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Come to Exeter!

The first International Conference hosted by BHS promises a wealth of papers, posters and discussion on six themes spanning *Hydrology in a Changing Environment.*

Hydrologists from all over the world will come together in Exeter for the week 6-10 July to share their vision of hydrology. Professor Jim Dooge will open the conference and help delegates to formulate the Exeter Statement, which will be an important input to UNESCO's International Hydrological Programme and WMO's Operational Hydrology Programme.

The papers will be pre-published in three hard-back volumes by John Wiley. One volume plus the book of poster papers is included in the registration fee:

Volume I	**Global hydrological processes; Ecological and hydrological interactions**
Volume II	**Groundwater at risk; Catchment management and resource assessment in dry areas**
Volume III	**Hydrology of environmental hazards; Hydrology of large cities**

To register please complete the form on pages 9 and 10 or use the internet: http://www.nwl.ac.uk/ih/www/server/bbhs.html

A report on the Fifth IAHS Scientific Assembly, Rabat, Morocco, 23 April-3 May 1997

Dr Kate Heal
Dept of Environmental Science, University of Stirling

I attended the second week of the IAHS Assembly, my main interest being Symposium S4 (Freshwater Contamination). I eventually located the venue for the assembly on the outskirts of Rabat, thanks to a lift from a helpful official, after my rudimentary French failed dismally in a taxi, and arrived in time for the closing session of Symposium S6 (Human Impact on Erosion and Sedimentation). **Des Walling** (Exeter) chaired the session, which continued the theme of Reservoir Sedimentation and the Impact of River Regulation with examples ranging from the Murrumbidgee River, Australia (**Laurie Olive**, Australian Defence Force Academy) to the Arno River, Italy (**Paolo Billi**, University of Florence). Paolo Billi's paper included fascinating historical evidence from the Arno River basin which has been managed since Roman times. Since this was my first international conference, I was rather apprehensive, but was reassured to see familiar faces on my arrival.

The Assembly Dinner was held at the Conference Centre in true Moroccan style. We dined on pastilla (pastries stuffed with pigeon meat), marinated chicken, couscous and seasonal fruits accompanied by Moroccan music. After dinner there were a number of presentations which were followed by an interesting slide show of the recent Iceland jökulhlaup. The evening was rounded off with assorted singing from the Australian, Japanese and Israeli contingents — future IAHS Symposium delegates beware!

Symposium S4 was held over the next three days (30 April - 2 May), ably chaired by **Bruce Webb** (Exeter), who rapidly became an expert in sign language with the translator at the back of the room. The Symposium papers were organised into eight themes: 1 Freshwater contamination and spatial scale, 2 Sediment-associated contamination, 3 Pollution and water quality degradation, 4 Nutrients in surface waters, 5 Subsurface contamination, 6 Contamination of lakes and reservoirs, 7 Modelling water pollution, and 8 Managing water quality. A total of 33 papers were presented, predominantly from Europe and North Africa.

The symposium kicked off at the global scale with a presentation about the world river chemistry database, GEMS (**Michel Meybeck**, Paris). Concern was expressed about the reliability of the chemical data, but apparently the accuracy of discharge and suspended sediment measurements are more important. **Chris Soulsby** (Aberdeen) then reduced the spatial scale in his presentation on the reversibility of surface water acidification in the Cairngorms. The chemistry of surface waters has responded to decreased sulphur deposition in the Cairngorms, but no biological recovery has been observed in the most impacted streams. The papers on sediment-associated contamination emphasised the role of sediments in contaminant accumulation and transport, but **Wolfhard Symader** (Trier) highlighted the considerable spatial and temporal variability in sediment quality. **Zahid Idlafkhil** (Université Pierre et Marie Curie, France) identified two different particulate metal behaviours in the River Seine at discharges higher and lower than 600 $m^3 s^{-1}$, whilst **Marcell Schorer** (Trier) found that particle size plays a minor role in the adsorption of organic micropollutants on sediment. In the UK, **Bruce Webb *et al.*** (Exeter) estimated that in basins with above average sediment yields, more than 50% of the total phosphorus flux is contributed from sediment, but for total nitrogen flux the contribution of sediment is unlikely to exceed 10%.

Examples of pollution and water quality degradation were presented from around the world in Theme 3. **Laurence Maurice-Bourgoin** (ORSTOM, Bolivia) characterised mercury contamination arising from goldmining activities in the Amazon and Madeira basins. Although dissolved and particulate mercury concentrations in both these rivers are below the WHO guideline, mercury contamination of fish had been found. **Ann-Marie Bremner** (Bristol) reported on the behaviour and sources of heavy metals in drainage rhynes at the Avonmouth industrial site. Lead concentrations appeared to be controlled by atmospheric deposition, whilst zinc and cadmium levels depended more on equilibrium adsorption-desorption processes. **Rameshwar Kanwar** (Iowa) then described an impressive experimental set-up to determine best agricultural management practices for groundwater protection. A case-study of nitrate contamination of surface waters in north-east Spain was presented by **Javier Machin** (Spain).

The nutrients in surface waters session demonstrated that this issue remains of considerable concern and that we still do not fully understand the processes involved. **Jake Peters *et al.*** (USGS) had analysed nutrient concentrations in the Chattahoochee basin, the main water supply for Atlanta. Eutrophication clogs river intakes and adversely affects water treatment processes. **Ian Foster *et al.*** (Coventry) were studying nutrient concentrations and planktonic biomass in the Avon, Warwickshire, a severely eutrophic river. Silica appeared to be the limiting chemical factor for algal blooms there. Phosphorus outputs from intensive livestock grassland systems formed the focus for **Louise Heathwaite**'s (Sheffield) presentation. Results from fertiliser applications to experimental plots suggest that the majority of phosphorus lost from grassland systems is in the dissolved form and that subsurface pathways are important.

Groundwater pollution is clearly a worldwide issue, judging from the number and variety of presentations in the subsurface contamination theme. **Eva Deseö** (Environmental Institute, Hungary) presented an overview of groundwater quality in her country. Extensive nitrate contamination was identified, especially in shallow aquifers, but it was emphasised that the actual drinking water quality is better than the raw water quality data presented. The importance of subsurface water quality in the Nile Delta, where most of Egypt's population is concentrated, was described by **Ismail El Ramly** (Egypt), whilst **Joanna Pociask-Karteczka** (Krakow) quantified the effects of radionuclides released from coal mining in the Vistula Basin, Poland, on surface and groundwaters. **Dinshaw Contractor** (Arizona) had modelled groundwater flow on Pacific island of Guam in order to limit saltwater intrusion into the aquifers which are essential are maintaining the island's tourist industry. However the picture was not all doom and gloom. **Antonio Castillo** (Granada) reported that nitrate concentrations in aquifers in southern Spain have been stable over the past 25 years probably due to rises in fertiliser prices and an increased awareness amongst farmers of the need to limit fertiliser use. Desalinisation of an aquifer in north-eastern Morocco was attributed to recharge from surface runoff by **Amina Chaouni Alia** and her colleagues (University of Gent).

The contamination of lakes and reservoirs theme was more restricted as three authors failed to appear. The sole remaining paper, presented by **Ali Foutlane** (ONEP, Morocco), focused on a water quality problem local to the conference venue. Thermal stratification occurring in waters stored behind dams results in eutrophication and

undesirable concentrations of iron and manganese. Strategies to improve water quality (artificial destratification, selective water abstraction, and biological control of phytoplankton with Chinese silvery carp) were tested in a dam between Casablanca and Rabat, Morocco, and found to be successful.

All the papers in the modelling water pollution theme were presented, encompassing a range of spatial and temporal scales. **Joop Steenvorden *et al.*** (Winand Staring Centre, Netherlands) and **Adilson Pinheiro** (Brazil) had tried to simulate nutrient contamination from diffuse sources, whilst **Mohamed Igouzal *et al.*** (Université Ibn Tofail, Morocco) were modelling water quality in a river affected by point source pollution from an industrial outfall. A more conceptual paper was presented by **Sergei Kondratyev** (Institute of Limnology, Russia) in which appropriate model types were identified for different temporal scales. Physically-based models should be used for daily timescales, lumped conceptual models with an hour or daily timestep for synoptic timescales, and seasonal and annual timescales require conceptual or empirical models. The sole paper presented in the managing water quality theme was by **Kate Heal** (Stirling). She presented results for manganese in runoff from a study in Yorkshire which demonstrated that hydrochemistry should be taken account of when managing upland water supply catchments. The non-appearance of authors meant that the final day of the Assembly finished at lunchtime, allowing the delegates more time to explore the sights and souks of Rabat.

The Assembly was well organised. The conference centre was set in lush gardens, with copious mint tea and coffee served outside in a marquee during the session breaks. The content was typically wide-ranging, but the failure of many authors to attend disrupted the programme and made it difficult to fully utilise the diverse material in parallel sessions.

I am grateful to the BHS for a travel grant towards the Symposium costs.

Kate Heal

Climate change — water and environmental management in the Midlands

BHS Midlands Section meeting + CIWEM West Midlands
National Motorcycle Museum, Solihull
21 October 1997

Since the 1991 Rio Summit, global warming and climate change have been at the forefront of scientific, political and public attention. This half-day meeting was held to disseminate both the predicted physical consequences of climate change and its environmental management implications, with particular reference to the English Midlands.

Government & industry response

George Martin (Stanger Science & Environment — Tarmac's subsidiary) represented the Advisory Committee on Business and the Environment and gave the keynote address.

At the UN Climate Change Convention in Kyoto, Japan, in December 1997, the UK government was expected to sign up to a significant reduction in emissions of greenhouse gases between 2008 and 2012, compared to 1990 levels. George advised that business needs to adopt an environmental strategy that is part of their corporate strategy, not separate from it. It is in their interests to plan and act now, before changes are forced upon them by government policy.

Evidence and consequences

Dr Nigel Arnell (Southampton University) emphasised the difficulties in detecting human-induced climate change against a backdrop of natural variability of climate. Despite these difficulties, the report of the United Nations Intergovernmental Panel on Climate Change (IPCC, 1996) stated that "the balance of evidence suggests a discernible human influence on climate" — official acceptance that climate change *is* happening.

Modelling climate change is complicated, and climate scenarios are generally defined by expressing the speed and magnitude of the changes, rather than the absolute values. The projections are applied to current measured data to give a *feasible average* future rather than a forecast or a prediction of extremes. The four UK climate change scenarios most widely used and accepted originate from two Hadley Centre global climate models. Various models have then been used to estimate the hydrological effects of these climate changes, summarised in Table 1.

Nigel concluded that it is no longer reasonable to assume we can predict the future from the past — there will be considerable uncertainty in any forecasts. Thus, management plans must adopt the precautionary principle and be tested against feasible climate change scenarios. The preferred management plans will be those that are flexible and robust, to enable uncertain water resource needs to be met without entailing excessive economic or environmental costs.

Impact on the aquatic environment

Steve Morley (Environment Agency Midlands Region) highlighted the Agency's current trials and investigations into new procedures to help define the 'environmental fraction' — that part of the water resource reserved for the environment and unavailable for abstraction. A new Surface Water Abstraction Licensing Policy, reflecting individual reaches environmental sensitivity, is now undergoing trials.

Techniques such as RIVPACS, PHABSIM and Multimetrics will help the Agency to understand the sensitivity of river systems to changes, including climate change impacts, and can be used to establish or adjust the environmental fraction. This could eventually result in changes to the system constraints being used in the current 'Agenda for Action' review of all water supply system yields

(e.g. reservoir compensation releases, abstraction reduction / cessation flow thresholds), leading to changes in available surface and groundwater yields.

Steve believes that quantifying the effects of climate change on the aquatic environment is much more difficult than assessing the impact on yields. There are complex interrelationships between the key change areas. Man can further influence the climate change impacts by, for example, planting trees, changing agricultural policy, changing abstraction licensing policy. Society's response to climate change may have a greater impact on the environment than climate change itself.

He described some of the expected effects most relevant to the Environment Agency, apart from the more obvious hydrological changes:

- To prevent a deterioration of water quality, discharge consent conditions might have to be changed to reflect reduced dilution of the effluent
- Increased algal blooms in lakes and rivers
- Increased eutrophication unless farm practices change
- Increased frequency of storm sewer overflows to rivers
- Increased saline intrusion up estuaries
- Changes to sedimentation patterns and pollution flushing, particularly important in the Severn Estuary. Rising sea levels would only compound the problem.
- Fish physiology, habitat, food sources and migration patterns could all be affected, and could result in alterations to the species balance with more adaptable and tolerant species becoming more dominant.
- More frequent high flows could increase habitat scouring.
- The sensitivity of wetland sites to climate change is uncertain, but many are already at risk from overabstraction. Managed retreat may become an option where it becomes impractical to maintain a particular ecosystem, but this poses a dilemma for an organisation with responsibility to enhance conservation interests. Perhaps the environmental assets can be replaced by development at another site?

Impact on Severn Trent water resources

Dr Terry Kitson (Severn Trent Water Ltd) concentrated on the Government's 'Agenda for Action' resource yield reassessments, and the impact of climate change on both resources and demands.

Their planning assumptions are based on the worst-case climate change scenario from the 1997 UKWIR/Environment Agency report, and conclude that in 20 years time, natural summer flows will be reduced by 10% during August and September in the River Severn, and 20% less in the River Trent. Under this scenario Severn Trent Water are most vulnerable to a four to six month drought, rather than a longer (e.g. 18 month) drought.

Terry predicts that climate change will result in a significant increase in demand by unmeasured customers, and endorsed the need for selective metering and variable tariffs to reduce garden watering peaks. He was adamant that there would never be another Severn Trent hosepipe ban (or he resigns!), and claims he does not need to raid the environment to meet this commitment.

Initial estimates suggest that the new yield assessments, will result in a 15-20% drop in overall company reliable yield, presently taken as 2400 Ml/d. This is due to a combination of factors:

- Climate change scenarios
- 20 more years of (dry) data since the last yield assessments were made
- Abstraction reductions to help alleviate low river flow and wetland problem sites
- Improved service levels to meet rising customer expectations.
- Increased reservoir emergency storage

Terry concluded that the impact of climate change in the Severn Trent area will be quite dramatic. Severn Trent Water are committed to a range of demand management measures, but, as an inland water company where waste water is returned to rivers and frequently reabstracted, do not support cistern Hippo Bags. Despite managing demand, there will still be a need for environmentally-friendly resource enhancement in the next five years and more substantial enhancements towards the end of the 30-year outlook period.

Climate change & biodiversity

Barnaby Briggs (RSPB) gave the final presentation of the day — a real tear-jerker. He began by describing the possible ways that wildlife populations could be affected by climate change:

- The timing of lifecycles (phenology), resulting in changes in predator/prey or host/parasite relationships, eventually leading to a breakdown of the ecosystems e.g. chicks hatch when caterpillars are plentiful
- The availability of food for migrating birds
- The weather at vulnerable lifestages e.g. capercaillie chicks die if it is too wet in June
- The distribution of species: northerly species may retreat north, whilst southerly species may expand further north, but these movements are dependent upon the availability of suitable habitat.

Barnaby cited many examples from the scientific journals where migration of species and changes to life cycles are *already* observed, and whilst it cannot be proved that climate change is the cause,

Table 1 *Summary of predicted changes in UK hydrological parameters as a result of climate change*

Parameter	Predicted Change
Air temperature	Rise, ~1.1 °C by 2050
Rainfall	Possible increase in annual total ~10% by 2050; increase in winter; decrease in summer ~10% in Southern England. Also a decrease in summer effective rainfall.
Potential evaporation	Higher except in far north-west where effect is offset by increased humidity.
River flows	Increase in annual runoff except in south and east; increase in winter; decrease in summer except in northern catchments for some scenarios. Monthly averages change by up to ~50% by 2020, more typically <20%. Flow duration curves become more extreme, steeper curve: = more frequent low flows. Catchments reliant on soil and aquifer storage to provide baseflow support will show the greatest relative changes due to the greatest impact of reduced summer effective rainfall. Effect on flooding uncertain. Higher winter flood risk: catchments saturated for longer. Changes in the intensity of summer storms will be important in small, flashy response catchments.
SMD	Hotter, drier summer suggests higher or more persistent soil moisture deficits.
Groundwater recharge	Uncertain and aquifer specific. Balance between opposing effects difficult to predict, and different models give different results. Higher SMD requires more time to satisfy, resulting in shorter recharge season. Increased availability of winter water for recharge, but large proportion may rapidly runoff without contributing to recharge.

Note: Predictions for some of these parameters vary significantly for different models or assumptions. *Source*: Author's summary of comments/tables of the speakers at this meeting, particularly Dr Nigel Arnell.

there is frequently a lack of any other feasible option.

He emphasised the need for good conservation practices *now* to maintain variety and make sites robust to changes. We cannot afford to sit back and wait until scientists come up with more certain predictions of future impacts of climate change.

Rachel Spence
Environment Agency, Solihull

Hydroclimatic variability in Scotland — trends, potential causes and impacts

Scottish Hydrological Group meeting Strathclyde University, Glasgow 26 November 1997

This was a presentation by *Professor Alan Werritty* (Department of Geography, University of Dundee) of work carried out by him with *Miranda Foster* (Dundee) and *Keith Smith* (Stirling), funded by the Scottish and Northern Ireland Forum for Environmental Research (SNIFFER).

In setting the scene, Alan showed pictures of flooding in Scotland, including the second largest flood ever recorded in Britain (January 1993), and also a drought period in 1995 when the Scottish reservoirs were very low. He asked the question: is Scotland's climate becoming more erratic and variable?

The rainfall record for Scotland (1757-1992) shows that the decade 1980-1990 was the wettest on record, with the years 1990 and 1992 being two of the six wettest since 1869. Picking out two stations, Fort William in the west showed a striking increase (~700 mm) in annual totals between 1970 and 1990, followed by a decrease: the increase was mainly due to the winter and spring rainfall. At Braemar in the east there was a smaller increase (~200 mm) up to the mid-1980s, followed by a decrease, but there was no consistent seasonal pattern. These stations characterised the general trend: the contrast between the wetter west and the drier east becoming greater.

The river flow records for Scotland go back to the 1930s, but for this project the records have been standardised to the period 1970-1994 and only stations with no land-use effect have been used. Trends in high flows were illustrated by three stations: the Spey at Invertruim, the Dee at Woodend and the Annan at Brydekirk, which all showed a two-fold increase in the number of peaks over threshold. Mean flows showed the Nith at Friars Carse increased strongly up to the early 1980s, mostly in the winter and spring, followed by a smaller increase to the 1990s, while the Dee at Woodend showed a strong increase up to the mid-1980s, followed by a modest decline. The low flows (Q_{95}) for the Spey at Boat o' Brig and the Dee at Woodend showed a slight rise to 1980 but then a steepening decline since 1986, whereas the Clyde at Sills showed a steady increase during the same period. The regional picture shows a contrast in annual mean flows, with the eastern rivers increasing up to the mid-1980s followed by a decline, but the western rivers increasing steadily throughout the period.

The possible causes of these trends in river flows are land-use change or climate change. The stations used in the project were however specifically selected in catchments where minimal land-use changes had occurred, so most of the trends must be driven by climate. The Lamb weather types have been correlated with rainfall for the period 1970-1996. East coast stations showed a strongly significant correlation (5% level) between cyclonic weather types and rainfall, while the west coast stations showed a strongly significant correlation (5% level) between westerly airflows and rainfall.

The North Atlantic Oscillation Index (NAOI) showed strong correlations for the western stations with seasonal (winter and spring) rainfall but only weak correlations in the east. Since the early 1980s the NAOI has increased steadily, resulting in an increase in winter rainfall in the west. River flows in the west are generated by westerly storms while flows in the east are generated by cyclonic storms. The westerly storms are increasing, and therefore the west-east partitioning in river flows is becoming stronger.

To open the discussion session **Frank Law** (Institute of Hydrology) reflected that some very old flow records were being found, although most of them were very short, giving problems in their analysis and interpretation. He also suggested that further significant changes in rainfall may not be revealed for many years because of the climatic dampening effect of the atmosphere and oceans.

Alastair Moir noted that the stepped rise in rainfall and river flows in recent years could also be seen in previous periods, so maybe this was not such an unusual event. **John Burns** pointed out that the length of record was very important in identifying trends in river flows, and also the flow statistics used in the analysis: in south-west Scotland Q_{95} was decreasing by some 1-2% per year but Q_{20} was increasing.

Ian Fox agreed with the speaker that stationarity in the flood record should not be assumed, which was particularly relevant on an operational basis for hydro-power and water abstraction. **James Curran** had noted that, in the long-term predictions of climate change, Scotland suffers from being located on a steep gradient of change.

Alan Werritty agreed and suggested that, when looking for trends in neighbouring regions, Scotland is associated more with Scandinavia and Iceland than with south-east England. **Andrew Black** (University of Dundee) noted that the most striking output from this work was that variability is increasing and we are likely to see more confusion in the record with greater extremes. **Robin Wardlaw** asked if rainfall trends had been linked to the Southern Oscillations in the Pacific. Alan Werritty said the project had looked at this, but no significant link had been found.

Dick Johnson
Institute of Hydrology

Reservoirs

Pennines Hydrology Group Meeting
5 November 1997
University of Newcastle

This afternoon meeting provided four distinctive presentations on the topic of reservoirs.

The first paper was presented by **Hilary Smithers** (Environment Agency North West Region) who gave an overview of the role of reservoirs in the water supply of north-west England, with particular emphasis on environmental issues.

Reservoirs provide the majority (65%) of water supply in the region, with the remainder coming from aquifers (10%), lakes and other intakes (5%) and the River Dee abstraction (20%). They have a wide range of uses, including water supply, compensation, recreation, conservation and fisheries, as well as maintaining the canal networks. There are those involved in direct supply (e.g. Stocks and Ennerdale reservoir), those used for river regulation (e.g. Brenig and Colwyn), those dedicated entirely to compensation releases (e.g. Langley Bottoms) and those which are environmentally important (e.g. Haweswater and Ennerdale).

The large range of yield definitions emphasises the operationally defined nature of the yield concept. Yield definitions range from maximum drawdown rate through a period of minimum reservoir inflow to definitions of reservoir failure and customer levels of service. The operation of reservoirs is often defined by control lines relating releases to stocks level and time of year. Control lines can be derived from reservoir inflows. Additional control rules relating to flood alleviation and fisheries protection are also used. Control rules are often constructed for use within conjunctive use schemes such as the Lancashire Conjunctive Use Scheme. For example, Stocks reservoir plays an important role in this scheme, providing a 'cheap' gravity-fed source. The derivation of control lines requires a reservoir inflow record. Many reservoirs (e.g. Stocks, Thirlmere and Lake Vrywny) have long daily inflow records starting from the 1920s. This presents problems with data management and assessment of data quality. Data for sites without any (or very few) records can be generated by transposition of inflows from nearby catchments or by using rainfall-runoff modelling.

Some reservoirs have important environmental or conservation issues to consider. For example, Haweswater is home to a rare fish known as the Shelley which lives only at specific reservoir depths. Thus reservoir operation must take into account water supply and conservation issues.

The water resources in the region are simulated using the MOSPA model. This has recently been extended by combining the North, South and the River Dee models as well as increasing the number and length of data records around the region. MOSPA is used to define relationships between yield and reliability and improve operation from both economic and environmental perspectives.

Questioned on whether there are any plans to develop new resources in the region, Dr Smithers said that the preferred option is for demand management measures such as leakage reduction and water efficiency initiatives. Another question was whether the recent water company yield assessment had uncovered any early drought periods that were not previously known. The drought of 1934 was the most widespread, although it is known that there were drought events towards the end of the 19th century.

M.A. Yurdesev, a postgraduate student from Newcastle University, presented the second paper, proposing a methodology for assessing the environmental impact of reservoir schemes in large-scale water resource planning. Whilst the current emphasis in reducing demand is centred on demand management, such measures will not contain the expected rise in future demand and there may be a need to develop new surface water resources such as reservoirs. However, it is important that both the environmental and economic impacts are considered. Methods for economic assessment are varied and well proven. They include heuristic search methods and mixed integer programming methods such as those used by the Water Resources Board in the National Water Resources Plan.

The research described proposes an approach which combines the conventional environmental impact assessment methods of environmental impact statements and multi-criterion analysis. This is achieved by quantifying environmental impact using an Environmental Impact Factor (EIF) which can then be applied to weight construction and operational impacts in an economic model. An environmentally friendly scheme is assigned a value between zero and one, a value of one is assumed to have no environmental impact and an EIF between one and two is environmentally degrading. The EIFs are derived by assessing all relevant impacts for each option, either by objective or subjective means, then aggregating the EIFs to a higher level (of major impact category) and transforming between zero and two. Construction related impacts, for example, can include aesthetic changes during construction, whilst operational impacts can include installation of power supply, on-site (reservoir) and off-site (downstream) water quality changes, short-term water level fluctuations and longer term changes in the microclimate. Major impact categories for reservoirs include resource utilisation implications, quality implications on the physical system, ecosystem effects and social effects.

The techniques are integrated in a modelling framework known as ENRES. This combines the economic assessment model RESPLAN with the environmental impact assessment (EIA) model. Model results are generated with and without the EIA model to assess the impact on a particular scheme. The model is demonstrated using the Water Resources Plan of England and Wales undertaken by the National Rivers Authority (NRA) in 1994.

The ensuing discussion focused on the subjectivity of deriving the EIFs, and on whether risk analysis was considered in the methodology. It was stated that risk analysis was incorporated into the weights. A further discussion revolved around the resulting net present value (NPV) from the model with queries on whether it is discounted and, if so, over what time horizons. The accuracy of individual environmental costs was discussed but it was suggested that the utility of the approach was in the consideration of options in the holistic sense.

After the coffee break, **Professor Chris Collier** (University of Salford) discussed the role of meso-scale convective systems (MCS) on the design of water retaining structures such as dams. Major dams are designed to withstand the Probable Maximum Flood (PMF) arising from the probable maximum precipitation (or PMP) of the critical duration of the catchment being considered. The Daledyke dam, near Sheffield, was the last major dam failure in the UK (1864) when 244 people were killed, there have been no fatalities in the UK since 1925, however there have been a number of dam failures which highlights the relevance of this issue.

PMP can be derived from a number of methods including storm models, storm transposition, depth—duration analysis, statistical modelling and

paleohydrological studies. PMP is often derived from the Flood Studies Report (FSR) methodology which is based, from storm durations of less than 1 day upon a limited database of 33 raingauge stations.

The research described, conducted jointly between the Meteorological Office and the University of Salford, with funding from the Dept. of Environment, suggests that MCS's produce storm rainfall totals of duration 11 - 24 hours which are larger than the PMP values derived using the traditional estimation procedures. The model used here to estimate the possible PMP values is based a single column convective model able to model the vertical velocities seen in convective storms. The method assumes the storm is stationary. This is combined with the output from a three dimensional large eddy Simulation model, principally the temporal variation of the wind field, (model developed by the Meteorological Office). The PMP is defined in terms of storm efficiency and water content. Storm efficiency is the fraction of total storm water at ground level over the total storm water condensed and can be estimated from radiosonde or radar data. Storm efficiency as a function of storm duration clearly identifies the MCS storm type, with its higher storm efficiencies from longer duration storms, from those of single cell and multi-cell convective storms.

The model has been applied to a number of reservoir sites including Stocks and Ladybower to generate fields of PMP over the catchment through time. A 12 hour event PMP hyetograph from the Ladybower simulation shows the characteristic MSC behaviour of pulses of high intensity convective rainfall followed by less intense stratiform rain. The distribution is different to the triangular distribution assumed when estimating the PMP from the FSR method. In addition, the FSR methodology underestimates the rainfall totals when the storm duration, characteristic of MCS's, is greater than 10 hours.

Satellite imagery showed an example of a developing MCS over the eastern and southern half of the UK in June 1996 to cover a maximum area of 20,000 km2. It developed when a cold frontal system from the west met warm, continental air from the south east. MCS's are infrequent in the UK (~1 per year) but they are important in terms of flooding events especially when the MCS becomes stationary. It is thought that the extreme rainfall events at Lynmouth, Exmoor (12h) and Martinstown, Dorset (15h) may both have been due to MCS's.

The propagation of the PMP storm to a PMF is not always guaranteed. This was illustrated with a hydrological model based on electrical resistance theory. The model incorporates a definition of catchment resonance Q, which determines the peakedness of the flood. If the frequency of the input rainfall data, the PMP, and the resonance of the particular catchment are not similar then the PMF will not result.

Questions ranged from the effects of snowmelt and catchment wetness on the estimate of PMP. In the current case studies this was not thought to be a problem but the estimate of PMP can include these effects although they are difficult to estimate. Another question asked how the methodology could be incorporated into an engineering framework given the difficulty of assigning return periods to unlikely events.

The final paper of the day was presented by **John Rowan** (University of Lancaster) on the subject of modelling sediment transmission in reservoirs. Sedimentation in reservoirs is a widely acknowledged problem impacting both on reservoir capacity and water quality. This has both economic and environmental implications. There are also implications for climate change because of the hypothesised increase in hydrological extremities and the consequent implications for increased erosion rates. Sediment inputs are related to local climate and catchment characteristics. Sediment deposition rates and patterns, however, depend on inflow hydraulics, sediment properties, reservoir geometry and operational practices.

A monitoring programme was established at the small Wyresdale Park reservoir on Tithebarn Brook south of Lancaster University. Two years of intensive field monitoring was undertaken between 1994 and 1996 with discharge and turbidity being measured both in reservoir inflow and outflow. Continuous turbidity was measured using IR probes. Sediment concentrations entering the reservoir were flashy and isolated with sediment duration curves showing that for less than two percent of the time, 90% of the suspended load is flushed into the reservoir. The majority of sediment load was transported with the first peak in the storm. Subsequent storm peaks contained lower loads. This behaviour highlighted the need for an intensive monitoring programme. Trap efficiency, a measure of how much sediment is deposited for a given storm was shown to be highly correlated with the mean flow of a particular storm.

Physics-based models to predict sediment transport and capacity loss are complex and limited by the non-linear nature of the problem. An alternative is to use a data-based approach employing a parametrically robust, linear, lumped parameter transfer function model. Initial model development highlighted the processes controlling sediment routing through the reservoir. In

Ty'r Morwydd Environmental Study Centre in Wales have a flow meter for sale

It is an Ott type 10.002 (meter number 43688). The impeller calibration card is dated 8.3.76, but it is in pristine condition and I doubt very much if it has ever been used. I have tested it here in the Centre, and it appears to be in perfect working condition.

It consists of the following:

Meter body
Rods, 3m in 6 sections, 20mm diameter.
Counter type 12.404
Cable 4m
2 x 125mm plastic impellers, numbers 1-44810 and 2-44843
Instrument case

The replacement value (per Smailes of Glasgow, Ott agents) is quoted at about £5400, including VAT.

I would very much like to hear from anyone interested in buying this meter, or who can give us any advice on a realistic valuation. The meter is the property of the Royal Borough of Kensington and Chelsea, who are our landlords, from whom we rent our premises and their contents. They have agreed in principle to our selling the meter in order to allow us to replace it with meters more appropriate to our beneficiaries (A-level students mainly). As we are a self-supporting charity, we must get the best price we can.

Howard Ray
Deputy Head of Centre
Ty'r Morwydd Environmental Study Centre
Pen-y-Pound, Abergavenny, NP7 5UD
Wales
Tel 01873 855959
Fax 01873 855443

general, sediment outflow was predicted well from sediment inflow ($r^2 = 0.95$), except in some events when the initial rise in suspended sediment resulted in the model underestimating sediment load.

This was found to be a result of wind shear resuspending fine sediment ahead of the main density slug. This only occurred when wind direction was up the valley. The final model couples a non-linear rainfall-runoff response with sediment routing and trap efficiency and is driven by a daily rainfall record from 1910 to 1996 taken from a nearby catchment. The model is calibrated using data collected during the monitoring programme and it gave an r^2 of 0.98. A synthetic sediment accretion sequence is generated using the model output and this is compared to particle size data from lake bed cores dated independently using 137Cs. The comparison was favourable showing peaks in the sand fraction during high magnitude events corresponding to peaks in the accretion rates in the lake bed core.

Questions after the presentation reflected on the discrepancies between what how much deposition is calculated and what is actually deposited, and on whether the site of the lake bed core would influence interpretation. It was stated that the spatial distribution of deposition was primarily along the main axis of reservoir.

Jason Ball (Yorkshire Water) and Kevin Tilford (University of Salford)

BHS postgraduate symposium at Birmingham — book now!

The Eighth BHS Postgraduate Symposium will take place at The University of Birmingham from *30 March* to *1 April*. The format will be similar to previous Symposia: presentations, a field visit and more presentations and discussions in the evening. All activities (except the field visit) will be in the informal atmosphere of a Hall of Residence Lounge.

Reasonably priced accommodation will be available at the Hall. Arrangements have been made to visit some of the field sites operated by the University of Wolverhampton, including hill-slope and catchment experiments at Hilton Park near Bridgnorth.

The Symposium gives postgraduate students (current and recent) an opportunity to present their work and discuss it within their peer group in an informal setting. Valuable experience can be obtained, both through presenting your own research work and from the ensuing discussion. Contributions are invited on any hydrological topic — a prize will be awarded to the best presentation, as judged by the delegates themselves. Students who are not members of the Society are most welcome to attend.

Registration details may be found on the fly-sheet enclosed with this issue of *Circulation*. Further details may be obtained from **Paul Webster** (Tel 0121 414 5055, Fax 0121 414 3675, E-mail p.webster@bham.ac.uk).

BHS Committee: corrections

Apologies to anyone who tried to call **Cliff Dobson** and was connected instead to someone in Jersey. The last two digits in the code were transposed in *Circulation 56* (page 10), and a letter was omitted from Fradley Park. The correct entry (with direct fax no. and e-mail) is

Cliff Dobson (CIWEM Rep.)
Environment Agency Midland Region
Sentinel House, Wellington Crescent
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Tel 01543 444141 Fax 01543 444558
E-mail cliff.dobson@environment-agency.gov.uk

Bob Sargent's e-mail address is bob.sargent@sepa.org.uk

Rob Scarrott is also on e-mail at scarrotrmj@halcrow.com

The ICE subscriptions contact is **Shelagh Stapleton** (tel 0171 665 2125).



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Application forms and further details can be obtained from Louise Murphy, Environment Agency, Manley House, Kestrel Way, Exeter EX2 7LQ (Tel: 01392 444000 Ext. 2306) to whom all completed applications should be returned by 13 March 1998. If necessary, the closing date can be extended.

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Current trends in river water quality modelling

BHS Southern Section Meeting
Imperial College
10 December 1997

This evening meeting was well attended with over forty people present to hear *Paul Whitehead* (Reading University) and *Steven Chapra* (visiting Imperial College from Boulder, Colorado) deliver talks on current trends in river water quality modelling. *Matthew Lees* (Imperial College) was in the chair.

Paul Whitehead gave the first paper entitled "Linked models of hydro-ecology: applications to the River Kennet with regard to the Axford Inquiry." After an overview of recent water quality problems in the River Kennet and the background to the river system, he described the Environment Agency modelling using the Physical Habitat Simulation Model (PHABSIM), which links hydrological and hydraulic parameters with ecology and habitat indicators.

The Axford public inquiry was initiated because local people perceived a decline in water quality in the River Kennet. Extensive land use change had taken place over the last 50 years in the Kennet Valley and discharges into the river from wastewater treatment plants have also increased considerably with the development of Marlborough. The enriched river water has, in turn, altered macrophyte plant growth in the down-stream stretches, and correspondingly a decline in water quality has been noticed around Maidenhall. The ecological and water quality problem is particularly important under low flows. Therefore it has been suggested that water abstraction further downstream at Axford is causing severe impacts on the hydro-ecology of the river and that the abstraction licence requires revision: the public inquiry was set up to address this issue.

The upstream reaches of the River Kennet above Marlborough, primarily sustained by groundwater from the upstream Chalk catchment, are of good water quality. Hydrographs show groundwater-dominated recession curves with minimum annual flows occurring during the summer period. An investigation of possible climate change effects revealed statistically significant evidence of climate change in the Winter-Summer rainfall ratio data for the 200 hundred years of existing rainfall records. To enable analysis of long-term flows, Kennet flows had to be reconstructed from observed flows downstream in the River Thames, since flow data for the Kennet only extend back 30 years. This operation was carried out successfully using a transfer function model. The variability of flows over time, however, does not support such strong evidence of climate change as the rainfall data.

In terms of nitrate, the high mean concentration of around 4 mg l^{-1} shows an increasing trend since 1974. Similar trends have also been observed for phosphorus. In addition to long-term trends in nutrients, dissolved oxygen (DO) also exhibits high diurnal variation, between 20% and 200% of the mean values, particularly during the summer. These large variations are driven by macrophyte growth and algal growth in the Kennet.

Changes in habitat may result from catchment land-use changes, pollution, channel modification and many other types of human intervention. In the case of the Kennet, there is evidence that some of these factors may have induced some habitat change, with the effects being superimposed on those caused by low river flows. Land-use changes have mainly been in the upstream catchment. Channel drainage has been improved with dredging and this could be the cause of the observed water level drop. The removal of the channel bed may also have affected fisheries.

The Axford inquiry was aimed at determining the effect of the Axford abstraction on the hydro-ecology of the River Kennet, and was exclusively based on the application of the PHABSIM model. This empirical model was developed in the USA with the aim of explaining habitat changes from medium to long-term variations in flow. The Axford Inquiry case constitutes a unique application of the PHABSIM model because it is the first time that the model has been used in a legal context within the UK.

The main assumption in the model is that the quality of habitat is a surrogate for fish population in the river. This assumption is supported by the fact that better fisheries are present wherever better habitats are found. The model requires hydraulic information such as depth, wetted area and velocity for different flow conditions at different river transects. Habitat information is also required, and therefore mapping of river reach habitat has to be carried out. Three river stretches were selected in the Kennet, one upstream of the Axford abstraction, another immediately downstream of the abstraction, and a third one further downstream at Ramsbury. Paul posed the question of how appropriate the collected data were in terms of the model requirements, and stated that the data should constitute a representative mixture of the various habitats encountered in the river system. However, in this application only two different types of habitats were mapped in selected reaches: shallow glide and deep slack. These two habitat classifications may not be 100% representative of the River Kennet habitat.

The PHABSIM model is based on habitat suitability criteria represented by fish suitability criteria for different fish species. These criteria are specified by curves of suitability as a function of velocity, depth and habitat cover. The curves indicate the probability of encountering a particular fish species under particular flow conditions. Thus, by combining hydraulic information for the river with these curves, it is possible to obtain a "weighted usable area habitat" that shows habitat quality as a function of discharge. Considering a time series of river flows as input, a time series of habitat quality is produced as the model output. Thus, changes in flow regime over time are supposed to reflect habitat change. A "usable area habitat duration curve" can then be obtained showing the overall behaviour of the system.

Paul highlighted various difficulties with the model's assumptions. The weighted usable area habitat curves depend on the life stage, with different curves for juvenile and adult fish populations. The hydraulic models use a non-linear function for the stage-discharge relationship based on friction coefficients that have to be assumed. The weighted usable area habitat parameter is very sensitive to different hydraulic models.

Once the actual relationship between discharge and the weighted usable area habitat is established, different scenarios under different flow conditions can be tested. Furthermore, the flow regime corresponding to a given habitat loss, say X%, can be investigated, i.e. the lower flow that produces a habitat loss of X%. In the case of the Axford Inquiry, a level of 10% habitat loss was arbitrarily

fixed as the maximum admissible habitat loss. Applying the PHABSIM model, the lowest admissible flow was correspondingly computed, and from this value the Axford abstraction licence was revised.

Paul concluded by stressing relevant aspects of the modelling exercise, which in his opinion were not adequately taken into account. Firstly, no consideration was made of the different uncertainties and no attempt was made at quantifying them. He stressed that particularly in this modelling approach, measurement errors, but also model estimation errors and habitat modelling estimation errors can throw serious doubt on the model results. From a modelling strategy point of view it is necessary to quantify these uncertainties as a means of determining the reliability of the model and the decisions which are based on the model results. Secondly, the licence conditions upon the Axford abstraction were based exclusively on the model results. The model should have been used in a more consultative mode to get a better knowledge of the river system and the results used as a starting point. Also, there are serious doubts about how representative the selected reaches are. Finally, the selection of a "10% habitat loss" is an arbitrary decision, with important legal consequences on the constraint of abstractions.

Members of the audience wanted to know what the Environment Agency could have done to quantify the uncertainties and to improve the investigation. Paul stressed that there are various methods of reliability analysis that could be used to identify key sources of uncertainty and to produce suitable measures of output reliability. He mentioned as an example Monte Carlo analysis. The "usable area habitat duration curve" used to compute the flow level associated with the 10% loss of habitat is very flat and thus large variations in flow conditions do not produce significant changes in habitat quality: an uncertainty analysis would have been worth doing.

Howard Wheater (Imperial College, London) asked if an alternative approach could be considered by dropping areas of unsuitability instead of determining areas of suitable habitat, aimed at possibly reducing the uncertainty. Professor Whitehead agreed that this could be a valid approach. **Matthew Lees** (Imperial College) asked whether validation of this type of model has been carried out. Paul stressed that validation has been performed in very few cases. In New Zealand and the USA some successful attempts at linking fish populations to habitats have been obtained.

The second paper, "Stream water quality modelling: what is missing?", was presented by **Steven Chapra**. The talk addressed techniques in stream water quality modelling, and described the modelling gaps that need to be filled in the areas of physics, kinetics and sediment water interactions. Illustrating the different points with slides, he began by stating that new models are required to address the new set of problems that are emerging. Model development stagnated in the 1970s, mainly for economic reasons, but also because managers assumed that the available models were adequate. As a consequence scientific advances over the last 20 years have, in many cases, not been incorporated into water quality models.

In terms of physics, there have been important computing and theoretical advances that allow modellers to implement more accurate models. Modern computers present almost no limits to the scientist, and in conjunction with turbulence modelling advances, mechanistic representation of previously intractable problems is now possible. In his opinion the modeller can no longer "hide" behind the hydro-dynamical representation of a system to justify bad modelling results obtained when trying to explain chemical or biological processes. In other words the uncertainties of the physical representation of a system can now be reduced to a reasonably low level. In the field of river, stream and estuary physics, however, the modelling of "dead" or "storage zones" is still an important topic of research.

Steve described this area as "the missing link of water quality modelling" and stressed its importance. Investigation of the process by which organic carbon decomposition of bottom sediments leads to sediment oxygen demand (SOD) is an active and rapidly evolving area of research. He described a number of relevant issues such as the nonlinear relationship between SOD and down flux of COD, which is due primarily to methane bubble formation that today's models are not capturing, thereby underestimating SOD during recovery calculations. He also discussed the water-body memory issue, which refers to the importance that has to be given to avoiding the omission of sediment-water processes when modelling stream water quality. He stressed that the processes of settling, diffusion, and re-suspension add a slow component of system response because of the slow dynamics of sediments.

He noted the importance of improving organic carbon modelling, presently measured as a surrogate for other variables, but he concentrated on nutrient/food chain issues. It is a mistake to apply lake ecosystem frameworks to shallow streams, which has been done in the past, mainly because attached or fixed plants such as macrophytes and periphyton rather than free-floating phytoplankton can dominate the water quality biological processes in shallow streams. The plant distribution is affected in shallow streams: fixed plants tend to grow to higher biomass levels in shorter periods of space/time and tend to be concentrated closer to the point sources of enriched waters. Therefore in these zones other impacts on river quality such as oxygen depletion are enhanced.

Although some attached algae can extend up through the water column, most reside on or near the bottom and some are rooted and need a fine-grained, soil-type bottom. Therefore, light attenuation must be handled differently from phytoplankton. Nutrients and temperature interactions are also different and have to be characterised accordingly in the particular stream model. The competition framework for food looks totally different for lakes and flowing waters.

Steve finished his presentation by stressing that scientifically improved models are required today because of litigation and for economic reasons. In the region in which developed countries are modelling (tertiary treatment) a modelling mistake can cost millions of pounds and that in itself justifies the updating of current stream water quality models.

Howard Wheater asked if application of increasingly complex physically based models would be hindered by the large data requirements. Steve did not think this was a serious problem and he stated again that modellers should not hide behind bad physical representations; good models require good data, which is of course expensive to collect.

A member of the audience said that WMO had commissioned a study of chemical transport in rivers, carried out by a physics-based modeller. After much effort he gave up on the mechanistic equations and reverted to a simple empirical approach to predicting travel times. **Adrian Butler** (Imperial College) asked if it was possible to describe the detailed physical processes occurring in dead zones. Steve thought that this was possible, but that the spatially heterogeneous nature of riverbeds makes this approach extremely complex and measurement intensive. A questioner wondered if any research was taking place into the detailed behaviour of dead zones. Matthew Lees thought that Keith Beven and Paul Carling at Lancaster University were carrying out such research in the River Severn. Steve added that research on dead zones is important since their chemical and biological processes are thought to be different, and that where dead zones are important, data-based methods such as the Aggregated Dead Zone approach may be more appropriate.

Matthew Lees closed the meeting by thanking the speakers for excellent topical presentations that provoked a good discussion. The speakers and members of the audience then retired to the bar for extended debate.

Luis Camacho and Matthew Lees

New Members

We welcome the following members to the Society:

Adamson, M G E ..... Mott MacDonald
Archibald, E J ..... Meteorological Office
Aronica, G ..... Palermo, Italy
Ashworth, T J ..... Lytham, Lancashire
Barr, K M H ..... Glasgow
Blackham, D M ..... WS Atkins Water
Blunden, E K ..... Sir William Halcrow & Partners
Burke, N ..... Heriot Watt University, Edinburgh
Cafferkey, B ..... Bettridge, Turner & Partners, Cobham
Camacho, L A ..... Imperial College, London
Campbell, A J ..... Imperial College, London
Carpenter, V J ..... Imperial College, London
Charlton, M B ..... King's College, London
Cole, R A J ..... Rivers Agency, Belfast
Dawson, S H ..... Rivers Agency, Belfast
De Mowbray, S ..... Imperial College, London
Fearn, A M ..... Dept of Geography, University of Southampton
Fooks, C E ..... Environment Agency
Fox, N I ..... Dept of Civil and Environmental Engineering, University of Salford
Gilvear, D J ..... Dept of Environmental Science, University of Stirling
Hajjam, S ..... Institute of Geophysics, Tehran, Iran
Izatt, D ..... Brown & Root, Leatherhead
Johns, M ..... Apem Ltd, Manchester
Kelly, R ..... Dept of Geography, Birkbeck College, London
Kilsby, C ..... Dept of Civil Engineering, Univeristy of Newcastle upon Tyne
Kitchen, M ..... Meteorological Office
Litton, G S ..... Apem Ltd, Manchester
Masopha, M M F ..... Imperial College, London
Mocke, R ..... Imperial College, London
Monroy, R ..... Knight Piesold Ltd
O'Donoghue, M L ..... University of Birmingham
Onions, K R ..... Newcastle-under-Lyme, Staffordshire
Rawlins, B ..... British Geological Survey
Reddaway, J M .. Dept of Civil and Environmental Engineering, University of Salford
Riding, D F ..... C L Associates, West Midlands
Robinson, N J ..... Imperial College, London
Rose, A M ..... WS Atkins Consultants
Sale, R ..... Environment Agency
Shotbolt, L ..... Dept of Geography, University of Salford
Simons, E A ..... University of Birmingham
Turner, J H W ..... Leeds City Council
Wales, S ..... University of Birmingham
Whalley, N A ..... Flynn & Rothwell
Willo, A ..... Worthing, West Sussex

The Flood Studies Report rainfall-runoff method – a reply

We welcome David Archer's questioning article about the FSR rainfall-runoff method [*Circulation 56*, p.12]. Flood frequency estimation is a vital part of scheme design, and we share David's concern that methods are sometimes misused. While the basic concepts and limitations in flood frequency estimation seem to be generally recognised, we agree that some users mistake complexity for quality. Two areas of particular abuse are to neglect local flood records and to stretch methods beyond their natural compass.

The Archer and Kelway paper cited by David was one prompt to the review of the FSR rainfall-runoff method by Boorman *et al.* (1990). While their report was perhaps more equivocal than it might have been, careful reading of its diagrams and tables (try Table 5.7.1) confirms David's view that the rainfall-runoff method is often outperformed by the QBAR plus regional growth curve method — even when sufficient flood event data are available to allow parameters of the rainfall-runoff model to be adjusted locally. Despite these limitations, the FSR rainfall-runoff method remains in widespread use. One explanation may be that hydrologists are reluctant to give precedence to a conceptually crude statistical method over a conceptually sophisticated rainfall-runoff method. A second explanation is that, for some problems, there is no alternative but to use the rainfall-runoff approach. For example, estimating a spillway design flood by the QBAR plus national growth curve method is correctly discouraged in ICE reservoir safety guidelines.

For the moment, the best that one can do is to seek to reconcile the flood frequency curve synthesised by the rainfall-runoff method (preferably augmented by flood event analysis) with that observed or synthesised by the statistical method. Hybrid approaches have always been encouraged in floods training courses but are rather buried in the FSR literature. These include the one that David refers to at the end of his article. Some less orthodox approaches are suggested by Reed (1987). The essence is always to make full use of available local information. It is both inevitable and desirable that guidance leaves scope for experienced users to apply judgement.

Many research hydrologists are coming to share David's reservations about the approach to flood frequency estimation based on the concept of a design event. This was recognised in 1993 by a change in the strategy for inland flood estimation research funded by MAFF. In the short-term, greater emphasis is being given to statistical methods, which will form the centre-piece of the new procedures to appear in the *Flood Estimation Handbook*, to be published in early 1999. Continued thoughtful use of the FSR rainfall-runoff method will, however, be fostered by a technical restatement of the method as part of the *Handbook*. Our plan is that the FEH "Overview" volume will advise on ways of combining / reconciling estimates from different methods.

The research strategy holds that, in the longer term, improved flood frequency estimates will come from the approach based on *continuous simulation modelling*. This has three key merits:

It avoids the many assumptions necessary in the design event approach. No longer will we have to pray that the 50-year flood peak is adequately synthesised by putting an 81-year

design rain-fall of given duration through a rainfall-runoff model that has been initialised to a certain wetness condition.

The approach allows the extreme value analysis to be done on the variable that counts, typically water level at a key site. We wish that hydraulicians better understood the extent to which their "non steady-state" models will come of age when they are freed from having to use crude design events and their assumptions.

There is scope for more effective exploitation of good hydrological science and digital spatial data, especially regarding soils and land-cover. It is also possible to consider snow and snowmelt explicitly: another problem topic aired in the 1980s that it is easier to note than to act on.

Flood frequency estimates will still be imperfect — that is the nature when designs are required to meet conditions that are so rarely observed — so hydrologists will continue to be vulnerable to the mud flung in the aftermath of an inopportune flood. If a technical error is made (a depressingly common one is to neglect that construction of a major flood storage changes the range of flood events to which a catchment is sensitive) we hope that designers own up to it. Any who have trivialised the hydrological input required in scheme design should not be allowed to scapegoat it!

An example of an application that perhaps stretches the "design event" method too far is its use in mapping 100-year flood risk areas systematically throughout a river basin. We believe that as yet there is no satisfactory substitute for a classical "Section 105 survey" that researches flood flows and levels locally. It does not seem to be widely recognised that a basin-wide 100-year flood risk area map can only be prepared by merging (or "enveloping") design flood assessments for individual sites. There is no such thing as a *catchment-wide* 100-year flood event! We share the concern that computationally sophisticated packages (e.g. for hydrodynamic modelling of river flow in channels and flood-plains) may entice users to overlook weaknesses in the hydrological aspects of the flood design or risk assessment.

References

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Reed, D.W. 1987. Engaged on the ungauged: applications of the FSR rainfall-runoff method. BHS National Hydrology Symposium, Hull, 2.1-2.19.

Duncan Reed and Helen Houghton-Carr
Institute of Hydrology

Archer's latest arrow misses the bullseye? A reply to the article on the Flood Studies Report rainfall-runoff method

Most readers of the unattributed article on the Flood Studies Report's rainfall-runoff method (*Circulation 56*) will have twigged, or discovered later, that it was penned by **David Archer**. David is a respected hydrologist with a greater willingness than most to delve deeply into the details of recommended methodology with an eye for a flaw. If anybody can see the warts through the make-up, he can. Show him a box of worms and he will open it!

As the culprit mainly responsible for the rainfall-runoff method as originally presented in the FSR, the *Circulation* headline was always likely to make me sit up — even after 25 years. As David points out, he has voiced similar criticisms before, but perhaps not in such a focused way. There are two issues: is he right to suggest that there is a flaw in the method, and if he is right, or partially right, does it matter as much as he claims?

First, a general point. Underlying the rainfall-runoff approach is the need to apply the design package *as a whole*: it simply is not fair to take one element in isolation and highlight its weaknesses. The *combination* of (a) unit hydrograph, (b) percentage runoff, (c) design storm (amount, duration, profile) and (d) baseflow was designed *and calibrated* to match *observed flood frequency curves* on *individual* catchments (FSR Vol 1, Chapter 6.7, pp 437-456). Any criticism of the method must recognise this and address the calibration procedure as well as the basic approach. It is true, for example, that the FSR recommends a 50-year rainfall be used in designing a flood hydrograph with a peak discharge of 30-year return period, but this is meaningful only in the context of the design *package*. It does not imply that 50-year rainfalls cause 30-year floods. If we had known the confusion it would create, I am sure we would have decided to force the return periods to be the same and take up the 'slack' in some other part of the package (a more complicated specification for catchment wetness index for example). In the long term, it may be that the concept of an isolated 'design storm' event will be replaced by continuous simulation modelling but I, for one, will not be holding my breath!

As to the point about the use of local data: he is right. You ignore actual data at your peril. The very clear limitations of the 'ungauged catchment' methodology were never disguised.

Disparity of rainfall and flood growth curves. Yes (said, if you please, in the manner of Rory Bremner impersonating Jeremy Paxman), but let's probe a bit. David is setting a lot of store by the regional differences between flood growth curves derived by statistical analysis of peak discharges. But, as he says, revisions to these are under way. The whole notion of a sudden jump from one region curve to another as you cross any arbitrary administrative divide was heartily disliked by the FSR's authors, but they did not have the time or the computing resources to do anything else at the time: if a regional distinction led to closer predictions than a simple national equation, then it had to be applied. The forthcoming Flood Estimation Handbook (FEH) will apparently put this right at last. The problem is that the currently recommended regional flood growth curves are based on analysis of all gauged rivers with catchment sizes up to 10 000 km^2, whereas the (non-regional) rainfall-runoff method is based on analysis of catchments up to 500 km^2. It would have been more telling if David had been able to compare like with like.

David Archer goes on to quantify 'errors' in rainfall-runoff method based flood growth curves, but he could have made it clearer that he was talking about differences between the two methods rather than errors. Experience has shown that differences do exist and that they are as large as he claims, or larger. Given that the two methods were based on entirely separate analyses of different data sets, it would have been surprising to have obtained perfect agreement. However, the question remains, is there a bias when the predicted rainfall-runoff growth curve is compared to a 'real' growth curve derived from analysis of observed flood peaks *on the same catchment*? David thinks so — although he doesn't offer any evidence in the article — and attributes it to the way flood events were chosen for the unit hydrograph analysis. Whilst there may be a bias (method predicting high) on larger catchments (perhaps because no allowance is made

for flood plain storage), I remain to be convinced that there is a bias on smaller catchments, and I do not think that the method of choosing events for analysis had anything to do with it. The calibration procedure (see above) should perhaps have discriminated between catchments of different size but it did make a worthy attempt to tie the method back to the Met Office *rainfall* analyses. Apart from the minor impact of the rainfall term in the percentage runoff prediction, there is no sense in which the selection of rainfall events for *hydrological* analysis had any impact on the shape of the growth curve. If, in the light of the much greater body of data available now, careful comparisons of rainfall-runoff method growth curves with observed growth curves show that there is a bias then the calibration should be revisited and new recommendations for design storm construction would be in order.

David suggests that the rainfall-runoff method's resultant hydrograph should be scaled to ensure that the peak agrees with that derived from the regional growth curve. MicroFSR (and other programs) allows this but I think it is too blunt an instrument. Although I do not know how the forthcoming Flood Estimation Handbook will handle it, the FSR recommends that only the rainfall-runoff method should be used for return periods above 10 000 years. In general, the method's synthesis of a Probable Maximum Flood has been viewed as 'about right'. There has been about as much criticism that it underestimates as the opposite. David himself has been vocal on its failure to make enough allowance for the potential of snowmelt!

If the engineer's adopted flood growth curve were to be based solely on the statistical method up to, say, 1000 years and then jump suddenly to the PMF, then I fear a gross discontinuity could sometimes arise. Personally I prefer to give more weight to the statistical method peaks at lower return periods and gradually change over until the rainfall-runoff growth curve dominates at return periods above 500 years. One obvious difficulty of rescaling all hydrograph ordinates is that runoff volumes are distorted too: in many studies, the volume is at least as important as the peak. There is scope for more work on this and perhaps some formalised advice.

Finally, what does all this mean for those charged with applying the FSR to real world problems of today? Despite my attempts to refute David Archer's criticisms, I have a strong regard for his judgment and I would be the first to admit that a more rigorous attempt to reconcile the two main FSR methods is overdue. However, provided the methods are applied by experienced hydrologists with a good understanding of the underlying principles, and provided all possible use is made of local data, they continue to offer a consistent basis for design. Those two provisos are important though. Like David, I would be concerned if, in the name of economy and haste, handles were being turned without the requisite understanding.

Finally, I would like to thank David for the provocation. We may not agree on the significance of this particular criticism but I am sure we would agree that user pressure for improved methodology is a vital ingredient in advancing engineering science. Many 'improvements' may simply be glossy repackaging or esoteric theoretical niceties but the fundamental rethinks (such as those embodied in the Handbook) — which seem to come at 20-30 year intervals — are worth waiting for. David has pointed to an aspect that deserves another look: I hope the Institute and its paymasters are listening.

Mike Lowing, Water Resource Associates

News from members

Member on the move

Richard Boak has recently joined Sir William Halcrow & Partners Ltd, and will be based in their new Crawley office. He is making the move along with about 70 other former employees of the Southern Water Technology Group, under an outsourcing agreement.

Richard will be in Halcrow's Water and Environment Department, which undertakes consultancy work in a wide range of fields, including environmental assessment and protection, groundwater resources and hydrogeology, water supply and wastewater engineering.

He can be contacted on Tel: 01293 534932, Fax: 01293 530830.

Seventh international symposium on regulated streams, 25-29 August 1997

The seventh international symposium on regulated streams (SISORS) in Chattanooga, Tennessee was well organised and proved to be a very informative and interesting meeting. Almost 100 attended, from 16 countries, although large contingents were from the USA, UK, Norway and Australia.

Although most contributors had a biological background, there was a wide variety of oral presentations, from the habitat of floodplain spiders to sediment deposition. The papers were divided into 12 sessions, some very specific ("Atlantic salmon in the regulated River Alta"), others general ("River rehabilitation").

The rehabilitation and restoration of rivers were topics of particular interest throughout the symposium. As well as the general issues, many case studies were presented from various areas and using different techniques. In his closing lecture, J. Stanford suggested that large-scale re-regulation of rivers was now possible. He stressed the importance of reference streams in river rehabilitation and restoration, and further stated that prehistoric conditions were not required, but rather a situation where ecological processes could operate.

Throughout the sessions, modelling was ofttten used as a technique for analysis. PHABSIM in particular was used in a number of studies and it became clear that such techniques were relevant to a range of applications, not just to assess minimum flow criteria.

The day excursion to the Tennessee Valley Authority facilities proved very interesting and the Smokey Mountain scenery was spectacular. Taking in three states, the party visited several sites in the heavily regulated Tennessee River catchment.

The social aspects of the symposium were also excellent, including a visit to the impressive Tennessee Aquarium and a banquet on the *"Southern Belle"* river boat. The organisation and hospitality of Jim Layzer and the Tennessee Cooperative Fishery Research Unit were much appreciated and the symposium was an invaluable forum on regulated rivers.

I am grateful for financial assistance from BHS that enabled me to attend.

Hamish Moir
University of Aberdeen

Meetings

ICE Scottish Hydrological Group
REMOTE SENSING AND GIS IN HYDROLOGY
Edinburgh
15 April 1998

This full-day meeting will review the current state of the development and application of remote sensing and GIS in hydrology in a number of key areas,

and indicate where we might expect these developments to lead at a practical level.

The venue will be the UnivEd Conference Centre in central Edinburgh. Alongside the technical programme, GIS providers will mount an exhibition. The cost for the full day (including coffee, lunch and tea) will be £50; some places are available for students at the reduced rate of £25.

Further information may be obtained from Robin Wardlaw (tel 0131 650 5944, fax 0131 667 9238, email: Robin.Wardlaw @ed.ac.uk) or Neil Stuart (tel 0131 650 2549, fax: 0131 650 2524, email: Dr.N.Stuart@ed.ac.uk).

To book, please send your details and payment to Dr A Folkard, Dept. of Civil & Environmental Engineering, University of Strathclyde, John Anderson Bldg, 107 Rotten Row, Glasgow G4 0NG (Tel: 0141 548 3280, Fax: 0141 553 2066).

CALL for PAPERS
IGU Hydrology Study Group on ENVIRONMENTAL CHANGE AND EXTREME HYDROLOGICAL EVENTS
Lisbon, Portugal
29 August - 2 September, 1998

This is the first meeting of a new hydrology study group. It will be held at the IGU Regional Conference in Lisbon.

Papers are invited: abstracts should be submitted for approval by **3rd April** to Dr J A A Jones, Institute of Geography and Earth Sciences, University of Wales, Aberystwyth, SY23 3DB.

Courses

Advanced Study Course on RADAR HYDROLOGY FOR REAL-TIME FLOOD FORECASTING
Bristol, UK
24 June - 3 July, 1998

This course is funded by the European Commission's Environment and Climate Programme and aimed at young researchers and recent graduates.

The course comprises a structured programme of lectures, compuer-based workshops and field visits. Subjects covered will include operating weather radar for real-time hydrological applications, properties of weather radar data, radar rainfall forecasting, distributed flood forecasting models, flash flooding and urban flood forecasting.

Up to 40 students will be seected by a scientific panel and the EU's services. Accommodation and subsistence are provided free and there may be travel scholarships for outstanding applicants on request.

To apply, please obtain a form from Professor Ian Cluckie, Marinetech Research, P.O. Box 88, Sackville Street, Manchester, M60 1QD, UK. The deadline for the receipt of completed forms is **27th March 1998**.

Details are also on the internet at http://www.fen.bris.ac.uk/civil/wmrc/course98.htm

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Internet: http://www.ncl.ac.uk/~ncivil

Diary

26th March 1998
CIWEM / ICE one-day conference "Maintaining the flow" *(see meetings)* and *Water Environment '98* exhibition
Venue: ICE, London
Contact: Jenny Eele, Thomas Telford Conferences, 1 Great George Street, London SW1P 3AA *(Fax 0171 233 1743).*

30th March – 1st April 1998
8th BHS Postgraduate Symposium
Venue: University of Birmingham
Contact: Paul Webster *(Tel 0121 414 5055 Fax 0121 414 3675 E-mail p.webster@bham.ac.uk)* – see page 9

3rd April 1998
Welsh Hydrological Group
Day visit to the Llyn Brianne hydroelectric scheme
Contact: Terry Newman
(Tel 01222 666234, Fax 01222 666180)

15th April 1998
Scottish Hydrological Group & SHSG
"Remote sesing and GIS in hydrology"
Venue: University of Edinburgh
Registration required — fee payable
Contact: Dr Andrew Black, Dept of Geography, University of Dundee *(Tel 01382 344433, fax 01382 344434, e-mail a.z.Black@dundee.ac.uk, internet http://www.dundee.ac.uk/geography/shg/)*

20th May 1997
BHS Southern Section AGM
"The channel tunnel: potential impacts on groundwater"
Venue: Imperial College, London
Time: 17.30
Contact: Prof. Howard Wheater, Dept of Civil Engineering, Imperial College, London SW7 2BU *(Tel 0171 594 6066, Fax 0171 594 6053)*

20th May 1997
BHS Pennines Hydrological Group AGM
"Groundwater Protection and Management" Venue: University of Central Lancashire, Preston
Contact: Dr Kevin Tilford, Dept of Civil & Environ. Engineering, University of Salford, Manchester M5 4WT *(Tel 0161 295 3458, Fax 0161 295 5060, E-mail k.a.tilford@civils.salford.ac.uk)*

17th-20th August 1997
Second International Conference on Climate and Water, Espoo, Finland
Contact: Ms Nea Helenius, Tietotie 1, 02150 Espoo, Finland, Fax +358 9 451 38 27, E-mail nheleniu@ahti.hut.fi

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