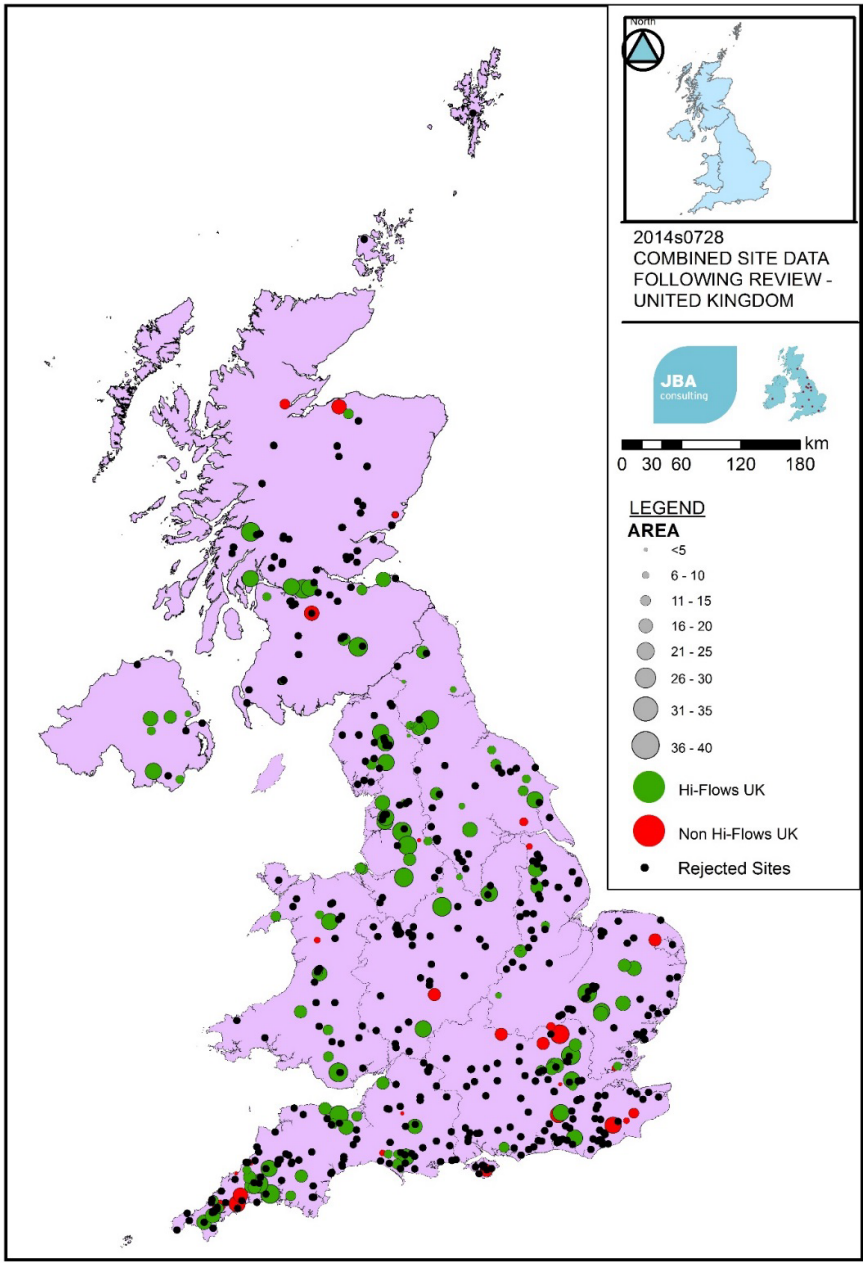

Figure 8 - Geographic distribution of all shortlisted sites

South-West region

Of 119 small catchment gauges considered, 35 made the final shortlist. The majority were already on HiFlows-UK, but a good number of additional gauges were identified through the data quality review process as having high flow data good enough to be included in the study.

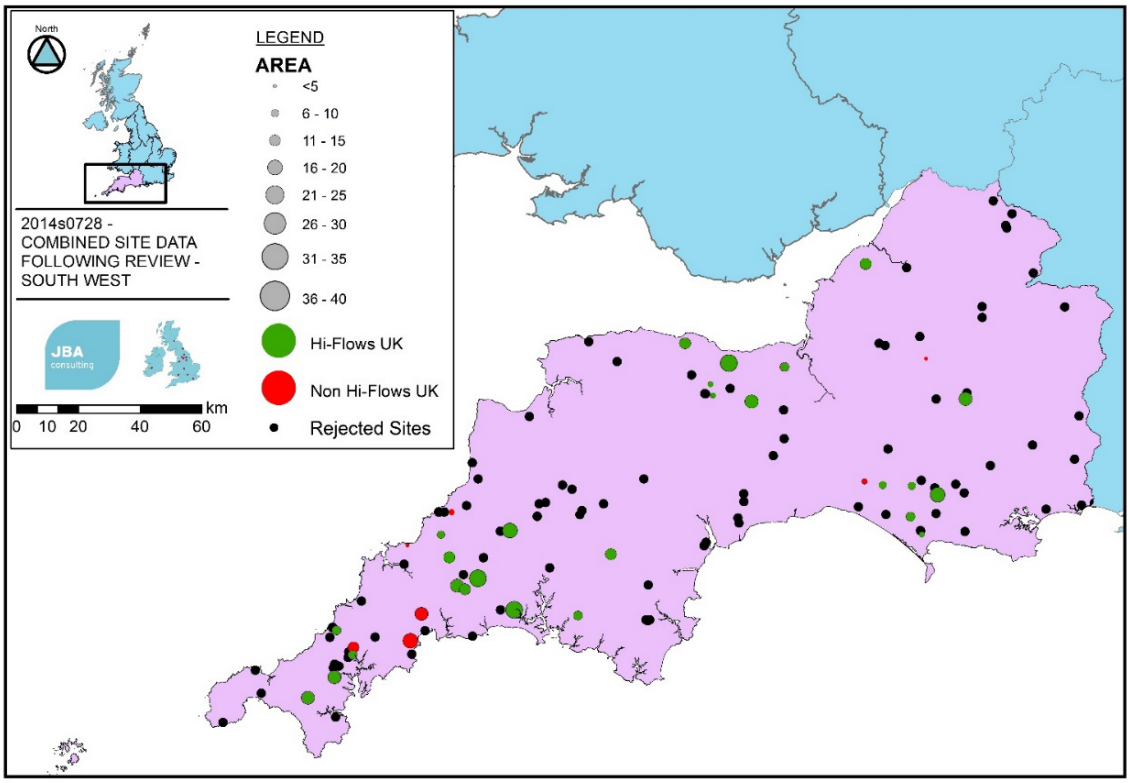

Figure 9 - Geographic distribution of shortlisted and rejected sites in the former South-West region

The map in Figure 9 shows the 119 small catchment gauges in the South-West. Sites deemed suitable based on their HiFlows-UK designations are shown in green. Sites identified through the data quality review are shown in red. The bigger the catchment the larger the symbol. The map also shows the locations of those small catchment gauges whose flood peak data was not considered robust enough to inform the study (black dots).

South-East region

Of 104 small catchment gauges located in the former South-East region, 22 made the final shortlist. Only around half of these were already on HiFlows-UK and known to provide good quality flood peak data, the remainder were found through the data quality review process.

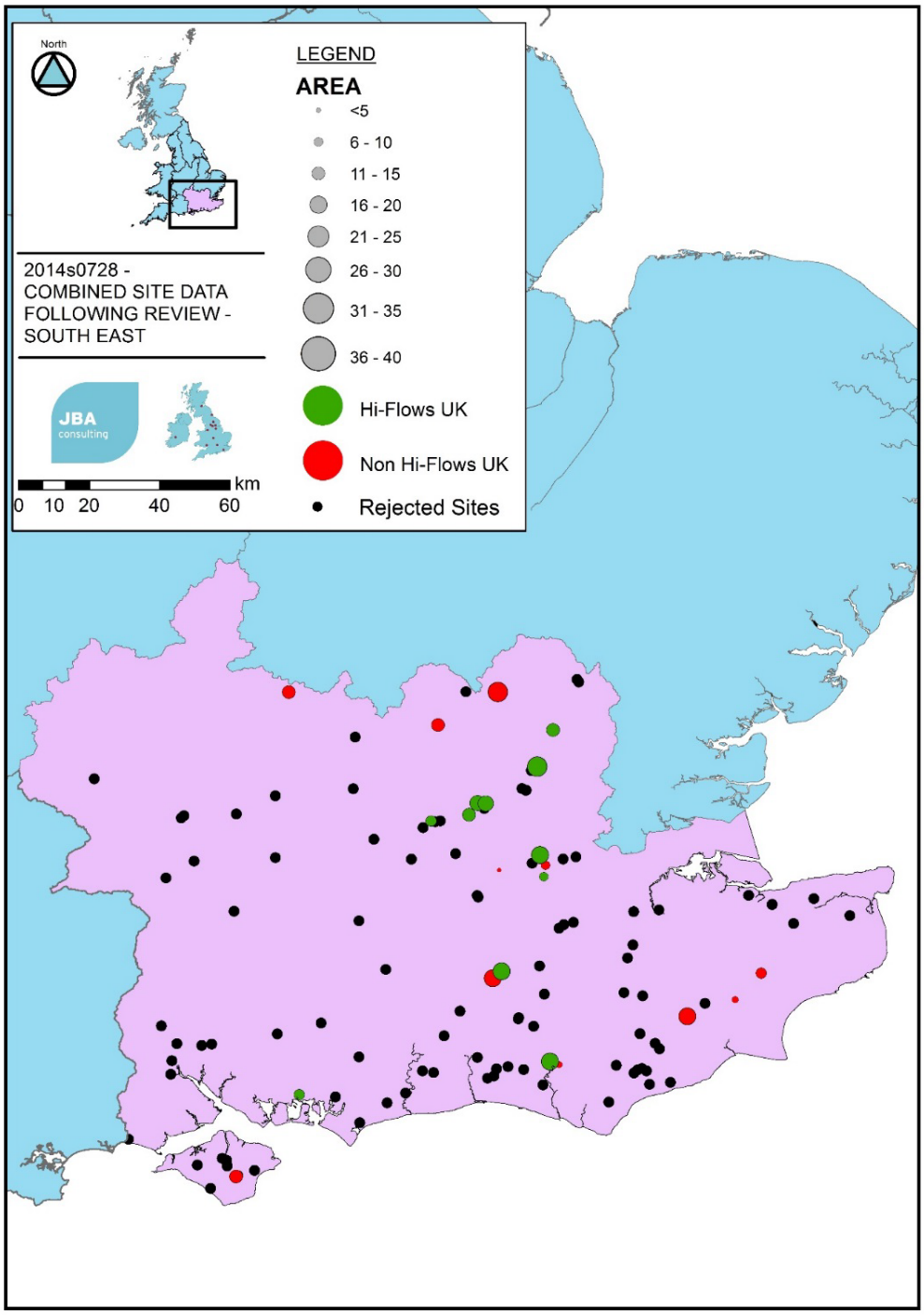

Figure 10 - Geographic distribution of shortlisted and rejected sites in the former South-East region

The map in Figure 10 shows the 104 small catchment gauges in the South-East. Sites deemed suitable based on their HiFlows-UK designations are shown in green. Sites identified through the data quality review are shown in red. The bigger the catchment the larger the symbol. The map also shows the locations of those small catchment gauges whose flood peak data was not considered robust enough to inform the study (black dots).

Anglian and Midlands regions

60 small catchment gauges were identified in the Anglian region, but only 19 of these have adequate flood peak data. The data quality review identified four gauging stations as well as the 15 sites already on HiFlows-UK. Of the 30 potential candidates in the Midlands, only nine performed acceptably at high flows. The data quality review only identified a couple of stations; the rest having already appeared on HiFlows-UK.

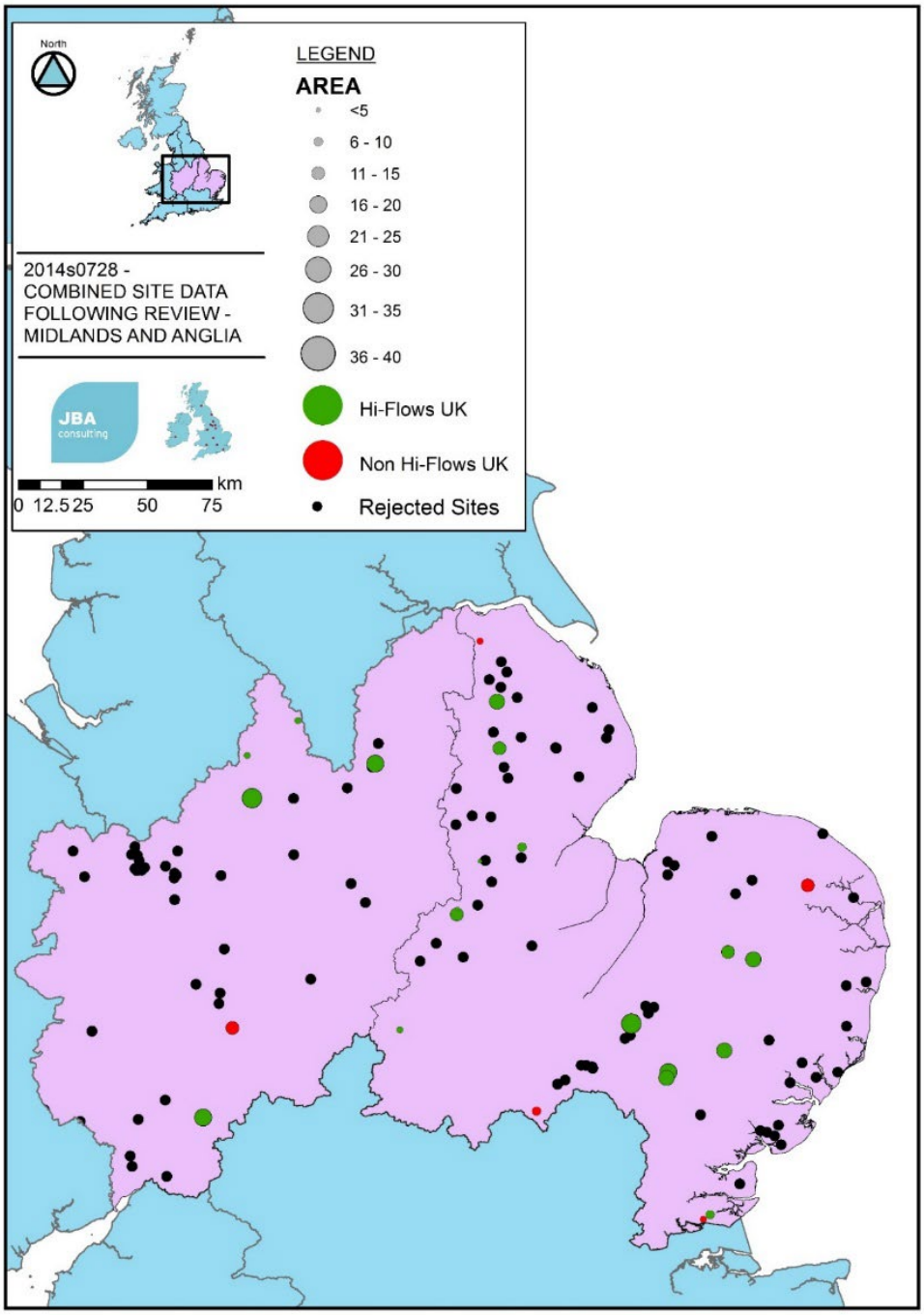

Figure 11 - Geographic distribution of shortlisted and rejected sites in the former Anglian and Midlands regions

The map in Figure 11 shows the 60 small catchment gauges in the Anglian and Midlands regions. Sites deemed suitable based on their HiFlows-UK designations are shown in green. Sites identified through the data quality review are shown in red. The bigger the catchment the larger the symbol. The map also shows the locations of those small catchment gauges whose flood peak data was not considered robust enough to inform the study (black dots).

North-West region

17 of 49 potential stations made the final shortlist for the North-West region. The data quality review identified only one station with adequate performance at high flows that was not already considered in HiFlows-UK.

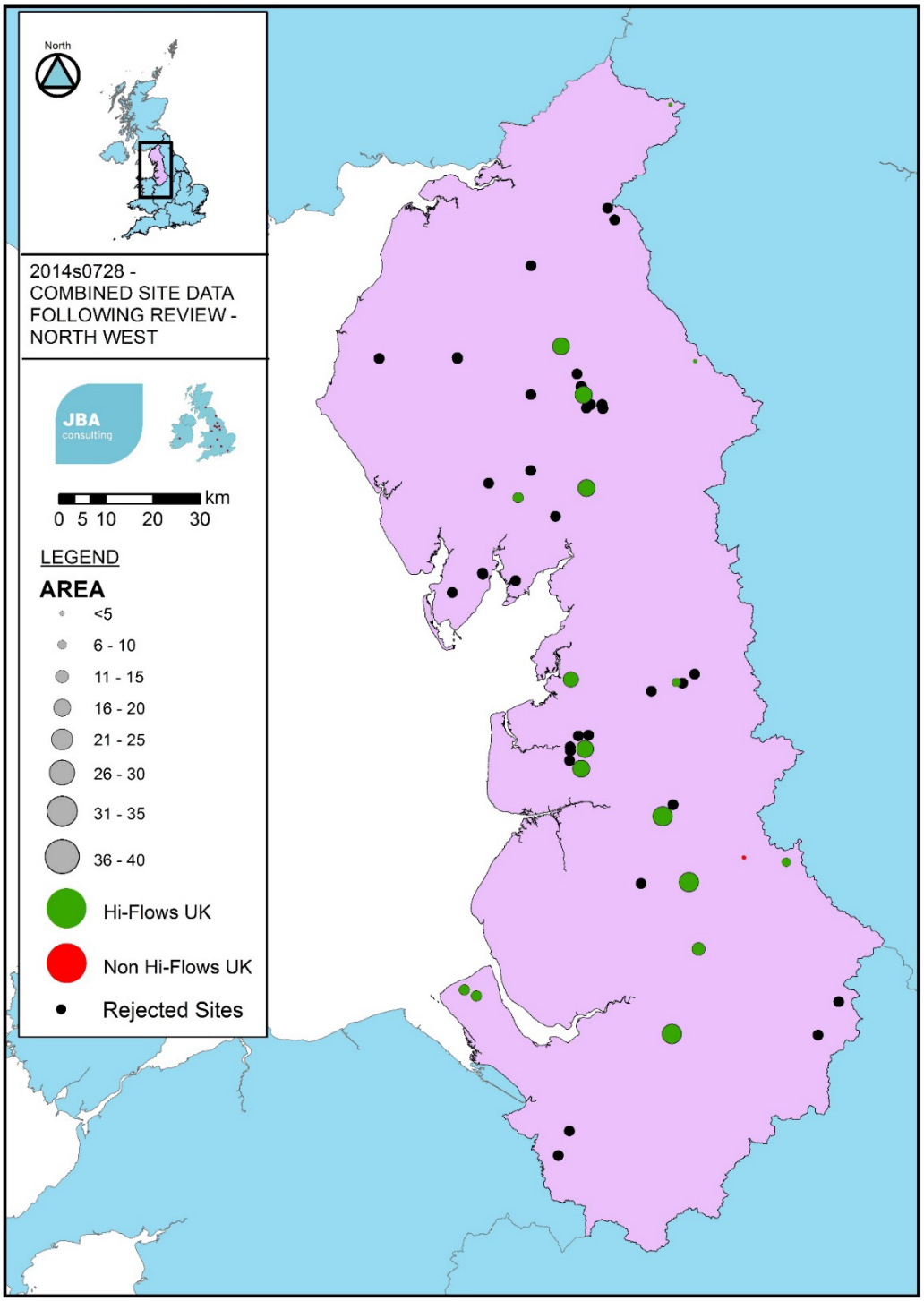

Figure 12 - Geographic distribution of shortlisted and rejected sites in the former North-West region

The map in Figure 12 shows the 49 small catchment gauges in the North-West region. Sites deemed suitable based on their HiFlows-UK designations are shown in green. Sites identified through the data quality review are shown in red. The bigger the catchment the larger the symbol. The map also shows the locations of those small catchment gauges whose flood peak data was not considered robust enough to inform the study (black dots).

North-East region

18 of 32 potential stations made the final shortlist for the North-East region. The data quality review identified only one station with adequate performance at high flows that was not already considered in HiFlows-UK.

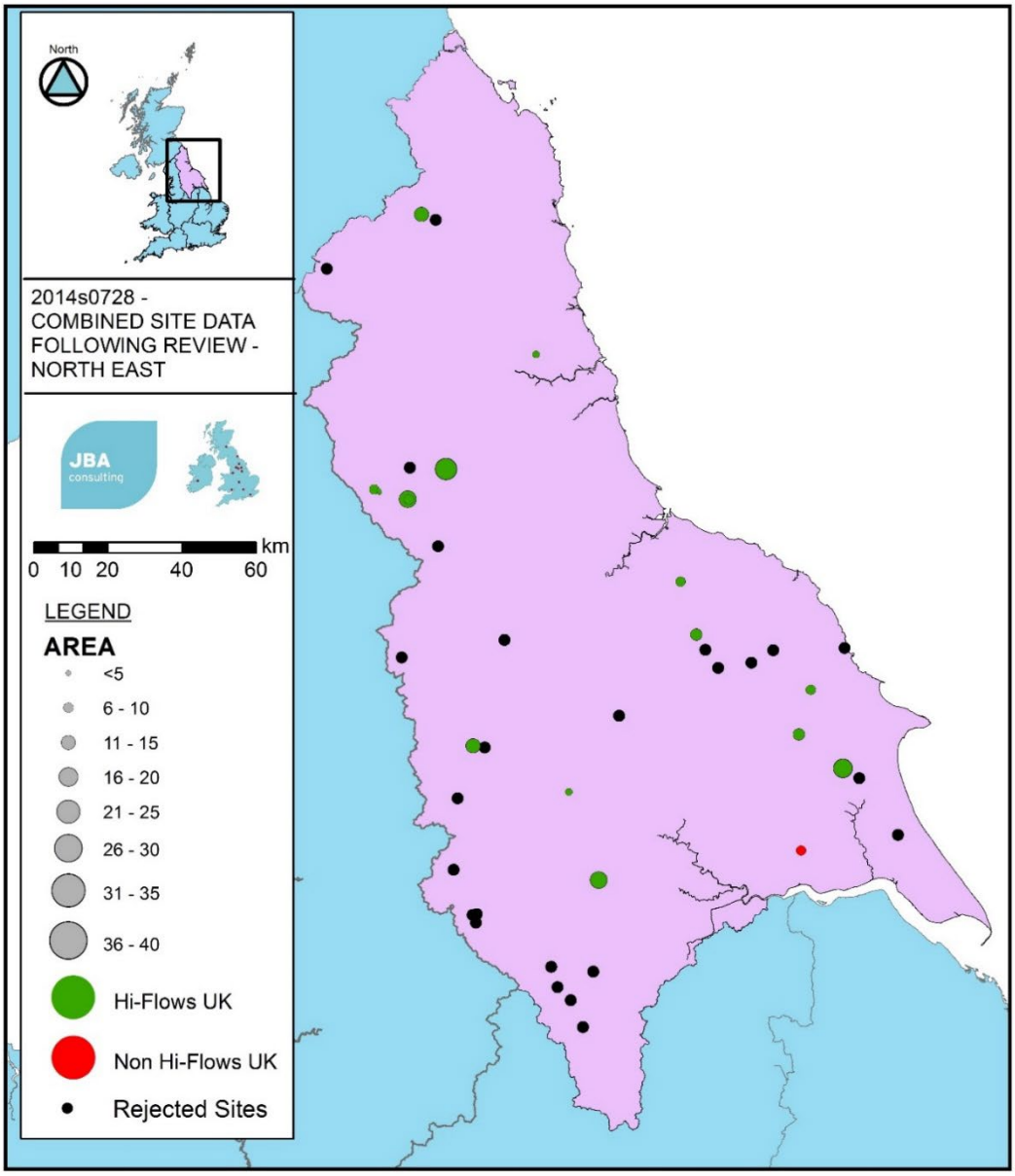

Figure 13 - Geographic distribution of shortlisted and rejected sites in the former North-East region

The map in Figure 13 shows the 32 small catchment gauges in the North-East region. Sites deemed suitable based on their HiFlows-UK designations are shown in green. Sites identified through the data quality review are shown in red. The bigger the catchment the larger the symbol. The map also shows the locations of those small catchment gauges whose flood peak data was not considered robust enough to inform the study (black dots).

Wales

Of the 44 small catchment gauges identified in Wales (and managed by Natural Resources Wales), only 10 were found to have adequate flood peak data. The majority of these were already on HiFlows-UK.

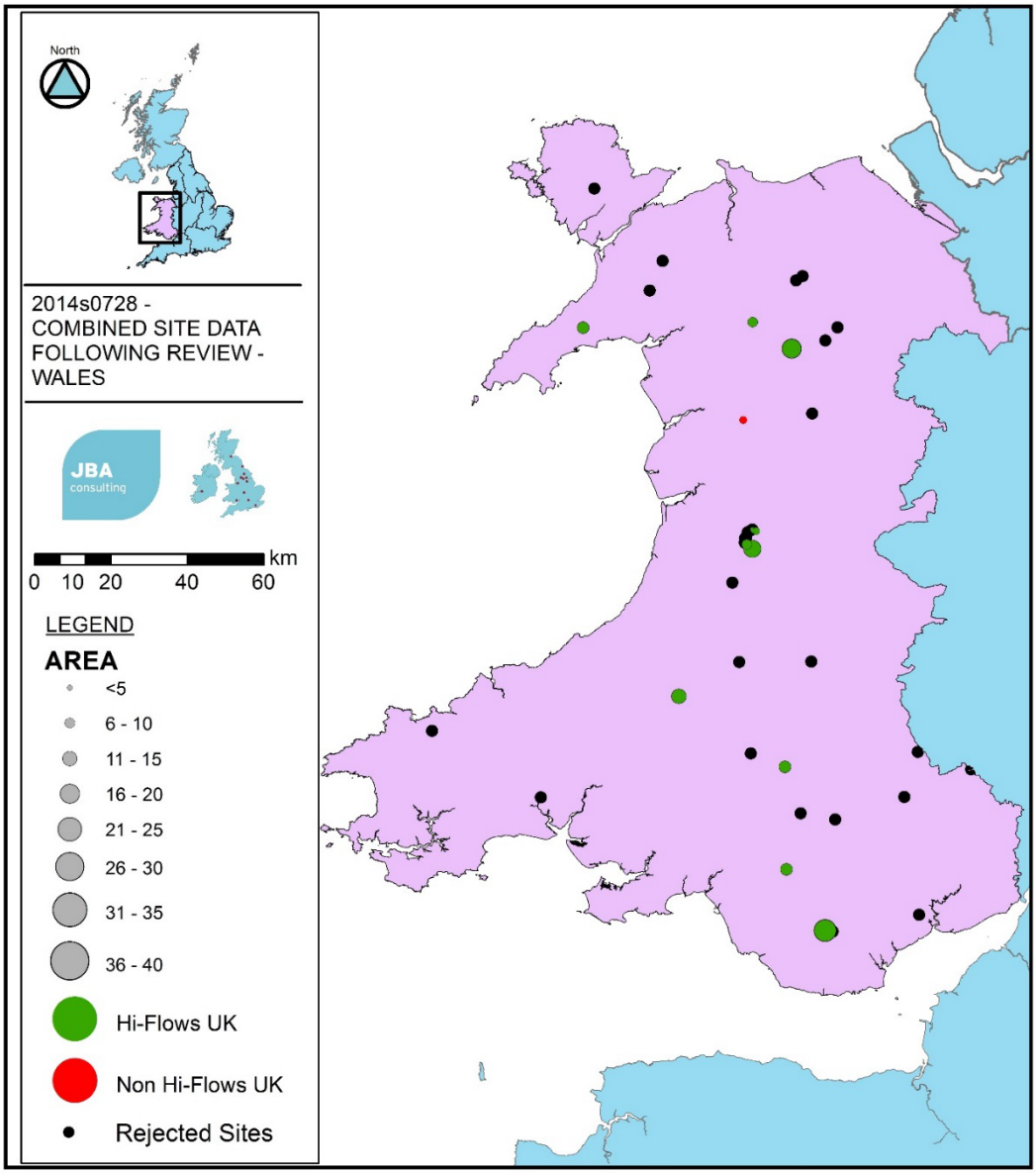

Figure 14 - Geographic distribution of shortlisted and rejected sites in Wales

The map in Figure 14 shows the 44 small catchment gauges in Wales. Sites deemed suitable based on their HiFlows-UK designations are shown in green. Sites identified through the data quality review are shown in red. The bigger the catchment the larger the symbol. The map also shows the locations of those

small catchment gauges whose flood peak data was not considered robust enough to inform the study (black dots).

Scotland

Over 110 gauging stations in Scotland are on small catchments. On the advice of SEPA, several stations were removed from the shortlist, leaving a total of 19 sites in Scotland that were deemed to provide data suitable to be included in the study. Of these, 12 were already in Hiflows-UK.

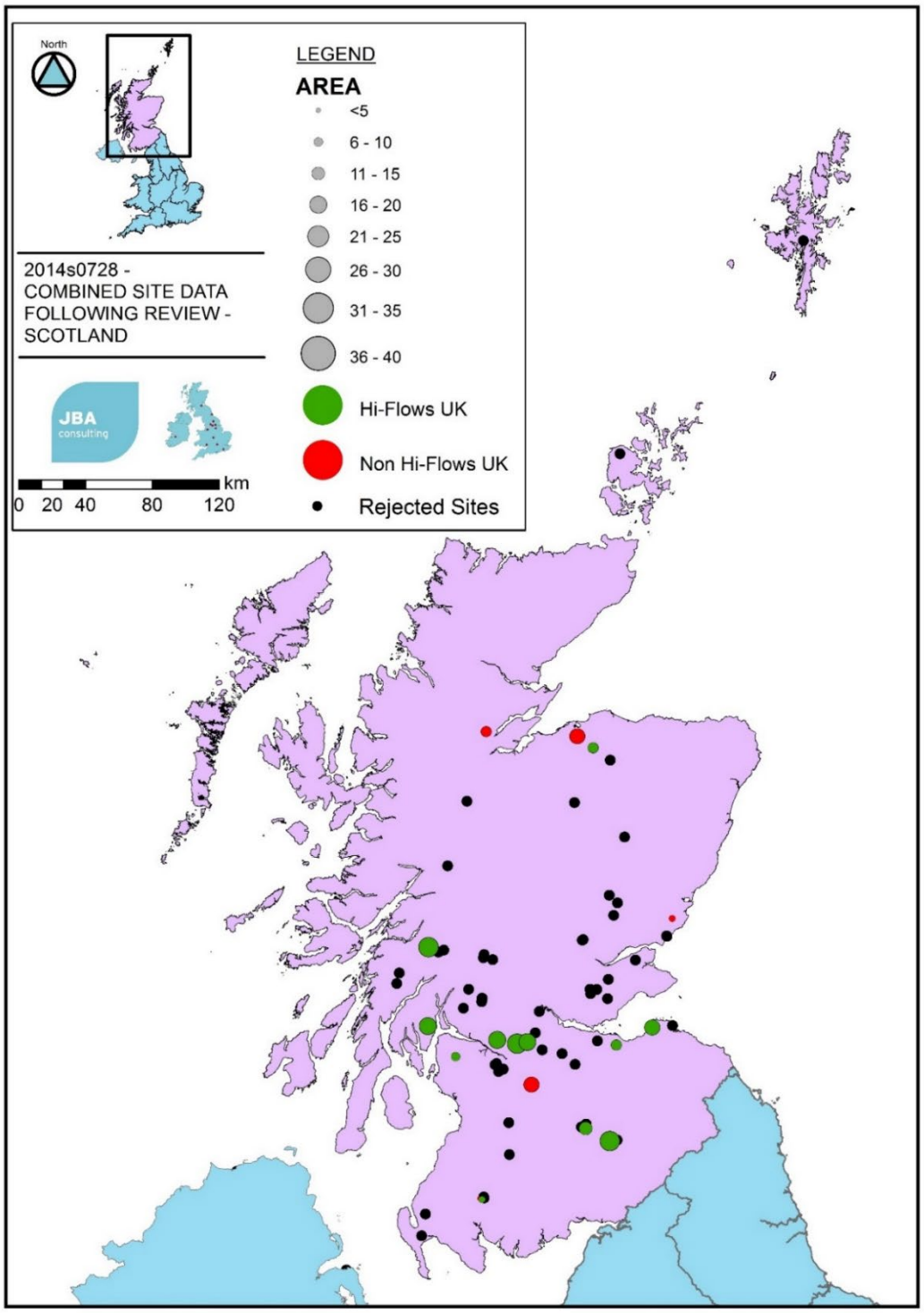

Figure 15 - Geographic distribution of shortlisted and rejected sites in Scotland

The map in Figure 15 shows the 110 small catchment gauges in Scotland. Sites deemed suitable based on their HiFlows-UK designations are shown in green. Sites identified through the data quality review are shown in red. The bigger the catchment the larger the symbol. The map also shows the locations of those

small catchment gauges whose flood peak data was not considered robust enough to inform the study (black dots).

Northern Ireland

As outlined previously, within Northern Ireland there are 10 official gauging stations that measure flows in catchments smaller than 40 km^2. Following the data quality review, only six of these (all HiFlows-UK stations) were considered suitable for the final shortlist.

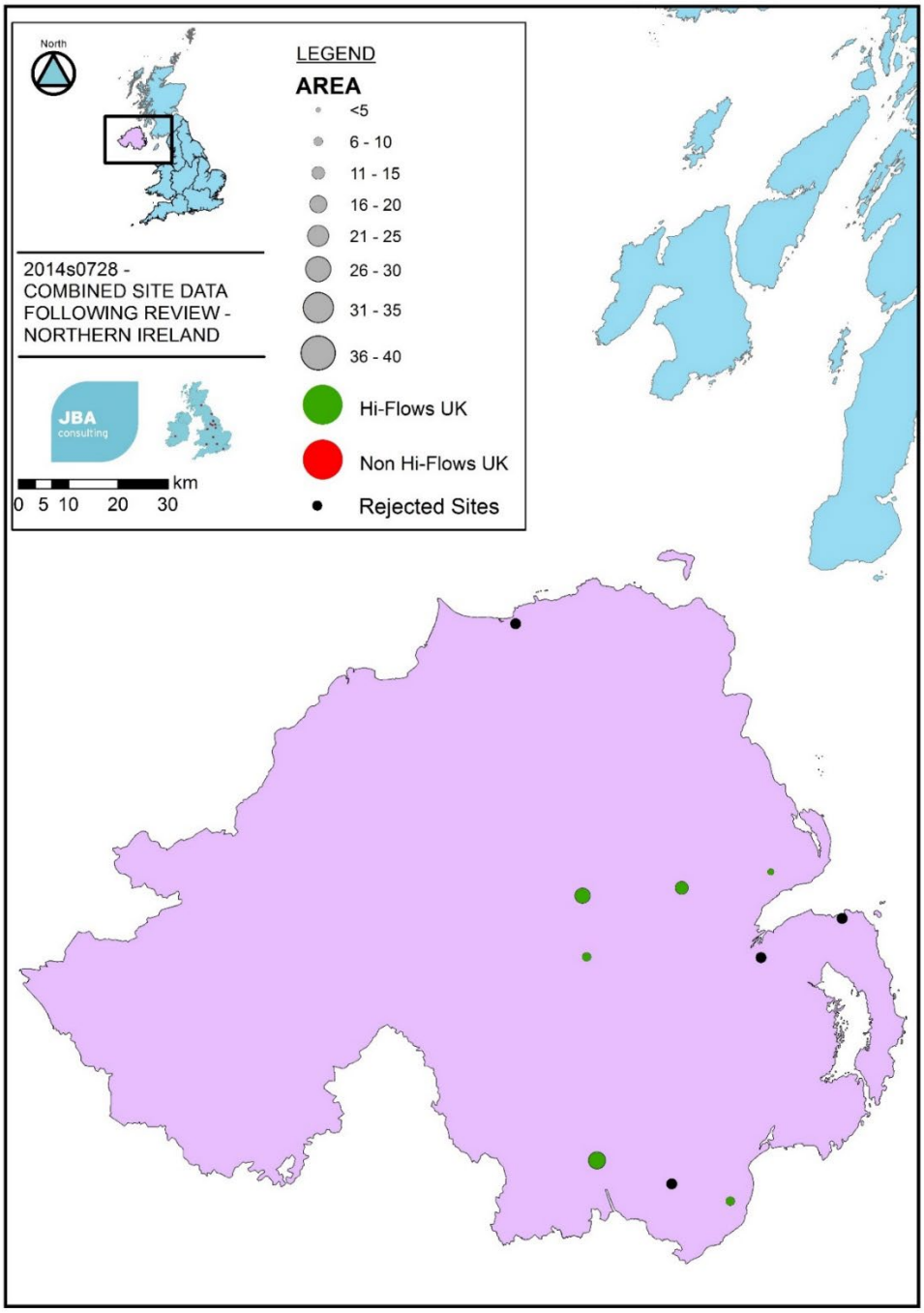

Figure 16 - Geographic distribution of shortlisted and rejected sites in Northern Ireland

The map in Figure 16 shows the 10 small catchment gauges in Northern Ireland. Sites deemed suitable based on their HiFlows-UK designations are shown in green. The bigger the catchment the larger the symbol. The map also shows the locations of those small catchment gauges whose flood peak data was not considered robust enough to inform the study (black dots).

5. Conclusions and recommendations

5.1 Comments on final shortlist

Method of derivation

As described in earlier sections of this report, an objective approach was used to identify those small catchment gauging stations whose high flow data might potentially be suitable to use in the study. Potential sites were then reviewed more subjectively to determine whether they should make the final shortlist. A site being included in the shortlist does not guarantee the suitability of its flood peak data sets for the detailed statistical work to be carried out by CEH. The shortlist will inevitably include some sites whose data are outliers or show variations in data quality across the period of record. Where such issues exist, they may in fact be subtle and only come to light as the analysis progresses; sites with obvious data quality problems having been removed already before the shortlist stage. The 'final' shortlist described here was therefore slightly modified as the project developed; changes from this list are detailed in Section 5 of the main project report.

Assumptions relating to HiFlows-UK stations

One major assumption is the automatic acceptance of the data quality of all small catchment gauging stations that already appear on HiFlows-UK. Before the handover of HiFlows-UK to CEH Wallingford the Environment Agency and Natural Resources Wales jointly carried out a project to review and update all flood peak data for HiFlows-UK stations in England and Wales. This included reviews of stage-discharge ratings, revisions of flood peak series and re-evaluation of suitability flags. For this reason, the assumption can be considered acceptable for England and Wales stations. Measuring authority staff sometimes had slightly different views of particular stations, but ultimately these did not result in stations being removed from the shortlist. The assumption was less valid for Scottish stations, with feedback from SEPA giving a relatively different picture of data quality than the one indicated by HiFlows-UK. However, only two HiFlows-UK stations in Scotland were rejected.

Review process for non HiFlows-UK stations

A review of measuring authority inventories identified a further 480 flow gauging stations in small catchments (that is, those not already included in HiFlows-UK). Due to the way stations are classified (for example, a site predominately used

for flood forecasting may have a reasonable rating curve but still be classified as a level-only station), not all relevant hydrometric monitoring sites may have been captured. No significant effort was put into identifying other data sources, such as flood peak data that is held for ‘experimental catchments’ by universities.

Assumptions were also made when identifying the 42 stations in Scotland and 140 stations across England and Wales that were rejected because they were either already known to provide poor quality data at high flows, that were severely impacted by artificial influences (for example, gauges installed to monitor compensation releases from reservoirs) or were only operational for a short period in the past.

The scoring process used to determine which of the remaining stations might be prioritised for a data quality review had a subjective emphasis on more urbanised catchments and on the smaller catchments in the sample. While thresholds were set such that a significant number of stations (127 in England and Wales alone) were put forward for a data quality review, no doubt some of the remaining stations (not reviewed) could have provided useful data (around 25% of the reviewed stations were found to have acceptable data quality, so a similar proportion might be assumed for the non-reviewed sites). Measuring authority comments hopefully allowed the most useful to be reinstated into the data quality review process.

The data quality review process tried to be as detailed and objective as possible and aimed to apply the same kinds of criteria as applied in HiFlows-UK. There remained a level of subjectivity; however, the general rule being to consider a station as suitable unless evidence existed to show the data quality at high flows was of an insufficient standard. Nevertheless, only 33 stations (that is around 25% of the sites reviewed) were deemed to provide flood peak data of sufficient quality.

5.2 Representativeness of final shortlist

Catchment descriptors sampled

The histograms provided in Section 3 illustrate that, in terms of catchment descriptors sampled, the final shortlist is reasonably representative of the small catchment gauging station data set as a whole. There is an even spread of catchment sizes across the 0 to 40 km^2 range considered. Most shortlisted stations are in rural catchments, although there is a greater proportion of urbanised catchments in the final shortlist compared to the proportion in the whole small catchment data set - this was deliberate as such stations were

prioritised for data quality review. With regards to other catchment descriptors, the histograms mimic those for the whole sample – that is, any bias reflects the natural geography of the UK and/or historic gauging network development.

Spatial distribution

As shown by the maps in Section 4, the final shortlist is spread reasonably evenly over the UK. Gaps predominantly relate to the natural geography of the UK and/or historic gauging network development.

5.3 Recommendations for measuring authorities

Recommendations for newly identified stations

The following recommendations are put forward regarding the 32 non-HiFlows-UK stations identified as providing adequate quality flood peak data following the data quality review.

i) Each station should be considered by the measuring authority and CEH for future inclusion in HiFlows-UK.

ii) Measuring authorities should consider ring-fencing the identified sites against closure and formally incorporating them into high flow gauging programmes and other maintenance regimes.

Rejected sites worthy of data quality improvement

There are several sites that scored highly in JBA's prioritisation scheme (based on catchment descriptors) that were found to have inadequate data quality. The relevant measuring authorities may find it useful to consider options for improving high flow measurement at these sites. These sites are flagged separately (Appendix B).

Appendices

Appendices to this report are contained in separate files. They are published alongside this report, available on GOV.UK:

Appendix A: Master site list

Details all sites considered, abridged version of measuring authority feedback, findings of data quality review, reasons for acceptance/rejection.

Appendix B: Final shortlist

Details all the sites making the final shortlist, as of 11 February 2015. Also, details rejected sites, including those worthy of data improvement based on their catchment descriptors and site groups.

Would you like to find out more about us or your environment?

Then call us on

03708 506 506 (Monday to Friday, 8am to 6pm)

Email: enquiries@environment-agency.gov.uk

Or visit our website

www.gov.uk/environment-agency

incident hotline

0800 807060 **(24 hours)**

floodline

0345 988 1188 **(24 hours)**

Find out about call charges (https://www.gov.uk/call-charges)

Environment first

Are you viewing this onscreen? Please consider the environment and only print if absolutely necessary. If you are reading a paper copy, please don't forget to reuse and recycle.