No. 69 May 2001

THE NEWSLETTER OF THE BRITISH HYDROLOGICAL SOCIETY

Circulation

Contents

Please send your form for the membership directory back!

Birmingham Symposium 2002

President's piece
2-day flood risk meeting in November

Regulating rivers: groundwater schemes and bankside storage
Midlands Section meeting, Shrewsbury

The estimation of low flows
Scottish Hydrological Group Meeting

Hydrologist wanted in Warrington
Job advertisement for United Utilities

***Circulation* Plus**
Two articles — see below for details

One-day National Meeting in July
See the flyer enclosed with this issue

New members

PhD awarded to Hayley Fowler

Book review
The primer of rainfall-runoff modelling

Publications
Hydrological Sciences Journal contents

Advertising rates

Holistic hydrology: looking at the bigger picture
A report of the East Midlands Meeting in March at Loughborough University

News from members
Members on the move; new FICEs

Reintroducing HOMS
WMO's Hydrological Operational Multipurpose System explained

South West Section meets again
50 attended the Bristol Meeting

Forthcoming meeting
IAHS Scientific Assembly, Maastricht

Diary of BHS and other events

Circulation is published quarterly. It is free to members of the British Hydrological Society and costs £22 to nonmembers on annual subscription.

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- Web pages: **http://www.hydrology.org.uk/**

Circulation is produced at CEH Wallingford and indexed in *Geosystems' Hydrotitles* & *GeoArchive* and *NISC HydroROM.*

Please send your membership form back today

The complete BHS membership directory 2001 can only be issued if all BHS members return the form that was sent out recently (on yellow/gold paper). Please make sure that you send yours back to confirm your contact details (to be held on the ICE database) and to state whether you wish to be included in the published list.

We hope that most (if not all) members will respond positively: the directory will not be made available to outside bodies for direct marketing, but it will assist in publicising meetings, including those of regional groups and sections and related organisations.

If you have an email address, please consider two further options: you might allow the BHS Committee to use it to let you know about events between issues of *Circulation*; and you might wish to join the closed BHS mailbase, to exchange hydrological information. For further details please contact the Secretary *(address above)*.

Birmingham to host BHS Symposium in 2002

Birmingham University has been chosen to host the eighth BHS National Hydrology Symposium, from *8th* to *11th September 2002*.

The flyer enclosed with this issue of *Circulation* gives further details and invites contributions of papers or posters on appropriate themes.

In the Circulation* PLUS *section:

Irish floods, changing climate and Generalised Linear Models
Richard E. Chandler, University College London

Current and future requirements of weather radar use in the Midlands Region
Richard Cross, Environment Agency Midlands Region

President's piece

Sadly, our oldest member, **Victor Appleby**, passed away this month, having just reached 101. I represented the Society at his funeral in Essex. As *Circulation* reported his life last year when we celebrated his centenary, we are not publishing an obituary. I only knew Victor for the last 20 years, but his energy and enthusiasm for hydrology were inspirational — he always had time to read the latest paper in *Water Resources Research*, and would come into the Department at Imperial in his 90s expecting a challenging discussion. He was a truly remarkable man, and his notable presence in the hydrological community will be greatly missed.

To more mundane matters, at the time of writing the Committee continues to be embarrassed by the fact that subscription notices are not yet out. Hopefully by the time this is distributed they will be. The ICE MEMSYS data base has now been fully populated, however, and we are attempting to check that changes of address have been correctly tracked. The draft Membership Directory will be mailed with this *Circulation*, and if you are included, please could you check your entry and let the Hon. Sec. know of any discrepancies. Perhaps more importantly, members who did not return the form enclosed with the last issue are *not* included, and if you are one of those it would be most helpful if you would send back the form enclosed this time. If you are aware of any friends or colleagues who have dropped off the list, could you also please let **Tim Jolley** know.

Some of our strategic initiatives have been completed, and position statements produced. We are still working on education and training, and analysing support to members through the regional sections. The response to Roger Simpson's questionnaire was not overwhelming, so we are repeating the mailing that went out with the last *Circulation*. Please spare a few minutes to respond, so that we can do a better job in meeting your needs.

The BHS website has suffered from some logistical hiccups, and had also become outdated. **Jenny Thorne** is helping us to update this with current information, including the meetings programme, application forms, etc., so hopefully you will find it more useful than hitherto. However, we are aware that a major redesign is needed, as well as an expansion of web-based facilities, and the Committee continues to work on this. If you have views about what BHS could or should be providing via the website, please let me or **Steve Wade** know.

The hydrological year has continued to break records, and BHS is considering an Occasional Paper to bring together experiences of the 2000/2001 floods. If you have an interesting story to tell, please let me know. Many of you will be aware that these floods have stimulated much political and media interest, and that both the Environment Agency and MAFF have major initiatives in catchment flood management, and are working on refocussing strategic research needs. A set of review papers has been prepared for MAFF on the theme of Broad-Scale Modelling: these are available through the theme leader, **Edward Evans**, at Sir William Halcrow & Partners.

The Royal Society/BHS meeting in November will address *Flood risk in a changing climate*, with national and international speakers on climate change, rainfall and statistical modelling, fluvial and coastal flood modelling, ecological and socio-economic aspects, and a report from the ICE Commission, currently working for MAFF on a review of the flood defence implications of climate change. The Royal Society President, **Sir Robert May**, has offered to open the meeting, which gives the Society an important opportunity to raise the scientific profile of Hydrology within the UK. **Geoff Mance** of the Environment Agency will provide closing remarks. Poster papers are welcome, and posters will have summary oral presentations, so if you would like to contribute, please contact me.

I think that that is all I have to report on recent activities. Easter included a visit to Australia and New Zealand, so email messages might not have got an immediate response, but such contacts from members are always most welcome.

Howard Wheater
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Regulating rivers: groundwater schemes and bankside storage

BHS Midlands Section meeting
Shrewsbury
10 January 2001

45 people gathered at the Severn Trent Water Visitors Centre in Shrewsbury for the first Midlands Section meeting of 2001.

Following a brief introduction and welcome from the chair by **Richard Boak** (Water Management Consultants Ltd), **Kevin Voyce** (Environment Agency, Upper Severn Area) gave the first presentation, on the Shropshire Groundwater Scheme (SGS). He began with an overview of the engineering storage components that control flow regulation in the River Severn. These include the Clywedog and Vyrnwy reservoirs as well as the SGS, although storage in Vyrnwy reservoir is exported for water supply to Liverpool. There are heavy demands on flow in the Severn and there is a need to balance the demands of public water supply, industry and agriculture. During the 1970s it was realised that available reservoir storage was insufficient to augment flow in the Severn, and it was therefore decided to develop groundwater in Shropshire to increase the available flow. This presented several advantages over a new surface water reservoir, including lower costs, phased development, minimal land uptake and low visual impact.

The SGS scheme consists of eight phases of wellfield construction, testing and commissioning. Phase 1 was completed in the early 1980s followed by Phases 2 and 3 in the mid to late 1990s. Phase 4 is in progress and Phase 5 is scheduled for completion before the end of 2001. All the wellfields are in

Northern Shropshire and the wells are completed in the Permo-Triassic Sherwood Sandstone Aquifer. Part of the aquifer in the SGS area is confined by Boulder Clay. Recharge to the aquifer is estimated to be about 205,000 m^3/day. As each new well is installed, step and constant rate pumping tests are completed to characterise the aquifer system and determine optimal well yields. Sustainable yields are determined and permanent pumping facilities are designed accordingly.

Augmentation of the Severn begins when measured flow at Bewdley is less than 850 Ml/d. The maximum release from Clywedog Reservoir is 500 Ml/d, and operation of the SGS commences when demand exceeds this. The presentation finished with an overview of the environmental monitoring carried out by the Agency. This includes regular stream gauging and water quality measurement in the SGS area. Soil moisture monitoring is extremely important for crop protection. There are no measured impacts to the environment arising from the SGS.

Paul Martin and **Colin Richardson** of South Staffordshire Water (SSW) jointly gave the second presentation, on the Hampton Loade water treatment works and Chelmarsh Reservoir. Paul is Supply Manager for SSW, and Colin is the Manager of Hampton Loade works. They began with an overview of SSW, which was formed in 1853, when the company was pumping clean water from Lichfield to the Black Country. Now it supplies about 330 Ml/d, and operates two major treatment works with a combined output of up to 200 Ml/d, the rest being supplied mainly from groundwater sources. The Hampton Loade works provides about 39% of water supplied in the South Staffordshire area.

Abstraction and works licences were granted in 1963 to abstract and treat water from the River Severn at Hampton Loade. The facility was subsequently constructed, and was commissioned in 1966. The key operational aspects of the works were explained. Coarse screening takes place at the intake on the River Severn, and water is transferred to Chelmarsh bankside storage reservoir. From here, water goes to the main works and is treated for potable supply, using a system of clarifiers, 18 sets of filters and finally disinfection. Sludge generated during the treatment process is stored on-site for six months and then disposed of to land. The treated water is transferred to Sedgley reservoir using high-capacity pumps: these are needed in order to pump against a head of 230m. River abstraction is closely monitored for both quality and quantity, and control processes are used to ensure that operations remain within licence agreements. The use of historical data is important for forward planning.

The final part of the talk focused on the important role of Chelmarsh reservoir within the system. It provides improvement in water quality by acting as a settlement pond to reduce suspended solids prior to treatment. It also acts as a balancing facility that allows treatment and pumping during off-peak hours, significantly reducing operating costs. The reservoir does allow for some reduced abstraction from the Severn during periods of low flow, although the storage capacity of the lake is small compared with the annual output of the Hampton Loade works.

Matthew Hudson (Severn Trent Water, Water Strategies) gave the final presentation, on the Birmingham Groundwater Scheme. He started with some background to the scheme. Water supply and demand forecasts for the Birmingham area show that demands continue to increase while predicted available resources are decreasing, particularly during dry years. Climate change is considered to be a factor in supply and demand forecasting. The Birmingham Groundwater Scheme was established to augment river flow in the Trent catchment, through the abstraction of groundwater, with the objective being to permit continued use of river water for public water supply.

Severn Trent Water has a commitment to develop a first phase groundwater scheme with an output of about 30 Ml/d. An objective of this scheme will be to help maintain flow in the River Trent above the 2500 Ml/d minimum prescribed flow at Colwick. The scheme will be developed in the Birmingham groundwater unit, consisting of Permo-Triassic Sherwood Sandstone, where the available resource is estimated to be about 44 Ml/d. Groundwater levels in the Birmingham aquifer unit are recovering thanks to major reductions in abstraction over the past 30 years, from about 60 Ml/d during the 1960s down to current rates of about 10-15 Ml/d. Because groundwater levels in the aquifer are rebounding, some over-exploitation of the resource could be tolerated.

Water quality issues are important to the scheme. In general the unconfined aquifer water is calcium-bicarbonate type and groundwater from the confined section of the aquifer is more mineralised. There are groundwater contamination issues close to areas of historic industrial activity. At the moment the project is at an early stage: key project elements include the licensing of abstractions, discharge consents and planning permission for development works. Sites are being identified for drilling and construction of wells and one site has already been purchased.

The idea behind holding a Midlands Section meeting in Shrewsbury was to make it more accessible to the many water-related professionals based there. Several consultancy companies, the Environment Agency and Severn Trent Water all have offices in Shrewsbury. The good turnout fully justified the idea, and it may become a regular fixture. The Midlands Section would like to thank Severn Trent Water for providing their excellent facilities free-of-charge for the meeting.

Jeremy Dowling
Water Management Consultants Ltd

The estimation of low flows

Scottish Hydrological Group Meeting
Edinburgh
14 March 2001

The Scottish Hydrological Group were delighted to welcome **Alan Gustard** and **Andy Young** from CEH Wallingford to one of their evening meetings, where they presented a paper titled 'The estimation of low flows: a UK and international perspective'.

The presentation was in two parts. Alan first focused on the motivation for continued research into low flows, and then described low flows studies currently being conducted by CEH outwith the UK. Andy followed this with a technical discussion on the latest techniques proposed by CEH for estimating low flows in the UK.

Alan stressed that the commissioned low flows research within CEH is not driven by some 'blue sky' desire to understand processes, but rather by a host of current and impending water resource problems. The examples he presented included the effects of groundwater abstractions on low flows, water quality issues and the impacts of climate change.

In order to address these problems, new research will have to be targeted towards estimating flows in ungauged rather than gauged catchments, estimating time series of low flows rather than statistics, and on continental-scale water resource problems rather than on small sub-basins.

The progress of CEH low flows research in addressing these goals was demonstrated by an impressive list of international projects, two of which were singled out for further discussion. The first, built on the strengths of the FRIEND European Water Archive, was the production of a pan-European map, comparing low flows with urban water demand. The surprising result was that water resources in some of the heavily populated areas of Northern Europe are just as stressed as areas such as the Iberian Peninsula, traditionally thought of as being the most vulnerable. The aim of the second project was to assess the effects of climate change on low flows produced by snow and glacier melt in the Himalayas. The slides that accompanied this part of the presentation made most of the audience green with envy at the thought of the field trips that it had entailed.

Andy then described the research and development of new low flows estimation procedures that have been incorporated into the Low Flows 2000 software. The focus has been on enhancing the methods used to estimate low flows in ungauged catchments.

Andy demonstrated the new approach by considering low flows that are likely to be exceeded 95% of the time (Q95%). Firstly a set of gauged catchments that are deemed to have similar low flow characteristics are identified on the basis of a vector of hydrogeological variables (HOST classifications). The similarity of a gauged catchment to an ungauged catchment is measured by the Euclidean distance between the vectors that are used to describe them. For each of the gauged catchments the Q95%, as a fraction of mean flow (Q95% MF), is retrieved from a database. These values are used in a linear relationship to estimate Q95% MF for the ungauged basin: they have to be rescaled using an estimate of mean flow. In the Low Flows 2000 software, mean flows have been derived from a simple, regionalised time series water balance model. Andy went on to demonstrate the improved results obtained and the user-friendliness of the software.

The presentation provoked a wide variety of questions from **David Price** (Babtie), **Tim Jolley** (SEPA), **Bayo Adeloye** (Heriot Watt) and **Peter Eves** (Mott McDonald), as well as others. It was obvious from the discussion that the audience had appreciated the presentation.

Bill Sloan
University of Glasgow

United Utilities

Hydrologist

Warrington, Cheshire

£20-22.5k (plus bonus)

United Utilities is seeking a qualified and experienced hydrologist to join its water resources team within the Asset Management directorate. United Utilities owns 160 impounding reservoirs, 55 river abstractions, and 68 borehole sites, and operates major water resource systems in North Wales, the Lake District, and the Pennines. Our regional aqueduct systems have been developed to provide a highly integrated regional supply network.

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You should have a good first degree in a relevant subject, a master's degree in water resources, and at least 3 years' relevant work experience.

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The closing date for applications is 11 June 2001.

Equal consideration will be given to all applicants irrespective of sex, race, creed or disability.

United Utilities is the new name for North West Water

C+ Circulation PLUS

Irish floods, changing climate and Generalised Linear Models

The second C+ comprises an article by Richard Cross on the Environment Agency's use of weather radar in the Midlands, and one possible approach to studying extremes in a changing climate, based on an Irish case study by Richard Chandler. Have you an item to offer for the next issue of C+? Perhaps there is something that you wish to share with other members, but it is not appropriate for publication in a formal Journal. Why not send it in?

Richard E. Chandler
University College London

It is widely accepted that the frequency of "extreme" weather events has increased during the last decade in Europe. The recognition that severe event frequencies can vary on long timescales has consequences for practitioners in many disciplines. In hydrology in particular, the notion of a "return period" becomes difficult to interpret. This article discusses one possible approach to the study of extremes in a changing climate, with reference to a specific case study involving flooding in the West of Ireland.

The study itself was instigated by the Irish Office of Public Works (OPW), following a succession of large floods in the Galway Bay area (see Figure 1). This is a low-lying Karst system, which is subject to some flooding every year. However, the events in 1990, 1991, 1994 and 1995 were exceptionally severe and caused considerable hardship. In response, the OPW commissioned an extensive study whose objectives were: (a) to determine the causes of the flooding (a number of competing explanations had been suggested), and (b) to investigate the likely effectiveness of possible alleviation measures. Under the direction of **Denis Peach** (now at BGS Wallingford), a multidisciplinary team was assembled, with fields of expertise ranging from ecology to economics. The rainfall analysis was undertaken predominantly by **Howard Wheater** (Imperial College) and myself. The project ran from September 1995 to October 1997. It has stimulated a lot of subsequent activity within our research group, and the rainfall dataset continues to play a major role in our work.

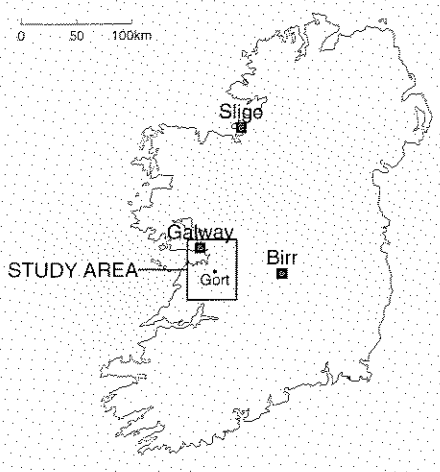


Figure 1 Map of Ireland, showing the Galway Bay study area. Long monthly raingauge records were available from Birr and Sligo.

Figure 2 provides convincing evidence that the primary cause of the flooding was a succession of extremely wet winters. The top panel shows the average winter (December, January and February) rainfall over the study area between 1941 and 1995, as measured by a network of daily raingauges. The winter rainfalls in the last few years are unprecedented in the daily record, but appear to relate to an increasing trend since the mid-1960s. A longer monthly record from Birr (bottom panel) shows similar features, but also indicates that the rising trend may represent nothing more than a return to levels that were perfectly normal in the first half of the 20th century.

Having determined that the flooding episodes are associated with extreme rainfall events, it is of interest to determine whether there is evidence of a systematic change in the area's rainfall patterns, and if so to determine its nature and extent. The high variability in daily rainfall records means that changes are difficult to detect; however, clearer signals emerge at timescales of 1 to 3 months as Figure 2 shows. Unfortunately, analysis of monthly data was not an option for this study, since an additional requirement was the provision of synthetic daily rainfall sequences for input to hydrological and hydrogeological models, in order to investigate potential flood alleviation methods. Hence, it was necessary to adopt a methodology that can (a) detect weak signals in noisy data, and (b) allow the generation of realistic synthetic sequences.

One such methodology is that of Generalised Linear Models (GLMs). The idea is: for each site and on each day, to forecast a probability distribution for the rainfall using various relevant predictors, whose values are known. Such predictors might include previous days' rainfalls at the site, as well as variables representing seasonality, regional variation, long-term trends and 'external' factors such as the North Atlantic Oscillation (NAO). In practice, it is the mean of the forecast distribution that is related, usually nonlinearly, to the predictors. GLMs for rainfall normally involve a logistic regression model to forecast a probability of rainfall occurrence, and then gamma distributions for the amount of rain if non-zero.

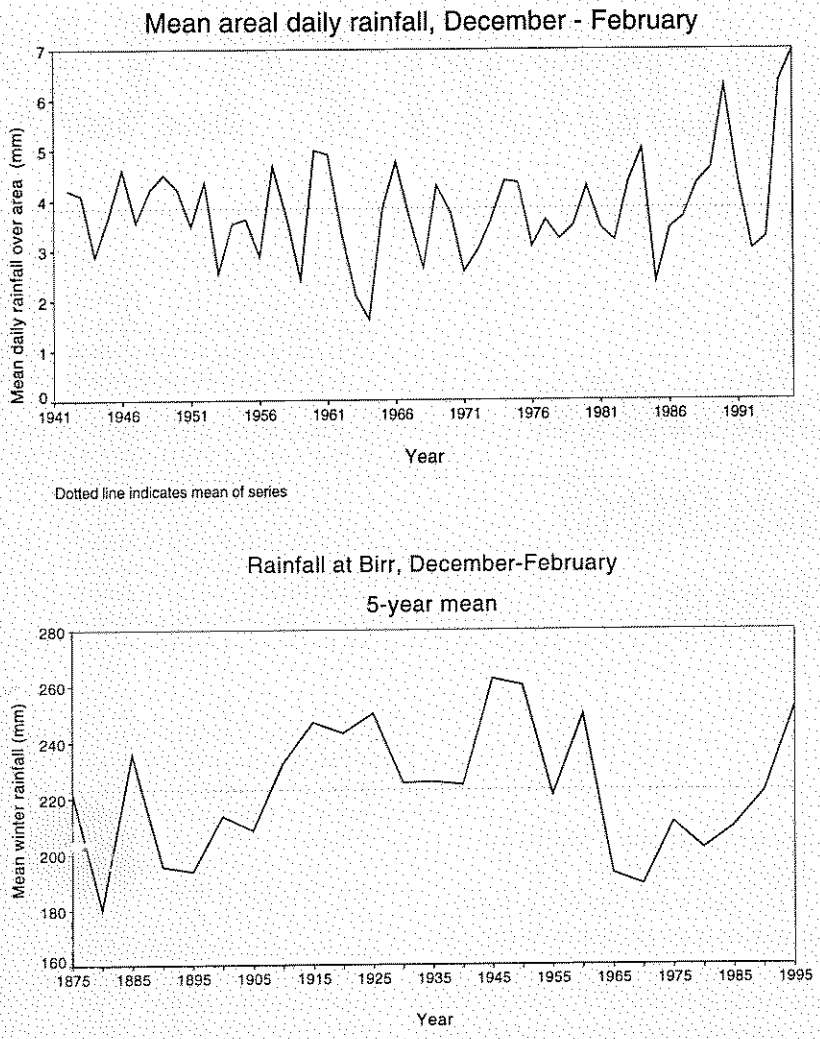


Figure 2 *Top: mean winter rainfalls for Galway study area, 1941-1995. Bottom: 5-year averages of winter rainfalls at Birr, 1875-1995. The 5-year averaging has been performed to smooth out high-frequency variability in this series from a single site.*

The benefits of GLMs for this type of application are numerous. Firstly, a powerful likelihood-based toolkit is available for parameter estimation, hypothesis testing (important for determining the strength of evidence for changing climate) and construction of confidence intervals. Secondly, all of the models' assumptions are easily checked using simple residual plots. Thirdly, interactions between predictors can be modelled. These tell us a lot about the mechanism producing the data. Interactions between previous days' rainfalls and predictors representing seasonality, for example, indicate seasonal structure in the autocorrelations; this reflects the increased relative frequency of convective rainfall in summer.

The final advantage of the approach is that GLMs are very cheap to simulate. Figure 3 is an example of the kind of output that can be obtained. This was produced by simulating 1000 daily rainfall sequences from January 1989 to December 1997. For each sequence, the winter rainfall in each year was calculated, whence simulated winter rainfall distributions were obtained. The observed winter rainfall series is also shown. The predictors here include previous days' rainfalls, seasonality, regional effects, the NAO and residual trends (there has been speculation that recent extreme weather in Northern Europe has been associated with enhanced NAO activity, but our analysis suggests that the NAO alone is not responsible for all of the rainfall enhancement in this area). The interesting points here are (a) the extent to which the rarity of the floods can be assessed using the simulations and (b) the simulations' response to changes in the NAO. For example, the 1990, 1994 and 1995 events are all in the upper 5% area of the simulated distributions, but they do not look 'extreme'; we would not be surprised if such events recurred. However, the simulated distributions for 1996 and 1997 are much lower than in previous years; this reflects a decrease in the strength of the NAO.

GLMs have been widely used in statistics since the early 1970s, but their full power has not yet been fully exploited in hydrology or climatology. By explicitly incorporating external factors into the rainfall models, and treating all values as being drawn from different probability distributions, we are able to enhance our understanding of where extreme events are coming from, and to use simulation to make informed judgements regarding future rainfalls in a changing climate. For example, Figure 3 tells us that a 1995 flood is perhaps not so unusual as a conventional return period estimate based on the top panel in Figure 2

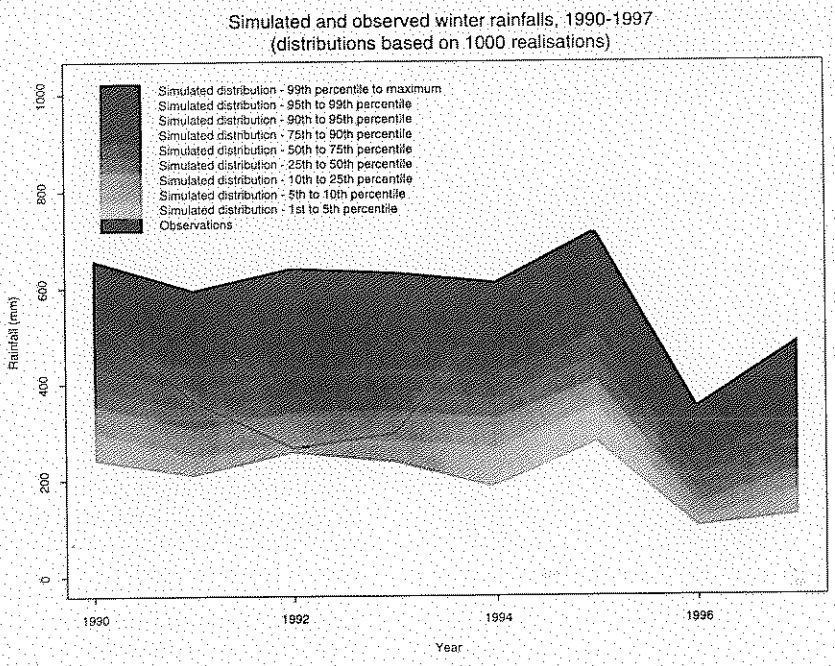


Figure 3 *Simulated and observed winter rainfalls for Galway, 1990-1996: simulated distributions are obtained from 1000 realisations.*

would suggest — although perhaps it does not fully support John Prescott's statement that "Extreme events will be the norm" (*The Guardian*, 1 November 2000)!

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Software

FORTRAN code for implementing the GLM methodology is available, free, from *http://www.ucl.ac.uk/~ucakarc/work/rain_glm.html*.

Current and future requirements of weather radar use in the Midlands Region

Richard Cross
Environment Agency

Quantitative use of weather radar data for flow forecasting relies on improvements being made in data quality. The Environment Agency's National Weather Radar Project Group is seeking these improvements through an Agency/Met Office ten-year plan for the weather radar service. The plan is to rationalise the management of the network and to improve quantitative radar performance through hardware and software upgrades. This is a summary of the present and possible future use of weather radar products in the Agency's Midlands Region, including options for quantitative use of radar data if data improvements occur.

Current use of radar data

Displays

Four radar data products are received at the regional office at Solihull on one BT private circuit, linked to the Birmingham Weather Centre. A Macroradar system sends all four radar products to eight remote Microradars, distributed on the Wide Area Network. The same data is available on ten dial-up Microradar laptops that log in to Macroradar.

Single site radar data from Clee Hill and Ingham are also available on demand via the Flow Forecasting System front end (REMUS), both in image and data forms. This means that >80 PCs, including remote terminals, using PSTN and Network links, can download single site radar data.

Network radar datastreams are available on all Microradars both networked and dial-ups. The Region has received Met Office NIMROD forecast data for the last three years. The data are derived into totals for 23 sub-areas for display on receiving Microradar PCs and for quantitative use by flow forecasters. Data are also sent to the flow forecasting VAX and displayed using REMUS.

There is currently no method of receiving or displaying NIMROD single site data.

Use in forecasting

Single site radar images display a qualitative estimate of rainfall over Wales and most of England. Start, duration and end of rainfall patterns provide the Monitoring and Forecasting Duty Officers with information which enables them to set appropriate data collection and modelling regimes and identify where potential flooding problems may occur.

Quantitative estimates of rainfall are derived from 5km x 5km pixels of rainfall intensity data into subcatchment areas corresponding to those modelled by the flow forecasting system. The data are not currently used in real time, but this datastream is displayed alongside raingauge-derived subcatchment totals in REMUS. This software also calculates the ratio of raingauge to radar derived areal rainfall for each of 80 subcatchments. The data are not routinely archived, but a 96-hour window of data is available on any REMUS PC at any time. Archiving of comparisons does occur after exceptional rainfall and when the Duty Officers observe large discrepancies between the two data streams.

Network data are used only qualitatively and complement the single site radars by giving a broader view of approaching rainfall covering most of the UK. The data are used to determine polling and modelling regimes in the same way as the single site images.

Forecast rainfall data from NIMROD are routinely incorporated into real-time model forecasts covering over 100 catchments. The NIMROD data stream is derived into hourly rainfall forecast profiles for up to six hours ahead over 23 sub-basins, each covering up to five flow forecasting system subcatchments. The benefits of NIMROD forecasts to the Midlands Region include increased warning lead-times for the existing service.

Shortcomings

The flow forecasting model code could, use the radar derived subcatchment areal rainfall, but does not do so currently because there are perceived inconsistencies in data quality. Clee Hill data are known to be poor over the Welsh Mountains, where rainfall develops below the radar beam. The radar signal is also blocked by local buildings, which means rainfall is underestimated in a small sector to the west of the aerial. Ingham radar is mainly used for the urban areas of the East Midlands. However, these areas fall at a distance from both Clee and Ingham. The Long-Range Calibration Study (LORCS) based on Ingham data gives details of the problems associated with performance

of Ingham radar particularly at a distance. The report also details the failure of the radar's data to achieve a strict hydrological standard.

Future requirements

Communications

Maximum data transmission speeds from the Met Office are currently only 2400 baud. Receipt of radar data via a more robust, reliable and fully supported (24hours, 365 days) method would be one way of increasing data reception speeds and make for wider and more timely use of the data. A national project is under way to address the issue of streamlining radar data delivery to the Agency.

Hardware/interface displays

The Region has prepared a user specification for the next generation of data gatherer and flow forecasting system (to be installed in 2002). Display options could include bespoke display software or 'off the shelf' packages or a combination of these. The timing of the proposed system specification lends itself to being led by recommendations of best practice for radar display as defined by the Agency's National Radar Group.

Use in forecasting

The planned upgrades to single site radars proposed under the National Radar Project could mean single site radar data are acceptable for use as an input to flow forecasting models. Upgrading performance to that of the Chenies radar would give greater confidence in using these datastreams as model inputs. Local calibration of radar subcatchment data, using raingauge data from the Region's extensive network, could be used to refine the raw radar datastream further. (Depending on the technique applied, this may require 0.5mm raingauge bucket sizes to be reduced to 0.2mm.)

Residual errors in radar data would be minimised by combining the radar and raingauge data. This could be achieved under development of the new data gatherer or using one of a number of techniques/systems that are available commercially.

Alternatively, the use of NIMROD single site subcatchment data would remove many of the weak spots in raw single site data and therefore give a more reliable model input without the need for local calibration.

The anticipated improvement in areal rainfall derivation from either of these two methods will have benefit to flow forecasts, especially those in areas prone to flooding from localised rainfall, as the current derivation suffers from sampling errors associated with deriving areal rainfall from point estimates.

Potential benefits of NIMROD forecast radar data that have not yet been exploited include extension of forecasting to fast response catchments in upland and urban areas. In extending flow forecasting to such localities there is a place for proven systems that can confidently estimate rainfall associated with short-lived intense convective systems (i.e. GANDOLF-type systems).

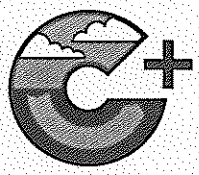
Local calibration of radar data or incorporation of NIMROD actuals into the modelling system will require investment in software. It would be preferable to adopt a system that could be used in the replacement modelling system due in 2002.

Met Office NIMROD products could benefit from the use of data from the Agency's real-time telemetry raingauge network. The way forward will be determined by the outcome of the joint Agency/Met Office project on the exchange of data.

Richard Cross
Environment Agency
Midlands Region, Solihull

[The original version of this article was drafted for an internal National Review of radar use in the Agency to form part of the Agency's radar strategy when Richard Cross was a member of the internal National Weather Radar Group. Other regions of the Agency use radar data in similar ways but only the Midlands Region routinely uses forecast NIMROD data in real-time forecasting. It will be useful to gauge the response of BHS members to the contents of this note and Richard hopes that it will generate some discussion, either through Circulation or directly with him.]

Have you found this section interesting? If so, why not send in a contribution for a future edition of C+?



One-day National Meeting

Continuous river flow simulation: methods, applications and uncertainties

to be held at the Centre for Ecology and Hydrology, Wallingford, Oxfordshire on *Thursday 5th July 2001*, from 10.00 a.m. to 5.45 p.m.

Cost, including a buffet lunch and refreshments: BHS Members £40, Non-members £50, Students/non-earning £20. Advance registration is essential.

Please see the loose-leaf Programme and Registration Form included with this issue of Circulation and return it to Tim Fuller by 25th June.

New members

We welcome the following new members to the Society:

Caroline L Anderton	Ewan Associates Ltd, Banchory, Kincardineshire
Emma L Bateman	Mott Macdonald Ltd, Cambridge
Dr Eleanor M Blyth	CEH Wallingford
Donna Bower	School of Geography & Environmental Sciences, University of Birmingham
Rory Callan	Environment Agency, Wallingford
Richard Crowder	Bullen Consultants Ltd, East Morton, W. Yorkshire
Roberto Fraile	Dept of Computer Science, University of Reading
Dr Peter Glanville	John Barnett & Associates, Dublin
Atul Haria	CEH Wallingford
Ned Hewitt	CEH Wallingford
Melissa Jenking	Truro, Cornwall
Dr Sergio Koide	University of Brazil, Brasilia
Peter Latimer	JBA Consulting Engineers & Scientists, Otley, W. Yorkshire
Colin K Patrick	Milnthorpe, Cumbria
Russell M S Smith	Dept of Civil & Environmental Engineering, Imperial College London

New PhD

Congratulations to **Hayley Fowler**, who has recently completed her PhD, on 'the impacts of climatic change and variability on water resources in Yorkshire', at Newcastle University.

Abstract

Observational evidence and future climate change scenarios suggest an amplification of climatic contrasts across the UK. This is seen most prominently in the marked increase in notable flood events and drought episodes and may profoundly affect water resource systems in vulnerable areas, as exemplified by the 1995 Yorkshire drought. The 1995-96 drought resulted in severe stress to the Yorkshire water supply, necessitating the emergency measure of tanking in water from outside the region, and was caused by an unusual pattern of weather and precipitation.

This research is an investigation into both natural climatic variability and possible future climate change in Yorkshire aiming to quantify the risk of future occurrence of severe drought events, such as that of 1995. Historical drought characteristics and spatial-temporal precipitation variability in Yorkshire are examined and linked to synoptic weather patterns. A multi-site stochastic rainfall model is then developed using conditioning by synoptic weather types.

The model can account for spatial variability and allows the concurrent simulation of precipitation time-series for very different climatological sub-regions within the same water resource area. This model is used to investigate the impact of natural climatic variability and possible future climate change upon water resource reliability, resilience and vulnerability in Yorkshire.

The structure of the stochastic rainfall model enables the impact of variations in weather type persistence or frequency to be investigated. In addition, rainfall model statistics can be altered to simulate instances of increased precipitation intensity or proportion dry days for example, for individual weather groups. The UKCIP98 Medium-High climate change scenarios for 2021-2050 and 2051- 2080 are investigated using modifications to weather type frequency, precipitation and potential evapotranspiration. Results indicate that water resources in Yorkshire are likely to become more reliable on average under the examined climate change scenarios due to increased winter precipitation.

However, model simulations also suggest a reduction in resource resilience and increased vulnerability to drought. Severe droughts comparable to that of 1995 show only a slight increase in frequency by 2080. However, there will be a significant increase in both magnitude and duration of severe drought, as a consequence of summer precipitation reductions and increased climatic variability.

Anyone interested in this research or any of the papers, or doing similar research, is invited to contact Hayley at WRSRL, Dept of Civil Engineering, Cassie Building, University of Newcastle Upon Tyne, NE1 7RU *(Tel: +44 (0)191 222 8599 Fax: +44 (0)191 222 6669 E-mail: h.j.fowler@ncl.ac.uk)*

Publications

Fowler HJ & Kilsby CG 2001. A weather-type approach to analysing water resource drought in the Yorkshire region from 1881-1998. Submitted to *J. Hydrol.*

Fowler HJ & Kilsby CG 2001. Precipitation and the NAO – a study of climatic variability in northern England. Submitted to *Internat. J. Climatol.*

Fowler HJ, Kilsby CG & O'Connell PE 2000. A stochastic rainfall model for the assessment of regional water resource systems under changed climatic conditions. *Hydrol. & Earth System Sci.* 4, 263-282.

Book review

'Rainfall-runoff modelling – the primer' by Keith Beven. John Wiley & Sons Ltd, 2001. ISBN 0471985538, hardback, 360 pp, price £40.

This book makes a refreshing change from the recent trend of producing books consisting of a group of rehashed papers, linked by some lowest common denominator, in that it has an extremely readable narrative. Inevitably, certain areas of the field are covered more comprehensively than others, but Keith Beven's almost encyclopaedic knowledge of the rainfall-runoff modelling literature means that there are very few gaps.

The readability is enhanced by separation of the mathematical detail from the main text, making the book accessible to a wider audience, including regulators, who are often responsible for making important decisions regarding model choice. The great strengths of the book are the way important developments in this field are described in a jargon-free manner; the highly comprehensive review of literature published over the last 30 years, which provides pointers to readers wishing to implement methods or investigate particular research areas further, and (as you would expect) there is an excellent discussion of modelling methodology, including a call to place uncertainty estimation at the heart of the modelling process.

This is an essential purchase for anyone involved in rainfall-runoff modelling work, but it will be of most use to postgraduate students starting out on a career in hydrology. However, in terms of more immediate impact, it could also make a great contribution to narrowing the communication gap between researchers and practitioners, if the latter group could find time to read, if not the whole book, at least the first three chapters plus the concluding comments.

Matthew Lees
Queens' College, Cambridge

Publications

HSJ contents

The two latest issues of the *Hydrological Sciences Journal* (Vol. **46**, Nos. 2 and 3) contain the following papers:

Vol. 46 No. 2, April 2001:

Serwan M. J. Baban & Kamaruzaman Wan Yusof: *Modelling soil erosion in tropical environments using remote sensing and geographical information systems*

A. Mahesha: *Effect of strip recharge on sea water intrusion into aquifers*

Gil Mahé, Yann L'Hôte, Jean Claude Olivry & Geoffroy Wotling: *Trends and discontinuities in regional rainfall of West and Central Africa, 1951–1989*

Francisco Sánchez-Martos, R. Jiménez-Espinosa & A. Pulido-Bosch *Mapping groundwater quality variables using PCA and geostatistics: a case study of Bajo Andarax, southeastern Spain*

Yadh Zahar & Jean Pierre Laborde: *Génération stochastique d'averses et de leurs index d'érosivité pour la simulation de la dynamique érosive en Tunisie centrale*

Zekai Sen & Ahmet Oztopal: *Genetic algorithms for the classification and prediction of precipitation occurrence*

Hafzullah Aksoy, Mehmetcik Bayazit & Hartmut Wittenberg: *Probabilistic approach to modelling of recession curves*

Ognjen Bonacci: *Monthly and annual effective infiltration coefficients in Dinaric karst: example of the Gradole karst spring catchment*

Emma L. Tate, Kevin J. Sene & John V. Sutcliffe: *A water balance study of the upper White Nile basin flows in the late nineteenth century*

Plus book reviews of *The blue revolution: land use and integrated resource management* (Ian Calder), *Inventory of the Himalayan Glaciers*, *Artificial Neural Networks in Hydrology* (R. S. Govindaraju & A. Ramachandra Rao), and *The Perspectives on Flood 1998* (ed. Q.K. Ahmad, A.K.A. Chowdhury, S.H. Imam & M. Sarker).

Vol. 46 No. 3, June 2001:

Surendra Kumar Mishra & Vijay P. Singh: *On the Seddon speed formula*

Kwan Tun Lee, Chin-Hsin Chang, Ming-Sang Yang & Wie-Sheng Yu: *Reservoir attenuation of floods from ungauged basins*

Yeshewatesfa Hundecha, András Bárdossy & Hans-Werner Theisen: *Development of a fuzzy logic-based rainfall–runoff model*

Bellie Sivakumar, Ronny Berndtsson & Magnus Persson: *Monthly runoff prediction using phase space reconstruction*

Magnus Persson, Ronny Berndtsson & Bellie Sivakumar: *Using neural networks for calibration of time-domain reflectometry measurements*

Armando Brath, Attilio Castellarin, Marco Franchini & Giorgio Galeati: *Estimating the index flood using indirect methods*

C. K. Jain: *Adsorption of zinc onto bed sediments of the River Ganga: adsorption models and kinetics*

Ray Kostaschuk, James Terry & Rishi Raj: *Tropical cyclones and floods in Fiji*

Jacques Callède, Pascal Kosuth & Eurides de Oliveira: *Etablissement de la relation hauteur–débit de l'Amazone à Óbidos: méthode de la dénivelée normale à "géométrie variable"*

Jaime Garatuza-Payan, Rachel T. Pinker, W. James Shuttleworth & Christopher J. Watts: *Solar radiation and evapotranspiration in northern Mexico estimated from remotely sensed measurements of cloudiness*

Plus book reviews of *The hydrology of the UK— a study of change* (edited by Mike Acreman), *Upscaling and downscaling methods for environmental research* (edited by Marc F. P. Bierkens, Peter A. Finke & Peter de Willigen), *Water Resources Engineering* (1st edn) by Larry W. Mays, *Open-Channel Flow* (Subhash C. Jain) and *Groundwater 2000* (edited by Poul L. Bjerg, Peter Engesgaard & Thomas D. Krom).

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Members wishing to refer to these or other publications may contact the National Hydro-Sciences Library at CEH Wallingford *(tel 01491 692266).*

Advertising rates

The standard rates for advertising in *Circulation* are as follows:

Full page	£250
Two-thirds	£170
Half-page	£130
One-third	£90
One-sixth (minimum)	£50

Loose inserts (other than BHS-related notices) may be included / charged at the Committee's discretion.

Holistic hydrology: looking at the bigger picture

BHS Midlands Section Meeting
28 March 2001
Loughborough University

This half-day East Midlands Meeting brought together four speakers and six posters spanning the interfaces between hydrology and climatology, geomorphology and/or ecology. The presentations showed clearly the benefits to hydrological understanding of "looking at the bigger picture" — that is, adopting an interdisciplinary approach and considering the role of processes operating at a range of spatial and temporal scales. The meeting, organised by *Paul Wood* and chaired by *Ian Reid* (both of Loughborough University) drew over forty people.

Paul Wood led off the afternoon with a presentation entitled "Hydroecological variability within a groundwater-dominated river". This focused upon changes in the macroinvertebrate community in response to climatic and river flow variations over six years (1992-1997) for the Little Stour River, Kent. A suite of hydroclimatic conditions was experienced during this period, including the final year of the 1988-1992 drought and relatively wet conditions between 1996 and 1997.

Macroinvertebrate samples were collected at 15 sites in the first week of September each year. Correspondence analysis identified clear differences between samples upstream ('natural' sector) and downstream (impacted sector) of the confluence with the tributary River Wingham, and also between drought and non-drought years. Application of stepwise multiple regression identified hydroclimatological indicators of community variation. For standardised (between-site) macroinvertebrate data, hydrological conditions are dominant in explaining ecological variation. Notably, indices of high discharge 4-7 months before sampling (i.e. winter-spring) were found to be the most important variables for describing the summer low flow community. Paul highlighted the need for rigorous collection of long-term, overlapping biological and physical datasets to further our understanding of hydroecological processes.

Jill Labadz (Nottingham Trent University) continued the hydro-ecology theme with a paper on the "Impacts of quarry discharge upon a raised bog ecosystem". This considered the impacts of falling water tables (due to peripheral drainage) and the influx of water pumped from an adjacent quarry upon Swath Moor, North Yorkshire. Integrated hydrological and ecological monitoring has provided baseline information for the site since 1996. Water level in one of the watercourses draining the bog was manipulated during the summer months, and the impact of quarry discharge upon water quality, macroinvertebrate communities and sedimentation rates was investigated. Together, these datasets allowed the scope for habitat restoration to be assessed. Dipwell results showed that low water tables are an issue close to peripheral drains, but not in the centre of the mire dome or in the fen/pool area. The best management solutions for this problem were shown as: (1) maintaining the volume of pumped water from the quarry but improving water quality, and (2) installing artificial blockages in the drains to maintain the highest possible water levels. Jill stressed the benefits of a whole system approach in assessing the hydrological problems.

During the mid-session coffee break, six posters were presented. Topics included: the water balance for a reedbed (**Kate Barbour** and **P.B. Leeds-Harrison**, Cranfield University); hydrology, soil aeration and nutrient status of grassland (**Catherine Peacock** and **Tim Hess**, Cranfield University); visualisation of coherent flow structures (presented by Ian Reid on behalf of several co-authors); hydroclimatology of a glacierised basin (**David Hannah**, University of Birmingham); river flow forecasting using Arctic sea-ice anomalies (**Cara Wedgbrow** (University of Derby), and grain size and macroinvertebrate communities in gravel-bed rivers (**Steve Rice** and **Malcolm Greenwood**, Loughborough University, and **Chris Joyce**, University

of Brighton). These posters reinforced further the meeting's strong cross-disciplinary theme.

After the poster session, **Rob Wilby** (on his final day at the University of Derby before moving to King's College London) explored the "Prospects for seasonal river flow forecasting in the UK". This paper demonstrated the potentially useful forecasting relationships between large-scale North Atlantic ocean-atmosphere indices in winter (January-February) and the following summer's (July-September) monthly mean flows for eleven British rivers. Rob also presented significant correlations between the North Atlantic Oscillation Index (NAOI), the Polar Eurasian teleconnection pattern and North Atlantic sea surface temperatures and gridded Palmer Drought Severity Index (PDSI) data for June to November over the UK.

The results for river flows suggested that up to 40% of the variance in August monthly mean discharge might be explained by the NAOI. Furthermore, for two groundwater-dominated rivers in southern and eastern England, positive phases of the winter NAOI were found to precede summer flows that were nearly 50% of long-term average. An inflated regression model to predict August flows in the Great Stour yielded a correlation score of 0.6 at a lead-time of six months. Interestingly, this lead-time was comparable to that suggested as most important in predicting summer low flow ecology for the Little Stour earlier in the afternoon (see above). River flow forecasts were shown to be spatially variable depending upon catchment characteristics and location with respect to the dominant patterns of North Atlantic atmospheric forcing.

The final presentation, by **Chris Bradley** (University of Birmingham), was entitled "Wetland water fluxes: Integration of fieldwork and modelling results". Chris reported some initial findings of a recently-completed, two-year hydrometeorological monitoring programme on the Insh Marshes, Speyside, a major wetland of international importance, more than 1000 ha in area, and one of the largest and most important floodplain wetlands in Northern Britain. It was designated a Site of Special Scientific Interest in 1963 and is managed by the RSPB.

The original intention of this field programme was to focus upon movements of water through the unsaturated zone above a fluctuating water table. However, thanks to unusually wet conditions during the study period (which Chris illustrated with some impressive slides), the emphasis changed to consider variations in soil-water pressure and periodic changes in the direction of water movement. The results showed the relationship between moisture content and key hydraulic properties of soil profiles typical of the wetland and showed how this relationship varies laterally along a transect. The field data are to be used to inform the development of a model to simulate the hydrological dynamics of a floodplain wetland.

Ian Reid summed up some of the general issues raised, thanked the presenters for the variety of talks and posters, and acknowledged the efforts of Paul Wood in organising the event.

David M. Hannah
University of Birmingham

News from members

Members on the move

Claire Hammond, who has been representing the Welsh Hydrological Group on the main committee, has now moved from Cardiff to work for WS Atkins in Epsom, Surrey *(email chammond@wsatkins.co.uk)*.

Dr Rob Wilby has moved from the University of Derby to a Lectureship at the Department of Geography, King's College London, and looks forward to contributing to the research endeavours of their Environmental Monitoring and Modelling Group. Contact Rob at KCL, Strand, London WC2R 2LS *(tel 020 7848 2632)*.

Michael Cranston has recently taken on the responsibility of Hon. Secretary of the Scottish Hydrological Group. Michael is senior hydrological consultant with Mountain Environments in Scotland, and previously worked with SEPA and the Institute of Hydrology. He can be contacted by telephone *(01877 331080)* or email *(mdcranston@mountain-environments.co.uk)*. For more information on the Scottish Hydrological Group visit the web site at *http://www.dundee.ac.uk/geography/shg*.

New Fellows

Congratulations to **Frank Law** (Past President) and **Dr Ann Calver** (Head of the Risk and Hydrological Extremes Division at CEH Wallingford) who have recently been made Fellows of the Institution of Civil Engineers.

Reintroducing HOMS: WMO's Hydrological Operational Multipurpose System

Members who have been around for a while may well be aware of HOMS, but newer members might not. HOMS is now on the Internet *(http://www.wmo.ch/web/homs/homshome.html)*. A visit to the HOMS website is strongly recommended in order to become familiar with it and find out what it does.

Briefly, HOMS is a network of some 120 HOMS National Reference Centres (HNRCs) around the world. The HOMS Office of the World Meteorological Organization Secretariat in Geneva manages the HOMS Reference Manual (HRM), with inputs from the HNRCs. The HRM comprises 'components' — details of instruments, computer software, manuals, training material, etc. — related to hydrology and water resources. HRM components need to be of proven efficacy and in regular use in a country, and should be transferable to meet the needs of hydrologists and water resources personnel in other countries. The HRM contains details of the components, rather than the instruments, software, etc. themselves. Commercial items are permitted but several criteria must be fulfilled for any component to be accepted into HOMS. The HRM provides global access to details of all the components (what each component does and how to obtain it).

The Department for International Development (DfID) currently funds the UK HNRC at the Centre for Ecology and Hydrology, Wallingford. DfID sees HOMS as one way of helping to fulfil its aims of poverty elimination and sustainable development. Further improvements are planned in order to make HOMS even more effective, and the UK continues to play a major role in helping WMO to design and bring about these changes.

Until February 2001 **Dr Howard Oliver** at CEH Wallingford managed the UK HNRC. Howard played a significant role in working with the WMO HOMS Office to draw up plans for HOMS in the 21st century (WMO

document *Implementation Plan for HOMS in the 21st Century* can be downloaded from the HOMS website). The new Manager of the UK HNRC is **Dr Ian Littlewood**, also at CEH Wallingford.

The continued success of the UK HNRC, and HOMS in general, depends to a large extent on the maintenance of a healthy list of relevant HOMS components for dissemination internationally. Currently the UK list of HRM components is largely made up of items from CEH, and its forerunner, the Institute of Hydrology. HOMS was initially set up with the exchange of information between National Hydrological and Meteorological Services as the primary aim, but it is now becoming a far more open system for advertising and disseminating components. The hydrology and water resources communities of the UK must surely rank amongst the world leaders in being able to generate new HOMS components. If you have a potential HRM component and want to share details of it with the world, or if you want to find out about any existing components, HOMS could be what you are looking for. The UK HNRC would be happy to receive proposals for new HRM components from anyone, or any organisation, involved in UK hydrology, water resources or raw water supply. Component details in the HRM are accessible globally — at no cost to the originator.

Look out for further developments concerning the UK HNRC and HOMS more generally. Ideas for HRM components, or observations and comments on any aspect of HOMS, particularly from readers of *Circulation*, are welcome at the UK HNRC.

Ian Littlewood
CEH Wallingford — igl@ceh.ac.uk

BHS South West Section meets again

On *7th February* around 50 people attended the first regional meeting of the South West Section since 1996. The afternoon meeting at Bristol University on "Hydrology in the South West" featured three speakers: **Robert Sellin** (Bristol University) on flood channel behaviour (specifically the Blackwater), **Graeme Boyce** (Environment Agency) on the recent flooding in the South West and **Des Walling** (Exeter University) on fine sediment transport in the rivers of the region.

The BHS Committee member representing the South West region is **Sam Green** *(tel 01392 443774, email sagreen@south-west-water.co.uk).*

Meeting

IAHS Scientific Assembly
MAASTRICHT 2001
18 – 27 July 2001
Maastricht, The Netherlands

Preparations are in progress towards an excellent and fruitful Assembly in Maastricht. To make it a great success, a large audience is vital, and all IAHS members are asked to disseminate the information as widely as possible.

Full information, including the provisional programme, timetable and abstracts, is on the IAHS Web Site at

http://www.cig.ensmp.fr/~iahs

and in IAHS Newsletter No. 72, but if you have any questions, or need any further information, please contact **Pierre Hubert**, IAHS Secretary General, Ecole des Mines de Paris, 35 rue Saint Honoré, F-77305 Fontainebleu, France *(tel +33 1 64 69 47 40, fax +33 1 64 69 47 03, email iahs@ensmp.fr).*

Diary

16th May 2001
BHS National Meeting
"Hydro-ecology of managed rivers"
Venue: Birmingham University
Contact: Dr Chris Bradley *(tel 0121 693 2888, fax 0121 693 2889, email C.Bradley@bham.ac.uk)*

23rd May 2001
BHS Pennines Hydrological Group AGM
"River flow objectives" *[postponed from 14th February: the meeting on hydrodynamical methods moves to 7th November]*
Venue: Yorkshire Museum, York
Time: 12.30 to 16.30
Cost: £3.50 including refreshments (students free)
Contact: Brian Darling, WS Atkins, Warrington *(tel 01925 622019, email bdarling@wsatkins.co.uk)*

13th June 2001
BHS Southern Section meeting
"Windsor & Maidenhead flood prevention scheme" *(presentation at 14.00, followed by a site visit)*
Venue: Environment Agency offices, 110-114 High Street, Maidenhead
Contact: Dr Adrian Butler, Dept of Civil & Env. Engineering, Imperial College, London SW7 2BU *(Tel 0207 594 6122, Fax 0207 594 6124, email a.butler@ic.ac.uk)*

18th–21st June 2001
Groundwater Quality 2001 (IAHS)
Venue: Sheffield University
Contact: Prof. David Lerner *(tel 0114 222 5743, fax 0114 222 5701, email gq2001@sheffield.ac.uk)*

27th June 2001
BHS South West Section
"Urban hydrology"
Venue: University of Exeter
Time: 14.00
Contact: Sam Green *(tel 01392 443774, fax 01392 443231 email sagreen@south-west-water.co.uk)*

5th July 2001
BHS National Meeting
"Continuous river flow simulation: methods, applications & uncertainties"
Venue: CEH Wallingford
Registration: *see separate flyer enclosed*
Contact: Dr Ian Littlewood *(tel 01491 692385, fax 01491 692424, email igl@ceh.ac.uk)*

18th–27th July 2001
6th Scientific Assembly of the IAHS
Venue: Maastricht, The Netherlands
Contact: IAHS office *(tel +31 43 3619192, fax +31 43 3619020, email Cal.conferenceagency@ wxs.nl, website www.cig.ensmp.fr/~iahs/)*

5th–7th September 2001
BHS Postgraduate Symposium
Venue: Dundee University
Contact: Dr Andrew Black *(tel 01382 344433, fax 01382 344434, email a.z.black@dundee.ac.uk)*

19th September 2001
BHS **AGM** and National Meeting
"Water resources planning and development"
Venue: Bristol University
Contact: Sam Green *(see above)*

25th October 2001
BHS National Meeting
"Recent advances in hydro-ecology"
Venue: ICE, London
Time: all day
Contact: Dr Mike Acreman *(tel 01491 692443, fax 01491 692424, email man@ceh.ac.uk)*

7th November 2001
BHS Pennines Hydrological Group
"Innovation in flood risk modelling"
Venue: University of Lancaster
Time: 13.00 for 13.30
Contact: Chris Kilsby *(tel 0191 222 5614, fax 0191 222 6669, email c.g.kilsby@ncl.ac.uk)*

21st–22nd November 2001
Royal Society / BHS 2-day Meeting
"Flood risk in a changing climate"
Venue: Royal Society, London
Contact: Prof. Howard Wheater *(tel 020 7594 6066, fax 020 7823 9401, email h.wheater@ic.ac.uk)*

Copy deadline for *Circulation* No. 70
6th July 2001