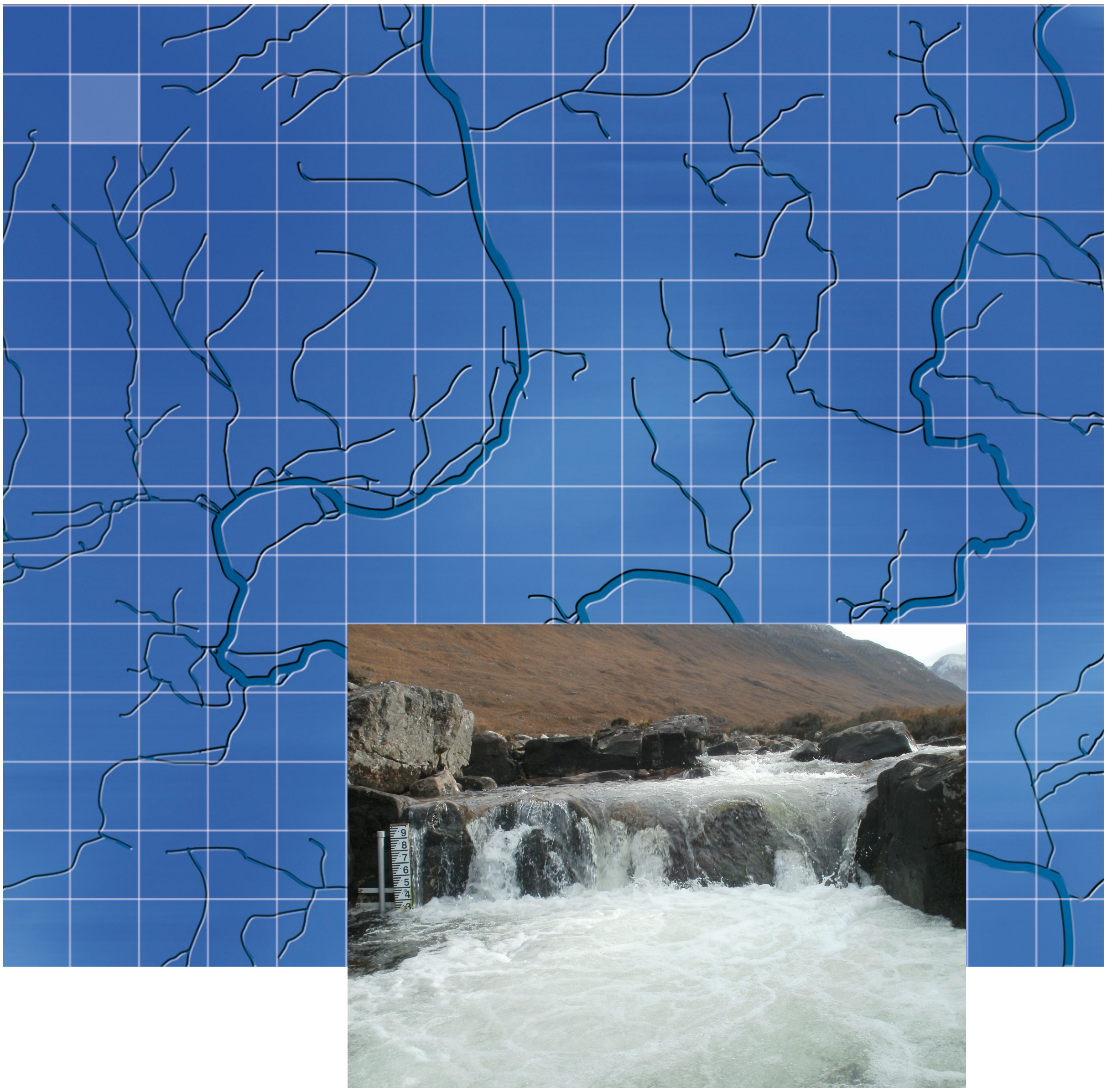
LowFlows Report 264/14

June 2014

Flow estimate for Afon Wnin



Wallingford HydroSolutions Limited

For and on behalf of Wallingford HydroSolutions Ltd

Client	Snowdonia Hydro
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Approved by	Jude Jeans
Position	*Senior Consultant*
Invoice value	£175 (excl. VAT)

This report has been produced in accordance with the WHS Quality Management system which is certified as meeting the requirements of ISO 9001:2008.

Contents

1 Introduction

This report presents the annual and seasonal flow statistics for the site(s) requested using the LowFlows Enterprise model. The site location(s) have been confirmed using a digital map and copies of the correspondence are contained within Annex 1.

The LowFlows software system is the standard software system used by the Environment Agency, the Scottish Environment Protection Agency and the Northern Ireland Environment Agency for providing estimates of river flows within ungauged catchments. The software and underpinning science have been widely published in the scientific literature. The LowFlows software system is available for purchase as two versions; LowFlows 2 and LowFlows Enterprise. Wallingford HydroSolutions (WHS) is the sole appointed developer and distributor of the LowFlows software system.

Section 2 of the report provides an overview of our consultancy services; specifically our hydrometry services for supplementing the flow statistics presented within this report with at site measurements and flood event estimation services. We also provide a range of software products ranging from the Flood Estimation Handbook (FEH) software through to Hydra 2 to support hydropower design.

Section 3 presents the methods for the derivation of catchment characteristics and the annual and monthly flow estimates. Following the results for each site, Sections 5 and 6 present the assumptions and uncertainties within the flow estimates, followed by the consideration for use in section 7 and the warranty and liability in section 8.

2 WHS Consultancy Services

WHS is an independent company founded by the Centre for Ecology and Hydrology to deliver high quality consultancy services and environmental software systems to the water, energy and development sectors. WHS has a team of experienced technical staff including leading UK scientists located in three offices across the UK. We have a proven track record in provision of flood risk, water resources, environmental (including EIA) and field measurement consultancy services across the whole of the UK.

Our field measurement services, range from hydrometric (flow), topographic, ecological and geomorphological surveys through to aquatic habitat mapping.

We are currently operating flow measurement installations at over fifty sites in support of a wide range of activities including hydropower development, water supply, flood risk and research.

WHS is committed to continuously improving company performance and customer satisfaction. We are proud of our ISO 9001 certification for the provision of environmental consultancy services, development of hydrological software and associated training. For further information on all of our services and software, please visit our website www.hydrosolutions.co.uk.

3 Derivation of the LowFlows Results

Section 3.1 presents the methods used to define the catchment characteristics, and section 3.2 provides an overview of the long term annual and monthly flow statistics provided for the site(s). The flow statistic estimates contained in this report have been produced by LowFlows Enterprise[1] using models and relationships that relate these flow statistics to the climatic and hydrological characteristics of the catchment of interest. All flow statistics provided in this report are for natural flows, thus do not contain any artificial influences such as abstractions, discharges or impounding reservoirs.

3.1 Catchment Characteristics

The following catchment characteristics are provided in the results section of this report:

- **Catchment Area:** The catchment boundary may be derived using either a digital terrain model or an analogue river network based method. The digital method is the default option used in preference to the analogue method but may be misleading or not possible in some areas. The estimation method used to estimate the catchment boundary is identified within the results section for the site(s).
  - The digital method uses a Digital Terrain Model (DTM) to determine the topographic boundaries of the catchment.
  - The analogue method associates grid squares (200 m resolution) to the nearest stretch of river and defines the boundary by selecting grid squares which are assigned to river reaches upstream of the ungauged point.
- **Base-Flow Index (BFI):** The proportion of a hydrograph occurring as base flow, hence varying between zero and unity. BFI is indicative of catchment permeability with values approaching unity associated with highly permeable systems. BFI is estimated from a revised form of the HOSTBFI multivariate linear regression equation [2].

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(1) Young A. R., Grew R. and Holmes M.G.R. 2003. Low Flows 2000: A national water resources assessment and decision support. Water Science and Technology, 48 (10).
(2) Boorman, D.B., Hollis, J.M. and Lilly, A. 1994. Hydrology of Soil Types: a Hydrologically-based Classification of the Soils of the United Kingdom. IH Report 126.

3.2 Long Term Natural Flow Statistics

The following long term flow statistics are provided in the results section of this report.

- **Annual Mean Flow (MF):** The estimation of Mean Flow is based on a grid of long term average annual runoff developed by the Centre for Ecology and Hydrology (CEH). This was derived using the outputs from a deterministic water balance model using observed data from over 500 gauged catchments(3).
- **Mean Monthly Flows (MMF):** The MMF for each month are derived from the natural MF estimate by distributing the total average flow volume for the year between the months of this year. This distribution is based upon observed data from hydrologically similar gauged catchments.
- **Annual Flow Duration Curve (FDC) statistics:** The flow duration curve statistics are estimated using a procedure based on measured flow data from hydrologically similar gauged catchments(4). This methodology was further updated by WHS in 2009. Flows are provided for the following exceedence percentiles: 5, 10, 20, 30, 40, 50, 60, 70, 80, 90, 95, 99.
- **Mean Monthly Flow Duration Curves (MFDC):** The MFDC for each month is estimated using gauged MFDCs from hydrologically and climatologically similar catchments and the estimate of MMF for that month. The MFDC statistics are presented, by month for the following exceedence percentiles: 5, 10, 20, 30, 40, 50, 60, 70, 80, 90, 95, 99.

If these long term natural flow statistics were calculated directly from a gauged flow record the annual statistics would be equivalent to those calculated using all of the daily flow data from all years of record and the monthly statistics for a month equivalent to those calculated from the gauged data for that month from all years.

(3) Holmes, M.G.R., Young, A.R., Gustard, A.G. and Grew, R. 2002. A new approach to estimating Mean Flow in the United Kingdom. Hydrology and Earth System Sciences. 6(4) 709-720.
(4) Holmes, M.G.R., Young, A.R., Gustard, A.G. and Grew, R. 2002. A Region of Influence approach to predicting Flow Duration Curves within ungauged catchments. Hydrology and Earth System Sciences. 6(4) 721-731.

4 LowFlows Results for Afon Wnin (271330, 321825)

4.1 Catchment Characteristics

The catchment characteristics and map for this catchment are presented in the table and figure below. This catchment is comprised of impermeable and permeable bedrock overlain by mineral soils and deep peat deposits. This is a very small catchment, less than 5km^2 in size. Please refer to the guidance associated with this in sections 6 & 7.

Table 4.1 Catchment Characteristics

Basin Details	
Outlet grid reference	271322, 321824
Hydrometric area	64 (Northern)
Catchment definition method	Digital
Basin area (km²)	0.637
Base-Flow Index	0.39

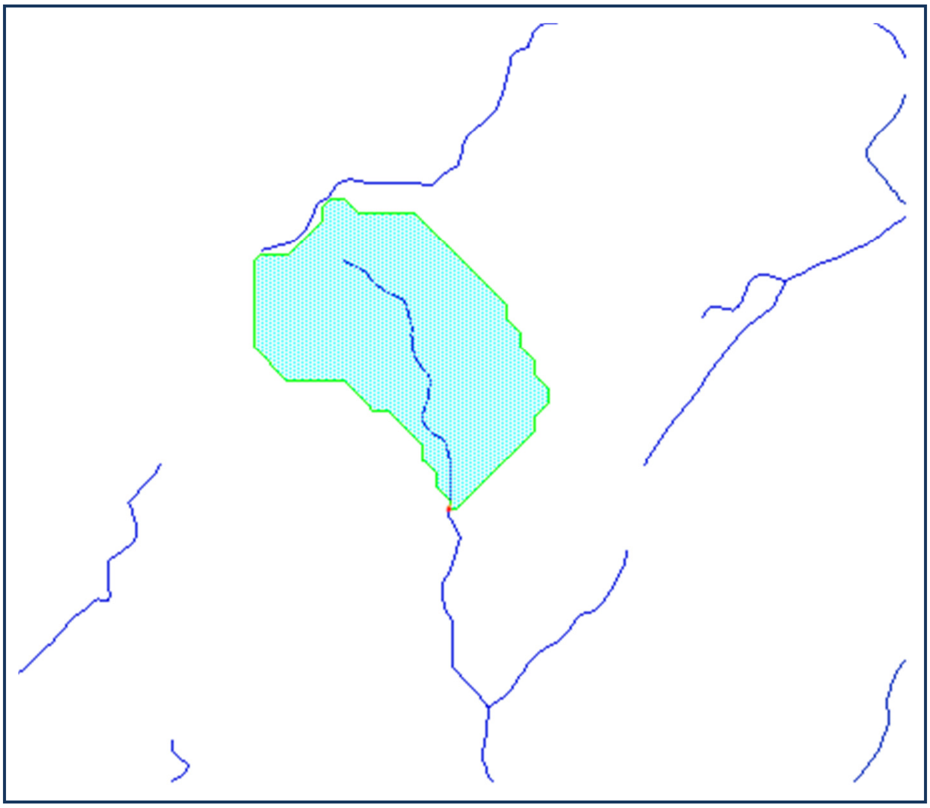

Figure 4.1 Catchment Boundary

4.2 Long Term Natural Flow Statistics

This section presents the long term natural flow statistics. The table below presents both the monthly mean flows and the annual flow duration statistics. The annual flow duration curve is also presented in the figure below, followed by a table displaying the monthly flow duration statistics.

Table 4.2 Mean Flows and Annual Flow Duration Curve Statistics

Mean Flows	Flow (m^3/s)
Annual	**0.029**
January	0.044
February	0.038
March	0.034
April	0.021
May	0.018
June	0.013
July	0.013
August	0.019
September	0.026
October	0.039
November	0.041
December	0.044

Percentile	Flow (m^3/s)
5	0.099
10	0.068
20	0.042
30	0.029
40	0.022
50	0.016
60	0.012
70	0.009
80	0.007
90	0.004
95	0.003
98	0.002
99	0.002

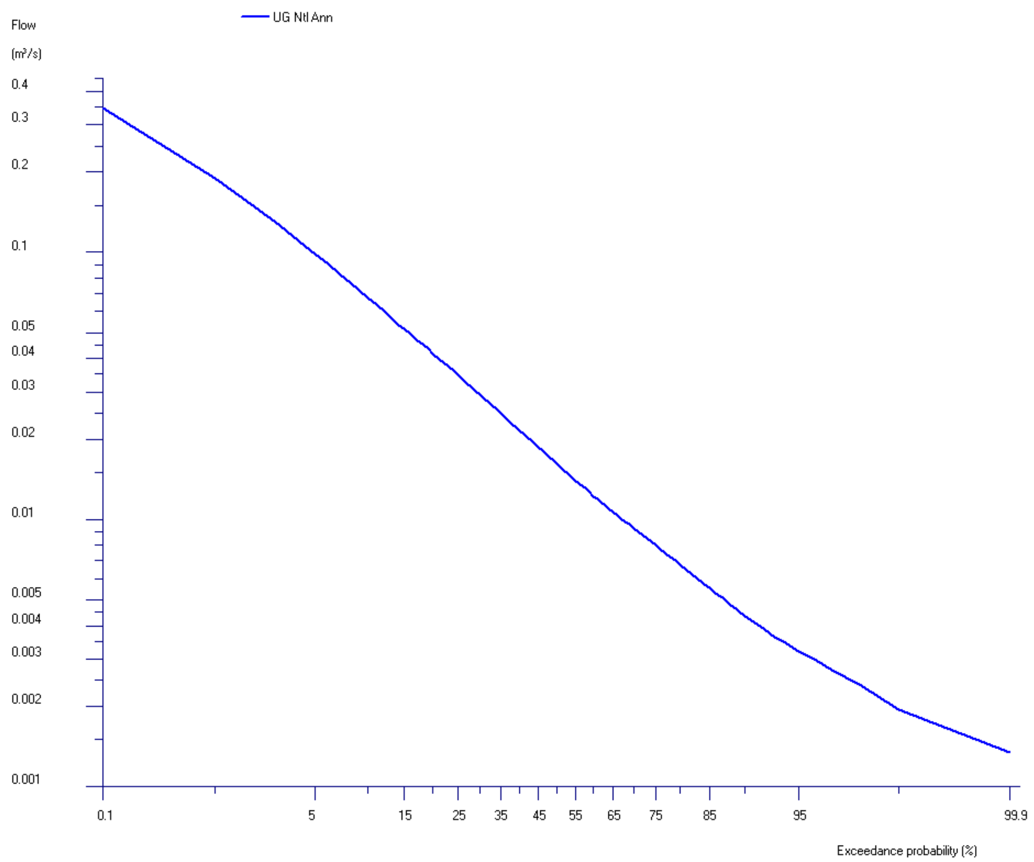

Figure 4.2 Annual Flow Duration Curve

Table 4.3 Monthly Flow Duration Curve Statistics

January		February		March		April	
Percentile	Q (m^3/s)	Percentile	Q (m^3/s)	Percentile	Q (m^3/s)	Percentile	Q (m^3/s)
5	0.124	5	0.117	5	0.099	5	0.067
10	0.090	10	0.079	10	0.068	10	0.046
20	0.061	20	0.053	20	0.044	20	0.028
30	0.047	30	0.038	30	0.033	30	0.021
40	0.038	40	0.028	40	0.027	40	0.017
50	0.030	50	0.021	50	0.021	50	0.014
60	0.024	60	0.017	60	0.017	60	0.011
70	0.018	70	0.013	70	0.013	70	0.009
80	0.014	80	0.010	80	0.010	80	0.007
90	0.010	90	0.008	90	0.008	90	0.005
95	0.008	95	0.007	95	0.007	95	0.004
99	0.006	99	0.005	99	0.005	99	0.003

May		June		July		August	
Percentile	Q (m^3/s)	Percentile	Q (m^3/s)	Percentile	Q (m^3/s)	Percentile	Q (m^3/s)
5	0.056	5	0.040	5	0.045	5	0.068
10	0.039	10	0.027	10	0.028	10	0.045
20	0.025	20	0.017	20	0.016	20	0.026
30	0.018	30	0.013	30	0.011	30	0.018
40	0.013	40	0.010	40	0.009	40	0.013
50	0.010	50	0.008	50	0.007	50	0.009
60	0.008	60	0.006	60	0.005	60	0.007
70	0.007	70	0.005	70	0.004	70	0.005
80	0.005	80	0.004	80	0.003	80	0.004
90	0.004	90	0.003	90	0.003	90	0.002
95	0.003	95	0.003	95	0.002	95	0.002
99	0.003	99	0.002	99	0.002	99	0.002

September		October		November		December	
Percentile	Q (m^3/s)	Percentile	Q (m^3/s)	Percentile	Q (m^3/s)	Percentile	Q (m^3/s)
5	0.088	5	0.118	5	0.113	5	0.130
10	0.060	10	0.084	10	0.087	10	0.096
20	0.036	20	0.054	20	0.058	20	0.062
30	0.025	30	0.039	30	0.043	30	0.045
40	0.019	40	0.031	40	0.034	40	0.036
50	0.015	50	0.023	50	0.027	50	0.028
60	0.011	60	0.018	60	0.022	60	0.022
70	0.008	70	0.014	70	0.017	70	0.016
80	0.006	80	0.010	80	0.013	80	0.013
90	0.004	90	0.007	90	0.009	90	0.010
95	0.003	95	0.006	95	0.006	95	0.008
99	0.002	99	0.003	99	0.005	99	0.005

5 Assumptions

Assumptions implicit in the estimated flow estimates are:

- Only natural flow statistics have been estimated and the impact of any artificial influences (for example abstractions, discharges or impounding reservoirs) is not included.
- The topographic catchment area identified is assumed to accurately reflect the true catchment area contributing to flows at the catchment outlet.
- The flow estimates are based on long term average records.

6 Model Uncertainty

The figures for factorial standard error of estimate for long term mean flow and Q95 are shown in Table 6.1. So, as an example the uncertainty in the estimate of mean flow in Scotland will generally be less than 11%. These standard errors are presented as a general guide only and should be considered in the context of the information presented within section 7. These errors are broadly comparable to the sampling errors that might be expected if mean flow was calculated from two to three years of error free gauged data and Q95 for in the order of five years error free gauged data.

If these estimates are to be used for high value decision making we would recommend that the estimates are corroborated through appropriate local flow measurement. For advice on flow measurement please contact us at info@hydrosolutions.co.uk.

Table 6.1 Model Factorial Standard Error (FSE)

Regions of the UK	FSE Mean Flow	FSE Q95
England and Wales	16	42
Scotland	11	35
Northern Ireland	11	30

7 Consideration for Use

The predictive performance of the Mean Flow and FDC Estimation Models may vary according to local conditions. The following is a list of significant, but not comprehensive, issues that need to be considered when estimating flows within ungauged catchments:

- Care needs to be taken when interpreting the results in smaller groundwater catchments in which river flows may be strongly influenced by point geological controls (such as spring lines and swallow holes).
- A catchment water balance is assumed within the LowFlows software; this assumption may be incorrect in smaller groundwater fed catchments where part of the regional groundwater flow bypasses the surface water catchment.
- The estimation of Mean Flow is based on a grid of long term average annual runoff developed by CEH. This was derived using the outputs from a deterministic water balance model using

observed data from over 500 gauged catchments. The predictive performance of the model may therefore be reduced in areas of low rainfall gauge density.

- Care needs to be taken when interpreting the result in very small catchments as the size of the catchment approached the spatial resolution of the underlying catchment characteristic datasets within LowFlows (1 km^2). For very small catchments it is recommended that the topographic contributing catchment is confirmed by a site walkover to identify any unmapped features that might modify the catchment area.
- Where available local measured flow data should be used to corroborate the LowFlows software estimates. This is good practice when using any generalised hydrological model.

8 Warranty and Liability

1. The assumptions and uncertainties associated with the flow estimation methods must be considered when making use of flow estimates produced by the system.
2. You are responsible for the interpretation of the Results presented within this report and training in the use of the estimation methods is strongly recommended.
3. Subject to 1 and 2 above, WHS do not seek to limit or exclude liability for personal injury or death arising from our negligence.
4. Except for 3 above our entire liability for any breach of our duties, whether or not attributable to our negligence, is limited to the fee that you have paid for this report.
5. Except for 3 and 4 above, in no event will WHS be liable to you for any damages, including lost profits, lost savings or other incidental or consequential damages arising on your use of the results even if we have been advised of the possibility of such damages.
6. Should any of these provisions be ruled invalid under any law or Act of Parliament, they shall be deemed modified or omitted only to the extent necessary to render them valid and the remainder of these provisions shall be upheld.

Annex 1: Copies of key correspondence with the client

From: amanda@snowdoniahydro.co.uk [mailto:amanda@snowdoniahydro.co.uk]
Sent: 13 June 2014 15:12
To: lowflows@hydrosolutions.co.uk
Subject: RE: Water data request

> Hi,
>
> I'd like to order the WHS Low Flows report for location 271330,321825
> on the Afon Wnin.
>
Maplink

http://www.streetmap.co.uk/map.srf?x=271330&y=321825&z=120&sv=271330,321825&st=4&ar=y&mapp=map.srf&searchp=ids.srf&dn=725&ax=271330&ay=321825&lm=0
> Kind Regards
> Amanda Forman
> Snowdonia Hydro
> 07513 950 525