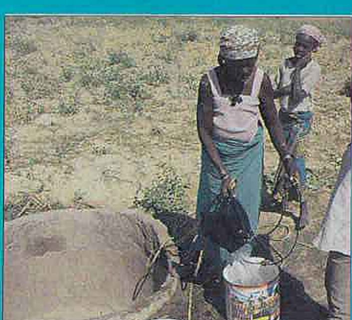
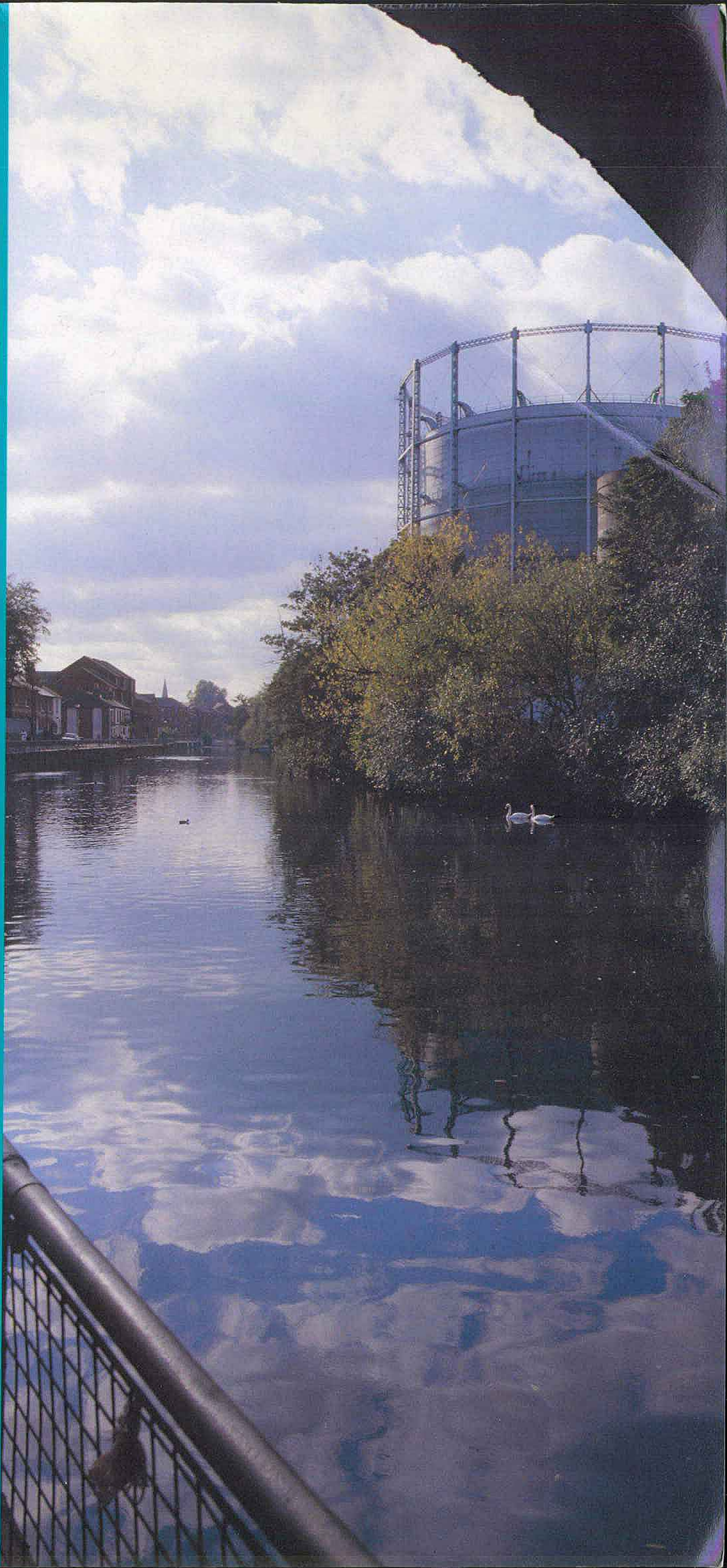




Institute of Hydrology

Annual Report 1995-96

Centre for Ecology & Hydrology

Natural Environment Research Council

Foreword

Robust and timely responses to major environmental problems, such as the sustainability of natural resources, climate change and pollution, are only possible if based on sound *interdisciplinary* science.

Recognising the importance of this holistic approach, the Natural Environment Research Council restructured its activities during 1994. A major element of this re-organisation was a grouping of four NERC Institutes into the Centre for Ecology and Hydrology (CEH). Research within CEH is concerned with the land on which we live, its fresh waters and the living organisms which share the environment with us. The component Institutes of CEH are

- Institute of Freshwater Ecology
- **Institute of Hydrology**
- Institute of Terrestrial Ecology
- Institute of Virology and Environmental Microbiology

CEH has some 625 staff (475 scientists) and about 300 visiting scientists and students, well-equipped laboratories located throughout the UK, and a reputation for excellence in national and international research, monitoring and data collection. As such CEH must have one of the strongest capabilities in the world for undertaking holistic research in the terrestrial and freshwater sciences.

The CEH capability to address multidisciplinary issues has been strengthened during the past year following a full review of its research and a reshaping into ten new Research Programmes. These set the course for research over the next five years and beyond. The new Programmes have been formulated by the CEH Directors and scientists working closely with the external assessors who constitute four Programme Review Groups. In drawing together the new Research Programmes the scientists have also been cognisant of the "wealth creation" and "quality of life" thrust in the 1993 White Paper *Realising our Potential — a Strategy for Science and Technology*, the National Technology Foresight Programme, the UK Government's and European Union's legislation and policy, and the content of the major international science programmes.

The Institutes' activities have been further cemented by cross-Institute interdisciplinary research projects. These form part of the Integrating Science Fund which was established last year. Some seven projects were funded during 1994/95. All have made good progress. During the present year a further six have been approved (see Appendix IV).

During 1994 the CEH Institutes were required to prepare papers and give evidence to the Office of Public Science and Services as part of the *Efficiency Survey of the Public Sector Research Establishments*. The published report of the Survey left unresolved the role of many Research Council Institutes within Public Sector science. In September 1995 the Government announced that 42 Public Sector Research establishments would be subject to further review to assess whether the "functions" of the establishments were needed and whether the Public Sector should provide these. Scope for further rationalisation was also to be examined.

CEH was subject to this so called "Prior Options" review. CEH provided extensive documentary evidence and made a verbal presentation to the Steering Committee undertaking the NERC Prior Options review. CEH took the opportunity to highlight the major benefits that have and will continue to flow to the ecological and hydrological sciences as a result of the strong interdisciplinary focus that is now possible through CEH. The NERC Steering Committee presented its report to Government in late July 1996. Neither the recommendations of the Steering Committee nor the Government response to these are known at the time of writing.

It is to the credit of all CEH staff that the research has remained buoyant and the science outputs have been maintained at a high level during the year against this background of uncertainty and potential change.

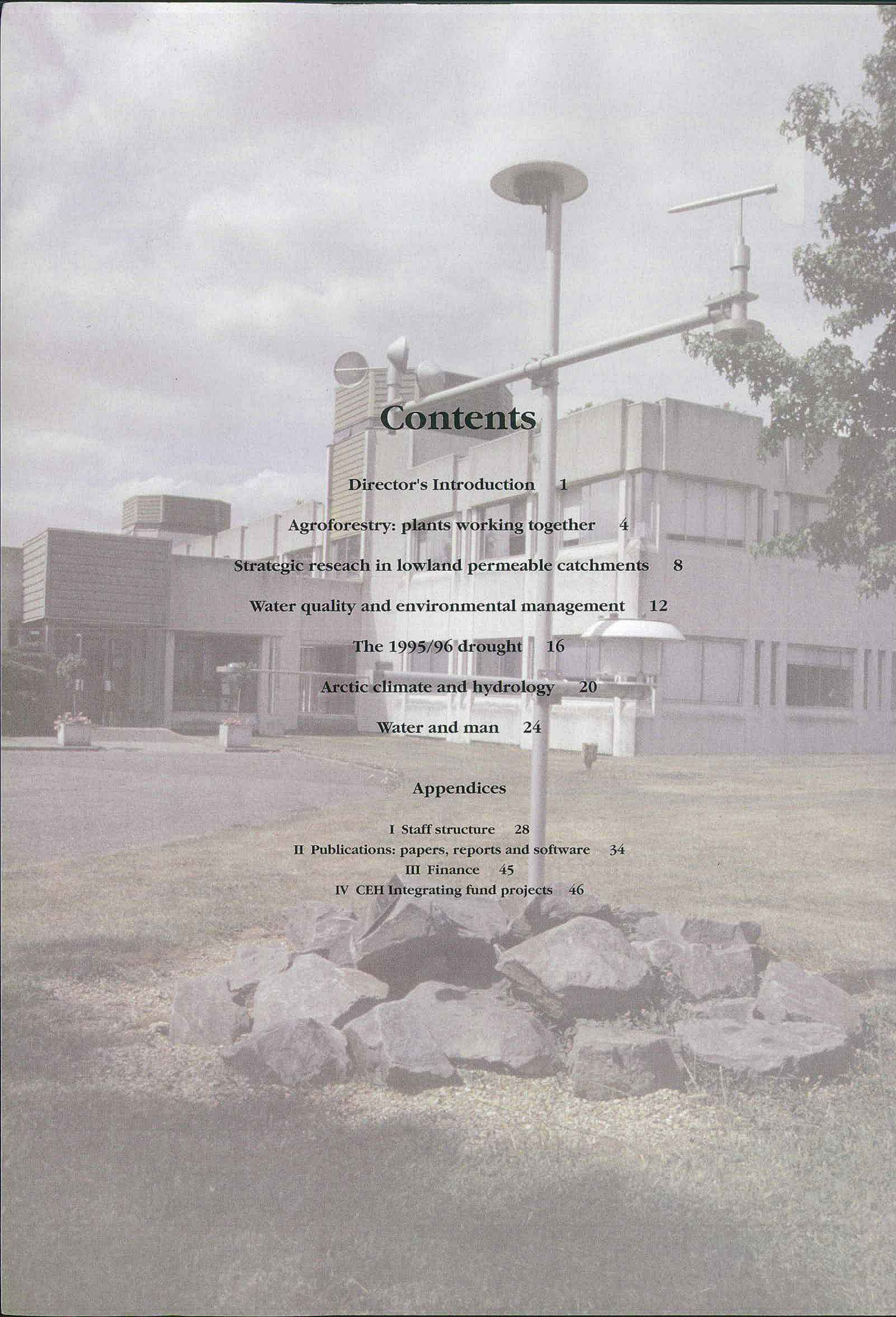
During the course of the year the **Institute of Hydrology** has made a major contribution in developing the new CEH Research Programme. Tony Debney, the Acting Director, took direct responsibility in steering four programme areas. IH also put forward a number of Integrating Fund proposals, several of which were successful and were subsequently funded. The Institute has also established many new links with other CEH Institutes during the course of the year. It will be seen from this Annual Report, which I commend to you, that under Tony Debney's Directorship, the Institute's science has flourished. I wish to record my thanks to Tony, who retires in 1996, for the significant contribution he has made to the management and science of IH over some 28 years. He will be sorely missed. Tony Debney is to be replaced by Dr Jim Wallace who takes over the IH Directorship in November.

I would also like to take this opportunity to draw your attention to the complementary Annual Reports for 1995/96 from the other CEH Institutes and to the CEH Overview Report.

Brian Wilkinson
Director
Centre for Ecology and Hydrology

Report of the Institute of Hydrology 1995-96

Natural Environment Research Council



Contents

Appendices

Director's Introduction

1995/96 seems set to be remembered as a year of exceptional importance and promise for this Institute. It was a year of many changes and of new directions. It saw a major reappraisal of our long-term strategic programmes, re-shaping and integrating them more closely with ecology and environmental microbiology in our new setting within the NERC Centre for Ecology and Hydrology.

Working with colleagues from three sister institutes and with four Programme Review Groups, greater emphasis is being given to multidisciplinary collaboration in core NERC-funded activities. Identifying priorities, re-allocating resources and completing past commitments takes time but will be done by the end of 1996/97. It will result in a larger role for this Institute in four CEH programmes: *Soil and Soil/Vegetation Interactions*, an expanding *Urban Environment* programme, within *Biodiversity and Population Processes* research and in *Pollution* studies. Our CEH colleagues will work more closely with us in four Programmes which have been cornerstones of our past strategic activities — *Land Use Science*, *Freshwater Resources*; within *Environmental Risks and Extreme Events* research and in *Global Change* studies.

This annual report presents the work of the year rather differently than in the past. We attempt to provide commentary on some contemporary issues which we expect to be central to our role within the CEH Programme Areas. These are:

- Below-ground competition for water and research into processes governing uptake of water by competing root systems;
- The vulnerability of groundwater-fed river systems in lowland Britain and the expansion of our catchment research into permeable areas;
- The challenge of developing integrated water quality models to aid environmental management at catchment or basin scale;
- Investigations into the role of snow and permafrost in global climate processes, extending our overseas work from tropical and arid regions to the Arctic;
- The increasing importance of the socio-economic dimension in our work, especially as this relates to water, urbanisation and health.

As before, we also give brief details of key projects from our current portfolio of research, with contact names should the reader wish to receive more information on work nearing completion.

It seems timely to provide special comment on the 1995/96 drought and we do so in the context of the Environmental Risks programme. The UK experienced the lowest UK summer rainfall sequence in more than 200 years. This is set within the warmest 12-month period (October 1994 – October 1995) in the 337-year temperature series for central England. IH and British Geological Survey staff from the National River Flow and Groundwater archives here at Wallingford mapped the drought and commented on its progress through monthly summaries intended to guide water management policy initiatives and increase public awareness. Details of this service can be found on the World Wide Web: http://www.nwl.ac.uk/ih/prototype/research/drought_watch.html.

Drought in the UK, creating pressures on water supply and distribution systems, serves to highlight an issue of growing global significance: escalating problems of water scarcity, allocation and use. It seems appropriate to comment here on one special aspect of such research — FRIEND networks. FRIEND (Flow Regimes from International Experimental and Network Data) is about sharing flow and catchment data from research basins and national networks and exporting know-how between partners to improve hydrological design to arrive quickly at better assessments of drought and water resources for improved basin management.

Director's Introduction

The first FRIEND project was instigated by IH in 1985 with initial collaboration with scientists from 13 European countries. This has now grown to a network of more than 50 organisations in 22 northern European countries. Three more FRIEND networks have been established during the year — Alpine and Mediterranean, Southern Africa and Central/Western Africa — whilst IH staff were involved in planning a further three: in South America, the Himalayan Hindukush and in South East Asia.

The motivation for FRIEND, and indeed its success, lies in realisation that all accessible surface water runoff will be committed world-wide within the opening decades of the next millennium. Physical and environmental issues simply have to be shared internationally in order that local economic, political, social and institutional factors can be integrated within sound water policy. FRIEND is a major component of the UNESCO International Hydrological Programme and was designated Project 1.1 of IHP-V in 1995.

1995/96 saw the Institute deeply involved in many aspects of flood research. 1995 may have finished with drought but it began with a second major flood event within two years on the Meuse and Rhine rivers. This corresponded with the start of a £1.5 million programme initiated by MAFF aimed at developing new generalisations of rainfall and flood frequency estimation for the UK.

For the hydrological researcher, estimation of extremes continues to set rich scientific challenges, particularly against the backdrop of potential climate change. With parallel research into real-time flood forecasting, the use of weather radar and exploitation of our hydrological digital terrain model in flood modelling, the occurrence of a rarely observed event seems set to encourage participation in floods research across the Community.

Another feature of the year was the great strengthening of our links within CEH and also with Europe. We were successful in nine new bids into the Agriculture and Environment programmes of EU Framework IV. We played a major role in the establishment of a European network of freshwater research organisations (EurAqua), began working with the European Environment Agency, and contributed to ALTENER and LIFE programmes. Freshwater sciences are increasingly prominent in the European research arena and the year saw the emergence of a special initiative — the European Task Force on Water. IH will contribute to setting priorities, both by working with the UK water industry in a "mirror group" and through the EurAqua network.

1995/96 was a year of significant changes in our relationships with public and government departments in the UK. The National Rivers Authority ceased to exist and we began working with the new Environment Agency, aligning elements of our core and European research activities with issues of strategic importance to their mission. Projects concerning enhanced low flow estimation and ecologically acceptable river flows were begun and the Agency commissioned studies on rainfall frequency within the framework of the MAFF Flood Estimation Handbook project.

Research for the Overseas Development Administration, our largest external customer, has begun to involve far greater emphasis on water resources issues. Water has growing importance in the UK overseas aid mission. Contracts relating to water resources and sediment problems in the Himalaya, regional groundwater recharge in semi-arid areas, and improved water resources assessment methodologies were won in open competition through the ODA TDR programmes.

IH contributions to the NERC TIGER and LOIS Thematic Programmes reached their peak during the year. LOIS has seen the collection and collation of an unparalleled wealth of water quality information covering decadal time scales for the east coast rivers from Berwick to the Humber. Diffuse inputs, point sources and in-river processes have been studied to evaluate the effects of different scenarios of change across a range of rural and urban catchments draining into the North Sea. A modelling structure is now in place and has been tested on flow and nitrate across 11 Yorkshire catchments. The ability to scale up from these relatively small units to the whole LOIS area (59 200 km^2) using digital base data is one of the important achievements of the year. Formulation of model components is proceeding for other determinands, notably carbon, pesticides and sediments.

We not only have a research role in the rivers element of LOIS but we are also charged with responsibility for one of the main end-products of the Land Ocean Interaction Study: publication of a CD-ROM containing all the research data from five separate disciplines. Managing the LOIS Datacentre and planning the CD-ROM is the most ambitious data manipulation by NERC.

At its core sits the IH Water Information System (WIS) now being tested way beyond its original design concepts to form a single harmonised and integrated database. For the operation of the data centre and the designers of the CD-ROM, the challenge is to overcome the problem that each discipline collects, processes, stores and uses its data differently.

Success will mean that a user studying the movement of, say, nitrate, will be able to extract data for groundwater, rivers, estuaries, coastal waters and the atmosphere without having to move through five different data systems. I have to recognise that the risk of failure to deliver the CD-ROM as a single system is real. The problems are not insurmountable but too little funding is yet becoming available to advance environmental information technology (EIT). Promoting and publishing the raw material of research — the data — is far more costly than publication of the results of research. It is, nevertheless, a most cost-effective step and a form of partnership able to transform research and teaching way beyond the community charged with its initial capture. EIT research thrived at IH in 1995: to flourish it needs better support and larger investment.

NERC Thematic programmes and small scale Special Topic research can involve participation of many different disciplines from across the whole of academia, the user communities and increasingly the Research Council structure. It is clear that such collaborative research has begun to permeate most of our activities. In 1995/96, 100 projects (53% of the IH research portfolio) involved partnerships with researchers from other organisations. Twenty-three different projects had co-funding either in partnership with NERC or through consortia from public and private sectors. Long gone are the days of a back-room boffin. project management and business administration skills are essential tools for the modern research hydrologist.

We are also seeing a significant increase in formal training. Currently, there are five in-house post-graduate placements, 25 CASE studentships, two MSc placements and eight core IH staff registered for higher degrees. We continue also to encourage under-graduate Sandwich Course placements and ten students have spent the year working with us

Over and above the many internal changes and external reorganisations that took place this year, there was great encouragement to prepare new avenues of research and to seek funding via the many competitive initiatives that emerged following the 1993 White Paper *Realising our potential* and through the national Technology Foresight Programme.

For IH, with over 60% of work from user-funded contracts, it was a period of unprecedented activity beyond the main function of research delivery. The year was particularly complicated, with some 76 projects involving overseas work and I wish to record my appreciation of the long hours spent by many staff in meeting the obligations I placed upon them. Nevertheless, they maintained our prime research output through 146 refereed papers and conference proceedings; 127 research reports were delivered to users. IH staff authored three books, edited a further eight, contributed 19 chapters in other books and delivered over 70 lectures/ seminars to universities.

Again I must record my thanks to all staff for their high level of performance against a background of escalating change and of increased expectations on them. Performance, dedication and quality of work do not seem to have been too badly affected by the Prior Options review and the continuing uncertainty over its outcome. Indeed, postponement of any rebuilding at the NERC Wallingford site, pending Prior Options recommendations, has had a greater impact on morale. Accommodation pressures continue to be a constraint on the efficiency of this Institute.

In touching on staff matters, it is with deep sadness that I have to record the untimely death of Mrs T K Jones who worked in catchment and floods research. The way in which Tanya organised her work and her life with husband and two young children as she battled against cancer was inspirational

Finally, I must record that Dr Jim Wallace replaces me as Director on my retirement in November 1996. He has led process research at IH over the past three years and is a physicist with exceptional dedication and determination to the delivery of excellence in hydrological research. The Institute will be in good hands under his leadership and I wish him and all staff great success and fortune as the emerging changes consolidate and the future of IH becomes certain.

Tony Debney, Director

Pressures on resources to provide for the needs of expanding populations means looking hard at alternative land-use systems. Agroforestry is often promoted as an attractive way of meeting rising demands for food and fuel without causing degradation of resources and losses in productivity.

Agroforestry: plants working together

Success in implementing agroforestry will only be improved if the processes controlling the partitioning of resources are understood

To be successful, both trees and crops in agroforestry systems ideally need to use water, light and nutrients at separate times or from separate sources. Without such spatial or temporal complementarity, competition for resources may limit the productivity of either trees or crops, or both. This could reduce the acceptance of the system by local land users and enhance the risk of environmental degradation.

Studies have been established with ICRAF (International Centre for Research in Agroforestry) to investigate above- and below-ground interactions between *Grevillea robusta* and crops in an agroforestry system at the Machakos field station in Kenya (see below).

Water balance and above-ground interactions

A central question is: does intercropping woody and non-woody plants increase total harvestable produce by making more effective use of rainfall? There are a number of ways in which agroforestry systems could use water more efficiently than monocultures but a clear picture of how this actually happens can only be obtained through a comprehensive water balance study. Considerable progress has been made in quantifying

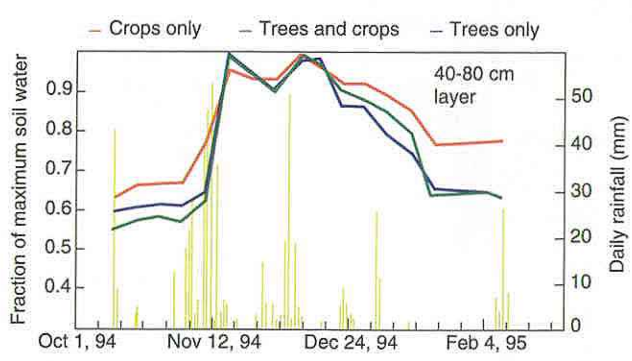
Mixed cropping at the Machakos field station, Kenya the individual components of the water balance. From this work we hope to develop a model for agroforestry systems on sloping land which can form an integral part of a growth and yield model. In particular, to evaluate the mechanisms by which agroforestry systems on sloping land can make better use of rainfall and hence increase yield.

Soil moisture measurements show that single crops do not use all the available soil moisture and that more water is used by trees grown alone, but that the greatest water use is by a combined tree/crop mixture. Surface soil water content measurements made using the Time Domain Reflectrometry (TDR) technique revealed dynamic changes in water content in the upper layers of soil. The spatial arrangement of these within the tree plots show great variability in the wetting and drying at different locations, primarily influenced by proximity to the trees. Rainfall inputs at the soil surface are reduced by the presence of the tree canopy but this is compensated to some extent by stemflow which preferentially wets the soil area immediately next to the tree trunks. Subsequent re-evaporation of surface soil water is different near to and far from the tree trunks.

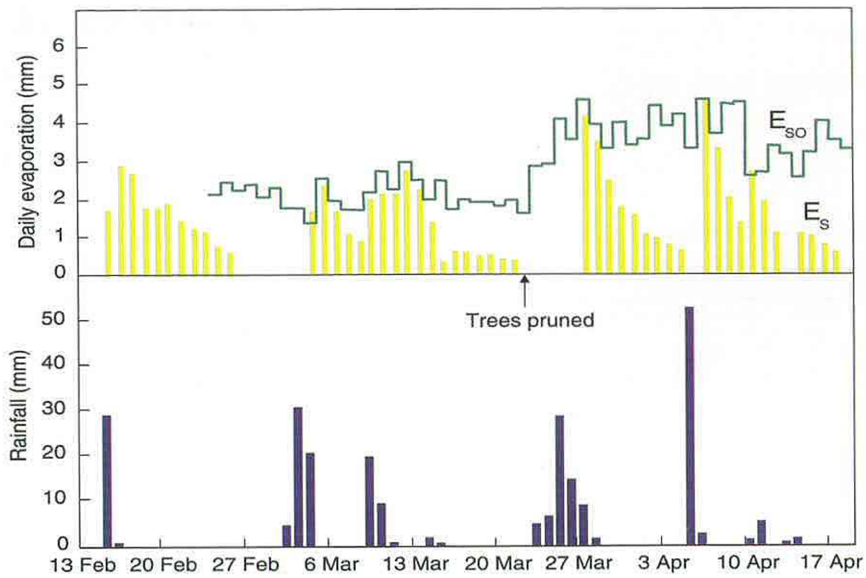
Before agroforestry systems can claim to increase the productive use of rainfall they have to compensate for the loss of rainfall by interception and evaporation from the tree canopy. In our studies in Kenya we find that where trees give ~50% ground cover the interception loss is between 11 and 14% of rainfall. However, although a tree canopy may suppress crop interception loss, it seems likely that the net effect will be a significant increase in total interception loss which needs to be offset by savings in other parts of the water balance if agroforestry systems are to make better use of rainfall.

One such possibility is in soil evaporation. The data collected in the current study show a clear reduction in evaporation rates under the tree canopy compared to concurrent rates in bare, exposed soil. This reduction only applies for the first day or so after rain: over longer periods, where evaporation is controlled by the hydraulic properties of the surface soil, the cumulative loss rates from exposed and shaded areas tend to converge. Thus, the net effect of canopy shade on soil evaporation during a wet season depends on the frequency and amount of rainfall. A simple simulation model shows that there is a saving in water equivalent to about 5% of rainfall.

A further important environmental constraint on agroforestry in semi-arid regions is below-ground competition for water. Few detailed studies have yet been made of the processes governing uptake of water by competing root systems in agroforestry. The first objective in our root studies is to define the spatial distribution and seasonal dynamics of roots in the experimental *G. robusta*-crop system. A traditional coring method was used to obtain samples of soil in discrete layers from which tree and crop roots were carefully separated and root length densities were estimated using a computerised scanning device. Root length densities derived in this way from coring at the time of anthesis in the maize during the short rains of 1995 are shown below. Root lengths of both maize and *G. robusta* declined approximately exponentially with soil



Changes in soil profile water storage for three treatments over three rainy seasons



Comparison of daily rainfall, potential and measured evaporation at the base of a tree in a crop-plus-tree experimental plot

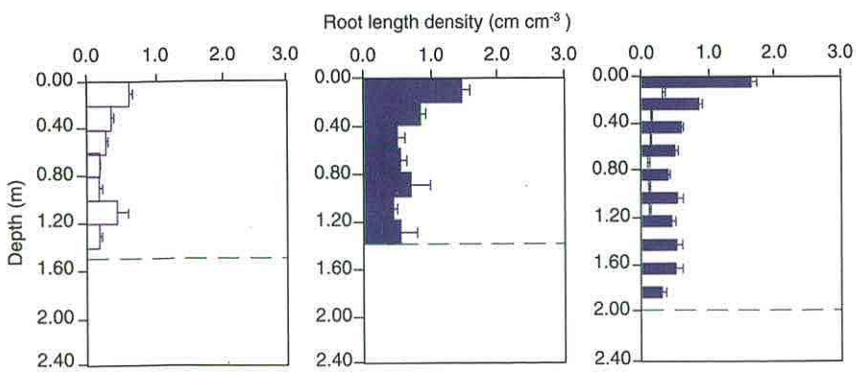
depth. There was little variation in root lengths of the trees with distance from the trunk, in either the crop-plus-tree or tree-only plots, suggesting that the trees were exploiting uniformly all available space in the plots. Root lengths of maize were highest close to the crop row and expansion of root length appears to have been suppressed by the trees in the crop-plus-tree treatment, probably caused by water uptake by the trees making the soil much drier.

Seasonal dynamics

The seasonal dynamics of root growth are being investigated by supplementing information from coring by viewing the appearance and disappearance of roots directly in the soil with a minirhizotron set up and developed at IH (see opposite page). This enables changes in root lengths to be assessed over shorter time periods than is possible by soil coring.

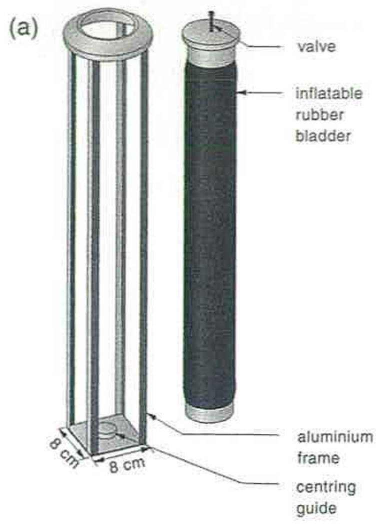
Further studies will investigate root functioning and its relationship with position in the soil. The information will be incorporated into models of water uptake from soil occupied by roots of more than one species. The root uptake model will be a key component in a combined growth and water use model:

- to act as a framework in which to place existing information on tree/crop interactions and to identify key areas of uncertainty;
- to serve as a decision-making tool for evaluating new agroforestry options;
- to assess the impact of climatic shifts and other land management impacts on particular agroforestry systems.



Root length densities for maize and Grevillea robusta *trees*

1995/96 highlights



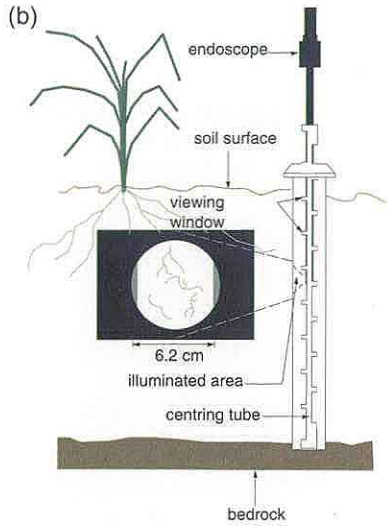


Diagram of a minirhizotron, a device that allows in situ *observation of roots in soil*

Measuring soil water potentials of less than –1 bar. IH is collaborating with Imperial College, London, to develop the field use of a novel tensiometer invented by Dr A Ridley of the Department of Civil Engineering. Until now, the device has been mainly used in laboratory-based soil mechanics applications. If it can be adapted to hydrological studies, it could revolutionise investigations in situations where the soil dries beyond the range of conventional tensiometers.

Contact: David Cooper

Soil water extraction by trees

Studies at Hosakote in India have now proved beyond doubt that Eucalyptus trees have the ability to extend their roots down at least 2.5 m per year to obtain water and nutrients.

Eucalyptus plot, Hosakote, where neutron probe access tubes were installed before the saplings were planted

This has important water resource implications where these trees are planted, and highlights the importance of ensuring that soil moisture measurements extend beyond the rooting depth of the vegetation type being studied.

Contact: Ian Calder

The vulnerability of groundwater-fed river systems in lowland Britain to reduced recharge was highlighted during the 1988-92 drought. The sustainable hydro-ecological management of these systems requires more equitable solutions to resolve conflicts between land use, water resources development and protection of the river ecology.

Strategic research in lowland permeable catchments

A water resources action plan is being developed to mitigate the degradation of European catchments caused by the over-exploitation of groundwater resources

There is a growing awareness throughout Europe of the damaging economic and ecological consequences resulting from the over exploitation of water resources in groundwater fed catchments, such as falling water tables, dried-up rivers and degraded wetlands. The sustainable management of these systems will require a more integrated approach at the catchment scale to resolve particular hydrological, ecological and socio-economic issues. A crucial part of the work of IH is to develop strategic hydrological research to address these problems. In the UK, the Chalk aquifer and its drainage system is of particular concern, since this is an important source of public water supply but susceptible to pollution and groundwater over-abstraction in its outcrop area.

A three year EU funded project led by IH in collaboration with six other European partners began in March 1996 to develop a decision-making framework for water resources management planning to combat the adverse effects of over exploitation. This project, Groundwater and river Resources Action Programme on a European Scale (GRAPES), will focus on the River Pang, a Chalk catchment in the West Berkshire Downs, as one of three case study catchments in Europe. Key work packages include database collation and analysis of hydrological data, hydrological modelling, catchment management planning and a guidance manual for water resources planners throughout Europe.

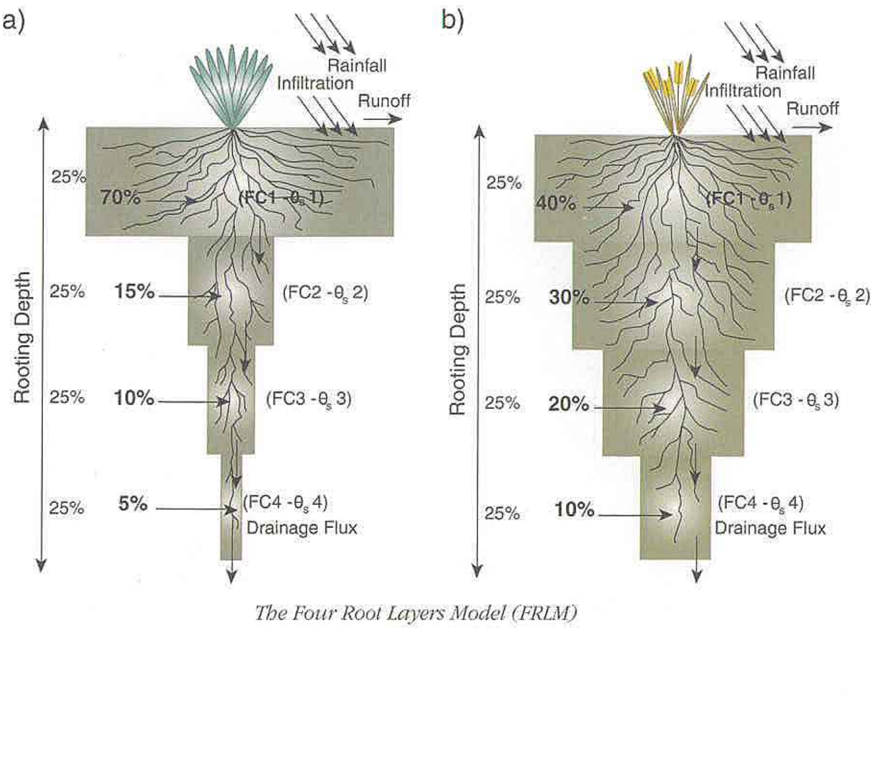
The Pang catchment is also being used as a pilot study area for a study commissioned by the European Space Agency into the suitability of low resolution (150m-1km) side aperture radar products (which may become available from future

European satellites such as ENVISAT) for soil moisture determinations to support catchment-scale hydrological models.

Restoration of the River Pang, a previously over-exploited groundwater-fed catchment

Processes governing recharge to the Chalk and Permo-Triassic aquifers are still uncertain, which has implications for resources management. However, a new soil moisture model being developed by IH, the Four Root Layers Model (FRLM) has been shown to match field measurements of soil moisture deficits more closely than other models in current use. It uses daily time-steps and calculates potential evaporation (PE) from MORECS data or from the Penman-Monteith equation. Already this model has been used to prepare a series of nomographs that allow annual recharge to be readily estimated from values of annual rainfall and MORECS annual PE, taking into account the main land covers of the Permo-Trias and by-pass flow in the unsaturated zone of the Chalk.

The establishment of a lowland permeable catchment research facility to address strategic issues has been identified as a high priority within the Core Strategic Programme of CEH. The work being undertaken in the Pang catchment could provide a suitable foundation for future programmes of integrated, multi-disciplinary research to investigate the processes governing recharge, contaminant transport, and the complex interaction between groundwater-surface water systems and stream ecology in Chalk catchments. Steps are now being taken to establish such a facility and to highlight strategic research issues that would be of particular benefit to the Environment Agency, water utilitites and conservation groups. Examples include the response of the Chalk system to the extremes of droughts and floods, the impact of climate and land use change and the development of integrated ecological, water quality and physical habitat models of Chalk rivers.



The Four Root Layers Model (FRLM)

1995/96 highlights

Lebanese Hydrometry (for Litani River Authority and British Partnership Scheme). Advice on rehabilitating river flow monitoring and data processing facilities for the Lebanon, plus provision of computer database software and assistance with publication of a national hydrological databook.

Contact: Kevin Sene

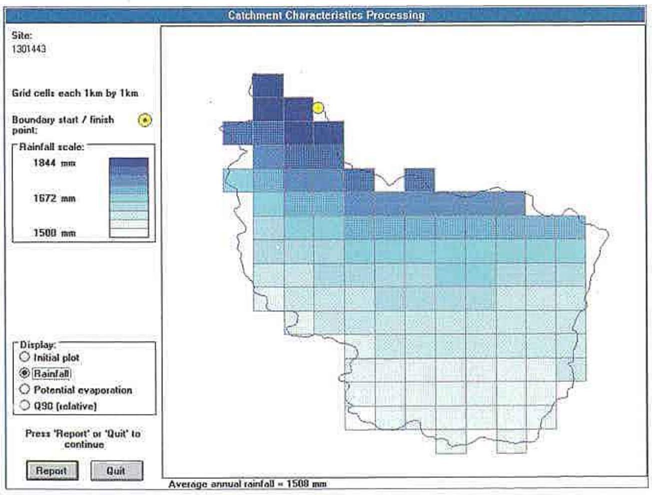
A flow gauging station near Beirut

Combining hydraulic design and environmental impact assessment for flood defence schemes for MAFF involved the integration of the physical habitat model PHABSIM with standard hydraulic design models including ISIS, HEC-RAS and Mike-11. The PHABSIM software has also been enhanced and further objective techniques developed for the Environment Agency to select representative PHABSIM study reaches.

Contact: Craig Elliott

Naturalised river flow records. The development of a consistent automated method has been developed for the Environment Agency's Anglian Region, initially for assessment of the yield of the Ely Ouse transfer scheme.

Contact: Andy Young



Catchment average rainfall derived with the HydrA software

European atlas of small-scale hydropower (for EU Altener Programme). HydrA, the software implementation of the atlas, has been completed, providing a tool to estimate low flows and hydropower potential at any site in Spain and the UK.

Contact: Gwyn Rees

Stochastic flow generation for royalty assessment of the Lesotho Highlands Water Project (for Lesotho Highlands Development Authority). Long-term reservoir inflow series for this scheme were derived upon which to fix the royalty payments for water transfers by the Republic of South Africa to Lesotho. An innovative model was developed which was capable of making best use of scarce and incomplete rainfall and flow records.

Contact: Frank Farquharson

Groundwater management in drought-prone areas of Africa. A joint BGS/IH project to understand hydrogeological/ hydrological and socio-economic aspects of groundwater drought and translate this into guidelines for short- and long-term strategies for groundwater management in drought-prone areas, using Malawi and Ghana as case studies.

Contact: Tony Andrews

Jersey catchment study. A model to predict the hydrological response of this catchment has been calibrated and tested using three years of observed streamflow and soil moisture data. Existing rainfall and Penman evaporation figures are now being used to predict 25-year sequences of soil moisture deficits, groundwater recharge and streamflow to assess the long-term effects of varying intensities of groundwater abstraction.

Contact: Matthew McCartney

Estimation of renewable water resources in the EU (for Eurostat). Derivation of a well-defined estimation method for water resources that can be compared with abstraction data to get stress indicators reflecting seasonal problems as well as regional differences.

Contact: Gwyn Rees

Artificial flood releases from Mutonga and Grand Falls dams, Kenya (for Nippon Koei Ltd, Japan, through the Natural Resources Institute). The Tana River, the largest in Kenya, already has five hydropower dams, and feasibility studies were undertaken for two more. IH looked at the feasibility of making artificial flood releases from these new dams to maintain downstream flood spate agriculture.

Contact: Frank Farquharson

Review of hydrological monitoring in Palestine (for ODA). In conjunction with BGS, the status of both surface and groundwater monitoring systems in the West Bank and Gaza Strip was assessed, and recommendations made for planning the future system to be operated by the newly-established Palestinian Water Authority.

Contact: Jeremy Meigh

Modernisation of hydro-meteorological observations in Rajasthan, India (for Rajasthan Irrigation Department, funded by World Bank). Design of improved hydrological and meteorological data collection systems for the 342,000 km^2 State of Rajasthan. New river gauging stations, autographic and daily raingauges, and meteorological stations were recommended, along with improved equipment, operational and maintenance procedures, data processing and storage and substantial staff training. The project also included real-time data collection systems and the preliminary design of flood forecasting systems for two basins.

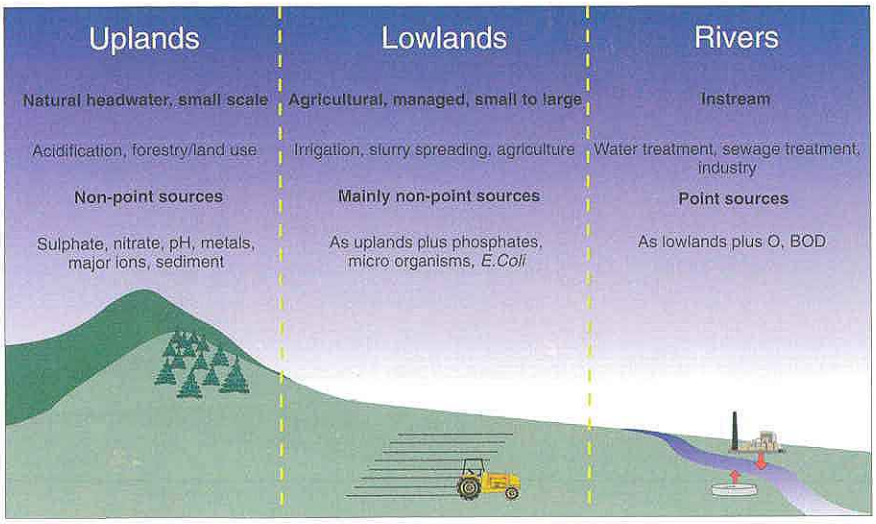
Contact: Jeremy Meigh

Inspecting flow gauging equipment in Rajasthan

Historically, understanding the processes affecting water quality has advanced as the result of investigations into particular problems or issues. Such detailed studies, focused on a small geographical region or chemical determinand, are likely to continue both as a practical means of solving problems and as a way of developing a better understanding of the processes controlling the quality of water in soils and rivers.

Water quality and environmental management

Studies in environmental hydrology may conveniently be divided into three categories that reflect the physical scale and setting, the issue or problem, and the investigative approach or model framework. These are the uplands, the lowlands and the rivers themselves.



Water pollution: issues and physical settings

Upland studies focus on small headwater catchments and the current relevant issues are acidification from the deposition of oxides of nitrogen and sulphur, and the effects of changes in land use, especially forestry. It is generally appropriate to use lumped or semi-distributed models.

The scale of interest in the lowlands broadens to encompass both field-based and large catchment studies. Agriculture becomes the dominant land use and most water quality issues relate to land use (e.g. arable, pasture and forestry) or land management (e.g. the use of agrochemicals). As the scale of the study increases so does the need for a partially of fully distributed approach to modelling that recognises the heterogeneity of the catchment.

Within rivers, especially larger rivers, point sources — industrial and sewage treatment works discharges and abstractions for water supply — assume greatest importance, and oxygen and nutrient dynamics are the prime concern. Model complexity can vary to suit data availability and the purpose of the study.

Some issues transcend this simple categorisation and apply to all three physical settings, a notable example being climate change.

All hydrochemical studies rely on good quality data to describe the water quality and to enable investigation into the causes of problems and an assessment of remedial measures. While many geographical data sets now exist at a national scale, and are available for access and display within geographical information systems, time series data describing hydrochemical properties of catchments are spatially scarce and temporally coarse. As a consequence, collecting and collating such data is a significant component of many environmental hydrology studies.

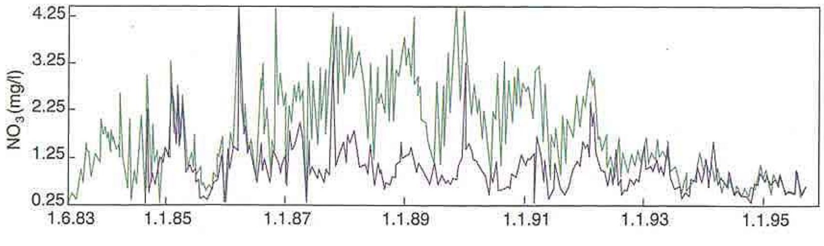
The UK Acid Waters Monitoring Network (AWMN) was established to monitor acidification in upland areas and to quantify long-term changes. A comprehensive five-year review was recently completed, and this anniversary has been marked by a special issue of *Freshwater Biology*. The hydrochemical data reveal trends in increasing sulphate concentrations in south-west Scotland and north Wales despite constant sulphur deposition in these areas. The data also reveal the importance of nitrogen in surface water acidification and strengthens the cases for the implementation of controls on future nitrogen emissions.

As well as being used to describe the hydrochemistry of the monitored sites, the data have been used within the lumped hydrochemical model MAGIC (Model of the Acidification of Groundwater In Catchments) to simulate changes over time. This model which currently represents sulphate processes is being developed to include nitrogen dynamics and again the AWMN data provide an underpinning resource for this development.

Studying the impacts of conifer harvesting and replanting on stream water quality with a view to identifying best practice management strategies has centred on the Institute's experimental catchments at Plynlimon and builds on background hydrochemical studies undertaken for the past decade. Changes in water chemistry associated with clear-felling of parts of the Hafren forest during the mid to late 1980s are now complete, with rises in nutrient concentrations and declines in pH; alkalinity and base cation levels have now returned to background levels.

Within the lowland environment, a field-scale project on the movement of solutes in soils showed that the pathway followed by infiltrating water was crucial in determining the concentrations and amounts of herbicide leaving the study site.

Bridging the upland-lowland division of catchment hydrochemistry has been the development of a hydrochemical model to represent nitrate delivery into river systems at the catchment scale. While earlier work led to the development of a distributed nitrate catchment model, for widespread application as part of the NERC Land Ocean Interaction Study (LOIS) to all catchments between the Tweed and Humber estuaries (an area of over 42 000 km^2) it was decided to adopt a



The effect of clear-felling on nitrate concentrations: a comparison between the upper Afon Hore (control, blue) and the lower Afon Hore (site harvested 1985-88, green) simpler lumped approach. This is based on hydrological response units automatically defined from a digital terrain model, in which flow routing is performed on a 50 m grid and nitrogen leaching estimated from soil type and land use.

An exhaustive collation of in-stream water quality data for the River Tweed has been prepared, again as part of the LOIS programme. Within the Tweed, diffuse pollutants are nitrate, from agriculture, and iron, derived from the underlying geology, while copper has industrial point sources, and zinc and phosphorus come from both agricultural and point sources.

The in-stream water quality model QUASAR (QUAlity Simulation Along Rivers) developed at IH and considerably enhanced within LOIS, provides a means of assessing such data within the framework of a process-based model. QUASAR incorporates the degree of process representation and spatial scale that is consistent with available data and with management requirements. It has been applied to the Yorkshire Ouse river system over a total river length of almost 200 km which is represented by 69 model reaches with 39 tributaries, 19 discharges and five abstractions. The temporal resolution of data describing the inputs to the rivers vary greatly, from 15 minutes for flow data to no data at all for some of the industrial discharges. This uncertainty surrounding the quantification the inputs predicates the use of a water quality model of this type which, for example, treats diffuse input at the river bank as a point source at the reach end. Simulations of existing conditions show that QUASAR can reproduce the characteristic of the water chemistry both as time series and distributions.

Underpinning all studies of water quality is an understanding and, where necessary, representation, of the movement of water in both soils and river channels. It is the flow of water from its arrival as precipitation at the soil or vegetation surface to its exit at the catchment outlet that transports pollutants, and indeed the presence or absence of water in the soil, or the volume and velocity of flow in a channel, can influence chemical processes.

The use of models is justified on the basis of providing an integrated framework within which the data can be assembled, compared, validated and used to investigate hydrological and hydrochemical processes. However, the benefits of modelling are much wider since models may also be used to interpolate and extrapolate, in both space and time and, most importantly, to explore scenarios representing possible future conditions. Recent examples using QUASAR include assessments of strategies for reduction in power station emissions, treatment options for acid mine-water discharges, effects of climate change, and effects of land use change.

While such studies have provided an effective problem solving approach to environmental management, there is a growing recognition that a proactive holistic approach is required and that new tools are needed which move beyond existing model structures. This is now possible since expertise in, and understanding of, modelling the various components of the whole catchment system has reached a stage at which confidence in both the process representation and model results is sufficient to allow integration of hitherto disparate elements.

Furthermore, as such stand-alone models develop in sophistication it becomes necessary for the model to include more inputs and processes and hence the domains of the models begin to overlap. In addition, data collection systems and data management facilities are improving so

Laboratory experiment to simulate isoproturon leaching through an unsaturated chalk column

that they can provide all of the data needed for such an integrated approach.

The development of a fully integrated catchment water quality model is still many years away, but the initial steps have already been taken as part of the LOIS programme and centred on QUASAR. Three examples illustrate how this integration will allow a far greater range of scenarios to be explored:

- Climate change is likely to effect changes in the quality and quantity of catchment runoff, which will change the flow regime in rivers and hence the physical and chemical processes in the river system. The result may well be a change in the trophic state of the river which will impact aquatic biology.

- Changes in legislation will prevent discharges of waste from sewage treatment works to coastal waters leaving operators with the options of incineration or disposal on land. Land disposal may lead to increased pollution of rivers and it is essential that only the most suitable sites should be used.

- Algal blooms in lowland rivers during the summer months are attributed to the combination of low flows and increased nutrient concentrations. The stripping of phosphate at sewage treatment works is one method of approaching the problem, but may have little effect because of continued, and increasing leaching of phosphate from agricultural land, and the release of phosphates stored on river sediments.

In these, and many other situations, the effects can be investigated using a integrated catchment water quality model. The scientific challenge of providing a realistic, robust and useful model to aid environmental management represents the principal focus of research for the coming years.

1995/96 highlights

Herbicide degradation in aquifers

A recent study of pesticides in the saturated and unsaturated zones of aquifers has provided quantification of the rates of degradation. A unexpected outcome was the discovery of a previous unknown bacteria population in groundwater that had the capacity to degrade the herbicide isoproturon at a very rapid rate.

Richard Williams

Oestrogenic substances in rivers

Experiments have been carried out to assess the rate of biodegradation of oestrogenic substances in rivers. Initial results from water samples taken from the Thames using 4,t-octyl phenol have shown degradation rates with half-lives of around 20 days.

Andrew Johnson

Bath hot springs — Analysis and interpretation of flow and temperature data (for NRA, South West Region). The potential effects of mine dewatering on temperature and flows of Bath hot springs were assessed and the need for additional monitoring identified.

Dick Bradford

Drought in the United Kingdom does not pose the threat to lives and livelihoods that accompanies exceptional rainfall deficiencies in many parts of the world. Nonetheless, the impact of very unusual weather conditions over the last decade has provided a clear demonstration of our continuing vulnerability to hydrological extremes.

The 1995/96 drought

Considerable skill is necessary to distinguish between climate-induced drought and water resources stress arising largely from shortcomings in water management

The seemingly endemic drought conditions which have afflicted many parts of the country over the last eight years have attracted substantial public, scientific and political interest. They have also raised important questions regarding the resilience of existing water management procedures and refocussed attention on many of the issues at the heart of hydrological research — and its practical application — in the UK.

The hydrological monitoring programme

In response to developing drought conditions through the winter of 1988/89, the Institute and the British Geological Survey jointly initiated a hydrological monitoring programme on behalf of the Department of the Environment. The underlying objectives are to guide water management policy initiatives and to increase scientific and public awareness of the issues involved. A wide range of reference and spatial information held on the National River Flow Archive (maintained by IH) and the National Groundwater Level Archive (maintained by the British Geological Survey) provide the historical perspective within which the severity of contemporary drought episodes can be assessed.

The current drought

Following the very protracted drought conditions of 1988-92, a dramatic recovery in river flows and groundwater levels resulted in the focus of hydrological concern shifting emphatically to the risk of flooding over the winters of 1992/93, 1993/94 and 1994/95. On a nationwide basis the latter was the wettest on record for the UK and with reservoirs at capacity and groundwater levels close to seasonal maxima in almost all regions, the UK appeared very well placed to withstand any spring and summer rainfall deficiency. However, the frequency of Atlantic depressions declined rapidly during March and a northward extension of the Azores high pressure cell began to deflect most rain-bearing frontal systems to the north – and bring subtropical air-masses across the British Isles. This persistent synoptic pattern resulted in remarkably hot and dry conditions through most of the late spring and summer, the aridity of England and Wales is underlined by the

April-August 1995 rainfall total — the lowest for *any* five-month sequence in more than 200 years.

River flows and groundwater levels generally remained well within the normal range through the spring of 1995 but, by May, unprecedented demands — commonly associated with garden watering — began to reveal weaknesses in the water distribution networks. As exceptional demands continued through the summer, reservoir stocks continued to decline steeply and a mostly localised inability to ship sufficient water from treatment works to tap was succeeded by a more general threat to water resources. Sprinkler and hosepipe bans spread rapidly across most of England and by August restrictions affected almost 20 million people.

A very wet interlude in September arrested the drought's progress but a dry and warm October — concluding the warmest 12-month sequence in the 337-year central England temperature series — heralded a second phase in the drought's development. Particularly severe drought conditions developed in the southern Pennines and tankering of water was required to maintain supplies in parts of West Yorkshire. Reservoirs failed to fill over the 1995/96 winter in many regions and, with evaporation rates accelerating through the spring, stocks were generally in decline by early May. Following a wet February the drought reintensified and by late summer large rainfall deficiencies extended across much of Britain. For England and Wales as a whole, the April 1995–July 1996 rainfall total was around 25% below average; the only drier 16-month sequences in the 230-year national rainfall series occurred during the droughts of 1975/76 and 1884/85 (the 1933/34 drought achieved a similar intensity). Entering the autumn many, mostly eastern, rivers had registered below average monthly flows for well over a year and the sustained decline in baseflows resulted in the extreme 1976 minima being eclipsed in some eastern

Stocks Reservoir, north-west England, autumn 1995

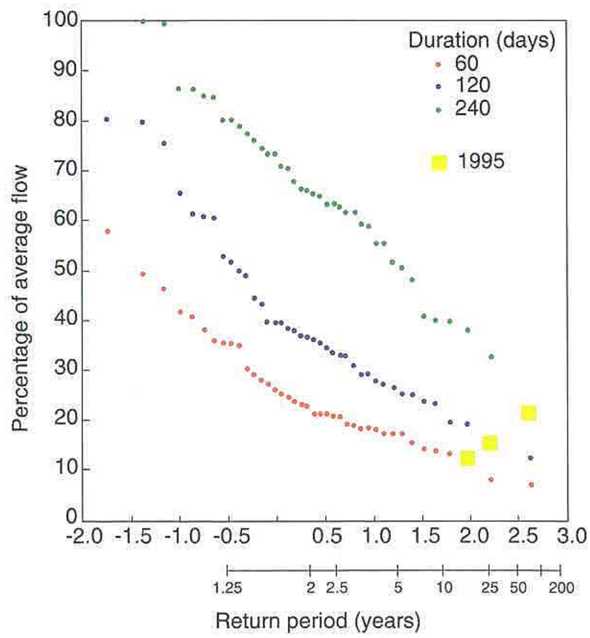
Chalk rivers. Lower temperatures and relatively moderate water demand — compared with 1995 — helped conserve reservoir stocks through the summer of 1996 but with groundwater levels much lower than a year before — and establishing new minimum levels in parts of north Wales and northern England — the water resources outlook remained fragile over wide areas entering the autumn of 1996.

The recent past

Notwithstanding the recent notable drought episodes, rainfall over Britain for the 1990s thus far is very close to the long term average. The severe stress on our water resources and river systems is attributable to the very atypical spatial and temporal distribution of the rainfall — exacerbated by the very high evaporation losses resulting from the exceptionally mild conditions. Taken together, the last 25 years have seen an accentuation in the north-west/south-east rainfall gradient across the British Isles and a tendency towards a more distinct partitioning of rainfall between the winter and summer half years. Importantly, the recent past has seen a cluster of hot, dry spring/summers (see figure below) for which there is no close modern parallel. This clustering raises the possibility that the level of risk adopted by the water industry — though vindicated during the droughts of 1976 and 1984 — may no longer be appropriate. This possibility is given added credibility by the broad, but incomplete, agreement between recent conditions and a number of favoured climate change scenarios.

The necessarily tentative nature of climate change scenarios at the national and regional scales, and the inherent variability of the UK climate, imply that any short term perturbation in our weather patterns needs to be treated with caution. However, recent hydrological conditions in the UK are undoubtedly close to the extreme range of historical variability. This, allied to the unprecedented water demands in recent summers, the heightened concern for the aquatic environment and, perhaps, a changing attitude to voluntary restraints on water use in the privatised world, means that the water industry faces very considerable challenges as we approach the 21st century. Fortunately, careful documentation and analysis of current hydrological conditions and their impact on both water resources and the aquatic environment are providing valuable insights into the type of problems likely to be encountered in a warmer world; these insights will help shape the development of more effective water management strategies should hitherto rare weather conditions become rather more familiar in the future.

Hydrological Summaries. Copies are available through the National Water Archive Office, Institute of Hydrology. The text of the reports can be found on the World Wide Web: http://www.nwl.ac.uk/~nrfadata/front_nw.html



Flow frequency diagram for the River Wharfe

1995/96 highlights

Flood-producing rainfalls (for MAFF). Rainfall events associated with recent damaging UK floods were investigated, with the aid of weather radar images, and the rainfall characteristics compared with the design values currently used in the Flood Studies Report rainfall-runoff method of flood estimation

Contact: Duncan Faulkner

Trend in flood occurrences (for MAFF, DANI, Scottish Office). As part of research on statistic flood frequency estimation, UK flood series have been tested for non stationary effects

Contact: Alice Robson

Long range study of water supply and demand in Europe (for EU-Forward Studies Unit) to assess trends has been extrapolated to provide forecasts for the year 2025

Contact: Gwyn Rees

European Topic Centre for Inland Waters (European Environment Agency) IH has contributed to the multi-annual work programme of the EEA by providing an assessment of hydrometric methods in Europe leading to the development of a pan-European water monitoring network.

Contact: Gwyn Rees

Environmental monitoring in the Aral Sea basin (for the UK Know How Fund). Assistance to the five countries of Central Asia in the Aral Sea basin — Kazakhstan, Krygyzstan, Tajikistan, Turkmenistan and Uzbekistan — in restoring computer facilities for processing hydrometric data. Provision of training courses in each country and at a regional workshop

Contact: Kevin Sene

In winter snow covers over 50% of the land surface of the northern hemisphere. Permafrost underlies about 25% of the global land surface. It is not surprising, therefore, that snow and permafrost play a fundamental role in global climate and hydrology.

Arctic climate and hydrology

Snow radically alters the proportion of light reflected from the land surface (what is known as a change in albedo) and its roughness. These two factors change the amount of surface energy available for the exchange of water vapour into the atmosphere, profoundly altering the local climate and large scale circulation patterns.

Snow-melt is a major component of many northern rivers. The freshwater inflows into the Arctic Ocean affect sea ice formation and ocean circulations. The permafrost impedes drainage causing much waterlogging in high latitudes. The permafrost also locks up considerable carbon deposits: it is estimated that at least one third of world's soil carbon occurs in permafrost affected regions.

The response of Arctic regions to possible climate warming is largely unknown. What we do know is that there is a strong positive feedback to global warming associated with changing snow cover, broadly speaking well described in the various global circulation models. However, the interactions between forest cover and snow, permafrost and the response of the carbon atoms to global warming are poorly understood.

Whatever the response of the stored soil carbon to global change there will be links with the hydrology. Global warming in the Arctic is likely to increase the depth of the active soil layer above the permafrost and increased temperatures will accelerate rates of decomposition in this layer, both processes will lead to the release of greenhouse gases. In Alaska, areas which have historically been carbon sinks have become carbon sources following increases in summer temperature of 3K in the last two decades. Whether decomposition produces carbon dioxide or methane will depend on the extent of waterlogging. It is also possible that the Arctic flora will evolve ways of reversing this efflux but this will depend on the water and nutrient status of the soils. The Institute has embarked on a measurement and modelling programme to understand and separate out some of these feedbacks.

The Institute has been making measurements of the fluxes of heat and water vapour above and below a snow covered forest in Canada and over a frozen lake, as part of the international BOREAS* experiment. The measurements show that the forest maintains a low albedo, even when snow covered, and thus absorbs considerably more radiation than was previously thought. When the snow is lying on the canopy the evaporation rates are large but when the snow is on the forest floor it is effectively isolated from the main energy exchanges, evaporation rates are low and the radiation input is converted into sensible heat.

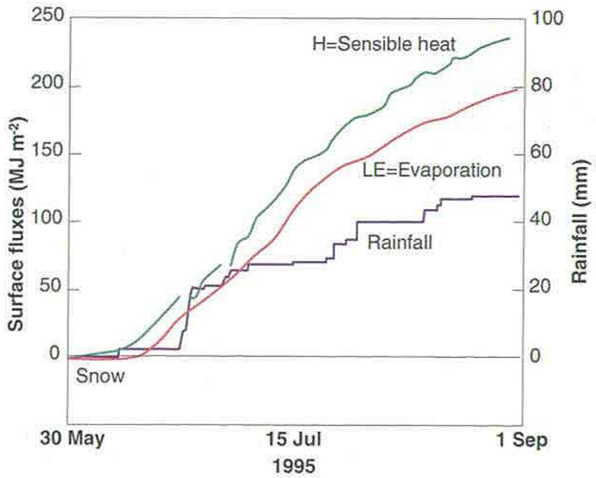
In contrast, over the snow-covered lake the albedo is high and therefore the net radiation is small or negative; evaporation rates are generally small and there is a negative (downward) flow of sensible heat. There is good evidence for a strong interaction between the lake and the forest through mesoscale atmospheric circulations.

The forest data are being used to develop a model of snow interception and melt. This is the first time a calibrated model of this important process has been constructed. The overall data set is also being used to validate a mesoscale model of the forest/lake interactions. This will be an important contribution to the description of the boreal forest mosaic.

Further north (at 80°N) the Institute has initiated a study of heat, water and carbon fluxes based at the NERC Arctic

Balloon measurements of the boundary layer over a frozen lake in Canada

Research Station, Ny-Ålesund, in Svalbard. The surface fluxes of heat, water vapour and carbon dioxide are being measured using eddy correlation. Supporting measurements include: snow depth and density, permafrost depth, soil moisture, surface runoff and climate. During the 1995 season (June through to August) the cumulative evaporation was 50% more than the rainfall (see below). Just under one-half of the net radiation was used for evaporation and during the same period the permafrost melted down to 0.5 m. The drying of the soil is largely by direct soil evaporation. The arctic vegetation, consisting mostly of woodrushes, have shallow roots and



Cumulative sensible heat, evaporation and rainfall for the 1995 summer period at Ny-Ålesund

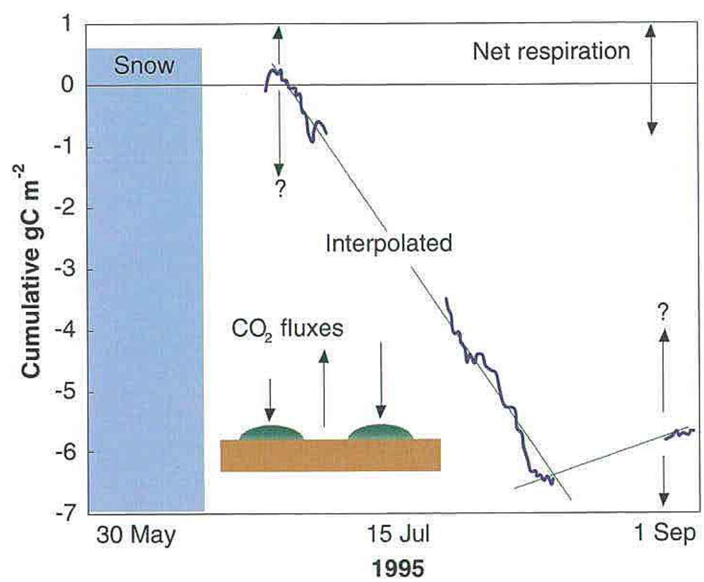
* **BOR**eal **E**cosystem **A**tmospheric **S**tudy

Eddy correlation equipment used for measuring carbon dioxide and water vapour fluxes at Ny-Ålesund

rapidly cease to transpire as the surface layer dries; mosses become inactive when dry. The data for 1995 suggest a small net uptake of carbon over the season (see diagram below).

During 1996 CO_2 fluxes will be measured over a complete season. In addition, chamber measurements are being made, in a collaboration with the Institute of Terrestrial Ecology (Bush). These measurements will allow the separation of CO_2 fluxes from the soil and vegetation and give the first estimates of methane fluxes from this area. This collaboration is being enabled by a recently won EU contract, the Land Arctic Physical Processes (LAPP) programme, which will operate measurement sites in Svalbard, Northern Finland and Greenland thus allowing the generalisation of the measurements over northern Europe. The data will be used to develop and calibrate land surface schemes of hydrological and climate models.

As well as being part of a European programme this arctic initiative can be seen in a larger international perspective. Institute staff are involved in the planning of IGBP sponsored transect experiments in Siberia and Scandinavia and a proposed tundra land surface experiment. The data taken by the current programmes will provide a valuable input to the planning of these new international experiments.

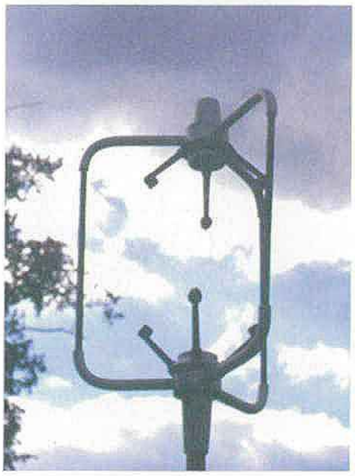


Carbon dioxide measured intermittently during the summer of 1995. Vegetation can be a sink or a source for carbon dioxide, while the soil is principally a source.

Impact of climate change on hydrological regimes and water resources in the European Community. Modelling runoff under current and climate change conditions, by applying rainfall and potential evaporation scenarios, across Europe on a 0.5° latitude grid.

Nick Reynard

Stand alone dual gas eddy correlation system. The close association between transpiration and photosynthesis, plus keen interest in CO_2 budgets and their link to climate change, is creating a strong demand for instruments able to measure both water vapour and CO_2 in the atmosphere. Based on IH's well-known *Hydra* system, this new instrument development will not only measure CO_2 flux but also incorporate a 3-D anemometer to make it more suitable for hilly terrain.



Two systems, using a commercially available closed-path infra-red gas analyser, have been used successfully in the Arctic and over the Amazonian forest. The new device is expected to be significantly cheaper than existing systems and capable of running unattended for up to two weeks.

Contact: David McNeil

Results from ABRACOS have now been published by John Wiley & Sons Ltd. *Amazonian Deforestation and Climate* (ISBN 0-471-96734-3) edited by J.H.C. Gash, C.A. Nobre, J.M. Roberts and R.L. Victoria, describes the results form the Anglo-Brazilian Climate Observation Study and provides a wealth of information to all those interested in the environmental effects of Amazonian deforestation and how it might affect the climatology, hydrology and ecology of the region.

1995/96 highlights

The call for sustainable development made in* Agenda 21 *was not simply belated recognition of the importance of environmental issues so central to Research Council science. The world now realises that sustainability must also include a new concept of economic growth which provides for fairness and opportunity for all without destroying the world's nature resources and without further compromising the carrying capacity of the globe.

Water and man

It is in towns and cities where most of us will live and work in the next century, where the most pollution will be generated and most of the natural resources consumed

Hydrological scientists have always understood the economic dimension to true sustainability: our portfolio of commissioned research ranges from problems relating to new water resources, flood risks, urbanisation, and improved crop water use, all designed to maximise resources. The new challenges provided by the CEH integrating science programme help us to build on this strength, to combine with other related disciplines and add the crucial dimension of socio-economics to match our research firmly with the needs of the time when all research needs to be judged as wealth-creating and/or life-enhancing.

Urbanisation

Ageing, changing and neglected urban infrastructures the world over cannot keep pace with the expanding urban population, numbering 3.4 billion in 1995 and expected to reach 5 billion by 2025.

Based on study catchments in Pakistan, Bangladesh and India where counter-part organisations in those countries are building up vital rainfall and runoff information, IH is establishing flow surveys and developing urban runoff models relevant to the kind of conditions found in rapidly developing cities where vastly different criteria apply to those of more affluent countries.

The Shadman/Gulberg study area in Lahore which experiences regular flooding

Hydrology and health

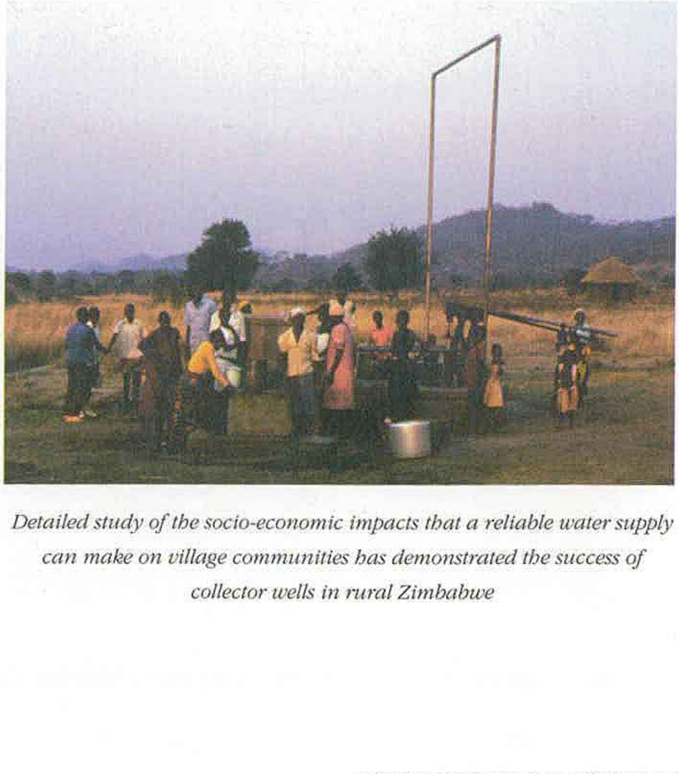
Throughout history, some of the greatest cooperative schemes have been engineering works to protect and control communal water sources for irrigation and flood control. Because cities concentrate populations and production capabilities, there are always environmental problems of faecal contamination, flooding and uncollected garbage.

These have serious impacts far beyond the urban boundary through ecological demands on natural resources of the surrounding area. But if the same population and production pressures are turned to advantage by generating income to provide better services, the long-term social returns and economic benefits are very high. For while it is the poor who invariably have worse health and lower life expectancy than richer groups (and probably always will), providing adequate water supply and safe sanitation still remains the most effective way of reducing the disparity in health status between high and low-income groups.

The expansion of built-up areas, the construction of roads, water storage and drains, together with land clearance and deforestation can make drastic changes in local ecology. Natural foci for disease vectors may become entrapped within suburban areas and new ecological niches created. Hydrological understanding of catchment behaviour is thus vital for environmental management for many health issues.

Vast sums of money are spent each year on health care in the fight against disease. The links between water and health are well-known — 21 out of the 37 major diseases of the world have an essential water link, either through an intermediate vector (as in malaria and schistosomiasis, for example) or through its spread by pollution as with the diarrhoeal diseases. To keep nations healthy, however, means not just tackling the known disease trouble spots by cleaning up polluted water. It is also vital to provide and conserve water supplies, sanitation and drainage in ways that are available to everyone. Mankind not only needs sufficient water to drink for basic life support, but also personal hygiene is extremely important.

Large-scale water projects are not always appropriate or affordable; in many countries village water sources are traditional dug wells or boreholes with hand pumps. Because they draw on unpolluted groundwater, such water sources are inherently safe, providing they are not over-exploited beyond the rate at which local water tables recharge. Recent research in Zimbabwe funded by ODA with the Institute of Hydrology and the British Geological Survey has helped to develop ways of amplifying village water supplies using collector wells where modified drilling techniques tap the basement aquifers more efficiently. The next stage of the project is to work with the Zimbabwe Ministry of Local Government on the installation of a 100 of these wells and associated community vegetable



Detailed study of the socio-economic impacts that a reliable water supply can make on village communities has demonstrated the success of collector wells in rural Zimbabwe

Understanding the routes by which village hand-dug wells become polluted has important implications for long-term health issues

Safe efficient water supplies and adequate sanitation could reduce infant and child mortality by more than 50%

growing schemes. The potential for improving quality of life in enhanced, reliable and safe water for family consumption and generating income through the sale of surplus produce is very exciting.

During the last wet season in Zimbabwe there were outbreaks of diarrhoeal disease in some of the villages, apparently caused by pollution from nearby latrines collapsing with the excessively high water table. Recent water quality sampling to detect the incidence of faecal coliform contamination in village wells indicates that further investigation is needed to see where and how the bacteria are entering the water supply.

If global weather patterns are now set to be more changeable and extreme than in the earlier part of the century, the threat of occasionally extreme high water tables must be taken into account in the siting of both new wells and latrines and active research collaboration is in hand to get a measure of the problem. For there is no doubt that understanding the underlying hydrological behaviour, the way water moves in the environment, will be vital in formulating practical design rules for all developing communities.

[Contact IH Publications Section for a copy of the ODA's *Water for Life* and *Groundwater, Geochemistry and Health* brochures if you would like more information on water and health issues.]

Environmental stability

It is still widely believed that there is a necessary conflict of competing demand for water, as though it was simply a matter of choice between water for people and water for wildlife, with the needs of people naturally taking priority.

A central principle of *Agenda 21,* however, is that the lives of people and the environment are profoundly inter-linked. Take wetlands for example. Conserving wetlands by ensuring that they have adequate supplies of water can be a positive benefit to man. Some wetlands perform important natural hydrological functions such as reducing flooding, recharging groundwater, improving water quality by recycling nutrients and removing pollutants, as well as supporting agriculture, fisheries and wildlife.

Ninety-three states are now signatories to the Ramsar Convention on wetlands and are thus committed to producing national wetlands policies. These aim to

The Kravasta lagoon, Albania

make wise use of these vital resources for the benefit of man by exploiting their hydrological sustainability in combination with water management planning. IH is providing hydrological advice to the Ramsar Convention and to IUCN, the World Conservation Union. The international advisory panel for the development of the management plan for Albania's first designated Ramsar site, the Karavasta lagoon, is chaired by IH on behalf of IUCN. This project links wetland conservation, water resources management and sustainable development in a rapidly developing country.

1995/96 highlights

In collaboration with the University of York, IH is producing a book entitled *Economic valuation of wetlands: guidelines for planners and decision makers*

Contact: Mike Acreman

Indexing catchment urbanisation (for MAFF and Scottish Office). As part of research for the *Flood Estimation Handbook*, IHDTM-derived catchment boundaries automatically overlain on gridded urban and suburban data (originally taken from the ITE *Land Cover Map of Great Britain* but subsequently refined) are being used to index the extent, location and concentration of catchment urbanisation

Adrian Bayliss

Scaling up hydrological variables took a major leap forward this year through the deliberations at an international workshop organised and held at IH. The papers presented at the workshop have been published as *Scaling up in hydrology using remote sensing* by John Wiley & Sons Ltd (ISBN 0-471-96829-3).

Impact of peat extraction. IH has been commissioned to advise on the impact of peat extraction and associated drainage upon the hydrology of nearby conservation wetlands. This involves detailed studies of the hydrological connections between the areas, and the development of a novel approach to measuring the areally averaged permeability of the peat.

John Bromley

Staff structure

Administration

Tony Debney *(Director)*
Jan Memish (Secretary)

Neil Runnalls *(Marketing coordinator)*

Stuart Pryde *(Head of Administration)*

Simon Barter *(Finance & Accounts)*
Angela Davies
Angie Dickerson
Huw Thomas
Thelma Gibson
Anita Napper
Lyn Ross
Val Lambert

Sue Fenton *(Establishments & Personnel)*
Trish Sanders
Eileen Younghusband

Melanie Purvey and Anke Watson *(Reception)*

Jean Hornsby *(Typing Pool)*
Debbie Norris
Heather Turner

John Fraser *(Site services)*
Ivor Standbridge
Bob Drewett
John Spencer
Harold Jones
Andy Sweetland *(Stores)*

New staff appointments


Anke Watson


Melanie Purvey


Andy Sweetland

NERC Community Science

Max Beran *(TIGER Programme)*
Sally Austin *(Secretary)*
Howard Oliver

Further details on staff qualifications and job descriptions may be obtained from our WWW pages (see back cover)

Information Hydrology Division

Mission Statement

Information Hydrology seeks to provide key data essential for regional water management or site design and to communicate that information via all the modern media required by users. To that end the Division will:

(i) Collate, quality control and publish time series and spatial datasets that describe any part of the hydrological cycle over a region;
(ii) Reveal the coherent structures within environmental datasets relevant to the water industry;
(iii) Program to commercial standards the science findings of the Institute as well as publishing them through every relevant outlet in printed and electronic form;
(iv) Use metadata cataloguing and wide area networks to collect and distribute the facts on which the subject flourishes;
(v) Bring advances in information technology into the hands of water scientists in NERC, the UK Water Industry and Academia.

While first priority is given to the United Kingdom, the division's remit is pan-European and will become increasingly international with time.

Frank Law (Division Head)
Sue Beresford (*Secretary*)

Roger Moore (*Environmental systems*)

Kevin Black *Software development*
Lawrence Beran
Richard Alexander
David Hill
Richard Boesch

Anne Roberts *Software operations*
Kevin Down
Isabella Tindall
Jeff Parker
Susan Jennings
Kara Moffatt

Martin Lees (*National Water Archive*)
Terry Marsh
Dave Morris
Eric Hermans
Samantha Green
Rob Scarrott
Oliver Swain
Felicity Sanderson
Shirley Black
Jackie Carr

Celia Kirby (*PR & publications*)
John Griffin
Rob Flavin
Charlotte Allen
Nick Fey

Sue Wharton (*Library*)
Pam Moorhouse
Denise Dolton

Chris Bottrell (*Computing policy*)
Simon Gray

Penny Kisby (*IAHS Press*)
Frances Watkins
Jill Gash

New staff appointments

Lawrence Beran

Susan Jennings

Eric Hermans

Rob Scarrott

Engineering Hydrology Division

New staff appointments

Mike Dunbar

Clare Round

Doerte Jakob

Emma Tate

Sean Wood

Ned Hewitt

Mission Statement

Our research seeks to provide advanced techniques for flood and low flow estimation, for forecasting extremes, for assessing the availability of water resources and increasingly for determining the impact of environmental change on the reliability of existing and proposed schemes. This is achieved by:

(i) Developing techniques for estimating the extremes of low flow discharges for given frequency and durations at both gauged and ungauged sites.

(ii) Deriving new generalised methods of rainfall and flood frequency estimation.

(iii) Assessing the impacts of climate change on water resources and flood frequency.

(iv) Modelling the impact of artificial influences including land use change and resource development.

(v) Developing techniques for assessing the impact of river flow regimes and channel morphology on freshwater ecology.

(vi) Developing procedures for estimating and forecasting precipitation rates using radar and raingauge information.

(vii) Combining hydrological models with data acquisition systems to develop real-time flood forecasting and drought management systems.

(viii) Improving the effectiveness of hydrological design by transferring the results of hydrological research to European and overseas applications and practitioners.

Alan Gustard *(Division Head)*
Sandra Smith (*Secretary*)

Mike Acreman *(River basin & hydro-ecology management)*
Andy Young
Ann Sekulin
Craig Elliott
Karen Croker
Mike Dunbar
Clare Round
Ian Gowing

Andy Bullock *(Regional flow regimes)*
Gwyn Rees
Tony Andrews
Matthew McCartney
Gwynneth Cole
Julia Dixon

Duncan Reed *(Flood, rainfall & climate analysis)*
David Marshall
Alice Robson
Lisa Stewart
Adrian Bayliss
Ian Dwyer
Nick Reynard
Duncan Faulkner
Doerte Jakob
Christel Prudhomme

Bob Moore *(Hydrological systems modelling)*
David Jones
Roger Austin
Vicky Bell
Sean Wood

Frank Farquharson *(Water resource systems)*
Jeremy Meigh
Dick Bradford
John Packman
Kevin Sene
Barney Austin
Helen Houghton-Carr
Val Bronsdon
Ned Hewitt
Emma Tate

Environmental Hydrology Division

Alan Jenkins *(Division Head)*
Josie Champkin (*Secretary*)

David Boorman *(Water quality systems)*
Gareth Roberts
Andy Eatherall
Rob Collins
Ray Kowe
Cath Sefton
Mike Renshaw
Jeremy Wilkinson
Simon Tolchard

Richard Williams *(Pollution hydrology)*
Andrew Johnson
Atul Haria
Tim Besien
Craig White

Pam Naden *(Cathment distributed modelling)*
Ann Calver
Eric Hermans
David M Cooper
Sue Crooks
Peter Broadhurst
Beate Gannon
Rob Lamb

Colin Neal *(Hydrochemistry)*
Helen Jarvie

Chris Smith *(Analytical chemistry)*
Lal Bhardwaj
Margaret Neal
James Dodd
Martin Harrow
Linda Hill
Heather Wickham

Mission Statement

The Environmental Hydrology Division seeks to: provide an understanding of the dynamics and key processes controlling pollution of surface water systems; represent the key processes within mathematical models; and aid scientific understanding and water quality management. To that end the Division will:

(i) Develop models describing the key hydrological, physical, chemical, sedimentological and biological mechanisms that determine water quality and capable of application within a GIS framework to provide tools to answer scientific, operational and strategic management questions;

(ii) Aid in the design of water quality monitoring networks and to interpret water quality databases through trend analysis and modelling;

(iii) Quantify the fluxes of pollutants and chemicals transported to estuaries;

(iv) Investigate and understand the processes controlling the behaviour of inorganic and organic pollutants in river systems;

(v) investigate the mechanisms by which chemical and pollutants are transported from land surface and soil into the fluvial system;

(vi) determine the potential impact of environmental change, including industrial, social policy, land-use, atmospheric deposition and climate change, on water quality;

(vii) Improve water quality monitoring and modelling as an aid in management both nationally and internationally through overseas partners and projects and through wide publication of scientific literature;

(viii) Develop the science of large-scale hydrological modelling with the aim of improving and validating atmospheric general circulation models.

(ix) Improve flood estimation methods for engineering design purposes using continuous rainfall-runoff simulation.

New staff appointments

Linda Hill

Rob Lamb

Land Use and Experimental Hydrology Division

Mission Statement

(i) To develop a holistic understanding of the impact of land use and other anthropogenic changes on hydrology, both within the UK and overseas, as a means towards improving quality of life and economic wellbeing.

(ii) To improve predictions of the impacts of land use change upon catchment water yield, floods, low flows, subsurface water and waterborne fluxes.

(iii) To develop and support 'state of the art' hydrological instrumentation systems to further IH science and for commercial exploitation.

Ian Calder *(Division Head)*
Kath Vann (*Secretary*)

Mark Robinson *(Land use and water efficiency)*
Jim Blackie
Henry Gunston
Sam Boyle
Paul Rosier
Helen Davies

Jim Hudson *(Plynlimon)*
Kevin Gilman
Sean Crane
Phil Hill
Sue Hill
Bill Hughes

Dick Johnson *(Stirling)*
David Price
Rachel Bronsdon
Michael Cranston

Graham Leeks *(Sediment and waterborne fluxes*
Ian Littlewood
Carol Watts
Stephen Marks
Geoff Ryland
Paul Wass

J David Cooper *(Instrumentation)*
Andy Dixon
Peter Hodgson
Dave McNeil
Roger Wyatt
Mike Stroud
Mike Walker
Jonathan Evans

Alan Warwick *(Workshop)*
John White
Geoff Walley

New staff appointment

Rachel Bronsdon

Hydrological Processes Division

Jim Wallace *(Division Head)*
Biddy Hawker (*Secretary*)

John Gash *(Global processes)*
Richard Harding
Eleanor Blyth
Alistair Culf
Colin Lloyd
Ivan Wright
Chris Huntingford
Chris Taylor
Tim Kyte

John Roberts *(Vegetation and soil processes)*
Simon Allen
Robin Hall
Martin Hodnett
Nick Jackson
David Smith
Anne Verhoef
Rebecca Hopkins

Charles Batchelor *(Sustainable agrohydrology)*
John Bromley
Chris Lovell
Ragab Ragab
Jeremy Cain
Dominic Waughray

Jon Finch *(Regional environmental change)*
John Stewart
David Biggin
Ken Blyth
Eleanor Burke

Mission Statement

To improve quantitative understanding of the physical and biological processes in the terrestrial hydrological cycle, from local to global scales, including the impacts of human activities which may alter it.

Priority is given to environmental issues which have a widespread effect on human quality of life and to evaluating the associated economic implications to provide well founded guidance to environmental managers and policy makers.

The Division's four strategic science areas are:

(i) Quantification of the effects of soil physical and plant physiological processes on the hydrological cycle, especially where dominated by trees and shrubs.

(ii) Measurements and modelling of hydrological processes occurring within and between the complete mosaic of land use systems within entire landscapes, e.g. forestry, agriculture.

(iii) Improving the ability to predict the hydrological consequences of environmental change at local to regional scales, with emphasis on use of remote sensing techniques, regional data sets and GIS.

(iv) Increasing understanding of hydrological processes at regional and global scales through field experiments and modelling; to foster improved representation in global climate and continental-scale models used to predict future climate and regional water resources.

New staff appointments

Anne Verhoef

Jeremy Cain

Eleanor Burke

APPENDIX II

Publications

Scientific papers

* denotes non-refereed publications

***Acreman, M.C.** 1995 Networking as a key to strategic action plan *Danube Watch — the newsletter of the Environment Programme for the Danube basin* 1. 14-15

Acreman, M.C. and Lahman, E 1995 Hydrological management and protected areas. *PARKS Int J Protected Area Managers* **5**, 1 5.

Acreman, M.C. 1996 The IUCN Sahelian floodplain initiative — networking to build capacity to manage Sahelian floodplain resources sustainably *Water Resources Development*

***Acreman, M.C** 1996 Economic valuation of wetlands and its role in wise use. *Proc 6th Conf of the contracting Parties to the Ramsar Convention*, Brisbane, Australia, March 1996

***Acreman, M.C** , Howard, G and Pirot, J-y 1996 Reconciling water resources management and wetland conservation a key challenge for Ramsar in the 21st century *Proc 6th Conf of the contracting parties to the Ramsar Convention*, Brisbane, Australia, March 1996

Albuquerque, M A , Wood, M and **Johnson, A.C.** 1995 Degradation of atrazine in soil I The ring ^{14}C labelled atrazine *Proc XXV Congresso Brasileiro de Ciencia do Solo*, Vicosa, Brazil 2351 2353

Albuquerque, M A , Wood, M and **Johnson, A.C.** 1995 Degradation of atrazine in soil II The ethyl ^{14}C labelled atrazine and ^{14}C acetate *Proc XXV Congresso Brasileiro de Ciencia do Solo*, Vicosa, Brasil 2354 2356

Albuquerque, M A , Wood, M and **Johnson, A.C.** 1995 Degradation of isoproturon in comparison with atrazine in soil *Proc XXV Congresso Brasileiro de Ciencia do Solo*, Vicosa, Brazil, 2417-2419

Albuquerque, M A , Wood, M. and **Johnson, A.C.** 1995. Adsorption of atrazine by a sandy loam, lysimeter soil *Proc. XXV Congresso Brasileiro de Ciencia do Solo*, Vicosa, Brazil 2420-2422

Andrews, A.J., de Hennat, P and **Bullock, A.** 1995 Southern Africa FRIEND spatial database *Proc 7th South Africa National Hydrology Symposium (SANCIAHS)*, Grahamstown, RSA.

Andrews, A.J. and Mwaikalinga, I P 1995. Southern Africa FRIEND Hydata time series hydrological database *Proc 7th South African National Hydrology Symposium (SANCIAHS)*, Grahamstown, RSA

***Andrews, A.J.**, **Reynard, N.S.** and Hatatule, A 1995 The derivation of an annual runoff map for the SADC Region Report submitted for discussion at WMO/UNESCO Programme for Freshwater Assessment of the World

*Anon 1995 *Hydrological summaries of Great Britain* Monthly reports on hydrological conditions throughout Great Britain Institute of Hydrology and British Geological Survey

Austin, R.M. and **Moore, R.J.** 1996 Evaluation of radar rainfall forecasts in real-time flood forecasting models *Quaderni Di Idronomia Montana* **16**, 19-28

Avila, A., Bonilla, D , Roda, F , Pinol, J and **Neal, C.** 1995 Soilwater chemistry in a Holm oak (*Quercus ilex*) forest: inferences on biogeochemical processes for a montane mediterranean area *J Hydrol* **166**, 15 35

Avila, A , **Neal, C.** and Terrada J 1996 Climate change implications for streamflow and streamwater chemistry in a Mediterranean catchment *J Hydrol* **177**, 99-116

Allen, S.J. and **Grime, V.L.** 1995 Measurements of transpiration from savannah shrubs using sap flow gauges *Agric For Met* **75**, 23-41

*Alvalá, R C S , Calvet, J C , Jaubert, G , Noilhan, J and **Wright, I.R.** 1996 Mapping surface parameters for mesoscale modeling in forested and deforested south-western Amazonia CNRM, France 1-11

Alvalá, R C.S , Gielow, R , **Wright, I.R.** and **Hodnett, M.G.** 1996 Thermal diffusivity of Amazonian soils In Gash, J H C , Nobre, C A , Roberts, J M and Victoria, R L (eds) *Amazonian Deforestation and Climate* John Wiley & Sons, Chichester 139-150

Barr, A G , **Smith, D.M.** and Brown, D M 1995 Estimating forage yield and quality changes during field drying for hay 1. Model of dry matter and quality losses *Agric For Met* **76**, 83-105

Batchelor, C.H., **Lovell, C.J.**, Murata, M and McGrath, S P M 1995. Improving water use effectiveness by subsurface irrigation *Aspects of Appl Biol* **38**, 269-278

***Batchelor, C.H.** and **Wallace, J.S.** 1995 Hydrological processes, dryland degradation and integrated catchment resource management. *UNEP Desertification Bull* No 27, 27 34

Bell, V.A. and **Moore, R.J.** 1996 A water balance rainfall model for flood forecasting using weather radar, satellite infra red and surface weather observations an assessment over Southern Britain HS11 — Remote Sensing in Hydrology. EGS XXI General Assembly. The Hague, The Netherlands 6-10 May 1996. (abstract)

***Bell, V.A.**, **Carrington, D.S.** and **Moore,**

R.J. 1995. Rainfall forecasting using a simple advected cloud model with weather radar, satellite infra-red and surface weather observations. Abstracts. Fifth International Conference on Precipitation, Space Time Variability and Dynamics of Rainfall, Elounda, Crete, Greece, 3.1.

***Besien, T.J.** 1996. The sorption of isoproturon to aquifer sediments. *Proc COST 66 Workshop*, Stratford-upon-Avon, UK. 33-34.

***Besien, T.J., Williams, R.J.** and Jarvis, N.J. 1996. Simulation of water movement and herbicide behaviour in a heavy clay soil using the MACRO model. *Ann. Geophys.* Suppl II, XXI Gen Assembly. C317.

Biggin, D.S. and **Blyth, K.** 1995. A comparison of ERS-1 satellite radar and aerial photography for river flood mapping. *Instn. Wat. & Environ Manage.* **10**, 59-64.

Black, A.R. and **Johnson, R.C.** (eds) 1995. *Proceedings of the British Hydrological Society Fifth National Hydrology Symposium*. Heriot-Watt University, Edinburgh, September 1995.

Blyth, E.M. 1995. Comments on 'The influence of surface texture on the effective roughness' by H P Schmid and D Bunzli (January A. 1995, 121,1-21). *Q. J Roy Meteorol Soc* **121**, 1169-1172

Blyth, E.M. 1995 Using a simple SVAT scheme to describe the effect of scale on aggregation. *Boundary Layer Met.* **72**, 267-285

***Blyth, K.** 1995 Seasonal changes in surface soil moisture and vegetation observed by ERS 1 SAR over temperate grassland in semi arid savannah. In Mougin, E., Jon Ransen, JK. and Smith J A (eds) Multispectral and microwave sensing of forestry, hydrology and natural resources. *SPIE Proceedings, EUROPTO Series*. **2314**, 449-460

Boorman, D.B., Hollis, J M and Lilly, A 1995 Hydrology of soil types a hydrologically-based classification of the soils of United Kingdom *IH Report No 126* Institute of Hydrology, Wallingford

***Boorman, D.B., Jenkins, A.** and **Collins, R.P.** 1996 Rainfall-runoff data and modelling in the Kikhu Khola catchment, Nepal In Chalise, S.R and Khanal, N R (eds) ICIMOD/UNESCO Int Conf on Ecohydrology of High Mountain Areas, Kathmandu, Nepal. March 1996. Extended Abstracts. 139-142

Bromley, J. and **Hodnett, M.G.** 1995 Water movement in the deep unsaturated zone below vines and irrigated cereal crops in the La Mancha region of Spain. *Ann Geophys*. Supp. II, part II. **13**, C451.

Bromley, J. and **Robinson, M.** 1995. Groundwater in raised mire systems: models, mounds and myths. In. *Hydrology and Hydrochemistry of British Wetlands* John Wiley and Son, Chichester. 95-109.

Bromley, J., Brouwer, J. and **Gaze, S.R.** 1995 The semi-arid groundwater recharge study (SAGRE). In: *Hydrologie et météorologie de méso-échelle dans HAPEX Sahel*: Dispositif de mesures au sol et premiers résultats. (ed. T. Lebel). ORSTOM Editions, Paris 161-179.

Bull, L.J., Lawler D.M., **Leeks G.J.L.** and **Marks S.D.** 1995. Downstream changes in suspended sediment fluxes in the River Severn, UK. In: *Effects of scale on interpretation and management of sediment and water quality*. XXI General Assembly of IUGG, 6 IAHS Symposia, Boulder, USA, July 3-14 1995. *IAHS Publ. No 226*, 27-37.

Bullock, A. and **Andrews, A.J.** 1995. Hydrological Summary for Southern Africa. Bulletins 1-4. In association with countries of the SADC region. Submitted to Overseas Development Administration.

Butterworth, J.A. and Mugabe, F.M. 1995. Romwe Catchment Study: Reducing environmental degradation and promoting sustainable agricultural development in semi-arid Zimbabwe. *Proc. ODA Plant Sciences Programme Conf. on the Semi-Arid System*. Manchester, 5-6 September 1995.

Cabral, O.M R., **McWilliam, A.C.** and **Roberts, J.M.** 1996. In-canopy microclimate of Amazonian forest and estimates of transpiration In. Gash, J.H.C., Nobre, C.A., Roberts, J.M. and Victoria, R L (eds) *Amazonian Deforestation and Climate* John Wiley & Sons, Chichester. 207-219

***Calder, I.R.** 1995 Review of "The Fresh Water of Scotland A National Resource of International Significance" by Maitland, P S., Boon, P J and McLusky, D.S (John Wiley, Chichester) *J Hydrol* **170**.

Calder, I.R., Hall, R.L., Bastable, H.G., Gunston, H.M., Sheia, O., Chirwa, A. and Kafundu, R 1995. The impact of land use change on water resources in sub-Saharan Africa a modelling study of Lake Malawi. *J. Hydrol* **170**, 123-135

Calder, I.R. 1996 Water use by forests at the plot and catchment scale. Special Issue on 'Forests and Climate'. *Tree Physiol.* **75**, 19-30.

Calder, I.R. and **Hall, R.L.** 1996 Comment on. 'Interception of tropical rain forest: performance of a canopy water balance model' by V.C. Jetten. *Hydrol. Processes* **10**, 671-685

Calver, A. and Wood, W L. 1995. The Institute of Hydrology Distributed Model. In V.P. Singh (ed) *Computer Models of Watershed Hydrology*. 595-626

Chandra, M., **Wood, S.J.**, Lux, S., Holt, A.R., Scroth, A 1995. The PADRE project. In C.G. Collier (ed) *COST 75 weather radar systems* Int. Seminar, Brussels, 20-23 Sept 1994. EUR 16013EN, European Commission. 507-518

Chilton, P.J., **Williams, R.J.**, Stuart, M.E., Gooddy, D.C., and Williamson, A.R. 1995. The occurrence of herbicides in and modelling of their transport to, the Chalk aquifer below arable land in Southern England. In: *British Crop Protection Council Monograph 62. Pesticide Movement to Water* 111-116.

Collins, A., Walling, D. and **Leeks, G.J.L.** 1995 Composite fingerprinting of the spatial source of fluvial suspended sediment. *Int. Symp. on Floods, Slopes and River Beds*, CNRS, Paris.

Collins, R.P. and **Jenkins, A.** 1995. Soil water monitoring and hydrological response. In: Dise, N. and Jenkins, A. (eds) *Climate Change Research*. Climex project: Whole catchment manipulation of CO_2 and temperature. Volume 5. NIVA, Oslo, Norway. 27-34.

Conroy, J.W.H. and **Johnson, R.C.** 1996. The Cairngorms in relation to the UK Environmental Change Network (ECN). *Bot J. Scotl.* **48**, 137-154.

Cooper, D.M., Wilkinson, W.B. and **Arnell, N.W.** 1995. The effects of climate changes on aquifer storage and river baseflow. *Hydrol. Sci. J.* **40**, 615-631.

***Cooper, J.D.** and Robinson, D.A. 1995. Dielectric methods of water content measurement. Brit. Soil Water Physics Grp. Meeting on Dielectric Measurements in Soil: Frequency vs Time Domain, Silsoe Research Institute, November 1995.

Culf, A.D., Fisch, G. and Lean, J 1995. A comparison of Amazonian climate observations with numerical model predictions European Geophysical Society Abstract. *Ann Geophys. Supplement* II 3

Culf, A.D., Fisch, G. and **Hodnett, M.G.** 1995 The albedo of Amazonian forest and ranch land *Int J. Climatol.* **8**, 1544-1554

Culf, A.D., Esteves, J L. da Rocha, H.R. and Marques Filho, A. de O 1996 Radiation, temperature and humidity over forest and pasture in Amazonia In: Gash, J.H.C., Nobre, C A., Roberts, J.M. and Victoria, R L (eds) *Amazonian Deforestation and Climate* John Wiley & Sons, Chichester 175-191

Clymo, R.S., Dawson, F.H., Bertram, B.C.R., Burt, T.P., **Gilman, K.**, Ingram, H.A.P., James, R., Kirkby, M.J., Lee, J A., Maltby, E., Wheeler, B.D and Wilcock, D 1995 Directions for research on wetlands in Britain. In Hughes J M R and Heathwaite, A.L (eds). *Hydrology and hydrochemistry of British wetlands* John Wiley, London 468-478

***Collins, R.R., Jenkins, A., Boorman, D.B.** and Whitehead, P G. 1996 Streamwater acidification in response to anthropogenic pollution inputs at forested and cultivated catchments in the Middle Hills, Nepal In. Chalise, S R and Khanal, N.R. (eds) ICIMOD/UNESCO Int. Conf. on Ecohydrology of High Mountain Areas, Kathmandu, Nepal, March 1996. Extended Abstracts. 147-149.

da Rocha, H.R., Sellers, P J., Collatz, J., **Wright, I.R.** and Grace, J. 1996. Using the SiB2-C model to estimate water vapour and carbon transfers in an Amazonian forest site In: Gash, J H.C., Nobre, C.A., Roberts, J.M. and Victoria, R L (eds) *Amazonian Deforestation and Climate* John Wiley & Sons, Chichester. 459-471

de Souza, J.R.S., Pinheiro, F.M.A., de Araujo, R.L.C., Pinheiro, H.S. and **Hodnett, M.G.** 1996. Temperature and moisture profiles in soil beneath forest and pasture areas in eastern Amazonia. In: Gash, J.H.C., Nobre, C.A., Roberts, J.M. and Victoria, R.L. (eds) *Amazonian*

Deforestation and Climate. John Wiley & Sons, Chichester. 125-137

Dise, N. B. and **Jenkins, A.** (eds) 1995 *CLIMEX project: Whole catchment manipulation of CO_2 and temperature.* NIVA and IH, Oslo and Wallingford

Dolman, A J., Kabat, P., Ashby, M., Noilhan, J., Calvet, C., Delire, C., **Gash, J.H.C., Wright, I.R.**, Jochum, A. and Nobre, C.A. 1996. Modelling studies supporting the planning of the Large Scale Biosphere Atmosphere Experiment in Amazonia (LBA). *2nd Int. Conf. on the Global Energy and Water cycle*, Washington, 1996. 197

Down, K., Raven, J.A., Mantora, R.F.A and Llewellyn, C. 1995. Photosynthesis in OMEGA 48-23, a coloured perspective. *Br. Phycol. J.*

Dwyer, I.J. and **Reed, D.W.** 1995 Correcting mean annual maxima for data discretization. *Proc. 6th Conf. on Stat. Climatol.* Galway, June 1995

*__Evans, J.G.__ 1995. WISER Operating Manual. *Institute of Hydrology*

*Fattorelli, S., Borga, M. and **Moore, R.J.**, 1996. Storms, floods and radar hydrology. In: R. Casale (ed.) *Hydrological and hydrogeological risks.* Proc. European Commission, 1st Review Meeting, Brussels, 30-31 January 1995. EUR 16799 EN. 232-245

*__Faulkner, D.S.__ 1996. Focusing on a Celtic region: Rainfall Frequency in south-west England. *Proc. 1st Inter-Celtic Colloquium on Hydrology and Water Management*, Rennes, July 1996

Ferrier, R. C., **Jenkins, A.** and Elston, D.A. 1995. The composition of rime ice as an indicator of the quality of winter deposition. *Envir. Pollut.* **87**, 259-266.

Ferrier, R.C., Whitehead, P.G., **Sefton, C.E.M.**, Edwards, A.C. and Pugh, K. 1995. Modelling impacts of land use change and climate change on nitrogen in the River Don, North East Scotland. *Wat. Res.* **29**, 1950-1956.

Ferrier, R.C., **Jenkins, A.**, Cosby, B.J., Helliwell, R.C. and Wright, R.F. 1995. Land use and deposition interactions. An evaluation of the effects of future N deposition scenarios on the Galloway region of SW Scotland using a coupled sulphur and nitrogen model (MAGIC-Wand). *Water, Air and Soil Pollution* **85**, 707-712

Ferrier, R.C., Wright, R.F., Cosby, B.J. and **Jenkins, A.** 1995. Application of the MAGIC model to the Norway spruce stand at Solling, Germany. *Ecological Modelling* **83**, 77-85

Fisch, G., **Culf, A.D.** and Nobre, C.A. 1996. Modelling convective boundary layer growth in Rondonia. In: Gash, J.H.C., Nobre, C.A., Roberts, J.M. and Victoria, R.L. (eds) *Amazonian Deforestation and Climate.* John Wiley & Sons, Chichester. 425-435.

Forti, M. C., **Neal, C.** and **Jenkins, A.** 1995. Modelling perspective of the deforestation impact in stream water quality of small preserved forested areas in the Amazonian rainforest. *Water, Air and Soil Pollution* **79**, 325-337.

Freeman, C., Gresswell, R., Lock, M.A., Swanson, C., Guasch, H., Sabater, F., Sabater, S., **Hudson, J.A.**, Hughes, S. and Reynolds, B. 1995. Climate change: Man's indirect influence on wetland microbial activity and the biofilms of a wetland stream. *Man's Influence on Freshwater Ecosystems and Water Use.* Proc. Boulder Symposium, July 1995, *IAHS Publ. No. 230.* 199-206

Gash, J.H.C., **Lloyd, C.R.** and Lachaud, G. 1995. Estimating sparse forest rainfall interception with an analytical model. *J. Hydrol.* **170**, 79-86.

*__Gash, J.H.C.__ and **Nobre, C.A.** 1996. Climatic effects of Amazonian deforestation. *Int. Congress on Environment and Climate* (Book of abstracts), Rome. 117

Gash, J.H.C., Nobre, C.A., **Roberts, J.M.** and Victoria, R.L. (Eds) 1996. *Amazonian Deforestation and Climate.* John Wiley & Sons, Chichester.

Gash, J.H.C., Nobre, C.A., **Roberts, J.M.** and Victoria, R.L. 1996. An overview of ABRACOS. In: Gash, J.H.C., Nobre, C.A., Roberts, J.M. and Victoria, R.L. (eds) *Amazonian Deforestation and Climate.* John Wiley & Sons, Chichester. 1-14.

Gash, J.H.C., **Wright, I.R.**, **Hodnett, M.G.**, Oyama, M.D., **Culf, A.D.** and Chatana, V.N. 1996. The water budget of Amazonian forest and pasture. *2nd Int. Conf. on Global Energy and Water Cycle*, Washington. 196

Gaze, S.R. 1996. Water balance of farmer-managed millet and fallow-savannah on sandy soils in south west Niger. *PhD Thesis*, University of Reading

Gibbins, C.N., Jeffries, M.J., Soulsby, C. and **Elliott, C.R.N** 1996. Modelling instream flow needs: the effects of a water transfer scheme on macro-invertebrate communities in the receiving River Wear. In: *Ecohydraulics 2000*, 2nd Int. Symp. on Habitat Hydraulics, Quebec

*__Gilman, K.__ 1995. Bog hydrology - the water budget of the mire expanse. *Proc. Scottish Wildlife Trust Peatlands Convention*, Edinburgh, 24-27 July 1995.

*__Gilman, K.__ 1996. Mire hydrology - the challenge of change. *Mires Res. Gp Newsletter*, July 1996

Gilman, K. 1996. Hydrological modelling of peatlands under management for agriculture and wildlife. In: Mérot, P. and Jigorel, A. (ed.) *Hydrologie dans les pays celtiques.* Proc. 1st Interceltic Colloq. on Hydrology and Water Management, Rennes. INRA Colloq. Series No. 79. 335-344

Green, S., Sanderson, F.J. and **Marsh, T.J.** 1996. Evidence for recent climatic instability in rainfall and runoff patterns in the Celtic regions of Western Europe. *Proc. Celtic Hydrology Symposium*, Rennes, July 1996.

*Gooddy, D.C., Chilton, P.J., Stuart, M.E., **Williams, R.J.**, **Johnson, A.C.**, **Besien, T.J.** and **White, C.** 1996. Preferential flow and the transport of herbicides in the chalk of southern England. *Proc. Cost 66 Workshop*, Stratford-upon-Avon, UK. 187-188.

Grace, J., Lloyd, J. McIntyre, J., Miranda, A.C., Meir, P., Miranda, H.S., Nobre, C.A., Moncrieff, J., Massheder, J.M., **Wright, I.R.** and **Gash, J.H.C.** 1995. Net carbon dioxide uptake by an undisturbed tropical rain forest in south west Amazonia during 1992-93. *Science* **270**, 778-780.

Gustard, A. 1995. A review of low flow studies in the Northern and Western European FRIEND project. *Romanian J. Hydrol. and Water Resources* **1**.

*__Gustard, A.__ 1995. Implementation, achievements and further plans for the Northern European FRIEND project. In: *Proc. of UNESCO IHP International symposium on rivers and people in Southeast Asia and the Pacific - partnership for the 21st Century*

Gustard, A., Irving, K.M., Rees, H.G. and **Young, A.R.** 1995. Hydrological models for small scale Hydropower Assessment. In: *Proc. Hidroenergia 95, 4th International Conference*, Milan, 18-20 September 95

Gustard, A. and Zebidi, H. 1995. Global FRIEND - Initiatives, achievements and new directions. *Int. Conf.*, *Grahamstown*, South Africa, September 1995

*__Hall, R.L.__ and **Calder I.R.** 1996. Modelling interception loss from Kandyan Forest Garden: dependence on rainfall intensity and drop size. In: H.P.M. Gunasena (Ed) *Proc. University of Peradeniya Oxford Forestry Institute Link Workshop on Forestry*, 28-30 November 1994. University of Peradeniya, Sri Lanka

Harding, R.J. and Jochum, A. 1995. Atmospheric and hydrological processes at the soil vegetation atmosphere interface. *J. Hydrol. (HAPEX-Sahel Special Issue)* **166**, 1-48

*__Harding, R.J.__ 1995. The tundra biome - issues for global change. (EGS Abstract) *Ann. Geophys.* **13**, 49

Harding, R.J., **Johnson, R.C.** and Sogaard, H. 1995. The energy balance of snow and partially snow covered areas in western Greenland. *Int. J. Climatol.* **15**, 1043-1058

Harding, R.J. 1995. Fluxes of heat and water vapour from forest and open areas in snow conditions in BOREAS. *Ann. Geophys.* **13**, 520

Harding, R.J., **Taylor, C.M.** and **Finch, J.W.** 1996. Areal average surface fluxes from mesoscale meteorological models: the application of remote sensing. In: Stewart, J., Engman, E.T., Feddes, R.A. and Kerr, Y. (eds) *Scaling up in hydrology using remote sensing.* John Wiley & Sons. 59-76

Hauhs, M., **Neal, C.** Christophersen, N., Hooper, R.P. and McCulloch, J.S.G. (eds) 1996. Modelling in environmental studies. *Sci. Tot. Envir.*, Special Issue

Hauhs, M. **Neal, C.**, Hooper, R.P. and Christophersen, N. 1996. Summary of a workshop on ecosystem modelling: the end of an era? *Sci. Tot. Envir.* **183**, 1-5

Hodnett, M.G., da Silva, L.P., da Rocha, H.R. and Senna, R.C. 1995. Seasonal soil water changes beneath central Amazonian rainforest and pastures. *J. Hydrol.* **170**, 233-254

Hodnett, M.G., Oyama, M.D., Tomasella, J. and Marques Filho, A. de O. 1996. Comparisons of long-term soil water storage behaviour under pasture and forest in three areas of Amazonia. In: Gash, J.H.C., Nobre, C.A., Roberts, J.M. and Victoria, R.L. (eds) *Amazonian Deforestation and Climate*. John Wiley & Sons, Chichester. 57 77.

Hodnett, M.G., Tomasella, J., Marques Filho, A.deO. and Oyama, M.D. 1996. Deep soil water uptake by forest and pasture in Central Amazonia predictions from long-term daily rainfall data using a simple water balance model In: Gash, J.H.C., Nobre, C.A., Roberts, J.M and Victoria, R.L (eds) *Amazonian Deforestation and Climate* John Wiley & Sons, Chichester 79-99

Hodgson, P., Quan, K M., MacKenzie, H A., Freeborn, S.S., Hannigan, J., Johnston, E.M., Greig, F and Binnie, T D 1995. Application of pulsed laser photoacoustic sensors in monitoring oil contamination in water. *Sensors and Actuators* **B29**, 339-344

Holt, A R., Chandra, M and **Wood, S.J.** 1995 Polarisation-diversity radar observations of storms at C-band 27th Conference on Radar Meteorology, 9-13 October 1995, Vail, Colorado American Meteorological Society 188-189

Houghton-Carr, H.A. and **Farquharson, F.A.K.** 1996. Models for optimal management of the total water resources of a river basin Proc First Intercelic Colloq Hydrology and Water Management, Brittany 427-434

Hudson, J.A., Hughes, S., Reynolds, B. and Freeman, C. 1996 The effects of simulated drought on streamflow chemistry in a flush wetland In *Hydrologie dans les pays celtiques* (Ed: P Mérot and A Jigorel) Proc 1st Intercelic Colloquium on hydrology and water management, Rennes, INRA Colloq Series No 79, 323-334.

Hughes, S., Reynolds, B and **Hudson, J.A.** 1996 Release of bromide following rewetting of a naturally-drained acid gully mire *Soil Use Manag* **12**, 62-66

Hughes, D A., Mazvimavi, D., **Bullock, A.** and **Andrews, A.J.** 1995. Save and Groot River Basin Contributions to *Water Resources management and Desertification problems and challenges*. WMO/Interim Secretariat of the Convention to combat Desertification (Joint collaboration Southern African FRIEND project collaboration between University of Zimbabwe, Rhodes University, South Africa, IH and the International Union for the Conservation of Nature)

Huntingford, C., **Allen, S.J.** and **Harding, R.J.** 1995 An intercomparison of single and dual-source vegetation atmosphere transfer models applied to transpiration from Sahelian Savannah. *Bound. Layer Met* **74**, 397-418

Huntingford, C. 1995. Non-dimensionalisation of the Penman-Monteith model. *J Hydrol* **170**, 215-232

***Irving, K.M.** 1995 Contingency plans for UK droughts Proceedings of the Hazards Forum Seminar, 4 Oct 1994 *Circulation* No 45 British Hydrological Society

Jackson, N.A., Griffiths, H and Zeroni, M 1995 Above-ground biomass of seedling and semi-mature *Sesbania sesban*, a multi-purpose tree species, estimated using allometric regressions *Agroforestry Systems*. **29**, 103-112.

Jenkins, A., Ferrier, R.C. and **Kirby, C.** (eds). 1995. *Ecosystem Manipulation Experiments: scientific approaches, experimental design and relevant research*. Ecosystems Research Report No 20 European Commission

Jakeman, A. J., Whitehead, P.G., **Robson, A.J.**, Taylor, J.A. and Bai, J 1995. Investigation of a new approach to predict water quality with a case study of chemical determinants in stream water. System Analysis in Water Quality Management II. *J Water Sci Technol*. **24**, 25 33.

Jenkins, A. and Wright, R.F 1995. The CLIMEX project. performance of the experimental facility during the first year of treatment. In. Jenkins, A., Ferrier, R., and Kirby, C (eds) *Ecosystem Manipulation Experiments*. Ecosystems Research Report No 20 European Commission

Jenkins, A. 1995 Dynamic modelling of chemical responses to future changes in acid deposition and land use In Battarbee, R.W (ed) *Critical Loads of Acid Deposition for United Kingdom Freshwaters* ITE Edinburgh

Jenkins, A, **Sloan, W.T.** and Cosby, J. 1995 Stream chemistry in the middle hills and high mountains of the Himalayas, Nepal *J Hydrol* **166**, 61-79.

Jenkins, A (ed) 1995 *CLIMEX project Progress Report December 1992-June 1993* NIVA and IH, Oslo and Wallingford

Jenkins, A. (ed) 1995 *CLIMEX project Progress Report July 1993-December 1993* NIVA, Oslo and IH, Wallingford

Jenkins, A. 1995 Critical Loads Freshwater recovery and future trends In. Battarbee, R W (ed) *Acid Rain and Its Impact: The Critical Loads Debate* ENSIS, London

Jenkins, A. 1995 Model of acidification of groundwaters in catchments with aggregated nitrogen dynamics (MAGIC WAND) In. Forsius, M and Kleemol, S (eds) *Effects of Nitrogen Deposition on Integrated Monitoring Sites*. ICPIM Programme Centre, Finnish Environment Agency, Helsinki, Finland.

Jenkins, A., Campbell, G., **Renshaw, M.**, **Boorman, D.B.**, Stedman, J and Patrick, S. 1995 Surface water acidification in the UK current status, recent trends and future predictions. *Water, Air and Soil Pollution* **85**, 565-570

Jenkins, A. Boorman, D.B. and **Renshaw, M.** 1996 The UK Acid Waters Monitoring Network: an assessment of chemistry data, 1988-93 *Freshwater Biol.* **36**, 169-178

***Jenkins, A. Wilkinson, R.J.** and **Collins, R.P.** 1996 Hydrochemical characteristics of headwater streams in the Middle Hills and High Mountains of the Himalyas, Nepal. In. Chalise, S.R. and Khanal, N R (eds) ICIMOD/UNESCO Int Conf. on Ecohydrology of High Mountain Areas, Kathmandu, Nepal, March 1996 Extended Abstracts 163-165

Johnson, A.C. 1995 The use of mini-lysimeters to study the influence of rainfall intensity on pesticide transport and water pathways In: *British Crop Protection Council Monograph No 62: Pesticide Movement to Water* 33-38.

***Johnson, A.C.**, **Batchelor, C.H.**, and **Haria, A.H.** 1995. Processes influencing pesticide transport in a drained clay catchment. In. *Effects of scale on interpretation and management of sediment and water quality* Proc. Boulder Symposium, July 1995. *IAHS Publ No. 226*, 39-46

***Johnson, A.C.**, **Haria, A.H.**, **Cruxton, V.L.**, **Batchelor, C.H.**, **Williams, R.J.**, Heppell, K. and Burt, T 1995. Isoproturon and anion transport by preferential flow through a drained clay soil In *British Crop Protection Council Monograph 62: Pesticide Movement to Water* 105-110.

***Johnson, A.C.**, **White, C.**, **Besien, T.J.**, **Williams, R.J.**, Worrall, F. and Walker, A 1996 The potential of incorporated organic matter to reduce pesticide leaching. *Proc. COST 66 Workshop*, Stratford-upon-Avon, UK 55-56

Johnson, I.W., **Elliott, C.R.N.** and **Gustard, A.** 1995 Using the IFIM to model salmonid fish habitat in the River Allen, England. *Bull Fr Peche Piscic* (337/338/339), 355-363

Johnson, I.W., **Elliott, C.R.N.** and **Gustard, A.** 1995 Modelling the effect of groundwater abstraction on salmonid habitat availability in the River Allen, Dorset, England. *Regulated Rivers: Research and Management* **10**, 229 238.

Johnson, R.C. 1995 The spatial distribution of rainfall in two Scottish Highland catchments *Proc. 1995 BHS National Hydrology Symposium, Edinburgh* 8.17-8.21.

Johnson, R.C. 1995 The sensitivity of water levels in the River Spey to channel changes *Earth Surf Proc & Landforms*

Johnson, R.C. 1995 Framework of a methodology for classifying sediments in Himalayan rivers *Proc Third International Seminar on Sustainable Reconstruction of Highland and Headwater Regions*. Delhi, October 1995

Johnson, R.C. and **Bronsdon, R.K.** 1995. Erosion of forest roads *Agricultural Engineer* **50**, 22 27

***Johnson, R.C.** and **Collins, R.P.** 1996. Developments in a methodology of classifying sediments in Himalyan rivers In: Chalise, S.R. and Khanal, N.R (eds) ICIMOD/UNESCO Int Conf on Ecohydrology of High Mountain Areas, Kathmandu, Nepal, March 1996 Extended Abstracts 61

Kannangara, N. and **Rosier P.T.W.** 1996 Soil moisture deficits beneath forest and grassland In Gunasena, H P M. (ed) *Proceedings of the University of Peradeniya-Oxford Forestry Institute Link Workshop on Forestry*, 28-30 November 1994. University of Peradeniya, Kandy, Sri Lanka

Kirchner, J W., Hooper, R P., Kendall, C., **Neal, C.** and Leavesley, G. 1996 Testing and validating environmental models. *Sci Tot Envir*, **183**, 33-47

Law, F.M. 1995. Letter to the editor concerning Early nineteenth century weather in Yorkshire' *J Meteorol (UK)*.

204, 392

*Law, F.M. 1996. Limits to surface water development in South East England. Water Environment '96 Conf. *Supply and Demand—a Fragile Balance.* CIWEM. London

Law, F.M. and Gunston, H.M. 1996 Dam failures *Dams and Reservoirs* 6, 6

Lawson, G J., Croat, N.M J., Levy, P E., Mobbs, D.C., Wallace, J.S., Cannell, M.G R. and Bradley, R G 1995 The tree-crop interface representation by coupling of forest and crop process-models *Agroforestry Systems* 30, 199-221

*Lees, M.L. 1995 EURAQUA. Second Technical Meeting, Paris. 18 19 October 1995. UK Contribution

*Linder, W., Noilhan, J., Berger, M., Bluemel, K., Blyth, E.M., Boulet, G., Braud, I., Dolman, A J., Fiedler, F., Grunwald, J., Harding, R.J., van der Hurk, B., Jaubert, G., Mueller, A and Ogink, M 1996 Intercomparison of surface schemes using EFEDA flux data CNRM, France. 1 42

*Littlewood, I.G. and Marsh, T.J. 1995 Monthly flows for the Thames at Kingston an assessment of measurements since 1853 and derivation of earlier estimates based on rainfall at Kew and Central England temperatures *National River Flow Archive Long Flow Record Data Quality Report No 1* Institute of Hydrology

Littlewood, I.G. and Marsh, T.J. 1996. An assessment of the monthly naturalised flow record for the River Thames at Kingston since 1883 *Regulated Rivers Research and Management* 12, 13-26

Lloyd, J., Grace, J., Miranda, A C., Meir, P., Wong, S C., Miranda, H S., Wright, I.R., Gash, J.H.C. and McIntyre, J 1995. A simple calibrated (SiC) model of Amazon rainforest productivity based on leaf biochemistry properties *Plant, Cell & Environment* 18, 1129-1145

Lloyd, J., Kruit, B., Hollinger, D Y., Grace, J Wong, S C., Francey, R J., Kelliher, F Farquar, G D., Schulze, E D., Miranda, A.C., Miranda, H S., Wright, I.R., Gash, J.H.C. and Vygodskaya, N N. 1996 Vegetation effects on the isotopic composition of atmospheric CO_2 at local and regional scales theoretical aspects and a comparison between rain forest in amazonia and a boreal forest in Siberia *Australian J Plant Physiol* 23, 371-399

Lukewille, A., Arp, A., Verburg, P., Jenkins, A., and Wright, R F. 1995 The CLIMEX soil heating experiment at Risdalsheia, Southern Norway In Jenkins, A., Ferrier, R C., and Kirby, C. (eds) *Ecosystem Manipulation Experiments Scientific Approaches, Experimental Design and Relevant Results* Ecosystems Research Report No. 20. European Commission, Brussels 331-334.

Maitelli, G.T and Wright, I.R. 1996 The climate of a riverside city in the Amazon Basin urban-rural differences in temperature and humidity In. Gash, J.H C., Nobre, C A., Roberts, J M and Victoria, R L (eds) *Amazonian Deforestation and Climate* John Wiley & Sons, Chichester. 193-206

Marsh, T. J. 1995 Water Resources - Process and Management (6th form/ undergraduate textbook) (Authors V Bishop and R Prosser) Collins Educational Publications 250

Marsh, T.J and Turton, P S 1995 Not a drop to drink *Utility Week* 13 14-15

Marsh, T.J. 1995 Rainfall, replenishment and resources In *Digest of Environmental Protection and Water Statistics* (Chapter 7) Department of the Environment 41-48

Marsh, T.J. 1996. River flow and groundwater level records - the instrumented era In Palaeohydrology. *British Hydrological Society Occasional Paper No 7*

Marsh, T.J. and Turton, P S 1996 The 1995 drought - a water resources perspective *Weather*, Feb. 1996.

Marsh, T.J. 1995 Maximising the use and utility of hydrometric data *Proc National Rivers Authority Seminar on Hydrometry*, Coventry, 1994

Marsh, T.J. (Editor) 1995 *1994 Yearbook* Hydrological Data UK series. Institute of Hydrology, Wallingford

Matthiessen, P., Sheahan, D., Harrison, R., Kirkby, M., Rycroft, R., Turnbull, A., Volkner, C and Williams, R.J. 1995 Use of *Gammarus pulex* bioassay to measure the effects of transient Carbofuran runoff from farmland *Ecotoxicology and Environmental Safety* 30, 111 119.

McCartney, M.P., Balckie, J.R. and Moores J.P. 1995. A small catchment study on the island of Jersey. *Proc Fifth BHS National Hydrology Symp.*, Edinburgh, 2 09 2.16

McCartney, M.P., Whitehead, P G., Bolton, C and Brown, S 1995 Simulation of acid mine drainage prior to wetland treatment in the Pelenna catchment, Wales *Proc Fifth BHS National Hydrology Symp*, Edinburgh, 10 19-10 22

McWilliam, A.C., Cabral, O M R., Gomes, B M., Esteves, J.L Roberts, J.M. 1996 Forest and pasture leaf-gas exchange in South West Amazonia In Gash, J H C., Nobre, C A., Roberts, J M and Victoria, R L (eds) *Amazonian Deforestation and Climate* John Wiley & Sons. Chichester 265-285

Meigh, J.R. 1995 Regional flood estimation methods for developing countries Institute of Hydrology/ODA Report 95/1

*Moore, R.J. 1996 Snowmelt flooding *Flood and Coastal Defence*, Issue No 9, 5-6

Moore, R.J. 1996 Weather radar and storm and flood hazard. In R Casale (ed). *Hydrological and Hydrogeological risks* Proc. European Commission, 1st Review Meeting, Brussels, 30-31 January 1995, EUR 16799 EN, 23-36

*Moore, R.J. and Bell, V.A. 1996 A grid based flood forecasting model using weather radar, digital terrain and Landsat data *Quaderni Di Idronomia Montana*, 16, 97-105

Naden, P.S. 1996. A routing model for continental-scale hydrology *IAHS Publ no 214*, 67 79.

Neal, C. 1995. Aluminium speciation variations in an acidic upland stream draining the Hafren spruce forest, Plynlimon, mid Wales *J Hydrol* 164, 39 51.

Neal, C., Avila, A and Roda, F 1995. Modelling the long term impacts of atmospheric pollution deposition and repeated forestry cycles on stream water chemistry for a Holm oak forest in northeastern Spain *J Hydrol* 168, 51 71.

Neal, C. 1996 Towards lumped integrated models of complex heterogeneous systems *Sci Tot Envir* 183, 115-124

Nobre, C A., Gash, J.H.C., Roberts, J.M Victoria, R.L 1996. The conclusions from ABRACOS In Gash, J.H.C., Nobre, C A., Roberts, J M and Victoria, R L (eds) *Amazonian Deforestation and Climate* John Wiley & Sons, Chichester 577-595

*Ormerod, S J., Buckton, S T., Brewein, P.A., Jenkins, A., Johnson, R.C. and Suren, A 1996. Biodiversity, chemistry and structure in streams of the Nepalese Himalaya In Chalise, S R and Khanal, N.R (eds) ICIMOD/UNESCO Int Conf. on Ecohydrology of High Mountain Areas, Kathmandu, Nepal, March 1996 Extended Abstracts 187-200

*Parks, Y.P., Sene, K.J., Andrews, A.J. and Bullock, A. 1995 Establishing a regional operational hydrological database for the SADC countries Poster presentation WMO Conference on Meteorological Technology and its management Geneva, 22 26 May.

Patrick, S., Battarbee, R and Jenkins, A. 1996 Monitoring acid waters in the UK. an overview of the UK Acid Waters Monitoring Network and summary of the first interpretative exercise *Freshwater Biol* 36, 131-150

Price, D.J. and Jefferies A 1995 Ultrasonic doppler shift velocity measurement for river flows. *Proc 1995 BHS National Hydrology Symposium, Edinburgh* 10 23-10.28.

Quinn, P.F., Beven, K J. and Culf, A.D. 1995. The introduction of macroscale hydrological complexity into land surface-atmosphere transfer models and the effect on planetary boundary layer development. *J Hydrol* 166, 421-444

Ragab, R. 1995 Towards a continuous operational system to estimate the root zone soil moisture from intermittent remotely sensed surface moisture *J Hydrol* 173, 1 25.

Ragab, R. 1995 Approaches to modelling nitrogen transformation and transport in agrosystems In *Nitrogen Cycle in Agrosystems* Proc INRA Workshop, Laon, France 56-59

Ragab, R. 1996 Soil hydraulic conductivity issues in measuring, predicting and upscaling European Workshop on advanced methods to determine hydraulic properties of soils. Thurnau, Germany, 10-12 June 1996 *European Workshop*, 1.

Ragab, R., Cooper, D.M., Harris, G L and Catt, J A 1996. Simulating nitrate leaching under winter wheat grown on a structured clay soil considering bypass flow *J. Hydrol* 182, 157-173

Ragab, R., El Quosy, D Van den Broek, B. and Santos Pereira, L. (eds) 1996 *Crop-water-environment models* Proc

ICID Workshop, Cairo, 17 Sept. 1996

Reed, D.W. 1995. Rainfall assessments of drought severity and centennial events. *Proc. CIWEM Centenary Conf.* London, 25-26 Oct. 1995.

***Reed, D.W.** 1995. Water issues - a European perspective. Extended abstract: *Norsk hydrologi perspektiver etter 100 ar*, 6 October 1995, Oslo.

***Reed, D.W., Bayliss, A.C.**, Jakob, D., **Jones, T.K., Marshall, D.C.W.** 1995. The use of date information in proposing regions for flood frequency analysis. Paper to FEH Advisory Group

***Rees, H.G.** and Roald, L.A. 1995. The FRIEND European Water Archive - design and operation of an international hydrological database. In: *Proc. of UNESCO IHP International Symposium on rivers and people in Southeast Asia and the Pacific - partnership for the 21st Century*

Reynolds, B., Chapman, P.J., French, M.C., **Jenkins, A.**, and Wheater, H.S. 1995. Major, minor and trace element chemistry of surface waters in the Everest region of Nepal. In: Biogeochemistry of seasonally snow covered catchments. *IAHS Publ. No. 228*, 405-412

Ribeiro, A., Victoria, R.L., Martinelli, L.A., Moreira, M.Z. and **Roberts, J.M.** 1996. The isotopic composition of atmospheric water vapour inside a canopy in Amazonian forest: vertical and diurnal variation. In: Gash, J.H.C., Nobre, C.A., Roberts, J.M. and Victoria, R.L. (eds) *Amazonian Deforestation and Climate*. John Wiley & Sons, Chichester. 163-173

Roberts, A.M. 1996. Tales (and hints) from a Programme Manager's office. *Themes* Issue 1, June 1996. Natural Environment Research Council

Roberts, A.M., Hudson, J.A. and **Roberts, G.** 1995. Upland pasture improvement. *The Agricultural Engineer* **46**, 26-29.

Roberts, G. and **Harding, R.J.** 1996. The use of simple process based models in the estimate of water balances for mixed land use catchments in East Africa. *J Hydrol* **180**, 251-266

***Roberts, J.M.**, Cabral, O.M.R., da Costa, J.P.R., **McWilliam, A.C.**, da Costa, J.d.P. and Sá, T.D.d.A. 1995. Plant physiological studies in tropical rainforest and pasture in Amazonia. In: *Proc. 5th Brazilian Plant Physiology Congress*. Lavras, Minas Gerais, Brazil. July 1995. 134-174

Roberts, J.M., Cabral, O.M.R., da Costa, J.P., **McWilliam, A.-L.C.** and Sá, T.D.d.A. 1996. An overview of the leaf area index and physiological measurements during ABRACOS. In: Gash, J.H.C., Nobre, C.A., Roberts, J.M. and Victoria, R.L. (eds) *Amazonian Deforestation and Climate*. John Wiley & Sons, Chichester. 287-306

*Robinson, D.A., **Bell, J.P.** and **Batchelor, C.H.** 1995. Influence of iron and titanium on water content determination by TDR. *Proc. TDR Symp.* Danish Inst. of Plant and Soil Science - SP Report 11. 63-70

Robinson, M. 1995. Stormy waters. *Landscape Design* **245**, 14-16

Robinson, M. and Stamm, M.H. 1996. A study of soil moisture controls on streamflow behaviour: Results from the OCK basin, UK. *Acta Geologica Hispanica* **28**, 75-84.

Robson, A.J., Neal, C., and Beven, K. 1995. Linking mixing techniques to a hydrological framework: an upland application. In: Trudgill, S. (ed) *Solute Processes in Catchment Systems*. John Wiley & Sons Ltd. 347-369.

Robson, A.J., Jenkins, A. and **Neal, C.** 1995. Towards predicting future episodic changes in stream chemistry. *J Hydrol* **125**, 161-174.

Robson, A.J. and **Neal, C.** 1996. Water quality trends at an upland Welsh site. *Hydro. Proc.* **10**, 183-203.

Robson, A.J., Neal, C., Currie, J.C., Virtue, W.A. and Ringrose, A. 1996. The water quality of the Tweed and its tributaries. *IH Report No 128*, Institute of Hydrology, Wallingford

Rosier, P.T.W., Bastable H.G., Kannangara N. and Gunawardena E.R.N. 1996. Water use of cloud forest, Kandyan forest gardens and grass at two sites in Sri Lanka. In: Gunasena, H.P.M. (ed) *Proc. University of Peradeniya-Oxford Forestry Institute Link Workshop on Forestry*. 28-30 November 1994. University of Peradeniya, Kandy, Sri Lanka

Sá, T.D.d., da Costa, J.P.R. and **Roberts, J.M.** 1996. Forest and pasture conductances in southern Para, Amazonia. In: Gash, J.H.C., Nobre, C.A., Roberts, J.M. and Victoria, R.L. (eds) *Amazonian Deforestation and Climate*. John Wiley & Sons, Chichester. 241-263

Sene, K.J. 1996. Meteorological estimates for the water balance of a sparse vine crop growing under semi-arid conditions. *J. Hydrol.* **179**, 259-280

Sefton, C.E.M., Whitehead, P.G., **Eatherall, A., Littlewood, I.G.** and Jakeman, A.J. 1995. Dynamic response characteristics of the Plynlimon catchments and preliminary analysis of relationships to physical descriptors. *Environmetrics* **6**, 465-472.

Sklash, M.G., Beven, K.J., **Gilman, K.** and Darling, W.G. 1996. Isotope studies of pipeflow at Plynlimon, Wales, UK. *Hydrol. Processes* **10**, 921-944.

Smith, D.M. 1995. Water use by windbreak trees in the Sahel. PhD Thesis, University of Edinburgh.

***Smith, D.M.**, Jarvis, P.G. and Odongo, J.C.W. 1996. Water use by sahelian windbreak trees. In: Buerkert, B., Allison, B.E. and Von Oppen, M. (eds) *Proc. Int. Symp. on wind erosion in West Africa: the problem and its control*. Margraf Verlag, Weikersheim, Germany. 115-128

Soulsby, A., Helliwell, R.C., Ferrier, R.C. and **Jenkins, A.** 1995. Influence of snow on the hydrology and hydrochemistry of rivers draining the Cairngorm Mountains, Scotland. *Proc. 5th BHS National Hydrology Symposium, Edinburgh*. 4.11-4.16

Spijkers, T., Houghton-Carr, H.A. and **Naden, P.S.** 1995. Continuous rainfall-runoff modelling at daily and sub-daily time intervals for flood frequency estimation. *Proc. Fifth BHS National Hydrology Symposium, Edinburgh*. 4.39-4.46.

Stewart, J.B. 1995. Turbulent surface fluxes derived from radiometric surface temperature of sparse prairie grass. 2nd FIFE Special Issue. *J. Geophys. Res.* **100**, D12, 25429-25433

Stewart, J.B., De Bruin, H.A.R., Garatuza Payan, J. and **Watts, C.J.** 1995. Use of satellite data to estimate hydrological variables for northwest Mexico. *Proc. Remote Sensing in Action, 21st Remote Sensing Soc. Conf.*, 91-98.

Stewart, J.B. 1995. Surface fluxes from satellite measurements of the surface temperature for Sahel regions. *The Observatory*, **115**, 231-234.

***Stewart, J.B., Biggin, D.S.** and **Bullock A.** 1995. Potential evaporation areas in Dambos in Zimbabwe identified using Landsat TIR data. Proc. European Geophys. Soc. XX Gen. Assembly, 3-7 april 1994, Hamburg. *Ann. Geophys.* **13** (II), 497

Stewart, J.B. 1996. Extrapolation of evaporation at time of satellite overpass to daily totals. In: Stewart, J.B., Engman, E.T., Feddes, R.A. and Kerr, Y. (eds) *Scaling up in hydrology using remote sensing*. John Wiley & Sons Ltd. 245-255

Sutcliffe, J.V. and **Farquharson, F.A.K.** 1995. Flood frequency studies using regional methods. Conference in honour of Jacques Bernier, Unesco, Paris, September 1995

Sutcliffe, J.V. and **Parks, Y.P.** 1995. Hydrology controls of Sudd ecology. In: *Hydrological Management and Wetland Conservation*. IUCN, Geneva

Taylor, C.M. 1995. Aggregation of wet and dry land surfaces in interception schemes for General Circulation Models. *J. Climate* **8**, 441-448

Taylor, C.M. 1996. The influence of mesoscale variability on the atmosphere. PhD Thesis, Reading University

***Tindall, C. I.** 1995. LOIS chemical determinand dictionary. NERC LOIS Report 99

Tinnion, M. and **Moore, R.J.** 1995. The UK National Rivers Authority Northumbria and Yorkshire Region's River Flow Forecasting and Warning System (RFFS). Int. Conf. Flood Protection of Towns. Ideas and Experiences, 20-22 September 1995, Cracow, Poland

Tomasella, J. and **Hodnett, M.G.** 1996. Soil hydraulic properties and van Genuchten parameters for an oxisol under pasture in central Amazonia. In: Gash, J.H.C., Nobre, C.A., Roberts, J.M. and Victoria, R.L. (eds) *Amazonian Deforestation and Climate*. John Wiley & Sons, Chichester. 101-124

Valente, F. **Gash, J.H.C.** and David, J.S. 1995. Modelling rainfall interception from Les Landes Forest in HAPEX-MOBILHY with sparse forest models. *Ann. Geophys. Suppl. II* **13** (C498)

Verhoef, A. 1996. *Surface energy balance of shrub vegetation in the Sahel*. Wageningen Agricultural University, The Netherlands

Verhoef, A., Van den Hurk, B.J.J.M., Jacobs, A.F.G. and Heusinkveld, B.G.

1996. Thermal soil properties for a vineyard (EFEDA-I) and a savanna (HAPEX Sahel) site. *Agric. For. Met.* **78**. 1-18

Verhoef, A., **Allen, S.J.**, De Bruin, H.A.R., Jacobs, C.M.J. and Heusinkveld, B.G. 1996. CO_2 and water vapour fluxes from a Sahelian savanna. *Agric. For. Met.* **80**. 231-248.

Wallace, J.S. 1995. Multidisciplinary program studies land-atmosphere interactions in semi-arid regions. *EOS, Trans. Amer. Geophys. Union.* **76**. 465-469.

Wallace, J.S. 1996. The water balance of mixed tree-crop systems. In: Ong, C.K. and Huxley, P.A. (eds) *Tree-crop interactions: a physiological approach.* CABI, Wallingford. 189-233

Watts, C.J., Rodriguez, J.C. De Bruin, H.A.R., van den Berg, A.R., Garuza-Payan, J. and **Stewart J.B.** 1995. Estimation of incoming solar radiation using satellite data. *Proc. 21st Remote Sens. Conf.*, Southampton, 11-14 Sept 1995. 903-910

Whitehead, P.G., **Hudson, J.A.** and **Neal, C.** 1995. Whole catchment manipulation, hydrochemical and biological impacts of land use change at Plynlimon and Llanbrynmair, mid-Wales. In: Jenkins, A., Ferrier, R.C., and Kirby, C. (eds) *Ecosystem Manipulation Experiments: Scientific approaches, experimental design and relevant results*. Ecosystems Research Report No. 20, European Commission. 236-245

Whitehead, P.G., **McCartney, M.P.**, **Williams, R.J.**, **Ishemo, C.A.L.**, Thomas, R. 1995. A method to simulate the impact of acid mine drainage on river systems. *J. Instn Wat. & Envir Manage* **9**. 119-131.

Wilcox, D.A. **Beslen, T.J.**, **Harla, A.H.** and **Johnson, A.C.** 1996. Isoproturon transport through upper chalk cores. *Proc. COST 66 Workshop*, Stratford upon Avon, UK. 89-90

Wilkinson, R.J., **Jenkins, A.**, Wyer, M., and Kay, D. 1995. Modelling faecal coliforms in Streams. *IH Report No 127.* Institute of Hydrology, Wallingford

Wilkinson, R.J., **Jenkins, A.**, Wyer, M. and Kay, D. 1995. Modelling faecal coliform dynamics in streams and rivers. *Wat. Res.* **29**, 847-855

Williams, R.J., Brooke, D.N., Matthiessen, P., Mills, M., Turnbull, A. and Harrison, R. 1995. Pesticide transport to surface waters within an agricultural catchment. *J. Instn Wat. & Envir Manage* **9**, 72-81

Worral, F., Parker, A., Rae, J., and **Johnson, A.C.** 1995. A study of suspended and colloidal matter in the leachate from lysimeters: implications for pollution and lysimeter studies. In: *British Crop Protection Council Monograph No.62: Pesticide Movement to Water.* 129-134

Worral, F., Parker, A., Rae, J.E. and **Johnson, A.C.** 1996. Equilibrium adsorption of isoproturon on soil and pure clays. *Eur. J. Soil Sci.* **47**, 265-272

Wright, I.R., Manzi, A.O. and da Rocha, H.R. 1995. Surface conductance of Amazonian pasture: model application and calibration for canopy climate. *Agric. For. Met.* **75**, 51-70

Wright, I.R., **Gash, J.H.C.** and da Rocha, H.R. 1996. Modelling surface conductance for Amazonian pasture and forest. In: Gash, J.H.C., Nobre, C.A., Roberts, J.M. and Victoria, R.L. (eds) *Amazonian Deforestation and Climate.* John Wiley & Sons, Chichester. 437-458

Wright, I.R., Nobre, C.A., Tomasella, J., da Rocha, H.R., **Roberts, J.M.**, Vertamatti, E., **Culf, A.D.**, Alvalá, R.C.S., **Hodnett, M.G.** and Ubarana, V. 1996. Towards a GCM surface parameterisation for Amazonia. In: Gash, J.H.C., Nobre, C.A., Roberts, J.M. and Victoria, R.L. (eds) *Amazonian Deforestation and Climate.* John Wiley & Sons, Chichester. 473-504

Wyatt, R.G. and **Collins, R.P.** 1995. Land use, soil conservation and water resource management in the Middle Hills, Nepal. Instrumentation. *Proc. Conf. Likhu Khola Project*, Kathmandu, Nepal, July 1995

Xue, Y., **Bastable, H.G.**, Dirmeyer, P.A. and Sellers, P.J. 1996. Sensitivity of simulated surface fluxes to changes in land surface parameterizations: a study using ABRACOS data. *J. App. Meteorol.* **35**, 386-400

Commissioned research reports

Although not peer reviewed in the same way as papers published in the scientific literature, all reports to clients are subject to rigorous internal refereeing procedures.

Andrews, A.J. 1995. African Water Resources Management Strategy. *The World Bank*.

Andrews, A.J and Bullock, A. 1995. Hydrological impact of afforestation in Eastern Zimbabwe. *Overseas Development Administration*.

Batchelor, C.H. 1995 Water resources management and agricultural production in the Central Asian Republics. WARMAP Project. *European Commission*.

Bell, V.A. and Moore, R.J. 1996 A water balance storm model for short-term rainfall forecasting using weather radar, satellite infra red and surface weather observations: an assessment over south west Britain. *Ministry of Agriculture, Fisheries and Food*.

Black, A.R., Lees, M L., Marsh, T J and Dixon, J.M. 1995 A review of the Northern Ireland hydrometric network *Department of the Environment for Northern Ireland*

Black, A.R., Bronsdon, R.K and Johnson, R C 1995. Advice notes on the impacts of forestry, turbid waters, channel change and agriculture on river catchments. *Scottish Natural Heritage*

Blackie, J R. 1996 River basin management project, Chile *University of Newcastle*

Bradford, R B 1995 Bourne Brook hydrological study *National Rivers Authority Anglian Region*.

Bradford, R B. and Reynard, N.S. 1995. Climate and land use change scenarios for flood estimation in the Severn, Thames and Trent basins *Ministry of Agriculture, Fisheries and Food*

Bradford, R.B. and Moores, J.P 1996 Bath hot springs: analysis and interpretation of flow and temperature data *National Rivers Authority*

Bromley, J., Fluctuating subsurface water losses in a cutover peatland: Thorne Moors, South Yorkshire. *Levington Horticulture*

Bullock, A., Keya, S O., Muthuri, S.M., Bailey-Watts, A., Williams, R.J. and Waughray, D K N 1995. Lake Victoria environmental management programme Task Force II. Water quality, non-point source pollution and wetlands *Food and Agriculture Organization*

Bullock, A., McCartney, M.P., Gilman, K., Waughray, D K N. and Blyth, K. 1995. A hydrological strategy for the development and management of African wetland resources for sustainable agricultural use *Food and Agriculture Organization*.

Butterworth, J A., Lovell, C.J., Bromley, J., Hodnett, M G., Batchelor C.H., Mharapara, I., Mugabe, F. and Simmonds, L. 1995 Romwe catchment study effect of land management on groundwater recharge and implications for small-scale irrigation using groundwater. First Interim Report *Overseas Development Administration*.

Calver, A., Naden, P.S., Broadhurst, P., Spijkers, T. and Leighfield, B 1995 Continuous rainfall-runoff modelling for flood estimation Progress and results December 1994 - May 1995 *Ministry of Agriculture, Fisheries and Food*.

Carrington, D.S. and Moore, R.J. 1995. Extension of the London weather radar local calibration procedure to the entire Thames basin. *National Rivers Authority Thames Region*.

Collins, R.P., Jenkins, A., Maskey, R.B., Khadka, M.S. and Thafa, K. 1995. Landuse, soil conservation and water resource management in the Nepal Middle Hills: Hydrochemical characteristics. *Overseas Development Administration*

Cooper, D.M. 1995. Bourne Brook monitoring data. *National Rivers Authority Severn Trent Region*.

Davies, H N. and M. Robinson. 1996 An appraisal of water levels at Thorne Moors SSSI, 1992-96 *English Nature*

Dixon, A J. 1995. Burnham Beeches groundwater monitoring 01 01.94 11 04 95. *City of London Corporation*

Dixon, A J 1995. Constant head permeameter for use with U100 plastic lined samples. *British Nuclear Fuels Ltd*.

Dunbar, M.J., Elliott, C R.N., Acreman, M.C and Gustard, A. 1996. Habitat time series analysis. Ecologically acceptable flows Phase II *Environment Agency* R&D Technical Report.

Dwyer, I J 1995 Confluence flood joint probability. *Ministry of Agriculture, Fisheries and Food*

Elliott, C.R.N., Gowing, I M., Dunbar, M J and Acreman, M C 1995 Assessment/design of habitat restoration/improvement procedures for river flood defence schemes *Ministry of Agriculture, Fisheries and Food*

Elliott, C R N., Dunbar, M.J and Gowing, I.M 1995 Assessment of the potential use of the Physical Habitat Simulation System (PHABSIM) to assess the impact of flow modification on juvenile fish habitat in the River thames *National Rivers Authority Thames Region*

Elliott, C.R.N., Johnson, I W., Sekulin, A.E., Dunbar, M J and Acreman, M.C. 1996. Guide to the use of the Physical Habitat Simulation system *National Rivers Authority*

Farquharson, F.A K and Houghton-Carr, H A 1995 IWRSM Integrated Water Resource Simulation Model Progress Report 1994/95. *Overseas Development Administration*.

Farquharson, F A K. and Moores, J P 1995. Mutonga and Grand Falls Environmental Impact assessment, Kenya Confidential Report.

Faulkner, D S., Mackay, N.G., Onof, C.J., Reed, D.W. and Wheater, H S 1996 A review of some recent flood-producing rainfalls *Ministry of Agriculture, Fisheries and Food*.

Finch, J., Calver, A., Harding, R J and Ragab, R. 1995. National system for groundwater recharge assessment. *National Rivers Authority*

Finch, J., Calver, A., Harding, R.J., and Ragab, R 1996 Estimating the groundwater recharge at drift free sites - chalk and permo-triassic sandstone aquifers *Environment Agency* R&D Technical Report W7

Gash, J.H.C., Lloyd, C.R Culf, A D Blyth, E.M. and Holwill, C.J 1995 Surface and boundary layer measurements and upscale modelling in

HAPEX Sahel. *Natural Environment Research Council* (TIGER Programme)

Gash, J.H.C., Roberts, J.M. and Nobre, C.A., Marques Filho, A.de O. and Victoria, R.L. 1995. The Anglo Brazilian Amazonian Climate Observation Study (ABRACOS). Final report on Phase I. *Overseas Development Administration*

Gash, J.H.C., Roberts, J.M. and Nobre, C.A. 1996. The Anglo-Brazilian Amazonian Climate Observation Study (ABRACOS). Final report on Phase II. *Overseas Development Administration*

Gilman, K. 1995. Impact of drainage on orchid rich slacks at Ynyslas golf course, Dyfed. *Countryside Council for Wales*

Gilman, K. and Hudson, J.A. 1995. River gauging techniques for assessment of small-scale hydropower schemes. Confidential report

Gilman, K. 1996. Assessment of the hydrological significance of a disused railway across Fenns & Whixall Mosses, Clwyd/Shropshire Border. *Countryside Council for Wales*

Gilman, K. 1996. Preliminary assessment of proposal to create amenity wetland as part of reclamation scheme near Nelson Bog, Mid Glamorgan. *Countryside Council for Wales*

Gilman, K. 1996. Interim report on progress of hydrological evaluation of reedbed re-creation at Ham Wall, Somerset. *Somerset County Council/RSPB*

Gilman, K. 1966. Specification for water budget model of Walmore Common, Gloucestershire. *Environment Agency*

Gilman, K. 1996. Hydrological assessment of drainage and restoration of Cors Goch raised mire, near Carmarthen, Dyfed. *Countryside Council for Wales*

Gilman, K. and Hudson, J.A. 1996. Hydrological contribution to a feasibility study for optimisation of water management of a hydro-electric power scheme at Dolgarrog, North Wales. *Dulas Engineering Ltd*

Gostelow, T.P., Naden, P.S., Del Prete, M., Koukis, G. and Corominas, J. 1995. Rainfall-induced landslides in selected Mediterranean mountainous zones of Italy, Spain and Greece: the application of geographic information Systems (GIS) to hazard mapping. *European Commission*

Green, S. and Marsh, T.J. 1996. Report to the Litani River Authority, Lebanon

Gunawardena, E.R.N. and Rosier, P.T.W. 1996. University of Peradeniya - Oxford Forestry Institute Link Project Hydrology Component: Annual Report 1995-1996. *Overseas Development Administration*

Gustard, A., Young, A.R., Bullock, A. 1995. Scoping Study to develop design tools for low flow estimation. *National Rivers Authority*

Gustard, A. and Young, A.R. 1995. "Low flows" in groundwater in the UK: a strategic study. *Foundation for Water Research*

Hall, R.L., Allen, S.J., Rosier, P.T.W., Smith, D.M., Hodnett, M.G., Roberts, J., Hopkins, R., Davies, H.N., Kinniburgh, D.G. and Goody, D.C. 1996. Hydrological effects of short Rotation energy coppice. *ETSU/Department of Industry*

Harding, R.J., Blyth, E.M., Taylor, C.M. and Thorpe, A.J. 1995. Understanding of SVATs for global modelling using mesoscale meteorological and hydrological models. *Natural Environment Research Council* (TIGER Programme)

Houghton-Carr, H.A. 1995. Assured performance demonstration of the real-time flood forecasting software for the Upper Narmada basin. *Narmada Control Authority*

Hughes, S., Brittain, A., Reynolds, B., Hudson, J.A., Hill, P.J., Crane, S.B., Hughes, W.A., Hill, T.J. and Freeman, C. 1995. The Cerrig yr Wyn wetland manipulation study, 1991-95. *Welsh Office*

Hughes, S., Reynolds, B., Hudson, J.A., Hill, P.J., Hughes, W.A., Brittain, A. and Freeman, C. 1995. The Cerrig yr Wyn wetland manipulation study - Phase 2 Experiment. *Welsh Office.*

Institute of Hydrology. 1995. Interagency Research Committee on the Hydrological Use of Weather Radar second report March 1993 - February 1995. *Natural Environment Research Council*

Irving, K.M., Young, A.R., Gustard, A. and Rees, H.G. 1995. European atlas of small hydropower resources. Phase I. *European Small Hydropower Association*

Irving, K.M., Young, A.R., Bullock, A. 1996. Low flow estimation in artificially influenced catchments. Series of reports for training course manual. *National Rivers Authority*

Jenkins, A. and Gardner, R. 1995. Land use, soil conservation and water resource management in the Nepal Middle Hills. *Overseas Development Administration*

Jenkins, A., Collins, R.P., Eatherall, A., Thapa, K. and Tripathi, R.C. 1995. Land use, soil conservation and water resources management in the Nepal Middle Hills: modelling nitrate leaching and soil acidification. *Overseas Development Administration*

Jenkins, A. and Renshaw, M. 1995. Model of acidification of groundwaters in catchments with aggregated Nitrogen dynamics. *National Rivers Authority* NRA R&D Note 468

Johnson, A.C. and Haria, A.H. 1995. Study release and transport of pesticides in rainstorm events. *Ministry of Agriculture, Fisheries and Food*

Johnson, I.W. and Elliott, C.R.N. 1995. Habitat modelling and instream flow requirements. River Piddle. *National Rivers Authority, South Western Region*

Johnson, R.C. and Bronsdon, R.K. 1995. The erosion of forest roads due to natural and man induced processes. Volume 1: Literature review and regional survey of management practices. Volume 2: Experimental results, conclusions and technical recommendations. *National Rivers Authority*

Johnson, R.C. 1996. Flooding at Balnacraig Farm. *Forest Enterprise*

Jones, D.A. 1995. Bayesian updating and forecasting for flow models. *Ministry of Agriculture, Fisheries & Food*

Jones, D.A. 1995. A hybrid updating and forecasting method for flow models. *Ministry of Agriculture, Fisheries and Food*

Jones, D.A. 1996. An evaluation of a Bayesian scheme for model updating and forecasting using a rainfall-runoff model. *Ministry of Agriculture, Fisheries & Food*

Law, F.M. and Austin, B.N. 1996. Confidential assessment of resource yield for two water companies.

Lees, M.L. 1995. An analysis of the need for different types of monitoring stations, surface freshwater-quality. *European Environment Agency*

Lees, M.L. and Marsh, T.J. 1996. River flow monitoring in the EU. Determine the requirements for density, sampling frequency, analytical methods, quality assurance schemes, data storage and estimate costs. *European Environment Agency Inland Waters Topic Centre*

Lovell, C.J., Mazhangara, E., Mtetwa, G., Dube, T., Thompson, D.M., MacDonald, D.M.J. and Batchelor, C.H. 1995. Small scale irrigation using collector wells. Fifth Progress Report. *Overseas Development Administration*

Lovell, C.J., Batchelor, C.H., Waughray, D.K., Semple, A.J., Mazhangara, E., Mtetwa, G., Murata, M., Brown, M.W., Dube, T., Thompson, D.M., Chilton, P.J., MacDonald, D.M.J., Conyers, D. and Mugweni, O. 1996. Small-scale irrigation using collector wells. Final Report. *Overseas Development Administration*

Macdonald, A.M., Calow, R.C., Andrews, A.J. and Appiah, S. 1996. Groundwater management in drought prone areas of Africa. Northern Ghana - inception report. *Overseas Development Administration*

Marsh, T.J. and Sene, K.J. 1995. Hydrometric Monitoring in the Lebanon. *Overseas Development Administration*

Mapaure, I., Mapaura, A., & Butterworth, J.A. 1995. Romwe Catchment Study, Zimbabwe: Baseline vegetation survey. *Overseas Development Administration*

Marks, S.D. and Leeks, G.J.L. 1995. The impacts of particulate outputs associated with timber harvesting. *National Rivers Authority*

Mazhangara, E., Mtetwa, G., Dube, T., Lovell, C.J., Batchelor, C.H. 1996. Small-scale irrigation using collector wells: collector well garden performance 1995 winter season. *Overseas Development Administration*

McCartney, M.P., Moores, J.P. and Blackie, J.R. 1995. The Trinity Catchment Study Year 2. *Jersey Public Services Department*

McKenzie, A.A., Meigh, J.R., Stuart, M.E. and Zarour, H.I. 1995. Planning of a Palestinian hydrological monitoring programme. *Palestinian National Authority*

Meigh, J.R. 1995. Modernisation of hydro-meteorological observations in Rajasthan. *World Bank/Government of Rajasthan*

Meigh, J.R. 1995. Garnedd power station - estimation of rainfall and expected power for the first two years of operation. *Garnedd Power Co. Ltd*

Moore, R.J., Austin, R.M. and Carrington, D.S. 1995. Evaluation of FRONTIERS and local radar rainfall forecasts for use in flood forecasting models: Operational Guidance Note. *National Rivers Authority* R&D Note 387.

Moore, R.J. 1996. Alpine study tour on snow cover monitoring: the Jizera Mountains - training for data acquisition and evaluation. *European Commission*

Moore, R.J. 1996. A river flow forecasting system for Rajastham. *Wallingford Water*

Moore, R.J., Harding, R.J., Austin, R.M., Bell, V.A. and Lewis, D.R. 1996 Development of improved methods for snowmelt forecasting. *National Rivers Authority* R&D Note 402

Moore, R.V. 1995. The use of National Transfer Format for the exchange of environmental time-series data. *National Rivers Authority*

Moore, R.V. and Bellamy, S.P. 1995. Establishment of a hydrological information system for water resources planning, development and management. *SMHB Sdn Bhd/Jabatan Pengairan Dan Saliran, Malaysia.*

Moore, R.V. 1995. The IH logical data model for river data. *National Rivers Authority*

Morris, D.G. and Flavin, R.W. 1995. Flood risk map for England and Wales. *Ministry of Agriculture, Fisheries and Food*

Murata, M., Batchelor, C.H., Lovell, C.J., Brown, M.W., Semple, A.J., Mazhangara, E., Hana, A., McGrath, S.P. and Williams, R.J. 1995. Development of small-scale irrigation using limited groundwater resources: Fourth Interim Report. *Overseas Development Administration*

Neal, C., Wilkinson, R.J., Reynolds, B. and Robson, A.J. 1995. The impact of conifer harvesting and replanting on upland water quality. *National Rivers Authority* R & D Note 502/4/W

Norton, R.L., Rees, H.G., Norris, H., Gustard, A. and Spijkers, T. 1995. A review of water research programmes in Europe: water quality, water resources and flood defence. *National Rivers Authority* R&D Note 442

Ragab, R. and Batchelor, C.H. 1995. Towards strategic and tactical models for management of limited irrigation water resources. *European Commission*

Ragab, R. 1996. Modelling surface runoff generation and flow. A literature review. *Overseas Development Administration*

Ragab, R. and Batchelor, C.H. 1995. Contribution to project on Management of limited water resources. A simple soil water balance model for operational use in tactical and strategic models for management of limited irrigation water. *European Commission*

Rees, H.G., Cole, G.A. and Gustard, A. 1995. Surface water quantity monitoring in Europe. *European Environment Agency*

Rees, H.G., Gustard, A. and Spijkers, T. 1995. A review of water research programmes: Europe. Flood Defence and Water Resources. *Water Research Centre/National Rivers Authority*

Reynard, N.S., Reed, D.W., Marsh, T.J. and Naden, P.S. 1995. Trends and changes in rainfall patterns, runoff and flow frequencies. *Ministry of Agriculture, Fisheries and Food*

Robinson, M., Hall, R.L. and Rosier, P.T.W. 1995. Interception study at Coalburn: 1994/95 Results. *National Rivers Authority.*

Robinson, M. 1996. Continuous monitoring of soil moisture. *National Rivers Authority*

Sefton, C.E.M. and Whitehead, P.G. 1995. Modelling temporal and spatial impacts of climate change on hydrological systems. *Landscape Dynamics and Climate Change Consortium, NERC TIGER Programme.*

Sene, K.J. 1995. HYDATA planning meeting, Tashkent, Uzbekistan, 25-29 September 1995. *Foreign and Commonwealth Office*

Sene, K.J. 1995. UNDP/ICAS International Conference on Sustainable Development of the Aral Sea Basin, Nukus, Uzbekistan, 18-20 September 1995. *Foreign and Commonwealth Office*

Sene, K.J. and Houghton-Carr, H.A. 1996. ODA/JAU Know How Fund Aral Sea Project - Final Report. *Overseas Development Authority*

Sene, K.J., Jones, D.A. and Farquharson, F.A.K. 1995. Studies of the hydrology of the Lesotho Highlands Water Project for royalties assessment. *Lesotho Highlands Development Authority*

Sene, K.J., Andrews, A.J., Parks, Y.P. and Bronsdon, V.J. 1995. Hydata dissemination 1994/95. *Overseas Development Administration*

Sene, K.J., Down, K.D. and Parks, Y.P. 1996. HYDATA Dissemination 1995/96. *Overseas Development Administration*

Sene, K.J. and Marsh, T.J. 1996. Hydrometric Monitoring in the Lebanon - Interim Report on Installation and Training. *British Partnership Scheme - Beirut.*

Smith, D.M., Jackson, N.A., Roberts, J.M. and Wallace, J.S. 1996. Root quantity, activity and below-ground competition in *Grevillea robusta* agroforestry systems. *Overseas Development Administration*

Stewart, E.J., Faulkner, D.S. and Reynard, N.S. 1995. Rainfall frequency estimation in England and Wales. Phase 1b. Pilot study. *National Rivers Authority* R&D Note 478.

Stewart, J.B. 1996. Interim report on the Experimental & Representative Basins programme. 1995. *European Commission*

Swannell, R.P.J., Rose, C.L., Williams, R.J., Johnson, A.C., Besien, T.J. and Leeks, G.J.L. 1995. Test guideline on the biodegradability of pesticide in natural sediment/water system: a review. *Department of the Environment*

Wallace, J.S. 1995. Evaporation and radiation interception interactions in agroforestry. *Overseas Development Administration*

Wallace, J.S., Jackson, N.A. and Ong, C.K. 1995. Water balance of agroforestry systems on hillslopes. *Overseas Development Administration*

Wallace, J.S. and Okali, D.U.U. 1995/ Desert margins initiative: carbon fixation and measures against desertification in the fragile desert margins. *United Nations Development Programme.*

Wallace, J.S., Allen, S.J. and Milne, R. 1996. Combined growth and water use modelling of mixed vegetation. *Centre for Ecology & Hydrology*

Wallace, J.S. and Mobbs, D.C. 1996 Modelling light interception, micro-climatic interactions and their effect on crop yield in agroforestry systems using the ERIN and HyPAR models. (via Institute of Terrestrial Ecology). *Overseas Development Administration.*

Watts, G., Grew, R. and Young, A.R. 1995. Predicting artificially influenced flow statistics using Micro LOW FLOWS V2.1. *National Rivers Authority* R&D Note 448.

Waughray, D.K., Mazhanghara, E., Mtetwa, G., Mtetwa, M., Dube, T., Lovell, C.J., Batchelor, C.H. 1995 Small scale irrigation using collector wells. Return-to-households Survey Report. *Overseas Development Administration*

Waughray, D.K.N. and Dube, T. 1996 Small scale irrigation using collector wells pilot project: Zimbabwe. An environmental economic reconnaissance. *Overseas Development Administration*

Waughray, D.K.N., Mazhangara, E.M. and Lovell, C.J. 1996. Generating economic benefits in dryland areas: exploiting basement aquifers for small scale irrigation schemes. *World Development*

Williams, A., Gilman, K. and Barker, J. 1995. The protection of East Anglian wetlands - Phase 2. *National Rivers Authority Anglian Region*

Wright, I.R. and Gash, J.H.C. 1995 Carbon, Water and energy of tropical biomes. Surface conductance and evaporation modelling of Amazon rainforest. *Natural Environment Research Council* (TIGER Programme)

Wyatt, R.G. 1995. Installation of capacitance probe access tubes in Crete. *EFEDA*

Young, A.R. 1995. Groundwater and River resources Action Programme on a European Scale (GRAPES). *European Commission.*

Young, A.R. 1995. Water balance of EFEDA study area and recharge estimation. *Commission of the European Communities.*

Young, A.R. 1996. Surface water studies. EFEDA II 'Hydrological response to land use change and over exploitation of water resources in a semi arid area of Spain'. *Commission of the European Communities.*

Software development

Allchin, M., Irving, K.M. and Young, A.R. 1995. European Atlas of Small Scale Hydropower Resources. HydrA Technical Reference and User Guide.

Broadhurst, P. 1995. CDTM, Spatial Data Software Manual 4.2, Version 1.0.

Hill, D.R. 1995. Multi-media Dartmoor Information System. (Plymouth University student project)

Houghton-Carr, H.A. 1996. Micro FSR V2.2 Release Notes.

Institute of Hydrology. 1996. PDM Rainfall-Runoff Model Calibration Facility. User Guide. Version 1.1.

Institute of Hydrology. 1996. A guide to the PDM. Version 1.0.

Irving, K.M., Young, A.R., Bullock, A., Gustard, A., Sekulin, A.E. and Kennedy, N. 1995. Micro LOW FLOWS V2.1. Technical manual and user guide.

Littlewood, I.G., Down, K., and Parker, J.R.. 1995. A PC version of IHACRES for catchment scale rainfall- streamflow modelling: User Guide.

Meigh, J.R., Boesch, R. and Parks, Y.P. 1996. FLOODS version 1.0. Regional Flood Frequency Analysis Software (incorporating previous HYFAP manual).

Moore, R.V., Bonvoisin, N.J., Tilbury, J. and Howes, A. 1995. Water Information System Release 1.6.

Morris, D.G. 1995. Tsted, Spatial Data Software Manual 3.2, Version 1.0.

Parks, Y.P. 1995. HYFAP Operation Manual, Version 1.0

Parks, Y.P. 1996. HYDATA V3.2. User Manual.

Parks, Y.P. and Jennings, S.E. 1996. WINFAP. A Hydrological Frequency Analysis Package for Windows.

Swain, O.D. 1995. Gridlook, Spatial Data Software Manual 3.1, Version 1.0.

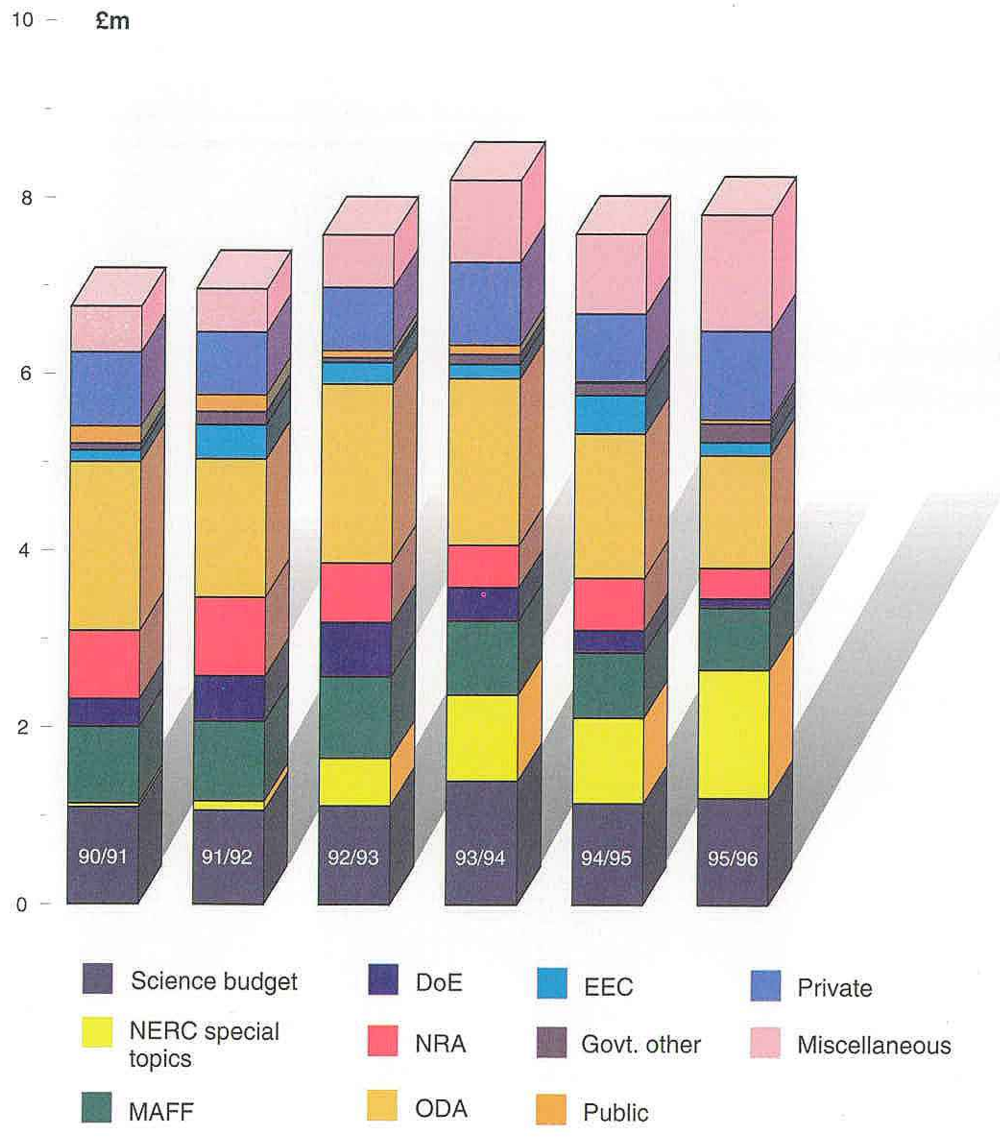
Young, A.R. 1995. HydrA — Software requirement specification. Software developed to meet the requirements of the CEC funded project *European Atlas of Small-Scale Hydropower Resouces*

APPENDIX Iii

Finance

Souces of income

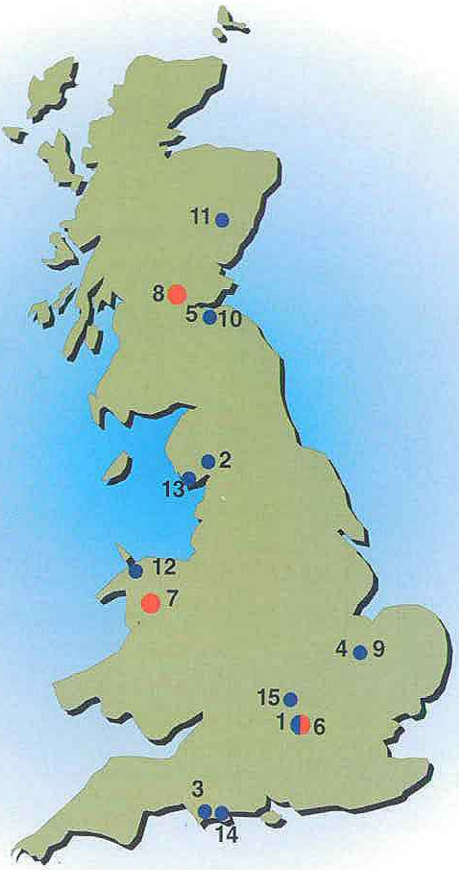
The histogram shows the sources of the Institute's income over the past six years, adjusted to 1995/96 prices



APPENDIX IV

CEH Integrating fund projects

Title	*IFE*	*IH*	*ITE*	*IVEM*
PROJECTS COMMENCING 1995/96				
The microbial basis of methane oxidation in soils	●		●	●
Interactions of viruses, aphids and wild brassica			●	●
Modelling the chemical availability of radionuclides in upland organic soils	●		●	
Combined growth and water use modelling of mixed vegetation		●	●	
Upland forest canopy closure - its significance for chemistry, ecology and hydrology	●	●	●	
Molecular genetics and process level events in the biodegradation of xenobiotics in rhizosphere soils			●	●
Microbial diversity and ecosystem function - Phase I	●	●	●	
PROJECTS COMMENCING 1996/97				
The role of seabirds in the epizootiology of lyme disease			●	●
Combined Hydro-ecological And Socio-economic Models of land use, land management and environmental degradation (CHASM)		●	●	
The environmental characteristics of urban environments	●	●	●	
The role of microbial diversity in regulating ecosystem function - Phase II	●		●	●
50m solar grids for the UK		●	●	
Modelling the fate of viruses in the aquatic environment		●		●



Centre for Ecology and Hydrology (CEH)

1. Wallingford

Institute of Freshwater Ecology (IFE)

2. Windermere
3. Wareham
4. Monks Wood
5. Edinburgh

Institute of Hydrology (IH)

6. Wallingford
7. Plynlimon
8. Stirling

Institute of Terrestrial Ecology (ITE)

9. Monks Wood
10. Edinburgh
11. Banchory
12. Bangor
13. Merlewood
14. Furzebrook

Institute of Virology and Environmental Microbiology (IVEM)

15. Oxford

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