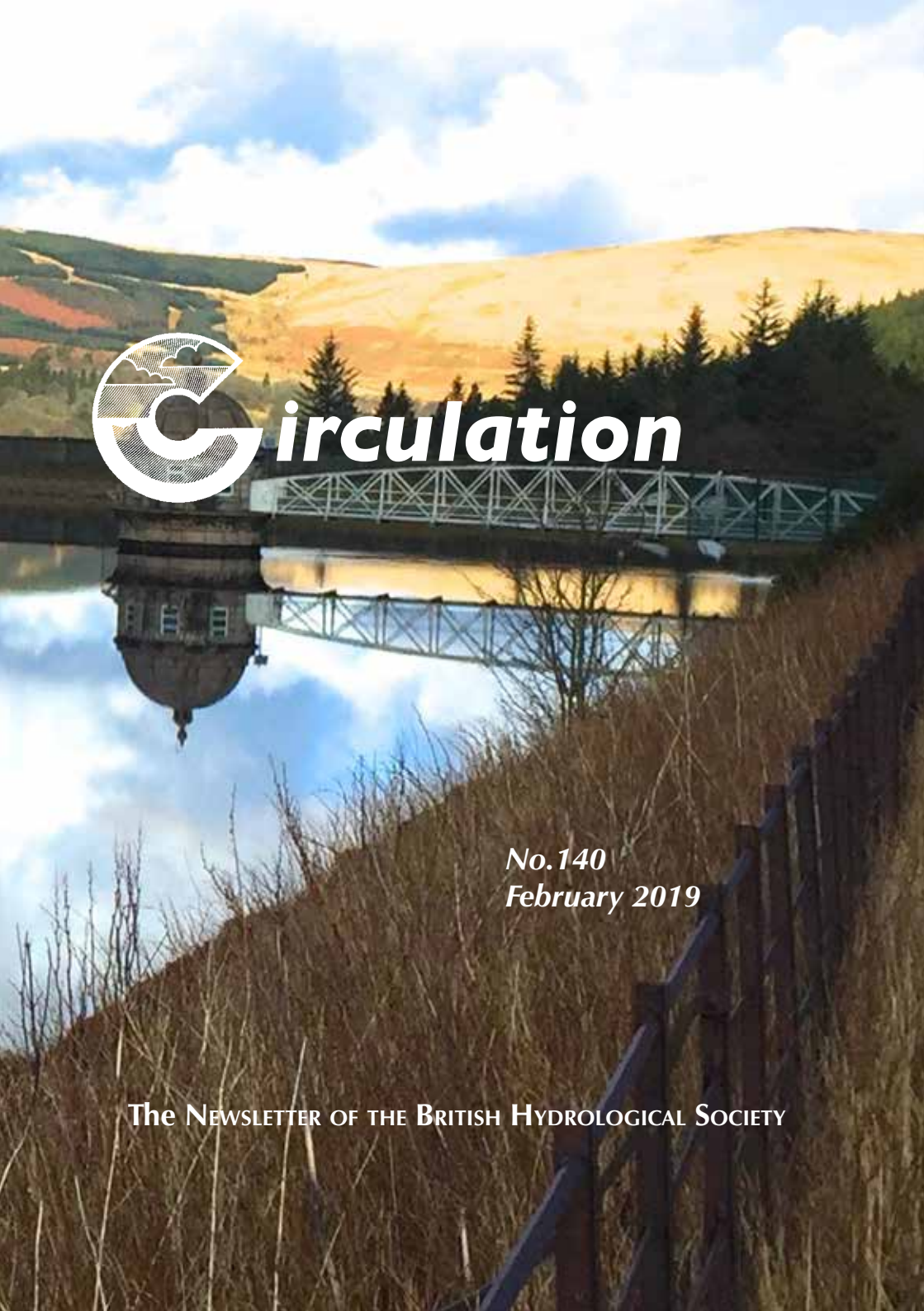


Circulation

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The Newsletter of the British Hydrological Society

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Final Call!

15 February

is the deadline for Applications for BHS grants for EGU, Vienna, April 2019. Please get your forms in to the Treasurer in time.
Full details of conditions and how to make a submission are given on the website under 'Conference Grants'

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President's Piece

Those of you who were at the Symposium in September will no doubt recall the informative and challenging keynote presentation by Keith Beven, FRS. One of the benefits of Keith's election to the Royal Society is that it gives him a platform for promoting hydrology, and an element of support for doing so. One of the things he is doing is to set up a group to discuss research priorities for hydrological science, something that I wholeheartedly support on behalf of BHS.

It is gratifying that the request for expressions of interest in joining this group drew a wide response, though it is of course a pity that Keith has had to disappoint a substantial number of those who applied. If you were one of those I hope you will find other ways to contribute your thoughts, perhaps through a BHS meeting, or an article for *Circulation*. And of course we look forward to dissemination of the work of the research group in due course.

In the last few months we have seen important developments in surely the most important issue of our time (yes, even more important than Brexit …). Whilst the long-awaited publication of UKCP18 may not directly impact on some of the research topics that Keith's group will be discussing, it will influence a great deal of what many of us do in the coming years. One of the gratifying features of UKCP18 is the access to the datasets, something that has not always been straightforward in the UK, at least for those of us not working in academia. I'm pleased that access to data has improved in other areas too – top marks to the person in SEPA who recently supplied me with data that went up to literally just a few hours prior to his email reaching me. More of that from all organisations, please!

Whilst it is always important to look forward, it is instructive also to look back, and one of the pleasures of my last 3 months was to represent BHS at the Thanksgiving Service to celebrate the National Year of Engineering, also marking the 200th anniversary of the ICE. As the President of ICE remarked afterwards, if a few years ago someone had said that Westminster Abbey would be packed with 2000 people from a wide range of backgrounds to celebrate engineering he would have thought it was a wind-up.

Now I know that many of you are not Engineers (at least with a capital E), but most of what we all do is in the end based on the desire to engineer a better future, and it was very good to look both back and forward at this event. In relation to the future, the diversity of the speakers in the Abbey was commendable. Which brings me to BHS where the committee has discussed the (at times) limited visible diversity in some of our activities. We are conscious of the need for, and benefits of, greater diversity in our meetings, and I encourage all of you to get involved in whatever way you can.

Finally, I was delighted to write to Terry Marsh to inform him of the committee's decision to elect him as an Honorary Member of BHS. Terry's contribution to British hydrology is covered elsewhere in this issue.

Peter Ede
President

Adjustment of QMED in ungauged catchments using two donor sites

Thomas Rodding Kjeldsen

This note proposes an analytical method for adjusting a purely catchment-descriptor based estimate of QMED with AMAX data from two nearby donor sites. The method is based on the QMED catchment descriptor equation published as part of the improved FEH statistical method (Environment Agency, 2008) and is an extension of the procedure for using one donor site from the same publication. The first section gives a summary of the method, the second section provides an example of how to use the method, and finally details of the theoretical derivation are provided for anyone interested. I presented a general framework for using multiple donors in Kjeldsen et al. (2014) and have adapted it here for the case of two donors.

Data transfer from two donor sites – a summary

According to the improved FEH statistical method (Environment Agency, 2008), estimating QMED based on catchment descriptors is based on the following equation:

$$QMED = 8.3062AREA^{0.8510}0.1536^{\frac{1000}{SAAR}}FARL^{3.4451}0.0460^{BFIHOST^2} \quad (1)$$

When adjusting the catchment-descriptors-only estimate of QMED at the subject site using two donors, Kjeldsen et al. (2014) suggested the following equation could be used

$$QMED_{s,adj} = QMED_{cd,s}\left(\frac{QMED_{1,obs}}{QMED_{1,cd}}\right)^{\omega_1}\left(\frac{QMED_{2,obs}}{QMED_{2,cd}}\right)^{\omega_2} \quad (2)$$

where subscripts s, 1 and 2 refer to the subject site and donor sites 1 and 2, respectively, and ω_1 and ω_2 are weights that must be determined. The subscripts *obs*, *cd* and *adj* refer to estimates of QMED obtained using: observed AMAX data, catchment descriptors only, Eq.(1), and, finally, the donor adjusted estimate. The method differs from the method proposed for multiple donor adjustment in FEH Volume 3, page 18 which gives no specific guidance on how to specify the weights when using more than one donor. Here the strategy pursued is that the most desirable estimate has the lowest possible uncertainty, which result in the following expressions of the weights ω_1 and ω_2 from Eq. (2):

$$\omega_1 = \frac{\rho_{s1}-\rho_{12}\rho_{s2}}{1-\rho_{12}^2}$$

$$\omega_2 = \frac{\rho_{s2}-\rho_{12}\rho_{s1}}{1-\rho_{12}^2} \quad (3)$$

where ρ_{ij} is a function of the Euclidian distance, d_{ij}, between centroids of catchment i and j, as measured in kilometres and given as

$$\rho_{ij} = 0.4598exp(-0.020d_{ij}) + (1 - 0.4598)exp(-0.4785d_{ij}) \quad (4)$$

When used for donor adjustment in Eq.(2) the weights in Eq.(3) give the value of $QMED_{s,adj}$ associated with the lowest possible level of uncertainty. Here, as in Kjeldsen (2015), the uncertainty of QMED is measured using the factorial standard error (*fse*) which for$QMED_{s,adj}$ in Eq.(2) is given as:

$$fse = exp\left(s\sqrt{1 - \rho_{s1}^2 - \rho_{s2}^2 + 2\rho_{s1}\rho_{s2}\rho_{12}}\right) \quad (5)$$

where *s* is the standard error of the model error variance for the QMED equation in Eq. (1) and given by Kjeldsen & Jones (2009) as *s*=0.1286. The 95% confidence interval for $QMED_{s,adj}$ can then be calculated as:

$[QMED_{s,adj}/\text{fse}^2 ; QMED_{s,adj} \times fse^2]$.

In the following sections a small example of application is presented, building on some previously published results published by Kjeldsen (2015). This is followed by a theoretical derivation of the weights in Eq.(3).

Example of QMED adjustment using two donors

The example here follows the example used in Kjeldsen, 2015) who considered different strategies for using local AMAX data to improve estimates of QMED in ungauged catchments. This paper considered estimates of QMED for the catchment draining to gauging station 56013 using one donor site (Donor site 1); the nearby 56003. A second gauging station with a long records of high quality flood data, a hydrologically similar catchment and within a 50 km geographical proximity is 54025 River Dulas at Rhos-y-pentref (Donor site 2), where 39 AMAX data are available for the period 1970--2008. A summary of the catchment descriptors for the subject site and each of the donor sites is shown in Table 1, while Table 2 shows the geometric distance between the catchment centroids (i.e. the values of d_{ij} for use in evaluation of Eq.(4)).

Table 1: Catchment descriptors for the subject site and each of the two donor sites

Catchment descriptors	*Subject site 56013*	*Donor site 1 56003*	*Donor site 2 54025*
East (centroid) [m]	297 622	302454	296 856
North (centroid) [m]	238 444	237 136	278 995
Area [km^2]	63.27	62.50	53.17
SAAR [mm]	1299	1171	1268
FARL [-]	1.000	0.999	1.000
BFIHOST [-]	0.494	0.528	0.439
$QMED_{obs}$ [m^3/s]	36.6	23.5	23.2
$QMED_{cd}$ [m^3/s]	31.6	23.9	30.8

Table 2: Distance between catchment centroids (km)

	Subject site	*Donor site 1*	*Donor site 2*
Subject site	-	5.0	40.6
Donor site 1	-		42.2
Donor site 2			-

Table 3: Correlation function, Eq. (4)

	Subject site	*Donor site 1*	*Donor site 2*
Subject site	-	0.47	0.20
Donor site 1		-	0.20
Donor site 2			-

The first step involves calculation of the correlation function ρ_{ij} in Eq.(4) using the distances in Table 2 and reported in Table 3. Next, the two weights ω_1 and ω_2 are calculated using the expression in Eq.(3) combined with the correlations in Table 3.

$$\omega_1 = \frac{0.47 - 0.20 \times 0.20}{1 - 0.20^2} = 0.45$$

$$\omega_2 = \frac{0.20 - 0.20 \times 0.47}{1 - 0.20^2} = 0.12$$

Finally, the adjusted estimate of QMED is obtained using Eq.(2), i.e.

$$QMED_{s,adj} = 31.6 \left(\frac{23.5}{23.9}\right)^{0.45} \left(\frac{23.2}{30.8}\right)^{0.12} = 30.3\ m^3/s$$

Note that at both donor site 1 and 2 the estimates of QMED obtained from catchment descriptors only are smaller than the medians of the observed AMAX data. Also, there is no requirement for the two weights to sum to one. For example, if both donor sites are located very far away from the subject site, then the adjusted QMED simply convert towards the catchment-descriptor only estimate.

The associated factorial standard error of the adjusted QMED is calculated using Eq.(5) as

$$fse = exp\left(0.1286\sqrt{1 - 0.47^2 - 0.20^2 + 2 \times 0.47 \times 0.20 \times 0.20}\right) = 1.32$$

Table 4 shows a comparison between the results obtained here using two donors and selected results from Kjeldsen (2015) based on the catchment-descriptors only QMED model (Eq. 1) and the use data transfer from only donor site 1.

Table 4: *Estimates of QMED and fse for the subject site using selected methods*

Method	QMED [m^3/s]	fse
Gauged (*n*=36)	36.6	1.08
Regression only	31.6	1.43
Regression + 1 donor	31.3	1.37
Regression + 2 donors	30.3	1.32

As can be seen in Table 4, there is only a minor change to the numerical value of the QMED value itself, but the fse has been reduced from 1.37 when using a single donor to 1.32 when including a second donor site into the analysis. Note also that at both donor sites, QMED from the catchment descriptor equation was smaller than QMED obtained from AMAX data, which reduces the adjusted QMED estimate.

Theoretical derivation of optimal weights

The derivations in this section follow the methodology developed by Kjeldsen and Jones (2007) for a single donor and later extended by Kjeldsen et al. (2014) to consider multiple donors. While it is possible to derive analytical expressions for weights when using more than two donors, these expressions quickly become very cumbersome and relatively little is gained in terms of precision. In an attempt to make the derivations clearer, the natural logarithm of QMED is denoted y and the following notation introduced for different log-transformed estimates of QMED:

y: estimate obtained using observed AMAX data
$\hat{y}$: estimate obtained using catchment descriptors (only)
$\tilde{y}$: estimate obtained through donor adjustment

The associated subscripts are defined as:

s: subject site
1: donor site number 1
2: donor site number 2

Starting from Equation (5) in the paper by Kjeldsen et al. (2014), for p = 2 donor sites the adjusted estimate of log-transformed QMED is

$$\tilde{y}_s = \hat{y}_s + \omega_1(y_1 - \hat{y}_1) + \omega_2(y_2 - \hat{y}_2) \quad (6)$$

This is equivalent to taking the natural logarithm of Eq. (2) in this note and adopting the notation above. Ignoring the sampling variance of the at-site estimators (error arising from estimating QMED using a finite number of AMAX events) as this is much smaller than the regression errors, the variance of the differences in the parenthesis can be considered just based on regression errors. All three terms on the right-hand side of Eq. (6) therefore have the same variance, and the total variance of the adjusted log-transformed QMED estimate $V\{\tilde{y}_s\}$ can be approximated as:

$$V\{\tilde{y}_s\} \approx \sigma_\eta^2 + \omega_1^2\sigma_\eta^2 + \omega_2^2\sigma_\eta^2 - 2\omega_1 cov\{\hat{y}_s, \hat{y}_1\} - 2\omega_1 cov\{\hat{y}_s, \hat{y}_1\} - 2\omega_2 cov\{\hat{y}_s, \hat{y}_2\} + 2\omega_2\omega_1 cov\{\hat{y}_1, \hat{y}_2\} \quad (7)$$

where σ_η^2 is the variance of the regression model errors given by Kjeldsen & Jones (2009) as $\sigma_\eta^2 = 0.1286^2$ and is constant for all catchments. Again ignoring the effect of sampling noise, the covariance between two estimates of catchment-descriptor estimates $\hat{y}$ at two different sites is given as

$$cov\{\hat{y}_i, \hat{y}_j\} = \sigma_\eta^2 \rho_{ij} \quad (8)$$

where the correlation between the model errors at the two sites is given by Kjeldsen & Jones (2009) as per Eq. (4) in this note, and based on the distance between catchment centroids.

The optimal set of weights is determined here as the values that minimises the variance of the adjusted log-transformed QMED (Eq, 7 above), i.e.

$$\frac{\partial V\{\tilde{y}_s\}}{\partial \omega_1} = (2\omega_1 - 2\rho_{s1} + 2\omega_2\rho_{12})\sigma_\eta^2 = 0$$
$$\frac{\partial V\{\tilde{y}_s\}}{\partial \omega_2} = (2\omega_2 - 2\rho_{s2} + 2\omega_1\rho_{12})\sigma_\eta^2 = 0 \quad (9)$$

Solving this set of equations for ω_1 and ω_2 gives the equations

$$\omega_1 = \frac{\rho_{s1} - \rho_{12}\rho_{s2}}{1 - \rho_{12}^2} \quad (10)$$
$$\omega_2 = \frac{\rho_{s2} - \rho_{12}\rho_{s1}}{1 - \rho_{12}^2}$$

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New members

David Bryan.....Tring
Mélanie Milin.....University of Worcester
Bidur Ghimire.....Dartford
Grace L Johnston.....Lisburn
Daphne Solomonidou.....London

The British Dam Society

British Hydrological Society

UK reservoir spillway flood hydrology

Institution of Civil Engineers,
One Great George Street, London

Some aspects of design flood estimation standard techniques for dam spillway hydrology are based on research and state-of-the-art thinking now more than four decades old. In the light of experience with these techniques, and given progress with extreme rainfall analysis, rainfall–streamflow modelling, etc, the question arises: Should current standard techniques for UK reservoir and spillway design flood es timation now be comprehensively reassessed with a view towards their possible improvement, or even replacement?

The meeting will bring together practitioners and research hydrologists to consider this question. The meeting will also be of interest to:

- **engineers and administrators with responsibilities for reservoir spillway design and dam safety inspections;**
- **reservoir/dam owners;**
- **government agency regulators.**

The registration fee of £80 for BHS and BDS Members (non-Members £110, students & retired BHS/BDS/ICE members £60) includes refreshments.

We recommend early online registration via

http://www.ice.org.uk/events/private-events/uk-reservoir-spillway-flood-hydrology-london.

Ice break-up dams and flash floods

David Archer

Circulation readers who have managed upland gauging stations may well have noticed the sharp upward spike in the stage hydrograph on the rising limb of runoff from melting snow. This arises from blockage of a gauging weir by ice as melt gets underway, but the blockage soon gives way as flow increases. Since the spike in stage does not represent a change in discharge, it is usually deleted in processing and considered irrelevant. However such ice jams are an important and hazardous feature of many high latitude rivers and, as noted below, are not unknown in Britain.

Ice jams or ice dams can occur during the period of early winter freeze-up or, more commonly and more severely, during spring break-up. Ice jams are accumulations of blocks and sheets of ice in the river channel that restrict stream flow.





Damage to intake structures at the Broken Scar Treatment works on the River Tees in northern England in January 1982 by ice jam

They form where breaking ice during melt comes into contact with an intact ice cover or where the channel gradient suddenly drops, for example at islands, bridges or at bends in the river. Depending on weather patterns and river morphology, ice jams can result in the upstream rise in water level of metres per hour and force ice floes to back up for several kilometres. Upstream rises in level are of such magnitude that they could be categorized as flash floods.

Initially ice jams reduce the downstream flow but sudden failure of the ice-jam then releases a flood wave with rapid increase in discharge and velocity as well as level that can cause extensive damage downstream. Such ice dam release floods with sudden onset can clearly be regarded as flash floods. The occurrence of extreme high water levels associated with ice dams in vulnerable catchments defies attempts to map flood levels of a given recurrence interval based solely on peak discharge statistics.

In addition to water damage, sharp-edged blocks of ice may be pushed more than 10 metres above the water level and may damage structures in or near to the river, including bridges, hydropower schemes and even riverside

houses. The most severe cases for upstream flooding are for the great northward flowing rivers of Russia, the Ob, Yenisei and Lena, and the Mackenzie and Yukon rivers of North America. These northward flowing rivers tend to have more ice jams because the upper, more southerly, part thaws first and the ice is then carried downstream into the still-frozen northerly part. In East Siberia river ice jams constitute some third of all floods. Ice dams may be 20–30 km long, causing rises of water level of 8–10 metres in the River Lena (Korytny and Kichigina, 2011). Analyses of ice jam data in the US show that more frequent ice jam floods are observed in Alaska and northern parts of contiguous United States, with New York and Montana being hotspots (White, 1996; White *et al.,* 2006). The economic cost of ice jam floods in North America was estimated at USD 300 million in 2017 (French, 2018). In Europe, ice jam floods have also been reported, for example on the Elbe, Oder, (Mudelsee *et al*., 2004) and Vistula (Nachlik and Kundzewicz, 2016).

But what about Britain?

Ice jam floods were severe and not uncommon in the nineteenth century in Scotland and northern England. The combination of blocks of ice and high flows in the river Aire in February 1795 caused much damage to shipping at Leeds; property was flooded and walls thrown down and several people drowned. Black and Anderson (1994) note that the level of the extreme flood from rainfall and snowmelt on the River Tay in January 1993 on Smeaton's Bridge in Perth was only exceeded by the flood augmented by an ice jam in February 1814. Serious damage was caused to shipping at Sunderland from ice floes in the River Wear in January 1841 and on the Clyde at Glasgow in January 1861 where the upstream water level above the ice jam rose 5 feet in less than an hour. Also in 1861 ice blocks on the Tweed at Kelso rose 20 feet above the flooded river. Further flooding from ice blockages and damage from the ice floes occurred in 1875 (Tyne, Yorkshire Ouse), in 1879 (Tweed and Clyde) and in 1881 (Tweed).

Little evidence of ice jam floods has been found in the twentieth century. Although thick ice has formed on rivers in the severely cold winters such as 1947 and 1963, no reference in those years to ice jams or ensuing floods was found. A section of ice 45 cm thick was cut from the River Tyne at Bywell in 1963 and the ice on the Tyne in 1929 was thick enough to support skaters and sliders (see below). The one instance of a recent ice jam and its impact was in the very cold winter of 1982 when the River Tees was blocked by ice upstream from the compound Crump weir at Broken Scar and b locks of ice damaged the intake works of a water treatment plant. Whether such severe past events have any relevance to the future seems unlikely given increasing global and local temperatures driven by greenhouse gas emissions. However, we may yet see a return of the conditions



which generated the Little Ice Age, given predicted solar energy reductions over the next few decades (Zharkova et al., 2015)

with increasing frequency of severe snow and frozen rivers.

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Temporary Rivers and Streams Workshop, 2019



There will be a cross-discipline workshop at Nottingham Trent University on 25 June 2019 for those with an interest in temporary (intermittent and ephemeral) rivers and streams.



Contributions from hydrologists, hydroecologists and others working in this field will be enthusiastically received. Attendance is free. Further information from **Cath Sefton**, Centre for Ecology & Hydrology, Wallingford : catsef@cehac.uk

Floods and Reservoir Safety:
Recommendations for bringing consistency in the estimation of the 1 in 10,000-year flow

The 1 in 10,000-year peak flow is an important parameter in the design of reservoirs and to assess their safety. The Floods and Reservoir Safety guidance[1] (F&RS, 4th edition) suggested using the 1 in 10,000-year peak flow as the design flow for Category A reservoirs and as the safety check in flood conditions for Category B reservoirs. The F&RS 4th guidance suggested that the Flood Studies Report (FSR) technique should be used to estimate the 1 in 10,000-year peak flow until new rainfall Depth-Duration- Frequency (DDF) was released. The new rainfall DDF, generally known as FEH13, is now available through the FEH web service, therefore invalidating the suitability of the FSR technique to estimate the 1 in 10,000-year flow even if this method remains valid for the estimation of the Probable Maximum Flood (PMF).

The guidance on PMF calculation described in Volume 4 of the FEH4 is robust, with every climatic aspect of flow estimation being covered. However, there is very little narrative on the estimation of the 1 in 10,000-year peak flow both in the F&RS 4th guidance[1] and in the FEH operational guidance[2] released in. As the 1 in 10,000-year peak flow is an important parameter to design spillways, its estimation can have a large bearing on capital costs.

Prior to discussing the current method of estimating the 1 in 10,000-year peak flow, the robustness of the PMF calculation methodology presented in the third edition of the F&RS guidance[3], in the FEH Volume 4 guidance[4] and in the Dams and Reservoirs guidance[5] must be highlighted. The PMF calculation covers both winter and summer conditions, with consideration being given to frozen surfaces under winter conditions. It is suggested that under winter conditions the Standard Percentage Runoff (SPR) should be taken as 53% as a minimum. An SPR of 53% will generate a runoff coefficient of approximately 70% which is quite a good assumption for frozen ground where more runoff is accepted. The third edition of F&RS also suggests considering a 'Rapid Assessment' which can provide a quick indication of the PMF peak flow, and thus a check for the PMF flow. This brings confidence in the PMF peak flow estimations.

According to the 4th edition of the F&RS guidance[1] and the release of FEH13, FEH13 rainfall shall now be used to estimate the 1 in 10,000-year peak flow. However, no suggestion is made on how to deal with saturated or frozen ground conditions where a higher amount of runoff is expected.

This is a grey area where consultants are expected to apply their own judgement. A consultant can then either adopt the SPR value available for the catchment or use a value of 53% for a more conservative approach.

An example is provided below to demonstrate how the selection of the SPR value can affect the estimation of the 1 in 10,000-year peak flow. For a proposed reservoir site in York, the SPR value was 34% for a catchment area of 65 km^2. The FEH13 rainfall yielded a 1 in 10,000-year peak flow of 69 m^3/s.

Adopting an SPR of 53% the estimated peak flow would become 100 m^3/s. In practice, the design spill height can vary by as much as 500–750 mm, with the higher estimate having a significant impact on its construction cost.

Of course the real question should be: which estimate is the most accurate? Whilst the higher estimate might be favoured by consultants as it is more conservative, clients might prefer adopting the lower value to reduce capital costs. There is nothing in the current guidance that would prevent the adoption of the lower value as the design flow.

In the previous example, the corresponding estimated PMF is 210 m^3/s, approximately double the 1 in 10,000-year peak flow derived with a SPR value of 53% and treble the 1 in 10,000-year flow for a catchment-based SPR value of 34%. It is generally recognised that, as a rule of thumb, the 1 in 10,000- year peak flow can be taken as half of the PMF peak flow. In this instance the 1 in 10,000-year peak flow derived with the modified SPR value of 53% does conform to this rule of thumb. In order to avoid future confusion and to bring consistency to the 1 in 10,000-year flow estimation, it is suggested that the following recommendations be included in the next version of the F&RS guidance:

- In the 1 in 10,000-year peak flow estimation, a minimum SPR value of 53% should be adopted. If the catchment value is greater than 53% then this is the value that should be used.
- The 1 in 10,000-year flow should be checked against the PMF peak flow. If the estimated 1 in 10,000-year peak flow is 'significantly' lower than half the PMF peak flow then the 1 in 10,000- year peak flow should be taken as half of the PMF peak flow.

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Advance Notice

Exeter Fund grants for IUGG General Assembly, Montreal, Canada, July 2019

The Exeter Fund provides grants to assist attendance at biennial IAHS Scientific Assemblies and International Union of Geodesy and Geophysics (IUGG) General Assemblies held outside the UK. Applicants should have submitted an abstract for a oral or poster presentation. Applications are particularly encouraged from early career scientists. Applications for grants for the IUGG General Assembly must reach the Hon. Treasurer as an attachment to an email with the heading "Exeter Fund: IUGG grant application ", by **1 March 2019**. Successful applicants will be notified before the Early Registration date of 5 April. The maximum amount of any one award is £1000. The application must be a digitally completed PDF (no handwriting, please) using the form available via the BHS web site.

Drought and Water Scarcity: addressing current and future challenges

20 and 21 March 2019, Oxford University, UK









DROUGHTS THREATEN SOCIETIES, ECONOMIES AND ECOSYSTEMS WORLDWIDE

They are costly natural hazards, feature on global risk registers, and are expected to become more severe due to the influence of climate change and pressure on water resources from economic and demographic changes.

This conference will take an international perspective on droughts affecting our world, covering themes of climatology, hydrology, risks and impacts of drought, planning and impacts on communities.

Invited Speakers

Massimiliano Pasqui, CNR: *Italy's approach to addressing increased drought, delivering a multi-user operational system*

Alison Browne, University of Manchester: *Drought and communities*

Henny van Lanen, Wageningen University: *The 2018 drought in NW Europe*

Anne van Loon, Birmingham University: *Feedbacks between drought and society*

Mike Morecroft, Natural England: *Impacts on the natural environment and lessons for climate change adaptation*

Rob Wilby, Loughborough University: *Challenging the mantra of wetter-winters and drier summers*

Ian Holman, Cranfield University: *Taking lessons from the 2018 drought forward into increased drought resilience in the agricultural sector*

About Drought

Maximising the impact of UK research on drought & water scarcity

Photos by (from top) Emma Sheppard, David Throup, Emma Sheppard, and Frank Moore

More info and booking:
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"Do people in other countries really need UK hydrologists?"

Some perspectives from one of those 'other' countries

I would like to congratulate Anita Asadullah (*Circulation No. 139*) for raising an important issue that is relevant for all countries of the 'north' (not only the UK) and for a very honest and thought provoking appraisal of the situation.

I have been living and working in South Africa since 1980 and have experience of working in other sub-Saharan African countries as part of locally funded projects, as well as projects (research and consultancies) funded through DFID, UNESCO, the World Bank, USAID, EU and others. Most of the consultancies as well as the research projects that were specifically targeting a particular issue generally failed to leave behind a legacy of better trained people in the region, who would be able to continue with hydrological science and practice into the future. These types of projects were generally dominated by the partners from the 'north', who also tended to have the bigger slice of the budget pie.

In contrast, some projects targeted local capacity development, typically through MSc and PhD projects registered at local academic institutions and often co-supervised by local and foreign academics. These were far more successful in enhancing local capacity.

One of the components of a recently completed 9-year programme funded by the Carnegie Corporation of New York (RISE – Regional Initiative for Science Education) resulted in some 16 MSc and 18 PhD graduates in the field of water resources science. The students were based at four universities in the region and all were supervised by local academics.

Andy Carr reported on the AGU Chapman Conference in the same edition of *Circulation* and mentions the Royal Society CRuHM project. This project is supporting 3 local PhD students investigating different aspects of hydrology and sediment transport in the Congo River. The students are co-supervised by local and UK (Bristol and Leeds) academics. Perhaps, more importantly, one of the PI's is a graduate of the Carnegie RISE programme who is based in Kinshasha University in the Democratic Republic of Congo.

The key point is that there are different ways in which scientists and practitioners from the 'north' can engage with projects in the 'south'. One is through real partnerships with local organistations, while another is though scientific/technical 'colonialism' (see the three bullet points in Anita's article). To put it bluntly, we don't need the latter (and perhaps this message needs to be passed on to the World Bank and other funders), but I think most people in the 'south' would agree that we certainly welcome the former.

However, it is unfortunate that for many different reasons (Hughes *et al*., 2014) it is not always easy for individuals and organisations in the 'south' to actively participate in partnerships with colleagues in the 'north'. Many African institutions still lack the critical mass required to participate as equal partners and this makes it difficult for young career hydrologists to progress. A further limitation that I find increasingly frustrating is the frequent lack of local support for recently graduated water

scientists from their institutions, their local funding agencies and their governments.

Finally, I really liked Anita's concluding statement. Yes please do ask what we need, but also ask about our constraints and how to overcome them, and then pass on this information to the funding agencies.

Denis Hughes
Emeritus Professor,
Institute for Water Research, Rhodes University, South Africa.

Hughes, D.A., Heal, K.V. and Leduc, C. (2014) Improving the visibility of hydrological sciences from developing countries. Hydrol. Sci. J., **59**(9), 1627–1635.

Flooding from Intense Rainfall

Royal Society meeting, Reading University, 27 November 2018

On the morning of July 18th 2017the Met Office issued a weather warning:

"Thundery showers are expected to push north across southern parts of the UK through Tuesday evening. Although many places won't see these showers, there is a chance of localised flooding of homes, businesses and susceptible roads. Frequent lightning may be an additional hazard with possible disruption to power networks.

By tea time Coverack had experienced one of the most extreme short duration rainfall events ever seen in the UK. 44 properties were flooded and fast flowing water and debris presented a risk to life. However the nearest Environment Agency rain gauge (8 km away) showed no recorded rainfall (JBA Flood Incident Review, 2018).

Over 3 million households are at risk of surface water flooding in England. Surface water and flash flood events develop quickly and affect small areas: surrounding regions may not see any rainfall at all making them difficult to forecast. They don't just restrict their impacts along rivers but can occur anywhere, making them difficult to prepare for. The joint NERC and Met Office funded *Flooding from Intense Rainfall programme* (FFIR) aims to help reduce the risk of damage and loss of life from these type of events.

Following the 2007 floods, one of the key recommendations to come out of the Pitt review was the need for co-operation between meteorological and hydrological agencies in both research and practice. Including academics from multiple universities and disciplines alongside consultants and operational experts,





the FFIR programme has demonstrated the benefits (and challenges!) of this approach. The research is structured around improving integration in an end-to-end forecasting framework. Each stage of the forecasting chain is considered from observations through to meteorological and hydrological models to support flood warnings and risk communication.

The research methods used are diverse, ranging from analysis of historic newspaper archives to drones and high speed computers. The outputs include:

- New methodologies, tools and datasets to identify places susceptible to flash flooding.
- Improved weather forecasts for intense rainfall through improvements to radar-rainfall methods, data assimilation and better understanding of probabilistic forecasts.
- New techniques for monitoring rivers during flood events.
- Demonstration of the potential for real time simulation of floods in urban areas and catchments.

The five year programme is now drawing to an end. The lively programme showcase at the Royal Society in November 2018 offered a hands-on opportunity to interact with the challenges of flooding from intense rainfall. Alongside presentations and an expert panel debate, participants could immerse themselves in a virtual reality simulation of a flash flood, watch convective rainfall develop on a giant forecast globe and share their thoughts on the modelling and communication chains that underpin flood forecasting.

A short video about the programme is available at: **https://youtu.be/aghcHOgIi1w** or you can find more details at **reading.ac.uk/flooding**

Sam Illingworth (Manchester Metropolitan University) wrote the following excellent poem summarising the programme which he read at the end of the showcase event.

Linda Speight
University of Reading

After the Flood

When I thought of floods
I thought of the heavens breaking forth
In biblical proportions.
Forty days and forty nights of rain.
I thought of Boxing Day 2015;
The pain in my left hand as I scooped
Dirty water out of my in-law's outhouse
Using nothing
More than a gravy boat and lashings
Of dampened Christmas spirit.

When I thought of floods
I thought about days of sustained rainfall.
It never even crossed my mind that Surface water flooding
Or thunderstorms could decimate the land
In hours;
Not days.

When I thought of floods
I thought about rain gauges and sandbags;
I didn't think about how convective events form,
How soil moisture could be used to forecast flow,
Or how our future of flood defence
Could ever be bound to our arid past.
To my great shame I did not evenconsider:
The conditioning of least-squares problems in variational data assimilation.

When I thought of floods
I thought of observations;
Of closing the floodgates after the horse had bolted.
Observations that masked an inevitable inability
To adapt to our environments.
I thought of shattered communities,
Broken apart not just by the unrelenting force of the rising waters
But by the isolation and helplessness of being
Told to sit and wait in silence
For the cavalry to arrive.

But now….
Now when I think of floods
I think of our improved knowledge of catchment susceptibility,
And how this will help decision makers
Identify locations at risk of flooding.
I think of being able to forecast a flood event in real time,
And how this will enable better decision making and communication.

But most of all I think about people.
Of end-to-end-forecasting, knowledge sharing, and upstream engagement.
I think about how flood chronologies can
Provide a powerful data set
To develop storylines around flood histories;
Histories which can be used to engage local communities.
And how these communities can not only learn
To be resilient,
But can help to build the resilience
That we need;
To stop us all
From being washed away.

Sam Illingworth

IWA's Diffuse Pollution Conference

Chiang Mai, Thailand

1. In November I had the pleasure of presenting my PhD research at the International Water Association's 3rd Regional Diffuse Pollution Conference in beautiful Chiang Mai, Thailand. I was particularly excited to have my abstract accepted for oral presentation given that: (i) it was my first international conference and (ii) this international meeting recognises the importance of stakeholder engagement in delivering successful integrated catchment management, which is central to my research.

Throughout my PhD I have been designing innovative mixed-method research approaches that embrace both natural and social sciences to inform effective and novel water management strategies. My talk at the conference focused on our recent publication in the journal *Science of the Total Environment* (Stosch *et al*., 2019, **651**, 2524–2534) where we quantified differences in stakeholder preferences and understanding within a land and water management trade-off.

The methodology revealed potential sources of conflict in natural resource use management between stakeholder groups, most markedly between Farm Advisors and Environmental Regulators, but also highlighted opportunities for synergies and cooperation between stakeholder groups.

The talk was a fantastic opportunity for me to present my results and obtain feedback from an international audience, and I was grateful for the platform to present alongside some of the leading experts in the field.

Talks at the conference ranged from hydro-sociology to water engineering and health-related microbiology and gave an insight into the great breadth and depth of current research relevant to the role of hydrology in diffuse pollution. In particular, I attended sessions focusing on: Water Management, River Basin Management and Microbial Contamination and Health, in which I saw much emphasis on ingenious low-cost, small-scale techniques to reduce diffuse pollution and promote water reuse. The research presented throughout the conference was fascinating and enhanced my knowledge; most importantly, it also provided much inspiration for my own research.

An extended stay allowed for plenty of opportunity to explore the area surrounding Chiang Mai, visiting a National Park and Thailand's highest mountain, and allowed for better insight into some of the local water management challenges – some of which were very similar to those we face in the UK.
In just a short boat trip down Chiang Mai's Ping River we saw a number of water uses such as fishing, bathing and agricultural irrigation, demonstrating the broad benefits people obtain from water resources. The trip also illustrated how different demands on fresh waters may sometimes be in conflict with one another, e.g. people fishing just feet away from a visibly polluted inlet stream.

The overwhelming feeling I was left with after the conference was, however, that the wealth of knowledge and enthusiasm

for water solutions more than match the severity of the water issues that challenge Thailand, thus suggesting opportunity for more sustainable land and water management in the future.

I would like to thank the British Hydrological Society for awarding me with a generous travel grant to help towards being able to attend the conference. It has been of great value to my project at a crucial stage of my PhD, presenting me with a wealth of networking opportunities and an enriching and unforgettable experience.



Kathleen Stosch
Stirling University



2. As I sat in the Presidential Forum Lecture on Day 1 and listened to the AGU President talk about the 27,000 registrants, 1,900 sessions, 8,000 oral presentations and 17,000 posters at the 2018 Fall Meeting I knew I was in for a busy week. This was my first time at a conference of this scale and of course it was bigger than I could ever have imagined!

I attended AGU to present on two areas of my work, which ended up scheduled in the same two-hour time slot. Luckily, they were at opposite ends of the session and in adjacent rooms, so I didn't need to be in two places at once or sprint across the vast conference centre to deliver both presentations.

Firstly, I presented on my research into rainfall undercatch using the raingauge trials underway in Wallingford. The measurement of rainfall has a long history but is not perfect, with each gauge currently in use presenting its own disadvantages. The newer technology of weighing raingauges resolves

several of these, but raises concerns due to the increased mounting height. The newer weighing gauge mounted at 1 m caught on average 6.6% less rainfall than the tipping bucket gauge mounted at 30 cm in the trials at Wallingford, which confirms the concerns raised in using these new gauges operationally as part of the UK's raingauge network.

Secondly, I presented the National River Flow Archive's framework for quality control and how we have driven improvements in the UK's hydrometric data. Following a decline in the completeness of hydrometric data in the 1990s, the NRFA put an agreement in place to monitor the submission of data, including a set of performance indicators.

Using the results from these indicators over the last 15 years, the completeness and quality of data submitted to the NRFA each year has consistently improved and now less than 1% of data submitted each year are missing and less than 10% have data quality issues that have to be queried. These improvements mean that the data provided to the NRFA's wide range of users is of the highest quality.

It took me several hours to go through the programme to look through and choose Hydrology sessions, let alone the many other geoscience topics on offer. Within Hydrology, I attended sessions on floods, drought, climate change and forecasting to name just a few. I was also determined to attend talks and posters on a wide range of topics: I learnt about the atmosphere of Mars, the glaciers of Greenland and the 2018 volcano eruptions in Hawaii! But by my far my favourite 'different' session was attending the talks in the Up-Goer Five Challenge. If you haven't heard of them before, the session contains 5-minute talks where presenters can only talk using the 1,000 most common words used in English. It resulted in some very funny moments as people tried to find words for degrees (of temperature; cold-to-hot points), earthquakes (ground shakes) and volcanic ash (tiny fire-rocks). It was an amazing way to communicate your science and I would encourage everyone to try it, it's harder than you think!

I thoroughly enjoyed my AGU experience, it was valuable to have the opportunity to meet so many scientists within my field. Thank you to the British Hydrology Society for providing the financial support to allow me to attend the AGU Fall Meeting.

Katie Muchan
CEH, Wallingford.

3. Attending the centennial AGU Fall Meeting for an oral presentation on "Citizen science evidence from the past century shows that Scottish rivers are warming" was a great honour to me.

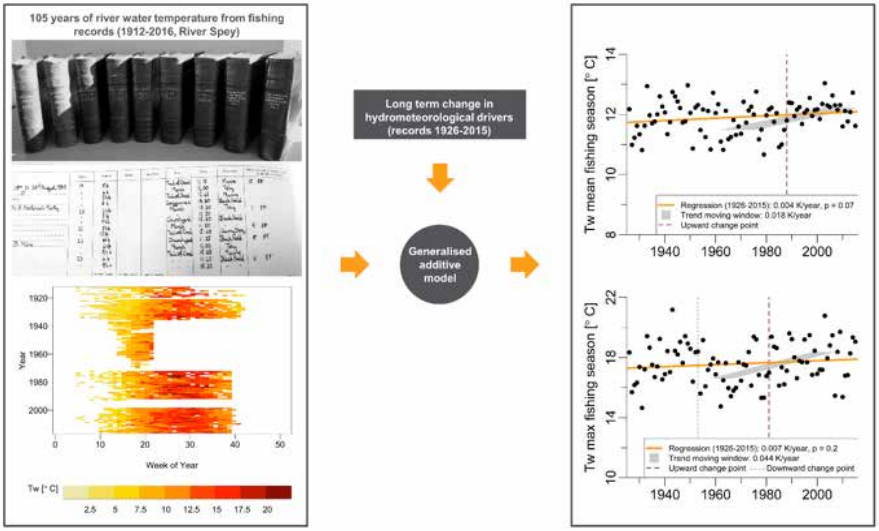
The study on which I worked with my co-authors Rachel Helliwell, Caroline Aube, Sheila Gibbs, Michael Spencer and Luigi Spezia investigates a unique 105-year record of river temperature of the River Spey (North-East Scotland) monitored by fishing attendants. We applied generalised additive models to explore influences on river temperature and to obtain continuous river temperature data in the fishing season (April – October) as there were gaps in the data. To that end, river temperature was modelled from air temperature, cumulative air temperature, day length and runoff. We found long-term warming trends in river temperature (an increase of 0.2°K per decade after 1961)

which can mostly be attributed to an air temperature increase by the same magnitude. Indirect impacts of rising air temperatures include less snow accumulation and snow melt as well as an earlier snow melt.

Our analysis of long-term citizen science records of river temperature provides a robust basis on which to assess future changes in river temperature and can help decision-makers about the desirability of enhancing the resilience of rivers and aquatic ecology to future warming. Our contribution is now accepted for publication in *Science of the Total Environment* (https://doi.org/10.1016/j.scitotenv.2018.12.325).

The session "Ecohydrologic General Contributions I" in which I presented covered a wide range of topics including "Assessing Spatiotemporal Variability in Mountain Ecosystem Productivity with Multispectral Unmanned Aerial Systems" by Oliver Wigmore, "Geneohydrology: Using Aquatic Gene Fragments to Quantify Macroscale Ecohydrologic Function" by Stephen P Good, "Eco-hydrology of natural urban reserves" by Valentina Marchionni, "How do evapotranspiration-driven discharge fluctuations alter reach-scale ecosystem function?" by Adam Ward, "Land cover changes, plant trait variability, and their impact on the terrestrial water and carbon cycles" by Simone Fatichi, "Scalar simulation and parameterization of water table dynamics in tropical peatlands" by Alex Cobb, and "Spatial Soil Moisture Patterns as a Driver of Ecohydrological Processes" by Charles I Scaife .

My personal interest at this meeting was focused on contributions investigating stream temperature which I found in various sessions. These contributions



Assessing long term river temperature changes from citizen science records. Left panel: images of fishing books containing river temperature records and data availability. Right panel: Mean (top row) and maximum (bottom row) river temperature in the fishing season and trend interpretation. Figure taken from Pohle et al. (2019, https://doi.org/10.1016/j.scitotenv.2018.12.325).

included presentations of:

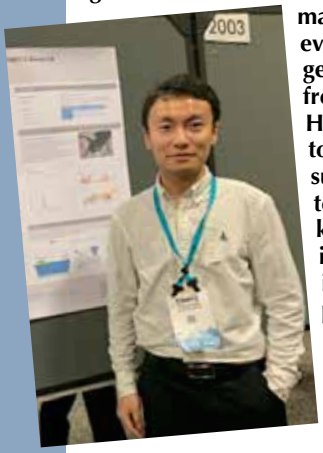
- Experimental river temperature networks, e.g. "Spatial and temporal analysis of stream water temperature in the upper Esopus Creek" watershed by Huicheng Chien,
- Novel remote sensing approaches to observe river temperature: "Improving the Accuracy of Stream Temperatures Acquired through Ground-Based Time-Lapse Thermal Infrared Imagery" by Emily A. Baker and "Utility of drone-based thermal imaging for mapping river temperature heterogeneity" by Stephen Dugdale,
- Approaches of using river temperature as indicator of hydrological processes: "Using Stream Temperature to Infer Runoff Generation Pathways: Implications for Thermal Refugia in the Southeastern US" by Christa Kelleher and
- Novel approaches to model river temperature: "Warming water in Arctic terrestrial rivers under climate change" by Hotaek Park, "Dynamic River Temperature Simulation of Urban Stormwater Inflows and Riparian Shading in an Urban Forest Landscape" by Reza Abdi, "Minimal data collection for maximal results, combining geospatial modeling and a heat flux approach to the thermal regimes of headwater streams in a humid, hardwood forest" by Laura Belica and "A Dynamic River Temperature Model for the Colorado River within Grand Canyon" by Bryce Mihalevich.

Attending AGU Fall Meeting provided me with an excellent opportunity to increase my knowledge, and to meet and discuss with international researchers working on different topics in hydrology. I am grateful to the British Hydrological Society and the Rural & Environment Science & Analytical Services Division of the Scottish Government for their financial support of this conference visit.

Ina Pohle
James Hutton Institute, Aberdeen

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4. This year is the 100th anniversary of the American Geophysical Union. Over 28,000+ attendees from all the world gathered in Washington DC to make it a successful event. Thanks for the generous support from the British Hydrological Society to enable me to join such a great event to acquire new knowledge, exchange ideas and, the most important, meet people.



I am currently a final year PhD student at the Water and Environment Management research group in the University of Bristol, working on the innovations on water quality data collection. I presented my poster on 'Water Quality Observation Using Hyperspectral Camera, A Pilot Project in Bristol, UK' on 11th Dec 2018. It demonstrates my most recent research work on building an unmanned surface vehicle with a water quality sonde and a hyperspectral camera for water quality data collection.
I have been working on this vehicle since this summer and we can now have it running in the Bristol Floating Harbour to

collect data. I have been working previously on smart water quality monitoring by setting up *in-situ* multiparameter sonde with wireless data transmission and cloud data visualisation system.

The Floating Harbour is the core area of Bristol. The harmful chemical substances and large populations of certain microorganisms in the water are potential threats to human activities (e.g., the Bristol Annual Triathlon event) and the harbour's aqua ecosystems. Our group have already built a smart water quality monitoring system using wireless sensor network technology for the Floating Harbour based on Bristol-Is-Open*.

The team is now equipped with a Headwall Nano-Hyperspec VNIR (400-1000nm) hyperspectral sensor mounted on a DJI M600 industrial UAV. The hyperspectral camera using the widely used push broom (spatial linear scan) method to cover 272 bands. The relationship between the percentage of reflectance and the wave-length captured by the hyperspectral camera when a substance is exposed to the electromagnetic spectrum is known as the spectral signature which is unique for every substance.



Thus, the amount of substance in water can be estimated by the intensity of the reflectance at different wavelengths through building an empirical statistical regression between them. However, the airborne package is difficult to fly in Bristol city centre due to regulation. An unmanned surface vehicle was designed and built on which to mount the water quality sonde and the hyperspectral camera to carry out water quality survey. The poster attracted great attentions from many attendees during the AGU meeting as it is quite unique to create a unique scientific platform to collect water quality data, while the majority of researchers focus on data analysis based on existing datasets. I also took the opportunity to learn from other hyperspectral camera users about the applications in water quality mapping. I also met researchers attracted by my work who would like to offer me post-doc opportunities in China. Again, I am grateful to the BHS travel grant to allow me to join this year's AGU fall meeting.

Yiheng Chen
University of Bristol

* Bristol Is Open is a joint venture between the University of Bristol and Bristol City Council. It is funded by local, national and European governments along with academic research funding and also by the private sector. We are delivering research and development initiatives that contribute to the development of a smart city.

5. My interest in attending and presenting at the AGU fall meeting 2018 was two-fold: firstly, I am in the final stages of writing up my PhD thesis at the University of Hull so I wanted to share the findings of my research and also gain a better understanding of how my research will impact other professionals and researchers to motivate me to finish writing my thesis! Secondly, I am currently a Senior Flood Risk Management Officer at Hull City Council so I wanted to learn more about communicating flood risk and modelling blue-green infrastructure. The sessions at this year's AGU definitely delivered everything I was hoping for and more!

Currently, there are 5.2 million properties in the UK that are at risk from flooding (National Flood Forum, 2018). People's perception of flood risk has changed over the last decade because of the increased frequency of flooding and the increasing cost of damages caused by it. Systematic records, such as river gauges, only extend back around 50 years in some UK rivers, which does not provide a long term perspective of the frequency of flood events. Furthermore, there is even more uncertainty associated with the effect global warming will have on flood frequency and magnitude. The field of palaeoflood hydrology studies long term records of fluvial activity to interpret flood frequency records. This research focuses specifically on geomorphological evidence of fluvial activity from UK depositional environments during the Holocene (~12 500 years BP).

The poster presentation that I delivered was titled: 'Reassessing Holocene Fluvial Records – Applying A New Quality Control Criterion To Radiocarbon Dated Geomorphological Data' and was presented in the session 'Advances in Incorporating Geomorphology and Flooding: Feedbacks and Impacts on Flood Risk'.

This study reassesses the British Holocene Record, which is a collection of radiocarbon dated material from fluvial depositional environments across the UK (Macklin et al, 2012). Summed probability distribution functions (PDFs) are a common method of analysing radiocarbon dates and have been used previously to interpret periods of increased fluvial activity (Macklin et al, 2010; Michczyńska et al, 2007). Summed PDFs are characterised by a curve that is constructed based on time (x-axis) and probability (y-axis) and peaks in the curve are typically interpreted to reflect the occurrence of an event, for example a flood event. Summed PDFs are also used to correlate fluvial records with environmental and climatic records (Macklin et al, 2010). However, there are limitations with this approach because the shape of the curve, including the location and height of peaks can be influenced by methodological factors (Chiverrell et al, 2011; Michczyński and Michczyńska, 2006).

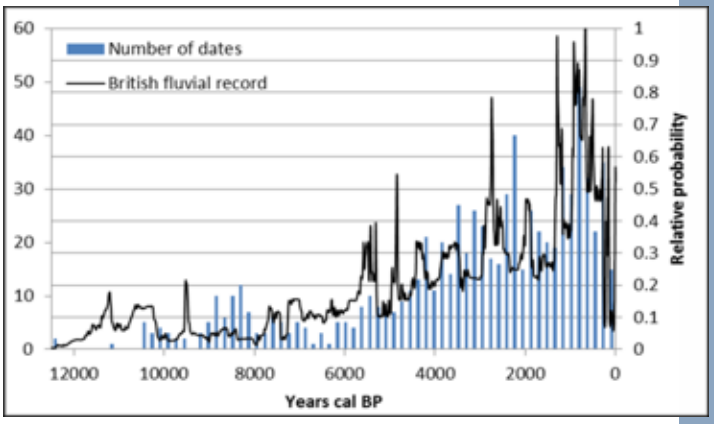
The methodology used in this study included sensitivity testing of summed PDFs generated using the British fluvial record to determine factors within the dataset that influence the shape of the curve. The British fluvial record was divided into sub-datasets based on the following criteria:

- Five or more dates per single site
- Sample material – wood or peat
- Archaeological context
- Sample association to a flood event

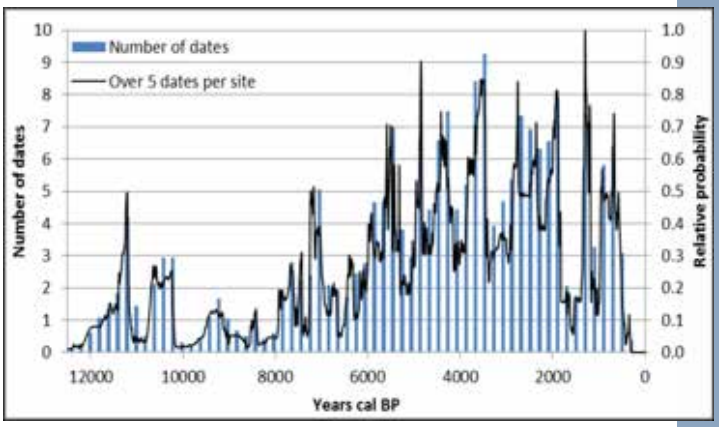
The sub-datasets were compared

based on statistical indicators, which shows the variance from the sub-sample mean (sum of squares of deviation) and the variance from the overall dataset mean (summed mean square error). The statistical indicators were used to comment on the viability of applying a quality control to fluvial radiocarbon dates to increase the reliability of flood record.

The results of this study determine that the shape of summed probability distribution functions is most sensitive to the minimum number of dates, which had the lowest summed mean square error, and least sensitive to non-archaeological dates, which had the highest summed mean square error value. This study concludes that the shape of summed PDFs is very sensitive to different characteristics of the data used in the British fluvial record and so data included in analysis should be chosen with care, taking into account the statistical reliability and the practical assumptions of data characteristics. This study highlights the limitations of using terrestrial fluvial data and also highlights the potential of using existing data by proposing a new robust methodology of careful data selection using quality control. Furthermore, the results presented here provide new evidence to the growing application of using summed



Summed probability distribution function (black line) of radiocarbon dates from the British fluvial record (n=776). The number of dates per 200 years is shown in blue.



Summed probability distribution function (black line) of a collection of radiocarbon dates from sites that contained five or more dates from British fluvial depositional environments (n=219). The number of dates per 200 years is shown in blue.

probability distribution functions to interpret radiocarbon dated material.

The opportunity to present my PhD findings at the AGU fall meeting gave me confidence in myself as a researcher and also provided me with the knowledge of how my research project fits into a bigger scientific perspective. For example, I spoke with researchers from Norwegian University of Science of Technology and US Bureau of Reclamation, who expressed how essential our understanding of the uncertainties associated with using summed PDFs to represent radiocarbon dates is to construct flood-frequency records.

Furthermore, the conference also provided me with new professional skills useful to my career. I was able to share my professional experiences and learn from other specialists by attending a workshop organised by the World Bank: Communicating Disaster Risk.
I cannot express my thanks to the British Hydrological Society for this opportunity.

Jessica Maloney,
Hull City Council/University of Hull

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Michczyński, A. and Michczyńska, D.J. (2006). The effect of PDF peaks' height increase during calibration of radiocarbon date sets. Geochronometria. 25. 1-4.

Michczyńska, D.J, Michczyński, A. and Padzur, A. (2007). Frequency distribution of radiocarbon dates as a tool for reconstructing environmental changes. Radiocarbon. 49(2). 799-806.

6. My name is Aaron Neill This was my second attenance at the AGU Fall Meeting, where I presented a poster on my latest work "Integrating an agent-based model for *E. coli* with a tracer-aided hydrological model to explore controls on microbial water quality", as part of the session "Frontiers in Surface Water Quality Measurements, Modelling, and Management". My PhD aims at understanding linkages between flow paths, hydrological connectivity and microbial water quality. To successfully maintain microbial water quality, and ultimately safeguard public health, it is necessary to understand the spatio-temporal dynamics of the sources and hydrological flow paths which contribute faecal indicator organisms (FIOs), such as *E. coli*, to water bodies. My work so far has included the use of long-term *E. coli* data and spatial-stream-network models to understand and predict spatio-temporal dynamics of faecal contamination at the catchment scale (Fig 1; Neill *et al*., 2018, doi: 10.1016/j.scitotenv.2017.08.151), and the coupling of a tracer-aided hydrological model to a simple faecal coliform model to test a hypothesised role of hydrological connectivity in governing stream FIO dynamics (Fig 2; Neill *et al*., 2019, doi: 10.1016/j.jhydrol.2018.12.066). .

Our poster outlined the initial development of an agent-based model which simulates the fate and transport of *E. coli* agents through a set of rules governing

their interaction with the "hydrological environment" as provided by spatially-distributed outputs from the tracer-aided ecohydrological model EcH2O-Iso (Kuppel *et al*., 2018, doi: 10.5194/gmd-11-3045-2018), developed by our NRI team at Aberdeen in collaboration with the University of Montana. The simulation of discharge and tracers (e.g. stable isotopes) by tracer-aided models, causes them to have significant potential in exploring hydrological controls on microbial water quality through offering greater insight into the success of the models in capturing the hydrological processes and internal catchment states to which water quality parameters are sensitive. Agent-based models, meanwhile, offer flexibility in defining rule sets that govern agent interactions with the simulation environment, and in allowing multiple agent attributes to be tracked.

The modelling approach was developed for a 0.42 km^2, mixed-agricultural catchment in NE Scotland. The initial agent-based model simply introduced *E. coli* agents into the model domain based on land cover and associated livestock counts, with agents moving probabilistically downslope when soil moisture simulated by EcH_2O-Iso exceeded a threshold value. EcH_2O-Iso was calibrated within a multi-criteria framework, incorporating discharge data and spatially-distributed stream isotopes from eight locations across the catchment as calibration targets. Preliminary outputs showed the potential of the combined tracer-aided and agent-based models to provide insight into how sources and fluxes of *E. coli* to the stream vary in time and space. For example, through being able to assign attributes such as 'Host Animal' and 'Entry Land Cover' to the agents, it was possible to assess how different land covers and associated grazing livestock contributed *E. coli* agents to the stream at different times.

Furthermore, by tracking the location history of agents as they moved through the model domain, it was possible to quantify the agent-contributing areas for specific events, as well as the overall likelihood of contribution from different parts of the catchment over the whole simulation period.

I was very pleased to receive so much positive feedback on my work thus far, as well as insightful discussions with a number of different researchers who offered new and valuable perspectives on how I might take the model development forward. My next steps will be to continue to develop the rule set for the agent-based model to incorporate additional processes to improve physical realism, and to validate the model using observed *E. coli* and bacterial source tracking data.

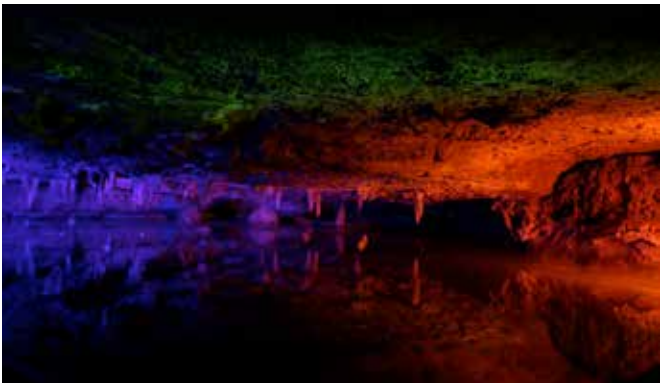
With around 28,000 scientists in attendance, the AGU Fall Meeting of course provided significant opportunities for attending oral and poster presentations to hear about the latest research in the field of hydrology (and beyond!), and to partake in discussions.

The Centennial Session on "100 Years of Progress in Hydrologic Science" provided some fascinating insights into how hydrology as a science has evolved, and what the future might hold. One of the invited speakers, **Doerthe Tetzlaff** of HU Berlin and IGB Leibniz Institute Germany, gave an overview of the usefulness of stable isotopes in catchment studies over the last 50 years or so, and presented exciting prospects for the integration of isotopes into ecohydrological models for investigating the partitioning of water between 'blue' and 'green' fluxes. This followed on well from a talk by **Naomi Tague**, another invited speaker, who

presented advances in ecohydrological modelling and the importance of understanding how our models work and what parameters mean as the use of such models in examining consequences of land use change on factors such as water partitioning become more prolific. Meanwhile, **Lieke Melsen** addressed the question of "Legacy versus adequacy in hydrological modelling" to examine whether the plethora of hydrological models now in existence has arisen due to genuine need or from a form of model attachment, and the consequences thereof. As part of the Catchment Science Symposium, **Martyn Clark** also looked back at how well issues of process representation, parameter identification and computational power in hydrological modelling have been addressed since being highlighted by Freeze and Harlan (1969, doi: 10.1016/0022-1694(69)90020-1) in their blueprint for a physically-based hydrological model proposed 50 years ago, to show that there is still progress to be made!

I was particularly keen to investigate the latest progress being made in terms of advancing hydrological modelling. An interesting theme that intersected a number of sessions and talks I attended was that of "co-evolution". Talks by **Ciaran Harma**n on "Co□evolution, bedrock weathering, and lateral flow in hillslopes", and discussions as part of the "Meet the Experts" session with **Andrew Western** and **Murugesu Sivapalan** were particularly inspiring, providing me with new perspectives on questions surrounding why heterogeneity and feedback processes exist at multiple scales, and the implications for their appropriate representation in numerical models. In addition, the session "Hydrochronology: Advances in Tracer Methods and Modelling of Residence Times in Hydrology" offered insightful presentations by **Daniel Wilusz** and **Matthias Sprenger** on opportunities for utilising novel modelling approaches incorporating particle-tracking and ideas of sub-surface connectivity, respectively, to better understand flow paths, travel times and the partitioning of water.

Outside of the main conference programme, I also took the opportunity to attend one of the field trips organised by AGU. Specifically, I went on the field trip "Karst Hydrology, Paleoclimate, and Landscape Evolution of the Great Valley in Northern Virginia", led by Daniel Doctor and colleagues from the USGS. The trip included four main stops. The first was Hupp's Hill, where we were introduced to the features characteristic of karst environments, contextualised within the wider geological setting of the region. Our next stop was Skyline Caverns (see below), where



we were taken on a tour to discover how the caverns had been carved out by processes that varied in time to reflect the evolution of the surrounding landscape.

Our last two stops were at the Spout Run tufa deposit and at Blandy Experimental Farm. At the latter, it was especially interesting to learn about groundwater and dye-tracing experiments carried out in the area that had revealed how highly divergent sinkhole drainage in karst systems can be! Overall, the field trip was very well organised, and provided a great opportunity to escape the city, gain some new hydrological knowledge and interact with people working outside of my immediate field of study. Indeed, the whole experience of attending the AGU Fall Meeting and the new knowledge and connections obtained was of great value to me as an early career scientist, and I am very grateful to BHS for their financial support.

Aaron Neill
Northern Rivers Institute
University of Aberdeen

Honory BHS Fellowship



We aew delighted to report the award of Hon Fellowship to **Terry Marsh**, a very longstanding member of BHS with a long and great service to UK hydrology and to the Society. He led the National Hydrology Monitoring Programme from CEH for some three decades until his supposed retirement in 2015. An important focus of Terry's career was maximising the utility of – and access to – UK hydrological data. Beginning at the Water Resources Board coding-up daily flow data for entry into the fledging National River Flow Archive, he eventually became head of the NRFA and thence, on transfer to, the Institute of Hydrology, Leader of the National Hydrology Monitoring Programme. The latter assumed enhanced importance as the impact of global warming on runoff on recharge patterns climbed higher on the scientific and political agendas.

The myriad reports and papers that Terry has produced reports are inevitably heavy with numbers and "facts" but he always maintains the reader's interest and has also often been a voice of reason when the more sensationalist parts of the media are clamouring to ascribe some hydrological event to climate change, or to overstate its rarity. He was the author of the monthly UK Hydrological Summary on an incredible 286 occasions. As you all know, Terry continues to publish the quarterly UK Hydrological Bulletin (which appears in *Circulation* first!)

Aquator™ User Group Autumn Meeting



In October 2018, Hydro-Logic Services (International) Limited (HLSI) held the Annual Aquator User Group Meeting, at Worcester College in Oxford. The meeting brought together over 45 modellers, experts and scientists from around the United Kingdom to share and discuss water resources modelling experiences using the Aquator software package. The meeting followed on from an Aquator Training Day event, which is held on a bi-annual basis for both new and experienced users.

The conference started with an introduction by **Colin Fenn**, Director at HLSI, and **Will Clark** informing the audience on the recent acquisition of both Aquator and Oxford Scientific Software by HLSI, who are now the new owners of AquatorTM. This serves to further strengthen Aquator and secure its long-term development, improvement and support, and the Oxford Scientific Software developers continue to be centrally involved.

The day was kicked off by a joint presentation between **Mark Smith** (HLSI) and **John Birkhead** (United Utilities), highlighting the evolution of both the Aquator software itself over time, and in terms of how United Utilities has refined, and broadened its use of the software towards the latest WRMP19 planning round. The increasing importance of simulation modelling in the planning process was a key theme, which was also reflected in other user presentations during the day.

Rob Tothill (Atkins), **Kate Norman** (DCWW) and **Nathan Morris** (DCWW) provided an interesting overview of the development of a number of water resource zones for Dwr Cymru Welsh Water's system in the latest version of Aquator, XV. Previously, the water resource zones were modelled in WRAPSim. The benefits of the new software version, along with experience in building the new models were shared, including how schematical representation has been targeted to help engagement with operators. Rob Lawson (Artesia) followed with a complementary presentation on demand analysis and supporting

tools used to help in the derivation of demand data for use in the new models.

David Crookall and **Andrew Low** (Scottish and Southern Energy) provided a non-water sector view of water resources modelling, and the different needs and objectives for modelling storage hydropower. The talk invoked much interest from the user community, given the different application of Aquator. Model development is in the early stages, and David and Andrew shared their initial observations whilst promoting dialogue and inputs from the audience on this type of modelling.

A more strategic keynote presentation was provided by **Doug Hunt** (Atkins) on the topic of "WRMP24 – What next for behavioural modelling?". The presentation took a look at the evolution of planning methods to WRMP19, with the increasing use of behavioural simulation modelling within the decision-making process, and then reflected on the future direction for WRMP24. The key themes and choices ahead included evolution or revolution in the planning methods, Regional and National Planning, and the representation / integration of risk and resilience in the planning process.

A presentation by **Daniel Wykeham** (Southern Water) on future uses and needs of water resources models, reflected on the recent use of Aquator in WRMP19, and the developments ahead of the models for WRMP24. Dan provided views on potential enhancements or developments that could be considered as useful in future.

The day was concluded by a semi-structured discussion session, chaired by **Mark Smith**. This sought to promote feedback and identify users' key priorities and potential suggestions for further modelling software improvements or expansions. The responses provided will be used by the Aquator team on balance with other feedback to inform the future Aquator development strategy.

Mark Smith

Recent PhD theses

Author	*Title*	*University*
Forber, Jessica Kirsty	The phosphorus transfer continuum under climate change uk.bl.ethos.753218	Lancaster
Lozano de Sosa Miralles, Laura	Riparian areas: delineation and contribution to ecosystem service provision uk.bl.ethos.760207	Bangor
Koleva, M. N.	Optimisation methodologies for the design and planning of water systems. uk.bl.ethods.747577	University College London
Zheng, Ying	Exploring how land use may influence the export, composition, and reprocessing of dissolvedorganic carbon in peat-rich catchment drainage. uk.bl.ethos.744102	Glasgow

Townsend, Philip James Andrew	Numerical simulation of the shallow water equations coupled with a precipitation system driven by random forcing. uk.bl.ethos.751889	Sussex
Green, Daniel	Understanding urban rainfall-runoff responses using physical and numerical modelling approaches. uk.bl.ethos.747955	Loughborough
Terlet, Julia Louise	Water behaviour modelling for efficient ICT-based water management in urban environments: a UK case study. uk.bl.ethos.753578	Cardiff
Huskova, Ivana	Planning for robust water supply system investments under global change. uk.bl.ethos.747516	University College London
Headley, Miguel Learie	Assessing the reliability, resilience and sustainability of water resources systems in data-rich and data-sparse regions. uk.bl.ethos.744066	Exeter
Tindale, Sophie Jade	Collaborative water-resource governance in the UK: understanding network structure and functionality of a catchment-based approach to water-quality management. uk.bl.ethos,743249	Durham
Wright, Hannah	Soil drying and re-wetting effects on phosphorus availability and plant yields. uk.bl.ethos.753266	Lancaster
Hen-Jones, Rosalind Mary	Quantitative electrical imaging of soil moisture dynamics. uk.bl.ethos.757172	Newcastle upon Tyne
Gao, Shen	Does the concept of 'resilience' offer new insighs for effective policy-making? Analysis of the feasibility and practicality for flood risk management in the UK https://www.repository.cam.ac.uk/handle/1810/274918	Cambridge

CIWEM Chartered Institution of Water and Environmental Management

British Hydrological Society

Celebrating hydrometry

Monday 24 June 2019

Institution of Civil Engineers,
One Great George Street, London

This joint CIWEM-BHS national meeting (part of an ongoing series of meetings designed to link researchers, policy makers and practitioners) will provide an excellent opportunity to learn more about the value that hydrometry provides for society, the environment and the economy. It will feature presentations and debate from those responsible for the collection and management of hydrometric data, through those who utilise it for studies, modelling and critical decision making, to the less obvious users who gain value from it.

Who should attend? The meeting will bring together academics, researchers, consultants, hydrologists, environmental managers, policy-makers, regulators and other stakeholders.

What will you learn? The meeting will be of interest to all who rely on good quality, long-term hydrometric data records to make informed, robust decisions on water resources management and flood risk, whether that is planning a new reservoir or flood alleviation scheme, through to abstractions and discharges. Good quality, continuous hydrometric data underpins almost every aspect of the way society interfaces with the hydrological cycle, yet can be undervalued, overlooked or misunderstood by many decision makers. This meeting seeks to promote the value of the ordinary – the seemingly routine observations of our rivers and streams, the groundwater beneath our feet, and the rainfall and other parameters that are measured – and recognise its importance and wider benefits for consultants and practitioners, as well as wider society, the environment and the economy, across the whole spectrum of water management. It will also signpost emerging developments in this field, and explain how concepts such as open data, big data and citizen science sit alongside technical standards, quality assurance and expert judgement to take hydrometry forward.

Meeting organiser:
Adam Comerford
BHS National Committee member and CIWEM Water Resource Panel member
Adam.Comerford@canalrivertrust.org.uk

UK Hydrological Bulletin: November 2018 – January 2019

Above average rainfall through the late autumn and early winter eliminated soil moisture deficits across almost all of the UK and spate conditions, with moderate local flooding, were common from mid-November until mid-December. The associated healthy runoff triggered an important recovery in reservoir stocks and groundwater levels across much of the country but, entering 2019, reservoir stocks remained appreciably below average in a few areas with slow-responding aquifers. Similarly, groundwater levels, whilst generally remaining within the normal seasonal range, were appreciably below average in a few areas, including East Anglia. As is often the case, the water resources outlook — and prospective summer flows in groundwater-fed streams and rivers — will be substantially influenced by late winter and early spring precipitation patterns.

November rainfall was close to the average for UK as a whole but considerably below across northern Scotland and much of north-west England. The month was punctuated by the passage of several very active low pressure systems bringing spells of heavy rainfall; in the Scottish Highlands, Achnagart reported a 52.5 mm total on the 30th. The wet interludes generally triggered steep river flow recoveries and flood alerts were common during the second week — particularly in rivers draining impermeable catchments in the English Lowlands (the Mole for example). Intense local downpours also caused substantial traffic disruption. By contrast, the legacy of the arid spring and early summer remained evident in relatively depressed groundwater levels, for example in the Chalk at Chilgrove (west Sussex) and continuing flow recessions in groundwater-fed streams and rivers.

In the Cotswolds, daily flows in the river Coln fell close to their late-autumn minimum. In Derbyshire, the normally submerged village of Derwent, remained partially exposed as a result of continuing low levels of Ladybower reservoir.

The 2018 rainfall totals for both Scotland and England & Wales were both marginally below average. Considering the full annual time series from 1910, Scotland shows less than half of the long term average — a deficiency reflected in flows for the river Helmsdale which fell below previous minima for the time of year. By contrast, flood alerts were common across southern Britain where runoff for the river Camel (Cornwall) was the second highest for December in a series from 1964.

The 2018 rainfall total for both Scotland and England & Wales were both marginally below average. in most index catchments across the English Lowlands. In addition, whilst December groundwater levels in most index wells were within the normal end-of-year range, moderately depressed levels were registered in Northern Ireland and parts of East Anglia (where recoveries typically don't gain momentum until the spring).

Considering annual rainfall series, Scotland shows an increase of 13% since 1910 but for England &Wales no discernible trend is evident (Fig. 1) over a timespan when

temperatures have increased by a little over one degree centigrade. The lack of trend in England & Wales annual rainfall totals is clearly of significance in the climate change debate.

Entering 2019, reservoir stocks for England &Wales as a whole were well within normal range (Fig. 2), having been at their lowest since the 2003 drought in the late summer of 2018. However, stocks in a few reservoirs (e.g. Grafham in East Anglia) remained considerably below the average for the time of year and, with high pressure dominating synoptic patterns, a dry spell which began at Christmas continued well into January across most of the UK. Parts of Cambridgeshire registered three weeks without rainfall.

Correspondingly, reservoir replenishment was meagre and most rivers were in recession by mid-month. Arctic conditions with appreciable snowfall characterised the fourth week of the month but precipitation totals were generally modest. It also means that the February and March rainfall patterns will assume considerable hydrological importance.

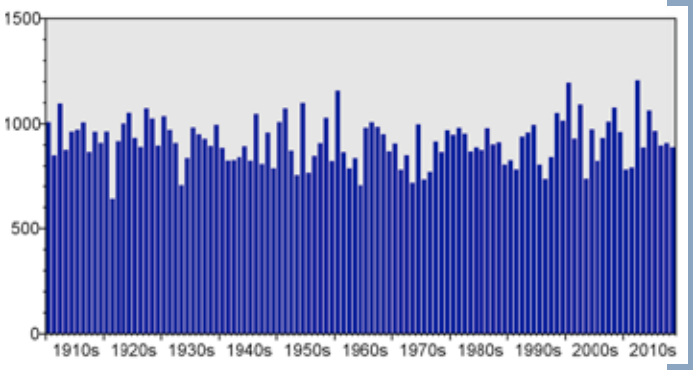


Fig 1 Annual rainfall totals (mm) for England & Wales (Data source: Met Office)

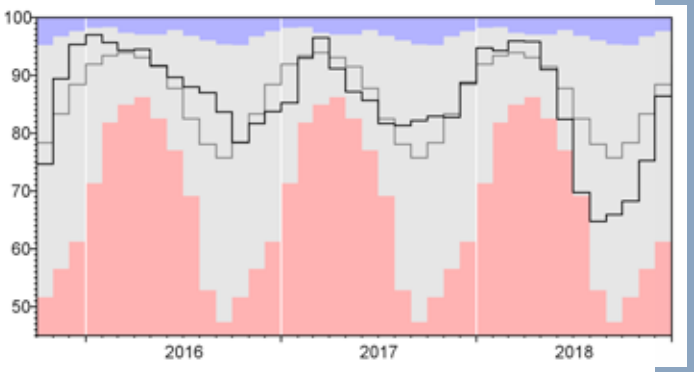


Fig 2 Estimated overall reservoir stocks for England & Wales (as a % of the 1990-2017 average) – the grey trace is the long term monthly average; the blue and pink envelopes represent the long term monthly max. and min

Terry Marsh
28/1/2019

