THE NEWSLETTER OF THE BRITISH HYDROLOGICAL SOCIETY

Circulation

No. 24 November 1989

UNIVERSITY RESEARCH ...Part IX

Department of Geography, Loughborough University of Technology

The Geography Department of Loughborough University came into being as recently as 1977 but has established an international reputation for research on freshwater environments. The development of research in physical geography has centered on hydrology. Currently within the Department the Freshwater Environments Group of six academic staff and nine post-graduates is working in three broad areas: river regulation by dams, reservoirs and engineering schemes, and wetland drainage; acidification of freshwaters; and long-term palaeohydrologic/ palaeoclimatic reconstructions. Links with the Department of Civil Engineering and the Water, Engineering and Development Centre at Loughborough extend these areas to include rural water supply and land management in developing countries.

Loughborough University of Technology, designated in 1966, was the first of Britain's technological universities. The Department of Geography was added when the University amalgamated with the College of Education. The next decade witnessed a rapid development of hydrology-related research. Our objective was to achieve truly integrated research at the interface of hydrology, geomorphology and ecology. By 1987 research was established in hydrology/fluvial geomorphology (**Geoff Petts**), climatology (**Keith Boucher**) and palaeoecology (**Neil Roberts**). The objective was realised in 1988 with the addition of three freshwater ecologists providing expertise in entomology (**Malcolm Greenwood**) with particular reference to river pollution and disease transmission, in botany (**Max Wade**) focussing on land-drainage schemes, and in biological conservation (**Gerry White**) especially with regard to fisheries and wildlife.

The work of the Freshwater Environments Group (FEG) benefits from contact with human geographers, interested in the socio-economic aspects of water projects, and engineers at Loughborough as well as from established links with scientists at the NERC Institutes and from collaboration with researchers at other universities in Britain and overseas. Currently, field investigations are being undertaken on rivers throughout Britain, in France, Zimbabwe, Kenya and Tanzania.

The Department is strongly involved in international activities. Members of FEG serve on scientific committees of the CNRS, France; US Department of the Interior, Fish and Wildlife Service; IUCN Ecology Commission; and Unesco's MAB Programme. In 1988 the Department hosted the Fourth International Symposium on Regulated Streams and Geoff Petts is editor-in-chief of the international journal *Regulated Rivers: Research and Management* published by John Wiley.

RIVER REGULATION

The approach to research on rivers influenced by dams, reservoirs, abstractions and inter-basin transfers (Petts, 1984) focusses first on the effects of changing hydrological regimes on water-quality, channel and floodplain dynamics, and biota, and secondly on the management of flows to mitigate deleterious effects. A review of the historical changes of large alluvial rivers in western Europe (Petts *et al.*, 1989) revealed that most rivers were significantly affected by human impact before 1900, and attention is now being directed to alternatives in river regulation (Gore

and Petts, 1989). Two major research themes have evolved over the past decade.

Effects of flood regulation

Changes to the magnitude and frequency of sediment transporting flows along regulated rivers have been a major research focus. Early work on changes of channel morphology below reservoirs in the UK demonstrated the importance of sediment yields from uncontrolled tributaries. Subsequent NERC-supported research has investigated lateral bar accretion; substrate siltation and suspended sediment transport under regulated flow conditions.

Coarse bedload introduced by tributaries has been shown to accumulate as lateral bars immediately below the confluence (Petts and Thoms, 1987), narrowing the channel and increasing the energy slope. Where flows in the regulated river are very low, aggradation occurs over the entire width of the channel bed (Petts and Thoms, 1986). As the channel form becomes adjusted to the regulated regime, the depositional front moves slowly downstream. The ecological effects of this succession of geomorphological changes have been investigated since 1981. The adjustment of channel morphology to the regulated flow regime is important as in large part this restores the hydraulic geometry, and most of the physical habitats, of the pre-regulation river channel. During the period of channel change, the existence of several transient habitats, together with refuges and relic patches, can create a high diversity of habitats within the river (Petts and Greenwood, 1985; Petts, 1987).

Currently, different successional pathways are being identified using CANOnical Community Ordination. In Britain, research has shown that a considerable time-lag exists between the imposition of a regulated flow regime and the completion of the succession of channel changes. Periods of greater than 100 years are common. Thus, along most regulated rivers a diversity of 'transient' habitats may be sustained for a long period of time.

The siltation of gravel-bed rivers is a more insidious process. Infiltration of fine suspended sediments into open framework substrate gravels is a major potential problem consequent upon flow regulation (Petts *et al.*, 1989). Compaction of the gravel bed has been demonstrated along regulated British rivers. Ecologically these changes are significant, affecting invertebrate populations and the success of salmonid reproduction, for example. However, low suspended sediment yields create only local problems along British rivers. A typical rate of bed compaction is 500 $m^2 year^{-1}$. Nevertheless, land disturbance generating elevated sediment loads can cause greater problems and the effects of construction works and land use changes, and their ecological consequences, are currently being investigated.

The incorporation of potentially toxic metals and organic wastes into substrate gravels may be a further potential problem. A freeze-coring technique is used routinely to sample fine sediments within gravel substrates for pollution and regional geochemical surveys. **Martin Thoms** demonstrated that potentially toxic metals can be concentrated within the gravel bed of rivers draining urban areas. **Nic Hughes** is investigating the incorporation of fine (<100 µm) heavy minerals within gravel substrates. Preliminary results indicate that sorting of some metals downstream from point inputs leads to locally elevated levels with predictable decay curves. The magnification of potential pollutants within gravel bed substrates is being investigated by **Dave Forrow**.

David Gilvear investigated the transport of suspended sediment in seven regulated rivers. Near to dams, diatom and algal fragments scoured from the channel bed dominate the seston. Downstream, reservoir releases flushed surface accumulations of fines but the armour layer of the gravel bed was rarely disrupted. Hysteresis between suspended sediment concentrations and discharge were related not only to sediment supply but also to the hydraulics of release wave movement elaborated by Gilvear (1989). His work suggested that flow manipulation to flush fines from within the substrate is problematic.

Subsequently, work has continued on the French Rhône in collaboration with scientists at the CNRS Freshwater Ecology Institute at Lyon University. Research is focussing on the transport and dispersion of fine sediments under different flow conditions along the river with particular regard to the sedimentation of fines released during reservoir cleaning and venting operations. During the operations, suspended sediment concentrations in a flow of 700 $m^3 s^{-1}$ exceeded 5 $g l^{-1}$. Ecologically this is significant particularly as, during the operations, the suspended sediments had high concentrations of some potentially toxic metals, notably cadmium.

Minimum ecological flows

River regulation alters minimum flows but these are also influenced by abstractions, including groundwater abstractions, and effluent discharges. **Ian Maddock** is undertaking research on a severely stressed river to investigate the discharges needed to sustain the biota (invertebrates and fish) and the diversity of riparian habitats. The specific effects of abstractions on invertebrate communities is being investigated in collaboration with the Institute of Freshwater Ecology (IFE).

Field investigations have included different types of abstraction and different types of river, as defined by the IFE's RIVPACS. Research is seeking to establish the sensitivity of invertebrates to low-flow manipulation and to evaluate the feasibility of using an invertebrate index as the basis for managing minimum flows. A third study, in collaboration with the Institute of Hydrology, IFE and the Institute of Terrestrial Ecology seeks to evaluate the Instream Flow Incremental Methodology (IFIM) and its principal component the Physical HABitat SIMulation model for setting instream flows in British rivers.

The fourth component of this research is a developing programme focussing on the land-water ecotone. **Tim Foulger** showed that flow manipulation can have significant consequences for water quality and subsequently **Paul Jose** undertook a NERC-supported investigation of the water quality dynamics of marginal backwaters, highlighting the importance of these as refuges and habitat for a wide range of biota. Following research on the role of aquatic macrophytes in wetland management (Wade, 1987), **Andrew Large** is studying the structure and function of riparian and relic floodplain habitats. This research focusses on hydrological controls of soil/vegetation patches and their biochemical dynamics.

Building on these studies, the FEG is developing a collaborative programme with researchers in Sweden, France and Spain to assess the hydrological requirements of habitats within the land-water ecotone. This is especially topical given the potential value of riparian woods not only for biological conservation but also in controlling non-point sources of nutrient runoff.

ACIDIFICATION

Catchment responses to atmospheric inputs are currently assessed using approaches which measure and compare the total annual load of ions deposited on a catchment with that exported annually. A catchment study is being undertaken in collaboration with **Val Black** and **Phil Peters** (Human Sciences Department) to test the general applicability of the widely used annual input:output approach to defining catchment responses. The catchment (of 66.2 hectares) is situated in the industrial East Midlands where atmospheric loadings of hydrogen, sulphur, chloride and nitrogen are high.

Research is also seeking to establish the potential modifying influence of vegetation on the flow of ions from atmosphere to freshwaters, including coniferous plantation, mixed deciduous woodland and a luxuriant community of bracken. A monitoring programme was initiated in 1984. The major anions deposited are sulphate, chloride and nitrate in concentrations that may exceed those observed in many other studies in the UK and, in particular, the peak concentrations. Rainfall pH over the first four-year period ranged from 8.9 to 2.54. Water draining from coniferous plantation is more extreme in its chemical composition especially in the winter period when aluminium concentrations may exceed 3 $mg l^{-1}$ and the pH may fall to below 4.0. Drainage from the deciduous woodland and especially the stands of bracken is less extreme in its chemical composition.

Another aspect which is being researched is the degree of stress freshwater invertebrates experience from the chemical components of their environment. Work is focussing on the effects of hydrogen and aluminium, and on the significance of toxic 'pulses' of various magnitudes, frequencies and durations. In particular, studies have been made of the life-cycle strategy and productivity of the mayfly (*Cloeon dipterum*), an insect of wide geographical distribution and one sensitive to low pH values. Its survival characteristics are being investigated by field transfer experiments and biotoxicological laboratory assays. Results indicate that a synergistic effect may exist between ions present in certain concentrations which ameliorate hydrogen ion stress or indeed enhance survival.

Hydro-climatic modelling

One extension of the project has been to investigate the significance of climatic variations over time-scales of 10-100 years for inputs of acidic ions to catchment hydrochemical systems, and their subsequent response. A multidisciplinary approach has been employed which incorporates aspects of hydrological and soil chemical modelling, statistical analyses of climatic trends, weather classification schemes and the generation of synthetic input data from observed precipitation chemistries. **Rob Wilby** has combined these elements in a Shifting Climate and Catchment Acidification Model (SCAM). By coupling the atmospheric and terrestrial solute processes, SCAM is being developed to forecast future changes in surface water chemistry resulting from variations in the state of either field of influence.

At the heart of SCAM's forecasting capability are the contemporary and long-term

variations in the properties and annual frequencies of eight main Lamb's Weather Types (LWTs). When these statistics are combined with long-term changes in the annual frequency of a given LWT, such as the westerly-type it is possible to retrodict and predict annual rainfall totals, precipitation acidities and consequently hydrogen-ion loads in the East Midlands. For example, the annual rainfall totals for the period 1969-1988 were all reconstructed using only weather type data to a mean accuracy of ±10%. Some recent results indicate that annual rainfall totals and the volume-weighted precipitation pH will decline steadily until the turn of the century due to the increasing predominance of the anticyclonic weather type (Fig. 1). Work is currently underway to assess the exact nature of the hydrochemical respose to these changing inputs, but provisional analyses suggest that even in the absence of reduced emissions, the projected weather-type proportions will favour accelerated acidification in certain catchments of the East Midlands region.

PALAEOCLIMATIC RECONSTRUCTION

In the context of increasing concern about global climatic change, high resolution records of past climate and hydrology form an essential basis for future projections. There is nowhere more important in this regard than the arid margins of Africa, already devastated by the consequences of drought and flood. Here the history of saline, non-outlet lakes provides a crucial record of changes in water balance. In essence, these lakes can act as natural raingauges, becoming deeper and more dilute at times of water surplus, and shallower and more saline during drought episodes. By studying the remains of diatoms (a type of algae) preserved in the lake bottom sediments, it is possible to attempt quantitative reconstruction of changes in water depth, pH, salinity and runoff. A joint project between the Geography Department of Loughborough University and CNRS Quaternary Geology Laboratory at Marseille, France, is investigating lake histories in the Rift Valley of Kenya and Tanzania.

Philip Barker is undertaking NERC-supported investigations of the Magadi-Natron and Manyara basin, whose lakes lie in the lowest part of the eastern Rift Valley and include the hydrological sink for this section of the rift. A number of sediment cores have already been taken, which span the last major dry-to-wet climatic transition (ca. 12,500 years BP). Diatom analysis has revealed important and rapid hydro-climatic shifts at this time, which may provide an analogue for the effects in tropical Africa of a greenhouse induced future climate change. The diatom investigation of a 9 m core from Lake Magadi is summarised in Fig. 2: water chemistry is reconstructed using transfer functions from modern autecological data. Zone 3 (19-17,000 years BP) has a flora typical of a shallow saline-alkaline lake with a pH of 10.5 and a conductivity in excess of 20,000 µS. This is superseded by a much more diverse zone which includes species indicative of both fresh and saline environments and it is thought that this may be a result of a fluvial input close to the coring site at this time. Less concentrated conditions are indicated by the diatoms at the base of zone 1 (pH 9, conductivity 8,000 µS) suggesting that a major deepwater phase occurred within the lake basin after 12,500

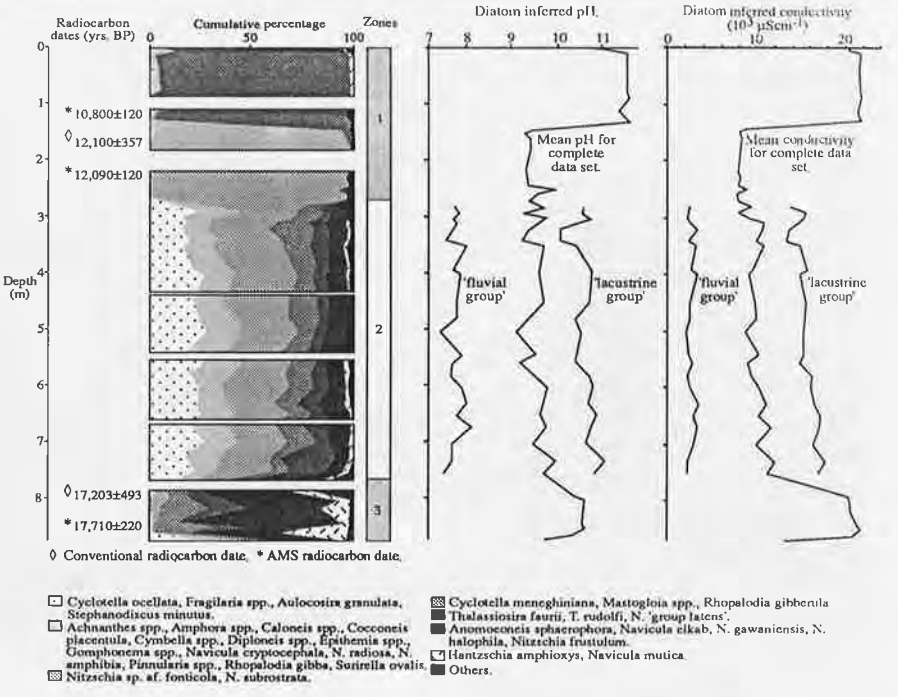


Figure 2. Summary of diatom analysis from Flamingo Nursery Core, Lake Magdi, Kenya

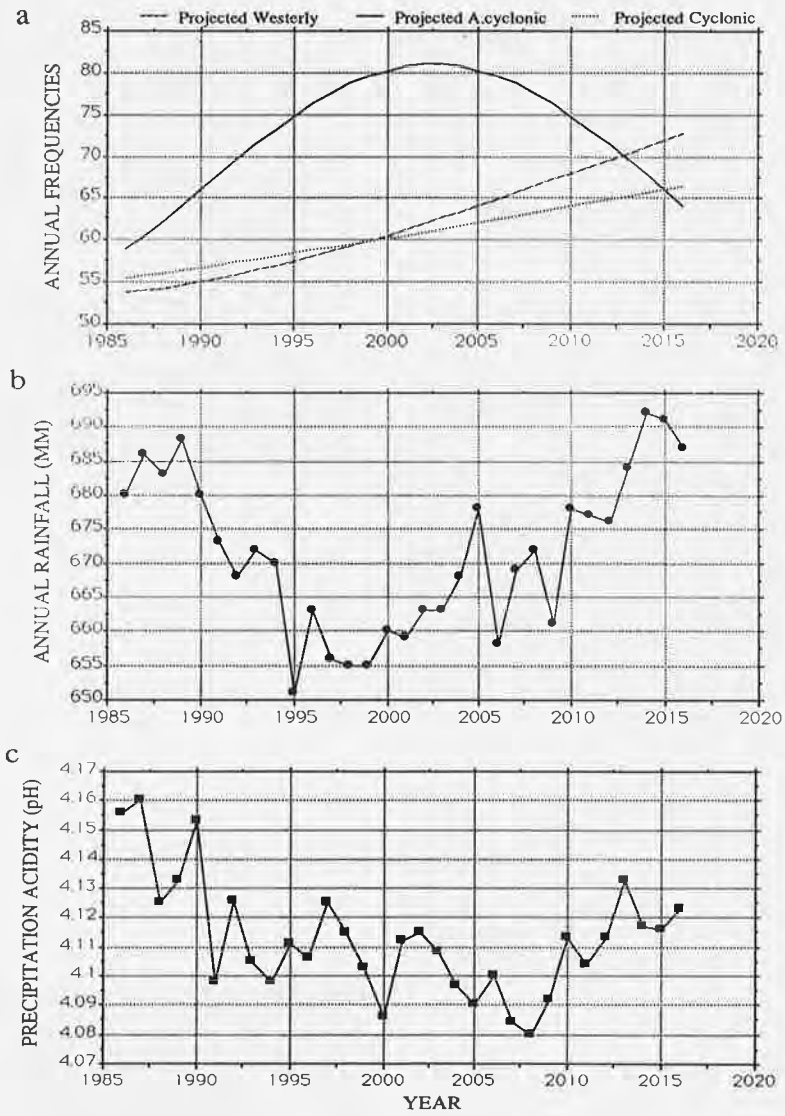


Figure 1. Forecasted rainfall data
a) annual frequencies for the 3 main Lamb's Weather Types
b) annual totals for the East Midlands
c) precipitation acidity for the East Midlands



Figure 3. Dambo cultivation in Zimbabwe

years BP. A fall in lake level after ca. 11,000 years BP is suggested by a return to a more saline-alkaline diatom flora.

In another rather different study **Carol David** is looking at the role of hydrological processes in the dispersal of pollen grains to lakes and lake sediments. Pollen analysis provides one of the main ways of reconstructing vegetation and land use histories, but in order to interpret pollen diagrams correctly, it is essential to know from where the pollen has been derived. Although airborne pathways are often most important, in small lakes inflow streams may make major contributions. Pollen input to Groby Pool, Leicestershire, is being monitored by means of stream and air traps and compared with other records of vegetation from this site.

RURAL WATER SUPPLY AND LAND MANAGEMENT

In collaboration with members of the Civil Engineering Department, researchers are examining the water resource potential of small catchments. The major interdisciplinary project has studied the role of dambo wetlands in small-scale rural development in southern Africa, which also involves the Water, Engineering and Development Centre (WEDC) at Loughborough and the University of Zimbabwe. The project team includes **Richard Faulkner, Morag Bell, Neil Roberts, Bobby Lambert** and **Pat Hotchkiss**.

Dambos are seasonally waterlogged depressions located at the headwaters of stream systems, common throughout Africa's plateau savannah lands. They are used for livestock grazing, domestic water supply and for garden cultivation of vegetables and other crops. Dambo horticulture (Fig. 3) often involves simple, dry-season irrigation, characterised by low capital investment and running costs, absence of the need for centralised administration or population relocation, and the direct control that farmers have over decision making. Nonetheless, such micro-scale irrigation is effectively ignored in most national irrigation plans as too small to be significant. In fact, dambo gardens in Zimbabwe alone cover an estimated 15-20,000 hectares compared with only 5000 ha of conventional small-holder irrigation introduced since 1980. This is despite government efforts to discourage dambo cultivation in that country during the colonial era.

Research has focussed on five aspects:

1. Mapping the distribution of dambos as a resource and assessing the extent of existing garden cultivation in Zimbabwe.

2. The socio-political constraints upon and socio-economic benefits of dambo use.

3. The effect of different forms of land use (notably micro-scale irrigation) on dambo water and soil budgets.

4. The effect of drawing water from shallow wells on the dambo for irrigation. This involves detailed investigation of evapotranspiration rates from the natural dambo grasses and from cultivated crops, and assessment of the dambo contribution to dry season runoff in the rivers downstream.

5. The development and testing of pumps appropriate for micro-scale irrigation.

Richard Faulkner of the Civil Engineering Department is particularly concerned with consumptive water crop use for irrigated areas. A large number of measurements of actual crop evapotranspiration has been made in arid and semi-arid zones. The methodology has been to utilise the Energy Balance (or Bowen ratio) method which does not disturb the crop or soil. Instrumentation known as DREAM (Direct Reading Evapotranspiration Assessment Monitor) has been developed for this. Results obtained have been compared to estimated values using concurrent meteorological data together with the semi-empirical equations commonly used by irrigation engineers. These have shown that even the best calculated estimates of evapotranspiration are often 25% in error, which has significant implications for the design and operation of irrigation schemes.

PROSPECT

Hydrology-related research at Loughborough will continue to focus on interdisciplinary studies at the interface of hydrology, geomorphology and ecology. Scientific research relevant to river and wetland management will be emphasised. Progressive developments over the past decade make the Geography Department well placed to promote research in these areas. One new programme is focussing on the hydrology, chemistry and ecology of springs - their vulnerability to groundwater abstraction and their value for biological conservation.

Whilst continuing to develop and expand our field-based studies in Britain we are committed to expanding our international activities. The Freshwater Environments Group is developing a collaborative programme with researchers in Sweden, France and Spain to assess the hydrological controls on patch structure and function within the land-water ecotones or large rivers. This is especially topical given the potential value of riparian woods not only for biological conservation but also in controlling non-point sources of nutrient runoff. Plans are complete to begin research on the regulation of large alluvial rivers in Latin America. New research opportunities in Africa, Malaysia and North America are currently being examined.

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Copy Deadline for Issue No. 25 4th January 1990

THE ROWDEN DRAINAGE EXPERIMENT - FIELD VISIT

BHS South-West Section Meeting
11 July 1989

Members of the South-West Section assembled in the splendid manor house of the Institute for Grassland and Animal Production (IGAP) Research Station at North Wyke near Okehampton for a field meeting which focussed on the major drainage experiment that has been in progress over much of the 1980s at the nearby Rowden Farm.

Roger Sheldrick (IGAP), provided a background to the meeting by briefly reviewing the history of research at North Wyke and by outlining the projects currently in progress. The station was set up in 1981 to investigate problems of grassland farming in areas of impermeable soils in the wetter western parts (>1000 mmyear^{-1}) of the country. It comprises some 500 acres (200 ha) of farmland, split between the North Wyke and nearby Rowden Farm sites, together with 100 acres (40 ha) of woodland. A dairy herd of 100 cows with 60 followers, 400 head of beef cattle and 380 breeding ewes, plus rams and lambs make up the livestock at the station.

The 20 scientific staff at North Wyke are divided into six project teams to research a number of topics within the contexts of grazing management and environmental impacts. Some of this work involves investigations at sites in other parts of the country, and the major research themes include: comparison of permanent swards with new or ageing re-seeds under varying management and fertiliser inputs; management of white clover pastures to improve animal nutrition and to reduce nitrogen use; study of nitrogen movement within the soil/sward environment, and the control of nitrogen losses; the management of grassland in Environmentally Sensitive Areas; improving the self-sufficiency of cattle production systems, and the development of agro-forestry land uses.

Roger explained that the research is increasingly being concentrated on the fostering of lower input grassland systems, the protection of the environment and diversification of the landscape. The development of sustainable low-input systems was the critical problem, to which the planting of trees into pasture at wide spacings might offer an acceptable solution. Agro-forestry of this sort had considerable advantages in relation to the cash-flow of small farming operations: it diversified habitat and landscape, and it could also increase animal production in the short-term through provision of additional shelter.

David Scholefield (IGAP) introduced the drainage experiment at Rowden, which was established jointly with the ADAS Field Drainage Experimental Unit (FDEU) in 1982 to investigate the economic value of drainage within the context of grazed grassland, and continues today as a joint FDEU/IGAP venture. The treatments involved drained and undrained old original sward plots receiving an annual fertiliser input of 200 and 400 kgNha^{-1}, and drained and undrained ryegrass re-seeded plots receiving an annual input of 400 kgNha^{-1}. These six treatments were replicated in the original 12-plot scheme, and the benefits of the various treatments have been assessed in relation to herbage production, sward composition and animal output. In more recent years, research has focussed on the effects of different treatments on nitrogen cycling and especially on the way that nitrogen is lost from grassland systems. Zero-N drained and undrained old sward plots were added to the experiment as controls in 1987, and increasing interest in low-input systems stimulated conversion of the two ryegrass re-seeded treatments to grass/clover swards under zero-N management in 1988.

Following the introductory presentations, the BHS party made its way to the Rowden site. In glorious sunshine, **Adrian Armstrong** (FDEU) explained the layout of the experiment and the instrumentation installed for collecting surface and subsurface flows from the plots and for measuring hydrological conditions within the plots. Each plot is hydrologically isolated and covers an area of 1 ha, which is sufficiently large for realistic agronomic management. In those plots which are drained, drainage is effected by mole channels drawn at 55 cm depth and 2 m spacing with water being collected from the moles by lateral interceptors at 40 m spacing and 85 cm depth (Fig. 1). Interceptor drains at 30 cm depth also collect the surface and near-surface flows on each plot. Flows from the drains and the surface interceptors are measured using 1/2 90° weirs capable of accommodating up to 30 ls^{-1}. The weirs and associated head recording devices are field calibrated every year.

Adrian reported that the major hydrological influence of drainage installation at Rowden was not on the total water balance but on the route which water takes through the soil. In the drained plots, 90% of the total runoff is discharged through the drains. Very rapid response to rainfall is typical of both drained and undrained plots under conditions of field capacity. The water table rises to the surface of the undrained plots and rapid surface runoff occurs, whereas on the drained plots, the mole channels generate rapid flow through the soil to the collector drains. Cracking of the soil associated with drawing of the moles has created a classic macropore situation with most of the flow occurring through only a small proportion of the soil body.

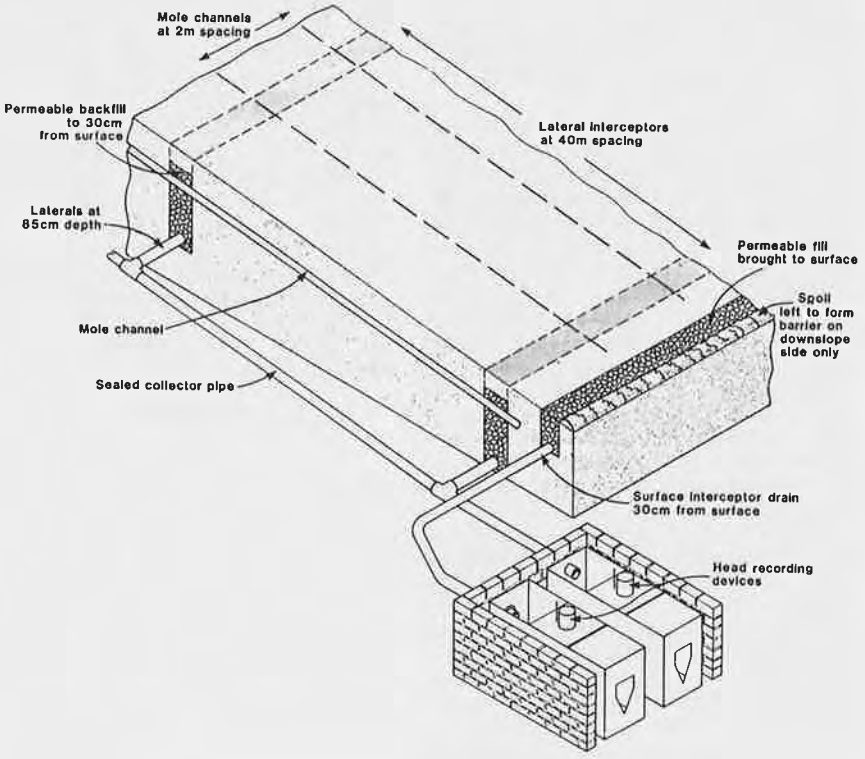


Figure 1. Drainage installation and arrangements for flow measurement at the Rowden experimental site.



Figure 2. Members of the BHS party examining 'soil and mole' at Rowden.

The BHS party had a chance to examine the silty-clay soil (Hallsworth 1 Association) of the site and to view a typical mole channel in a pit excavated within one of the drained plots (Fig. 2). **John Williams** (FDEU) highlighted the crumbly structure of the topsoil and the highly impermeable nature of the clayey subsoil derived from the underlying Culm Measures, and it was clearly seen how drainage had "pulled the plug" under the topsoil portion of the profile. The first "moling" had not been very effective and the moles were redrawn in the summer of 1984 and again in 1987. The re-moling operation is carried out in June when the soil is plastic at mole depth and brittle above. At this time, the soil mass is able to bear the burden of heavy vehicles without damage, and usually there is also a dry period when the stresses created by re-moling can be dissipated without causing collapse of the mole channels. The sight of an 'in situ' mole channel stimulated considerable discussion, particularly in relation to ideal depth for installation. The hydrological effects of a plough layer in promoting lateral flows within the soil profile of plots subjected to re-seeding operations were also noted at this site.

The group next moved on to the instrument enclosures located within individual plots which provide data on soil moisture status. Information on the height of the water table is collected by dipping open auger holes and from recording water-table meters. Arrays of piezometers are used to measure water pressures, and have revealed positive pore pressures in some plots, which originate from water under pressure in a fractured shale (shillet) layer lying at a depth of ca. 2 m. The enclosures also contain a number of access tubes for industrial endoscopes which are periodically used to examine the interior of mole channels without causing disturbance. Tensiometers have been installed from time to time in the enclosures, which are also sampled for soil moisture determinations.

A final halt was made by the outlet of one of the drained plots to hear something of the results relating to agronomy and to nitrogen cycling which have been generated by the Rowden experiment over the last five to six years. David Scholefield referred to mean figures for a five-year period which showed that annual herbage production (measured by exclusion cages) on drained and undrained plots receiving a low annual fertiliser nitrogen input (200 $KgNha^{-1}$) was the same at 7.6 tha^{-1} . Drainage caused a very slight increase in annual herbage production with high nitrogen inputs (400 $kgN\ ha^{-1}$) from 9.0 tha^{-1} in the undrained situation to 9.3 t ha^{-1} where drained. For re-seeded plots receiving high fertiliser inputs, the annual herbage production was 8.8 and 9.4 t ha^{-1} for undrained and drained cases respectively. With respect to animal production, five-year mean figures for undrained and drained plots receiving low fertiliser inputs were 0.75 and 0.82 t $ha^{-1}year^{-1}$ respectively, but for the re-seeded plots, the contrast in animal production between undrained (0.84 t $ha^{-1}year^{-1}$) and drained cases (1.01 t $ha^{-1}year^{-1}$) was somewhat greater. The relatively modest benefits of drainage to both herbage and animal production revealed by the Rowden results was seen to be at least partly a reflection of the low stocking densities (11 ha^{-1}) invoved in the experiment.

The Rowden experiment has also provided a unique opportunity to study the impact of drainage on nitrogen balances in grazing systems, and David reviewed the results with particular reference to different pathways of N loss. Table 1 indicates that installation of drainage has almost trebled the losses of nitrogen in leaching, although it is also clear that losses by this pathway are rather lower on the re-seeded plots compared with the old sward plots. When losses are plotted against accumulated excess runoff over a drainage season, a basic contrast is evident between drained and undrained plots which exhibit convex and concave graphs respectively. Losses of nitrogen through denitrification have been determined using an acetylene inhibition technique and by measurements which take into account the considerable spatial and temporal variability of this process in soils. Results indicate that denitrification losses are substantial, but vary on average from 41 - 94 kg $ha^{-1}year^{-1}$ according to plot treatment, and are approximately 25% lower on drained compared with undrained plots. Volatilisation of ammonia represents the third pathway of N loss, and David explained that this is currently being investigated by means of a micro-meteorological measurement system. Ammonia losses of 30 - 70 $kgha^{-1}year^{-1}$ are typical of plots receiving between 200 and 400 $kgNha^{-1}year^{-1}$, and represent 11% of urine N as voided on the pasture. The results from the Rowden experiment have allowed the construction of a dynamic model to predict the annual nitrogen budget under varying environmental conditions and treatment scenarios. The rate of mineralisation is seen as a key process of nitrogen cycling within this model, and it may be variation in this factor, rather than changes in the route that water takes through the soil, which is the main influence on altered nitrogen budgets following the installation of drainage.

Paul Blantern (Exeter University) summarised the research he has been conducting into nitrogen mineralisation at Rowden and described the new technique which has been developed to give a field assessment of ammonification, nitrification and denitrification. Results for the period June 1988 to June 1989 from the high input drained and undrained plots and from the zero-N drained and undrained controls indicate that the installation of drainage increases mineralisation by promoting aerobic conditions, and that the addition of fertiliser also enhances this process by increasing the amount of labile substrate available to the microbial population. Temperature is clearly a control on mineralisation rates with values of 1.5 $kgha^{-1}day^{-1}$ being recorded on the drained plot in the height of summer, but his process ceases when temperature falls below 6°C in winter months. Soil moisture conditions and, particularly, the wetting and drying of soils are also considered an important influence on mineralisation. Paul explained that 'flushes' of mineralisation followed precipitation by approximately 70 hours in summer months, and attributed this phenomenon to the creation of new and suitably moist aerobic 'pockets' within soils, which in turn provided new substrate for an expansion in microbial activity. Overall the higher rate of mineralisation on drained plots, both at the start of the drainage season and in the winter period, was seen as the cause of higher N leaching losses compared with undrained treatments.

Following a most interesting and entertaining afternoon in the field, BHS members repaired to North Wyke for refreshments in the form of tea and home-made cake!

Bruce Webb
Exeter University

Table 1. Nitrogen leaching losses (kg ha^{-1}) from plots under different treatments.

Season	83/84	84/85	85/86	86/87	87/88	5-year Mean
Treatment						
LNU	16	34	20	8	15	18
LND	58	68	60	36	61	57
HNU	55	84	38	13	56	49
HND	168	246	192	147	204	190
RHNU	36	27	14	21	26	25
RHND	80	90	78	50	107	81

LN = low nitrogen, HN = high nitrogen, U = undrained, D = drained, R = re-seeded

Climate change - and its economic and political impact

Mason Conference
14 September 1989

This annual meeting held at the British Association was organised jointly by the Association of British Climatologists, the Royal Meteorological Society and the Royal Geographical Society. **Dr K. Browning,** President of the Royal Meteorological Society, opened the meeting with a brief historical review of the study of the greenhouse effect, pointing out that the potential problem was first recognised as far back as the 19th century by Fourier and Arrhenius. **Dr R.A. Warrick** of the Climatic Research Unit gave an overview of the greenhouse effect, chronicling the rise in concentration of the greenhouse gases and the predictions of a 1.5-4.5 °C temperature rise and a 17-26 cm rise in sea level by the year 2030.

The uncertainties in General Circulation Models were described by **Dr J. Mitchell** of the Meteorological Office. In particular the problems relating to feedbacks, the ocean and the parameterisation of clouds were identified. **Dr J. Woods**, Director of Marine Services, NERC, outlined the major projects in his Directorate in ocean circulation, biology and observing systems. He advanced the idea that through an understanding of past climatic changes we can understand the future, and he showed how processes relating to radiation, ocean turbulence and plankton production might cause a positive feedback to CO_2 emission and global warming. **Terry Evans** of Mott Macdonald and Partners described how recent climatic fluctuations were having a serious effect on the already scarce water resources of Africa.

The afternoon concentrated on impacts and possible "solutions". **Dr M.I. Parry** of Birmingham University discussed the impact of climate change on agriculture and how some areas, such as the UK, might gain, while others further south might lose. **Dr D. Shannon,** Chief Scientist of MAFF, continued this argument but showed the very large changes which have occurred in agriculture in the last 50 years and how changes due to climate must be considered alongside expected changes in population, and economic and technological factors.

Addressing possible solutions, **Dr Fisk**, Chief Scientist at the Department of the Environment, emphasised the importance of sustainable development. The achievement of this would need a wide range of measures covering afforestation, energy efficiency, alternative transport and new energy sources. International cooperation was the only way forward and the Government had already made important international initiatives. The IPCC working group report due in 1990 would be an important milestone. **Dr A. Crane** of the CEGB continued the theme that a whole variety of measures would be needed to reduce CO_2 emissions. Improvements in production efficiency and the expansion of renewable sources and nuclear power would not be sufficient to meet anticipated demand for electrical power. Possible remedies were the more efficient use of electricity or the removal of CO_2 (either scrubbing flue gases or encouraging afforestation), but all of these would be extremely expensive.

Dr G. Goodman of the Stockholm Environment Institute completed the formal presentations with a review of possible strategies to reduce CO_2. A major problem was the need for development in the third world and the inevitable increase in energy consumption which this would entail. Emissions could be limited, but a whole range of additional measures were required, including the regeneration of forests, phasing out of CFCs and improvements in energy efficiency. Even if we are wrong about the greenhouse effect these measures are vital to the sustainable development of the world.

All of the speakers emphasised the need for more research into the processes - atmospheric, land surface and oceanographic - and into their impacts. Dr Mitchell suggested that there was a serious shortage of qualified scientists to tackle this important research.

The meeting was informative and stimulating. It is a tribute to the quality and interest of the presentations that the disruption caused by a bomb scare created only a minor distraction to an otherwise fine meeting.

Richard Harding
Wallingford

Sheffield proceedings

SESSION 1: HEADWATER AND HILLSLOPE

Chairman: Elizabeth Shaw (London)
Reporter: Rob Brown (Institute of Hydrology)

The first paper of the symposium, "Hillslope hydrology: a multiple interacting pathways model" by K.Beven (University of Lancaster), G.Hornberger (University of Virginia) and P.Germann (University of Berne), presented by **Keith Beven**, discussed the results of tracer experiments on a small forested hillslope plot in Maine, USA. Results showed that the role of macropores was other than suggested by general theory, with channels causing flow in directions other than directly downhill. A multiple interacting flow pathway model (the MIPS model) based on conditional distribution functions of tracer pathways was used to model results.

Howard Wheater presented "Hillslope processes - observations from the Allt a Mharcaidh catchment, Scotland" by H.S.Wheater, S.J.Langan, A.Brown and M.B.Beck (all of Imperial College). Observations from a 3-dimensional tensiometer array were shown to display classical expansion and contraction of the saturated zone in response to rainfall, but also with a highly unusual dynamic macropore response which was successfully modelled using a conceptual model.

"Modelling heterogeneous Darcian headwaters" by A.Binley and K. Beven (University of Lancaster), presented by **A.Binley**, focused on the use of the output from a 3-dimensional, Darcian, hillslope runoff model to assess predictive uncertainty in parameter estimates, and showed that current runoff models such as IHDM and SHE give a range of output response which the observed response lies outside.

Discussion of the papers centred on the problem that models were either producing right answers for the wrong reasons, or not producing the right answers at all, thus limiting their use in the predictive mode.

Paul Quinn (University of Lancaster) presented "The use of digital terrain data in modelling the response of hillslopes and headwaters" by P.Quinn, K.Beven (University of Lancaster), D.Morris and R.Moore (both of IH). Modelling results for the Plynlimon catchment at the head of the River Wye using TOPMODEL, and digital terrain data, were discussed. The model was used to predict saturated variable source areas under extreme flood and drought conditions.

"The role of sub-surface drainage in the generation of runoff from sloping clay land under different agricultural management regimes" by R.Arrowsmith, A.C.Armstrong and G.L.Harris

(ADAS Cambridge) was presented by **R.Arrowsmith**. Results from 10 years of field research at four experimental sites suggest that sub-surface drainage on clay soils reduces flood risk by introducing a catchment lag due to temporary storage. Deep ploughing as opposed to seed drilling allows deterioration of secondary drainage paths through the soil, thus leading to a higher risk of flooding.

A.T.McDonald presented "Discoloured runoff in the Yorkshire Pennines" by A.T.McDonald (Univ. Leeds), A.M.C.Edwards (Yorkshire Water), P.S.Naden (IH), D.Martin and G.Mitchell (both of Univ. Leeds). The paper explained how sources of natural colour in water could be related to specific small upland catchments, and neighbouring catchments could have totally different water colour regimes. A management policy was developed which allowed certain highly coloured catchwaters to be turned off, either temporarily or permanently, to reduce coloration in water for supply purposes.

"Coloured waters in Wales: spatial and temporal trends" by D. Kay, R.Boon and J.Crowther (St David's University College, University of Wales) was presented jointly by **D.Kay** and **J.Crowther**. Results from studies in two upland catchments were discussed. Two significant parameters were found to be responsible for high water colour: % flush peat present in the catchment; and % eroded peat present. Flush zone peat contributed proportionally more colour at high flow periods.

The main discussion on these papers focused on factors affecting the formation of colour in headwaters and the long-term observed increase in natural colour. There was also discussion on the possibility of modelling the throttling back of sub-surface field drains to delay peak flows.

SESSION 2: URBAN CATCHMENTS AND RECEIVING WATERS

Chairman: Frank Law (Institute of Hydrology)
Reporter: Steve Tuck (Institute of Hydrology)

The first paper of the session "The statistical distribution of event mean concentrations of pollutants in stormwater runoff" by M.G.Brizio, M.J.Hall and J.B. Ellis (all of Middlesex Poly) was presented by **Mike Hall**. A crucial assumption in terms of these distributions is that of log-normality. But how valid is this assumption? In this case, at least, one of the most comprehensive data sets in Europe has been assembled. Fitting of distributions was by two methods: Maximum Likelihood (ML) and the Method of Moments (MOM). Despite numerical problems, fitting by ML is generally superior to MOM; the best fit is by 3 parameter log-normal distribution although EV2 (Extreme Value Type 2) does well. "Is a single distribution appropriate?" Mixed distributions could be due to cross connection between foul water systems and other systems. The simplest combination is a mix of normals which leads to the "Expectation Maximisation" approach producing a goodness-of-fit index of 152 compared to 3pLN which produced 160. The existence of mixed distributions of EMCs is supported by the particle size distributions found to occur in sediment transport. Professor Bagwall has criticised this theory of "particle size v probability". In 1977 Bandorff Neilsen said this approach then gives a 4-parameter hyperbolic distribution which is equivalent to a mixture of normal distributions. The theory of mixed distributions of EMCs prompts the question " do particle-associated pollutants behave similarly to sediments?"

During discussion **John Mawdsley** (University of Newcastle upon Tyne) asked if, in this study, all data were included in the analysis but floods take an element that is fixed to the extremes. Mike replied that the use of the total data set allows more scope to assess two situations; that of short-term management as well as long-term trends.

In response to the question from **A.J. Tollow** (University of Durban SA) on whether mixed distributions could be separated into proportions e.g. 1/3 and 2/3, Mike said that that approach has not been dealt with before and preconceived notions as to the separation of distributions may be a problem. Caution should be exercised in separating out distributions e.g. unimodal curves could be due to a single distribution or a mix of distributions.

The second paper "Managing the effects of urbanisation in the Upper Lee" was presented by **Craig Woolhouse** (Thames Water). Traditionally there has been a low-key relationship between managers and Water Authorities on the one hand and planners and developers on the other hand. There is a need for the two sides to work together towards a common set of aims. Additionally a wider environmental view is needed in view of the public's increasing awareness of the environment.

Stevenage and Harlow are both planned 'New Towns' and have grown in a similar manner with similar results that contrast with the unplanned Luton conurbation. Hydrological investigations of the three catchments have shown up the importance of geology, notably its effect upon events with a return period of 30-40 years, as well as its effect on seasonability - the seasonal variation being greater on the clay catchment of Harlow than the chalk catchments.

Management of Urban Runoff has focussed on quantity to the detriment of quality although in the Upper Lee there are management strategies that have allowed some water-quality management, e.g. Stevenage has a system of seven reservoirs that achieve attenuation of flood flows and a degree of environmental management by retention of amenity/ environmental corridors. In contrast the strategy at Harlow where a pond was built but is subject to rapid infiltration has meant that its principal function has become as a recreational and amenity value. Strategy should be revised so that such ponds retain a multi-objective function. Additional problems of channel erosion have occurred due to this lack of storage facilities. Do these policies give us what we want? In general - No! Policies are not acceptable because perception of flood plain functions has reduced so that in some cases their primary function as a flood plain has been lost. A policy of catchment planning management is needed with a framework for management with the wider objectives of flood defence and land drainage as well as recreational and amenity value etc.

In discussion **J.B. Ellis** (Middlesex Poly) commented that the philosophy seems to concentrate on getting water away from the site as soon as possible and asked why this is when water quality benefits may be obtained by some retention. Also there is a lack of expertise in Water Quality in the Local Authorities which causes divisions because of conflicts of attitudes. Therefore a multi-objective approach is the best solution. The author agreed that more on-site storage is needed but problems occur in practice and this storage tends to appear as a remedial measure rather than as part of New Town planning. The NRAs should therefore give the Local Authorities a lead. **R. Sellin** then commented that the Roding catchment has two-stage channels which give a good combination of discharge capacity and conservation of wildlife. Craig responded saying that we are still in the process of learning and at the moment prefer on-site storage although in their absence would agree that two-stage channels provide an environmental solution.

The final paper of the session, " MOSQITO - A sewer flow quality model " by J.A. Payne and G.D. Moys (Hydraulics Research) was presented by **John Packman** (Institute of Hydrology). MOSQITO has the advantage of producing pollutographs, rather than event mean concentrations, which are of more use in analysing the problem of intermittent discharges via sewer overflows. Concentration has focussed upon smaller events because they are more frequent and so produce a greater overall loading. The model is divided into four components: catchment wash-off model; foul flow model; node behaviour model; sediment and pollutant transport model. MOSQITO is connected to WALLRUS and, during initial stages, the model had to be rewritten -although they both worked independently, their incorporation together resulted in both models 'blowing-up'. The catchment washoff model does work and can be calibrated against real data. The node model has the shortcoming of modelling manholes as constantly stirred tanks, thereby not incorporating the effect of settling out and so being inappropriate. The sediment model uses the Ackers-White formula for coarse sediments and a settling velocity approach for fine sediments. Coarse sediment can be entrained: a facility for settling out is not included but is being written into MOSQITO II.

In the discussion **Howard Wheater** asked what advantages MOSQITO might have over the US EPA's SWMM (Storm Water Management Model) which has been around for 10 years. John replied that MOSQITO produces pollutographs rather than EMCs as well as including more complex factors and a better level of science e.g. Ackers-White transport formula and a convective diffusion approach. Additionally you can get better back-up with MOSQITO than with SWMM; requests for help from the US EPA have not been well met.

In response to the question from **Craig Woolhouse** on whether the data input requirement is compatible with a realistic model representation, John said that there is not much data to support this package by comparison with observable data i.e. it is difficult to validate and fully calibrate. The onus is on the input data to make it work but this has deficiencies such as the fact that HR are using a standard sediment file to cover a whole range of existing conditions.

SESSION 3 - COPING WITH EXCESS

Chairman: Mike Mansell-Moullin (Effingham)
Reporter: Dick Johnson (Institute of Hydrology)

The session was opened by the chairman who pointed out that hydrologists are taking on a very big task in attempting to measure very intense rainfall and the largest floods.

In the first two papers "Focus on rainfall ground estimation" and "Spatial structure in point rainfall: a geostatistical approach" **Lisa Stewart** and **Duncan Reed** (Institute of Hydrology) introduced a new method of rainfall growth estimation. FORGE (FOcussed Rainfall Growth Estimation) avoids the difficulties found in conventional regionalisation procedures and takes account of the spatial dependence in extreme rainfalls recorded by a network of gauges. The technique was illustrated by a suite of 1-day rainfall growth curves for south west England. Geostationary techniques, in particular kriging, were introduced and again applied to data from the south west.

Professor Wolf (City University) asked how the 1 in 10,000 scale, which was used for the study, was decided on. Duncan answered that it was a combination of the South West Water requirement and also the scale which the technique was being developed for. Mike Hall (Middlesex Poly.) asked whether stationarity had been checked for and Duncan said it was not specifically checked but the method of sliding neighbours allows the assumption of stationarity to be relaxed. The Chairman complemented IH on not being complacent once the Flood Studies Report had been published but they were always apparently eager to make improvements.

In his paper on "The changing rôle of flood warning schemes in flood hazard mitration," **Jeremy Neal** (Middlesex Poly.) looked at the potential of the flood warning schemes in this country and how the NRA might improve them. The potential of flood warning schemes depends on many different factors e.g. the nature of the catchments, emergency preparedness planning etc. but there is no measure of the effectiveness of such a scheme in England and Wales. The NRA presents a new framework within which flood warnings can be improved and the actual potential becomes closer to the theoretical potential. **Alan Lambert** (Welsh Water) pointed out that in a flood warning scheme the larger lead times do not necessarily improve the scheme. Jeremy Neal agreed and said there was an optimum lead time with limits on what can be done beyond this.

The presentation of the paper "Maximum flood estimation in the UK" by M.C.Acreman and M.J.Lowing was given by **Mike Acreman** (IH). The method of estimating the maximum flood in the FSR has a large uncertainty which has practical implications, e.g. the design of spillway capacity. The methods used in estimating the probable maximum flood, interpolating with an envelope curve and extrapolating with a model, were both shown to have strengths and weaknesses. Comparisons were shown of historical records of the msximum floods in some catchments with the estimated values. The important point was made of how small catchments (<10km) seem to be the catchments where there are exceptionally large floods - well above expected values.

The paper entitled "An assessment of flood estimation using the FSR" by D.B.Boorman, M.C.Acreman and J.C.Packman (all from IH), presented by **Dave Boorman,** showed that there were two current objectives to the improvement of flood estimation. The first was the need to know how well the rainfall/runoff models work and the second is to look for new areas of research to improve the methods. The problems in finding data from suitable catchments were discussed and the limitations of the resulting return periods estimated to be less than twice the period of record (2N) and usually less than N. Comparisons of the rainfall/runoff model method with and without observed data were shown to give unbiased estimates of floods, but the method using observed data has more practical applications.

In the discussion on the two papers **John Gardiner** (Thames Water) asked whether local knowledge of channel changes was used in the flood estimates. Mike Acreman replied that geomorphological changes were used but this method is difficult to apply in the field. **Frank Law** (IH) pointed out that the two papers were using different methods of estimating the maximum floods. Dave Boorman said that in his work it was essential that actual data were used.

Alan Weston (Welsh Water) asked if the large floods identified by Mike Acreman could be caused by the break-up of temporary dams and Mike replied that there certainly were different mechanisms going on right through the catchment and also a possible two component system. **Frank Farquharson** (IH) was not sure whether it is a two component system but the flood extremes were real and when the record length is increased these floods do fit.

Nancy Balfour (Mott MacDonald) presented "Mathematical modelling of the Ouse Washes" by N.Balfour, K.Guganeshrajal and P.Halifax (all of Mott MacDonald). The work was carried out for Anglian Water to suggest improvements to the operation of the Ouse Washes and to examine the effect of increased summer flooding on the Washes. The computational model, HYDRO, was used and showed that the existing banks would not withstand a 1 in 25 year flood with an adequate margin of safety. The system is made complex because of the combined fluvial and tidal event. In the discussion, **Mike Acreman** (IH) asked whether the 100-year fluvial event had been considered with the 100-year tidal event. In reply Nancy said that this had been considered but such an event was beyond the limit of the Anglian Water return period limit. **John Gardiner** (Thames Water) asked whether a lumped model would produce the same answer; Nancy thought it probably would but the complex system in the Washes justified using the HYDRO model.

In the final paper of the session, "Limitations of design hydrographs in arid areas," **Howard Wheater** (Imperial College) and **Rob Brown** (IH) described work which has been done in Saudi Arabia over a 5-year period. The highly localised nature of the rainfall was illustrated and shown to give a large variability in unit hydrographs. The calibration of conventional design hydrograph methods is not practicable for this type of arid catchment but a possible way forward was shown, linking hydrograph peaks with runoff volume. **Mike Mansell-Moullin** commented that this work was very valuable as such intensively instrumented catchments in arid areas are very rare. **Professor Wolf** asked whether satellite imagery could be used for rainfall input estimation and also could the soil moisture data help in the hydrograph analysis. Howard replied that imagery was not available and soil moisture readings were taken but were not very helpful because the water table was so deep (8 metres) and there was a silt layer at about 1 metre depth which affects the hydrograph.

SESSION 4 - OPERATING SURFACE AND GROUNDWATER RESOURCES

Chairman: Peter Wolf (City University)
Reporter: Nancy Balfour (Mott MacDonald)

The paper on "Management and operation of groundwater resources" by K.R.Rushton and A.E.F.Spink (both of Birmingham University), presented by **Andrew Spink**, used case studies in India and UK. Key points which emerged were: the need to calculate recharge to give reliable output; groundwater is not like surface water - don't know how much there is or where it is; can assume input and output balance i.e. recharge reappears on the surface; when surface flow needs to be maintained, obstruction of groundwater is therefore limited.

There is a need to manage demand for resources so there can be a benefit in redistributing groundwater. In the example in Humberside, which is close to the river with boreholes near the estuary, erosion has caused saline intrusion. Removal of coastal boreholes and switching abstraction to the unconfined aquifer produced additional spring flow in existing springs, unexpectedly. The lesson to be learnt was that the system was not fully understood before work commenced. The example of artificial recharge, a limestone outcrop in NW India, provides good supply in the monsoon but less in the dry season. The recharge was tested to try to push back the saline zone on the coast but failed because recharged water entered the upper permeable layers and came out again at surface springs and hence to the sea; there was no recharge into fissures of impermeable layer where the saline water is dispersed. Conclusion: this form of

limestone (Miliolite) is not suitable for artificial recharge.

Allan Lambert (Welsh Water) then presented an outline of BHS Occasional Paper No. 1 "An introduction to operational control rules using the 10-component method." He stressed that in the present drought Plc's need control rules. He emphasised the key points in the publication written after the 1984 drought to help Plc operators develop control rules. The drought end date needs to be established and draw down curves drawn to identify critical operation procedure. It is important to conserve sources in the spring period before the drought situation. Refill curves need to be drawn to check that the reservoir will fill over the winter following a drought. The format of control rules should be free and up to the designer to set.

In the discussion **Frank Law** (IH) asked how operating rules take into account demand fluctuations such as increase in demand with sunshine hours etc. Alan replied that the increased demand due to tourism was assumed in summer, therefore maximum possible demand is used when setting up control rules to cover periods of fluctuation.

Mike Lowing (IH) commenting on Alan's prediction that the drought may continue until 17 October asked if Welsh Water intends to take account of the long-term forecast? Because of the need to assume an element of uncertainty, Alan said that the forecast was not taken into account; 17 October is taken as the end estimate for planning (plus an extra period for safety factor).

On **Susan Walker's** (NWW) comment that the planning of pumping is important for both hydrological and for power generation purposes and that pumping costs are lower in spring than in winter, Alan agreed that this reinforces the need for careful spring management.

Mike Mansell-Moulin said there is a choice to use a percentage of groundwater as well as surface water but what balance is ideal? Alan replied that a mixture is desirable because sources have different characteristics and can therefore be managed well to solve droughtproblems. In response to **Tim Wyatt**'s (Power and Water Systems) question he said it was not possible to guess what proportion of ground and surface resources provides a good balance.

The third presentation, "The development and use of medium-term policies for the operation of a major regional water resource system" by Susan Walker (North West Water) and T. Wyatt (Power and Water Systems) was made by **Tim Wyatt**. (NB £ signs are missing from the published version of the paper.) Talk concentrated on a description of the Modular Optimisation Simulation Programs (MOSP) and their use on the northern command zone of NWW (Lake District and Lancashire). The programs have 3 components: simulation (AMORS program); data preparation; optimisation procedure. AMORS is the Advanced Method of Resource Simulation Model and can include treatment works, power generation, groundwater abstraction etc. New operating policies were identified for the Northern Command Zone using the programs and showed big savings in costs.

Susan Walker commented that it is interesting how new policies on operating rules have affected the organisation of NWW in terms of operators from different areas getting together more often to discuss operation on a region wide basis.

The next paper " Control rules - conjunctive use - complexity?", presented by **Alan Weston** (Welsh Water Authority) and assisted by **Steve Bayliol** (?) looked at the operation of a large number of sources in North Wales. There is a need for a general simulation model to cope with all resource systems in the Welsh region but, as the Snowdonia area is most complex, model development concentrated on this area. All sources and different control rules are input to the model and the model outputs the action to be taken at any one time at each source. He gave a demonstration of the simple data input and output of the model and a visual display of results - useful as a training tool for managers because the results of decisions on operation policies can be seen immediately.

The paper by **A.J.Tollow** (University of Durban), "A further approach to the assessment of yield", was based on the Umgeni river system. Work was carried out as part of a project to assess proposals for two new reservoirs and transfer schemes to enhance the existing system. It is an interesting area subject to summer rainfall, coastal events and extreme events over the high Drakensberg mountains in the west. Different types of yield analysis were compared including a modified version of the Stall approach but all were found to give significantly different results. A method was established to assess yield at sites with a short flow record or none at all by applying a modified Stall approach to an adjacent catchment and using regionalised yield curves. Non-dimensional results allowed a semi-graphical approach to solving the problem of estimating reservoir size on catchments with sparse data.

In discussion, **Neil Whiter** (South West Water) asked what data the author had started with, as a 36-year-duration series with no overlaps does not leave a lot of data. In reply the author said he had started with 55 years of monthly data and he was confident to forecast to 121 months but no more.

Rob Brown (IH) asked if the critical duration is between 1 and 9 years, what is the meaning of 1% drought? The 1% drought represents the 1 in 100 year series, i.e. the series generated has a 1% probability of occurrence. The frequency is relevant for comparison only. (Note the reference in this paper to work by Thompson)

Tim Wyatt commented on the importance of taking into account hydropower reservoirs in the system as well as water supply and was told that there is only one power reservoir in the Umgeni system which was recently washed away and not replaced. He went on to ask if in the Umgeni system there was a problem of selecting one reservoir or optimising the use of several. The author replied that the system was complicated due to some of the reservoirs being regulating and some direct problems of spill etc. had to be taken into account.

"The Otter Valley catchment study - an integrated approach to modelling"was presented by the author, **W.J.Finlinson** (MRM Partnership). This multidisciplinary water resources and environmental study was carried out over two years for SWWA and was based on a rural catchment in East Devon where there is a need to maximise the use of available resources to meet rising demand. The main water course is the River Otter; further down the catchment permeable soils and intensive farm units lead to major pollution source. The estuary at the outfall is owned by a conservation trust and SSSI, and there is a sandstone aquifer in the lower part of the catchment. Problems for SWWA include: total recharge which is only 90 $Mlday^{-1}$. so offtake is a high proportion of recharge; rising metal content in borehole water; rising nitrate levels (boreholes are already up to EEC limit) - agricultural pollution is major problem.

Areas of study are land use and agriculture, groundwater resource modelling, river water quality model, and environmental studies. Available resource development options are: groundwater abstraction, river abstractions, conjunctive groundwater and river use and, finally, abstraction and artificial recharge. The main conclusions are that: groundwater abstraction is affecting stream flows, nitrate levels are rising independent of groundwater policy and well field development is possible.

In response to **A.J.Tollow**'s question on whether a nitrate reduction model was considered, the author said the essentially conservative WRc model was used but denitrification is now being built in.

Howard Wheater asked two questions: what information was available for calibration of the groundwater model and what is meant by multiple layer modelling? To the first he was told that the available data were river flows (continuous and spot measurements) and groundwater hydrographs over a wide network; no information was available on variable heads in different aquifers. The response to the second was that pumping tests gave data on different heads at different layers which were then used to calibrate the model.

The final paper of the symposium, "Stages of construction and operation of a scheme to augment river flows using seasonal groundwater abstraction" was presented by **Val Lowings** and **P.Midgley** (Southern Water). By way of introduction Val outlined the scheme to augment the River Itchen in Hampshire using groundwater abstraction and then concentrated on difficulties in construction and operation. Flows in the river need to be regulated due to increased abstraction and increased sewage disposal. The model showed that augmentation is needed for 1 in 5 years and groundwater is preferable to surface water reservoirs. Pumping tests are being carried out to test the operation of the scheme during the present drought. The scheme has some effect on aquifer draw-down so local water users need to be compensated for lowering of shallow well levels, or boreholes added. The watercress industry is important in Hampshire, relying on spring or borehole supplies, which need to be maintained.

On hydrological modelling **P.Midgley** described two models: the simulation model to simulate operation of the augmentation scheme, and the prediction model to determine the need for augmentation in any one year (it failed this year!!). The difficulties in operation of this and other augmentation schemes caused by privatisation and by the division of schemes between plc and NRA were pointed out.

Alan Weston said there are operating agreements between the plc and NRA in the Welsh region and asked why there were none in the Southern. There is no apparent reason for a division of schemes between the two. Operating agreements are being set due to shortages of staff in the NRA. Pump testing and the like are being contracted out.

The reply to **W.J.Finlinson**'s question on the extent of denegration which occurred during operation in previous droughts was that not much operation had taken place in the past except for 1976. Some temporary lowering of the water level occurred after '76 but returned to normal after one year. Remedial works were introduced when denegration takes place. Much modelling and calculations have taken place to determine the optimum augmentation volumes without permanent degradation. When asked if there was any need for a piped supply, he said that only two additional pipes were connected to the mains as a result. In general the public prefer to retain their own borehole supply.

Frank Law (IH), referring to Figure 1 which

shows a 140-year record including several extreme drought events, asked if these were taken into account so that design drought sequences were exceptionally high? The long record does show several events which could not have been helped by augmentation. The model was used to show likely frequency of operation which was not necessarily accurate for past events.

Rob Brown (IH) commented that IH were asked to predict low flows in some rivers including the Itchen which was the only river to show a clear low-flow pattern; the response was that the Itchen has changed flow routine in recent years due to increased abstraction (there is no longer a hose-pipe ban introduced in drought time) and some anomalies in groundwater behaviour.

W.J.Finlinson (MRM Partnership) asked if there is a problem with pump maintenance when pumps are left idle for long periods. Yes, both surface and subsurface stored pumps suffer damage and deterioration. Pumps should be operated once a month but Operations Division is not keen!

IH embraces the rainforest

***Jim Shuttleworth* and *John Roberts* have recently returned from Brazil and from Jim we learn about this important Anglo-Brazilian rainforest study. Jim heads the Hydrological Processes Division at IH and now leads the hydrology component in ODA's technical co-operation programme with Brazil.**

Both the Brazilian and British Governments are anxious to improve the value of climate model predictions and are discussing a proposal for a project called **ABRACOS**, standing for the Anglo-BRazilian Amazonian Climate Observation Study - 'abracos' means 'embraces' in Portuguese.

Faced with the necessity to plan the sustainable development of their country, Brazilians turn for advice to developed nations but too often find only accusation and condemnation. In the Memorandum of Understanding signed between the Governments of Brazil and Britain earlier this year there is a different spirit, the intention of the Overseas Development Administration to provide the constructive support and advice of Britain's best experts on those issues of most concern.

No question captures greater interest worldwide than the possibility that climate and rainforest are inexorably linked, and the history of Anglo-Brazilian research into this question has been substantial and productive. It is not surprising that amongst the first requests to come from Brazil under the Memorandum of Understanding is one for British expertise to help answer the question, 'How will Amazonian deforestation change the climate?'

One way is by contributing to greenhouse warming, but the often-repeated media description of Amazonia as the 'lungs of the world' is misconceived. The natural forest is in approximate equilibrium - nearly all the carbon dioxide it absorbs as it grows is released again when the vegetation and the animals which feed on it breathe and ultimately decay. The more direct link between deforestation and climate is also more certain. Changes in the vegetation covering the ground alter the energy and water released into the atmosphere - there is no greater change than from lush rainforest to degraded pasture.

Until recently climate models, General Circulation Models (GCMs) as they are commonly known, paid little attention to the complex but important hydrological control of vegetation. Now some incorporate more realistic descriptions but these are still poorly calibrated against field data. The problem is not just one of accuracy - it is also one of credibility. Until GCMs incorporate calibrated descriptions of these key processes, they will not be believable enough to resolve the controversy between conservationalists and developers as to how the climate will change if Amazonia is deforested.

Earlier this decade Brazil and Britain together took the first step towards providing credible predictions. Scientists from the Institute of Hydrology (IH) and the Brazilian Institutes of Space Research (INPE) and Amazonian Studies (INPA) carried out pioneering research, in 1983-85, north of the city of Manaus in central Amazonia where measurements were made using instruments installed on a 45 m tower, constructed through the forest canopy which was typically 35 m high (see Fig. 1). These data are being used to provide a calibration of the behaviour of natural Amazonian rainforest in GCMs. Results suggest a 2°C rise in temperature, a 20% reduction in evaporation and a 30% reduction in rainfall within Amazonia. Such changes clearly give cause for concern - what value an ecological reserve if it is exposed to a different climate for instance?



Figure 1. Forest canopy in central Amazonia, Brazil, showing the 45m instrument tower.

The proposal is to set up a comprehensive meteorological and hydrological experiment and, because the Amazon rainfall is so variable, to collect data over several years. A degraded pasture clearing used by the Worldwide Fund for Nature would be an ideal site. Unlike the pastures that Europeans know, it is littered with rotting trees and stumps, which is typical of the heavily grazed areas north of Manaus (Fig. 2). The results would go directly into GCMs in Brazil and at the UK's new National Climate Centre.

In order to test whether the models work for cloud cover changes, large clearings of uniform pasture are needed. Such clearings are found to the east in the state of Para, where clearance has been happening longest, and to the west of Amazonia in Rondonia where it is now happening quickly. Climate change data collected in these two states and over a large forest nearby would not only check whether GCMs can simulate small convective clouds but also that they can describe the change in climate across the basin.

It is right that the Brazilian people will ultimately decide what happens to the Brazilian rainforest. In reaching that decision Brazil will seek the advice of her scientists and the aim of ABRACOS will be to ensure that that advice, when given, is the best which can be given.



Figure 2. Cleared forest area used for cattle grazing

BOOKS

Watershed Management

Policy and Practice in the Management of Tropical Watersheds, H. C. Pereira, 1989. 237 + xvi pp; 6 tables, 42 figures, 31 photographs; Belhaven Press, London; £25.00 Hardback; ISBN 1 85293 089 6

Two-thirds of the world's population live in the tropics which will in the next two decades produce four-fifths of the world's population increase. One impact of this population density, and its expansion, is the exploitation and potential degradation of land previously considered unsuitable for farming. Since 1965, Africa's per capita food production has declined more than 20 percent. While part of this decline results from demographic increase, it also comes from reduced agricultural capacity. The source of much of this degradation is destructive occupation of upland catchments. Flooding, sediment discharge and reduced base flows extend the impact of this degredation to lowland areas and diminish their productive potential.

Sir Charles Pereira's elegant and straightforward book examines the impacts of human occupation of tropical catchments and proposes technical methods and policies for their management. It discusses the scientific basis of tropical watershed management and relates this in separate chapters to its component technologies: forestry, agroforestry animal husbandry and agriculture. The problems of alluvial lowland management and flooding are presented individually.

This text is important to hydrologists because its scope is worldwide and because it explains in plain language the key elements of collaborating disciplines. The epoch of mega-buck financing of large project design teams to the third world is over. Diminished financial resources cause design teams to be smaller than in the past but the environmental situation they have to deal with is worsening. Because of this, practitioners of disciplines such as hydrology are required to be knowledgeable of other fields. Dr Pereira's book provides a bridge to understanding these other disciplines, to being able to carry on an intelligent conversation about them, and to making project recommendations on the basis of this information. This breadth of scope is perhaps also a weakness: it may cover too much material for a single volume.

The tropics are complex. The hydrology of the Caribbean hurricane zone is entirely different from the hydrology of Central Africa or South East Asia. The climate and basalt-derived soils of Haiti are entirely different from the climate and volcanic soils of Comoros. The list could continue but , from a hydrologist's point of view, it is vital to know that resource management failures abound in the tropics. When failures occur, they happen not so much as a result of breaking principles of hydrology or forestry, but because of underlying and often obscure exceptions to these rules: because of variances in geology, soils, sociology, land tenure, or economic structure that invalidate their application. Dr. Pereira's book provides a review of resource management principles; it does not present enough information to analyse the risk of failure that may result from their application. For this, one needs a sounder foundation in soils, geology, sociology and other disciplines.

Dr Pereira states that technical solutions to resource management problems are known. I don't completely agree with this statement, having had to come to grips recently with problems of excess upland runoff in Haiti and no secure way of disposing of it. Technical solutions may be known but may not yet be acceptable because of problems related to land tenure, historical traditions or social condition The application of perfect technical solutions in an imperfect social environment may lead to conflict and failure.

In reviewing this book I tried to keep in mind what I would use it for. It is the kind of text I would like to leave with a counterpart, to donate to a client's technical library or a university or to use as a key text in training. Because it is not translated into French or Spanish, its usefulness to the third world is lessened: it relies entirely on English language references. The book is expensive - at £25 it is out of the reach of the people it should help - the technical people of the third world. I wonder if its format could have been modified to reduce its cost.

Dr Pereira's line drawings (drawn by the author himself) add a pleasing, personal touch to the book. They are more successful than the photographs which I find dark and grey. Occasional mistakes in editing occur: the text describes chitemene agriculture as occurring in Zambia, the accompanying figure shows it occurring in Tanzania; Figure 40 confuses a Pelton wheel with a turbine.

The final three pages of text include sources of information and recommended reading. This chapter could be expanded, particularly by including several of the classic books on tropical resource management which occur in languages other than English. A listing of the numerous international organizations which have as their mandate the improvement of the tropics, their addresses, and a brief statement of their objectives would be useful.

Curtis J. Paskett
Essex

Floods

Floods: Hydrological, Sedimentological and Geomorphological Implications, K. Beven and P. Carling (Eds), 1989. 290pp. John Wiley, Chichester. £39.00 Hardback. ISBN 0471 921 645.

This book is the second in the British Geomorphological Research Group Symposia series and arises from a joint BGRG/BHS workshop on Floods held at Lancaster in 1987. There are 16 contributions ranging from descriptions of individual flood events, to channel hydraulics, to sedimentological evidence for quaternary flood deposits. The general theme is the role played by flood events as agents for landscape change and development.

There are two important review papers by Newson and by Lewin. Newson, looking at Floods in a decade of drought, comments on the unreliability of return period estimation techniques and the relative effectiveness of floods of different magnitudes in shaping the landscape. He argues that the tendency to look at a reach, or the headwaters or floodplain individually, rather than at the basin as a whole tends to give rise to a lack of appreciation of the more complex erosion-deposition interactions, and stresses the need for multi-disciplinary approaches to flood analyses. Even so he says resources for undertaking such work are likely to be available only in the wake of another flood disaster. Lewin reviews the historical development of fluvial process studies, identifying the "orthodox model" as assuming that channels are adjusted to frequent and hydrologically identifiable events, and the dominance of the regression approach to analysis. Challenges to these ideas are considered under the headings of channel patterns, bankfull recurrence intervals, flood event observations and sediment transport concepts at the basin scale. He identifies three factors which cause rare floods to be geographically variable: flood magnitude, local physiographic features and the availability of sediment within the basin which may then be entrained; and five geomorphologically contrasting environments in which the same magnitude flood will generate very different landscape responses.

Other excellent contributions come from Knight on flood channel hydraulics, and from Komar assessing flow competence evaluations, pointing out the importance of entrainment relationships at different stages and the consequent need for further research. Baker describes the use of stratigraphic evidence to reconstruct ancient flood events, Maizels uses similar techniques to identify glacial bursts from a glacier through the Holocene in Southern Iceland, while Smith and Boardman consider lichens, soil profiles, terrace damage, boulder berms and flood deposits as evidence to reconstruct historic floods. Descriptions of recent floods come from Coxon *et al.* with the Yellow River flash flood and peat slides in Leitrim. Over a longer time-scale McEwen describes channel change in response to flooding in the Upper Dee.

Overall this is a very valuable addition to the literature with a number of themes emerging, for example, river sediment deposits and their value in flood reconstruction, as sources for transport, and their effect on channel transport capacity; the need for clearer process understanding of the geomorphic effect of a flood and recognition that this will be very different in the upper reaches compared with lowland plains.

Pauline Kneale
Leeds

Hydrological text

Hydrology and Floodplain Analysis - Philip B. Bedient & Wayne C. Huber, 1988. Addison-Wesley Publishing Company, 650pp. £18.95 Hardback. ISBN 0-201-12056-9

Despite its somewhat specialist title this book is essentially a modern introductory hyrological text with a bias to the civil engineering aspects of the subject. The first chapter introduces the subject and also touches on the major topics of precipitation, evaporation. transpiration, infiltration and streamflow. It is over 60 pages long and does not cover any topic in sufficient detail, for example, the Penman method for determining evaporation takes less than two pages. including a worked example together with a nomograph.

Chapter 2, entitled Rainfall-Runoff Analysis, concentrates on the unit hydrograph approach for determining surface runoff together with sections describing snowmelt and the kinematic wave method for determining overland flow, which are too short to be useful. Chapter 3 describes frequency analysis; it is clear and well written and will be appreciated by students, especially those who have not received any statistical training.

The next two chapters are concerned with flood routing and catchment modelling. They are conventionally written and do not offer any new insights into these topics; the flood hydrograph package HEC-1 is, however, described in adequate detail for anyone wishing to use this particular model. There follows a chapter on urban hydrology, which is well written and includes some useful worked examples. The next chapter, Flood Plain Hydraulics, is essentially an elementary introduction to open channel hydraulics with a slight bias to the hydraulics of a flood plain. Much of this material is unnecessary, for example the determination of the optimum channel cross-section for a trapezoidal channel - not very relevant for flow in a flood plain: some specific problems could have been discussed here. Approximately half the chapter is devoted to a description of the HEC-2 model. The final chapter is devoted to groundwater hydrology and covers a wide spectrum of groundwater problems including an introduction to groundwater modelling. The coverage is cursory and in places erratic; in a text of this nature it is not necessary to develop stream and equipotential lines.

The overall impression of the book is that the subject matter has been chosen arbitrarily. It is not a good introductory text although it has several good points and, if supplemented with other texts, it should be a useful book for students. The units used are largely fps but with some open channel examples and the groundwater section in SI. The ten computer programs are useful in helping to understand the methodologies described but would need a good deal of development in order to make them sufficiently useful for everyday applications. The book is well printed and stoutly bound.

Ian Goodwill
Leeds

HYDROLOGICAL PROCESSES

John Wiley, the publishers of this high quality international journal, are pleased to offer a special price of £45.00 to members of BHS for the 1990 volume - a discount of 50%! *Hydrological Processes* is currently in its third year of publication and enjoys an excellent reputation for reporting original research in physical, chemical and mathematical hydrology and is of considerable interest to BHS members.

If you would like to take up this offer, write direct, mentioning that you are a member of the British Hydrological Society, to: The Subscription Department
John Wiley & Sons Ltd
Baffins Lane
Chichester
West Sussex PO19 1UD.

NEW MEMBERS

We welcome the following new members to the Society:

Adamson,P.T.	Sir W.Halcrow & Partners
Bilgi,A.	Student
Bruen,M.(Dr)	University College, Ireland
Drayton,R.S.(Dr)	University of Wales
Heathwaite,A.L.(Dr)	University of Sheffield
Johnson,F.A.(Dr)	University of Sheffield
Kawecki,M.W.(Dr)	Saudi Arabia
Lee,J.K.(Ms)	Hydrologist
Hipolito,J.N.(Prof)	Technical University of Lisbon
Harun.S.	Student
Tzeranis,I.	Student
Tomkins,J.G.	Student
Law,P.J.K.	Student
Dempsey,P.	Student
Chapman,R.J.(Miss)	Student

BHS ANNUAL GENERAL MEETING

Computer Simulation Techniques in Water Management

4th December 1989

Institution of Civil Engineers, 1-7 Great George Street, London W1

PROGRAMME

River Basin Management (Yield Optimisation)

09.30	Coffee
10.00	Introduction by the Chairman, Professor George Fleming, Strathclyde University.
10.10	"The concept of operational yield" by Alan Lambert/Alan Weston, Welsh Water.
10.40	"Modern water resources assessment techniques for the Vaal System"
11.10	"Reassessment of yield from Lake Nasser" by Terry Evans, Mott MacDonald.
12.15	ANNUAL GENERAL MEETING followed by lunch at 1.15 pm

Computer Graphics and Water Management (Operational Tools)

2.15	Introduction by the Chairman, Terry Evans, Mott MacDonald.
2.20	"Presentation through the use of computer graphics" by Simon Marsden, Mott MacDonald.
2.45	"Nile basin model" by Peter Chesworth, Mott MacDonald.
3.15	Questions, followed by tea
3.45	WORKSHOP DEMONSTRATIONS followed by questions
5.00	Close

Report of the Honorary Treasurer

Unfortunately, as I am writing this report the accounts of the Society have not yet been audited, partly because it has not yet been possible to produce the final accounts for the second National Symposium at Sheffield. Thus this report is based only on provisional end of year financial figures, and a final statement will have to be made at the AGM in December. I apologise to all members for this situation.

The best figures available suggest that there has been a slight imbalance between income and expenditure, partly because of the Sheffield Symposium but also because expenditure on a number of items has been greater than anticipated at the beginning of the year. At present there is an apparent loss of about £1000 on the Sheffield symposium, but outstanding income should reduce this loss to no more than £200, which is considered to be acceptable. The aim of the committee has been to set the attendance level for the National Symposium as low as possible to attract the maximum number of delegates, and there were no plans to make a profit on the event. However, perhaps in future there should be some move towards ensuring a modest profit from major meetings and the National Symposium. Since many of those attending have their registration fees paid by employers there is probably no strong link between the number attending and the fee charged.

Another major item of expenditure has been the Membership Directory, which we produce biennially and which should be included with this copy of *Circulation*. The new publications series, BHS Occasional Papers, has also been a major item of expenditure, costing £771 and £1755 to print numbers 1 and 2 respectively, and although sales have brought in £1071 to date, the nett expenditure is £1455. Members are encouraged to buy copies of these publications, either personally or through their employers. We have stocks of both papers: number 1, "An introduction to operational control rules using the 10-component method" by Allan Lambert at £5, and number 2, "Weather radar and the water industry", a compilation of 8 papers at £10.

Most other expenses have also increased over the year, which is largely a reflection of the vigour of the society; more meetings are being organised which requires more postage to inform members and *Circulation* is getting thicker each year and hence costs more to print and to post.

Overall the society's financial state is believed to be healthy, with the end of year surplus expected to be in excess of £3000. This should be compared with the £4462 at the end of 1988 and £1823 in 1987. Because expenditure is increasing the subscription next year has had to be increased to £15, but this seems to be a small price to pay considering the wide range of meetings offered to members.

Finally as I am standing down after my two years in office, I would like to thank Norman Tyler and Mary McBride of the Institution of Civil Engineers for their efforts on behalf of the society. In reality it is they who keep the finances on an even keel and I thank you both on behalf of BHS.

Frank Farquharson

Education and Training

Members should note that all BHS meetings and symposia are now registered with the Education and Training Department of the Institution of Civil Engineers so that candidates for PE1 and PE2 may seek approval and qualification by attendance.

NEWS FROM MEMBERS

Polish Visit

Dr Stephen Trudgill, Department of Geography, University of Sheffield, recently visited the Adam Mickiewicz University in Poznan, Poland, under the auspices of the Royal Society. He learnt of the work being carried out by the Dynamic Geomorphology Section, Quarternary Research Institute (QRI),both in Poznan and at various research stations. Stephen was most impressed with their work on hydrological monitoring, chemical denudation, solute budgets, geomorphology and land use etc., considering it to be comparable to parallel work elsewhere. Their limitations lie in a lack of up-to-date information and a need for equipment support - not so much for the purchase of capital equipment but more for annoying deficiences in items such as chemicals, filter papers, etcetera.

If any BHS members involved in similar work could send published offprints, this would most certainly help towards reducing any feeling of academic isolation that they may have in Poland.

Please send to:

Professor Andrzej Kostrzewski
Quarternary Research Institute
Adam Mickiewicz University
ul. Fredry 10
61-701 Poznan, Poland

Members on the move

John Woods has joined Howard Humphries and Partners in Leatherhead from WRc Engineering, Swindon.

IAH Secretary-General

Dr Andrew Skinner, Regional Catchment Manager for the Severn-Trent region of the National Rivers Authority was elected to the Honorary post of Secretary-General of the International Association of Hydrologists at its General Assembly in Washington in July. The Association has over 2000 members in some 70 countries and is affiliated to the International Union of Geological Sciences.

Who's Who in the Water Industry?

With much help from **John Pirt** (Severn-Trent)we tried in *Circulation* 22 to help you find your way round the NRA. As the dust settles in both branches of the new water industry we will try to update that information in the "News from Members" columns. Meanwhile, however, the journal *Water Bulletin* has produced a couple of useful booklets on Who's Who in the plc's and the NRA which are worth hanging on to if you can get them through your Library.

PUBLICATIONS

Weather Radar and the Water Industry

Weather Radar and the Water Industry is the title of the BHS Occasional Paper No.2 . It is now available from the BHS Editorial Offices c/o Institute of Hydrology, Wallingford - see the separate order form enclosed with this issue of *Circulation.*

This publication contains the full text of papers presented at a very successful symposium held at IH earlier this year to publicise the capabilities of weather radar and report on recent developments and direction of current research.

Price: £10.00 (BHS members)
£7.00 (BHS student members)
£12.00 (Non members)

SECOND NATIONAL HYDROLOGY SYMPOSIUM

Proceedings of the BHS meeting at the University of Sheffield, 4-6 September 1989 are available (see this issue of Circulation for reports on the symposium).

Price: £20.00
£12.00 (Students)

REMINDER

BHS Occasional Paper No.1, "An Introduction to Operational Rules using the 10-Component Method" by Alan Lambert is still also availible.

Price: £5.00

FORTHCOMING EVENTS

Meetings

ROYAL METEOROLOGICAL SOCIETY
BRITISH HYDROLOGICAL SOCIETY
ROYAL SOCIETY
Natural Disaster Reduction:
How Meteorological and Hydrological Services can Help
28 March 1990
Royal Society,6 Carlton House Terrace, London

This meeting is to mark World Meteorological Organisation Day 1990 and the start of the UN International Decade for Natural Disaster Reduction (IDNDR). It aims to examine, through invited review papers, areas of research and operational expertise which the UK meteorological and hydrological communities can pursue with a view to contributing tothe IDNDR.
Topics are to include the following:

* Global perspective of meteorological and hydrological extremes - Dr J.Rasmusse(WMO)
* Extreme rainfall assessment - C.G.Collier (UKMO)
* Forecasting extratropical and tropical cyclones - R.M.Morris (UKMO)
* Probalistic rainfall prediction in the medium and extended range using ensembles of forecasts -Dr T.N.Palmer (ECMWF)
* Prediction of seasonal rainfall in the tropics - C.K.Folland (UKMO)
* Extreme flood assessment - Prof I.D.Cluckie (Univ. of Salford)
* Meteorological and hydrological disasters - an insurer's view - G.J.Dimmock (Swiss Reinsurance Co [UK] Ltd)
* Disaster alleviation in the UK and overseas - R.Hunt (UKMO)
* Engineering design for climatic extremes - Prof W.B.Wilkinson and F.M.Law (IH)

A special issue of *Weather* to be published in March 1990 will contain much of the content of these papers. For further details, please contact Chris Collier, Meteorological Office, London Road, Bracknell, Berks. RG12 2SZ. Tel: 0344 420242 Ext 6244. Telex: 849801

EUROPEAN GEOPHYSICAL SOCIETY
XV GENERAL ASSEMBLY
23-27 April 1990
Copenhagen

The XV General Assembly of the EGS will incorporate a one-week programme to be sponsored jointly by IAHS. Topics will include the following:

*Measurement, modelling and estimation of rainfall in space and time
*Land surface-atmosphere processes
*Physically-based modelling of flow - solutes and sediments at the catchment scale
*Modelling the impacts of climate change on water resources
*Theoretical basis for the estimation of extreme floods and droughts
*Snowmelt hydrology.

Within the interdisciplinary framework of the EGS Assembly, this Symposium will provide an excellent opportunity for interaction between the disciplines of hydrology, meteorology and climatology in relation to key issues such as global change, which will be a central theme of this Assembly. Abstracts are required by **31 January 1990** and will be pre-published in the EGS Journal *Annales Geophysicae*. Papers will be published in the IAHS Journal or *Annales Geophysicae*.

For further information please contact:
Professor P.E.O'Connell
Department of Civil Engineering
University of Newcastle upon Tyne
Newcastle upon Tyne NE1 7RU
Tel: 091-232 8511 Ext. 6405
Telex: 53654 UNINEW G
Fax: 091-261 1182

ONE -DAY SEMINAR
Biological standards for water quality assessment
9 February 1990
Middlesex Polytechnic, London
For further details please contact:
Mrs V.Norman
Centre for Urban Pollution Research
Middlesex Polytechnic
Queens Way
Enfield
Middlesex EM3 4SF
Tel: 01-368 1299 Ext. 2466

Copy Deadline for Issue No. 25 4th January 1990

Diary

29th November 1989
BHS South West Section-Joint Meeting with SW England Soils Discussion Group
"Soils, water and engineering." M.Anderson, N.Mackensie, J.Ponton & speaker from Fred Sherrill Associates.
Time: 1.30 pm
Venue: Faculty of Agriculture, Land-Use and Food, Polytechnic South-West, Newton Abbot, Devon.
Contact: Bruce Webb, University of Exeter

4th December 1989
BHS ANNUAL GENERAL MEETING
"Computer simulation techniques in water management."
Venue: ICE, Great George Street, London W1.
Programme in this issue of *Circulation*

8th December 1989
Scottish Hydrological Group
"Clyde dredging study."-D.Banks, R.Falconer (Babtie, Shaw & Morton)
Time: 6.00 pm for 6.30 pm
Venue: No.2 Lecture Theatre, University of Strathclyde, Glasgow.

13th December 1989
BHS Southern Section/IWEM
"Aspects of flooding on the Thames"
Time: 5.00 pm tea, 5.30 pm start
Venue: Imperial College, South Kensington, London.

12th January 1989
Scottish Hydrological Group
"The Loch Fleet project - restoring acid waters by catchment liming." - Dr T.R.K.Dalziel (Power Generation Division, CEGB)
Time: 6.00 pm for 6.30 pm
Venue: Wellcome Room, Royal Society of Edinburgh, 22-24 George Street, Edinburgh.

17th January 1990
BHS Midlands Section
"Measuring, archiving and analysis of short period rainfall" - E.Barratt (Bristol University), J.Brownscome (Met. Office), D. Grimshaw (NRA), R.Hawnt (Hydrologica), D.W.Reed(IH).
Time: 2.00 pm for 2.30pm.
Venue: Sapphire House, Solihull.

9th March 1990
Scottish Hydrological Group
"Satellite remote sensing in hydrology."
E.Barrett (Bristol University)
Time: 6.00 pm
Venue: No.2 Lecture Theatre, University of Strathclyde, Glasgow.

Circulation is the quarterly newsletter of the British Hydrological Society. It is issued free to members, but is also available on an annual subscription of £13. Please address all correspondence to the Editor, Institute of Hydrology, Wallingford, OX10 8BB. Telephone 0491–38800.