Expert Group meeting to consider the need for a new Experimental Hydrology Decade

A report on the UNESCO sponsored meeting held at

Wallingford, UK

30th November and 1st December 1998

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A. EXECUTIVE SUMMARY

A.1 Introduction

In response to, and in the light of, several recent international conferences and documents on freshwater issues a UNESCO sponsored meeting of International water experts was convened to consider the need for a new hydrological research initiative to deliver the scientific basis for future sustainable water management. Following this meeting an outline proposal for a new worldwide hydrology initiative was prepared. The initiative is provisionally named *World Hydrology Initiative for Policy and Development (WHIPD).*

The organizing principle behind WHIPD is that its research should be directly responsive to the water related public policy and development issues that are internationally recognized as of major importance at the beginning of the new millennium. The initiative recognizes that the basic hydrological unit is the drainage basin. The primary objective is therefore to establish a global network of representative hydrological catchments covering key climatic, hydro-geological, biophysical, socio-economic and policy environments.

WHIPD will be based as much as possible on existing monitoring sites, thereby capitalizing on current and historic hydrological knowledge. It will also develop new scientific knowledge where key gaps exist, for example to provide data and models for more accurate assessment of freshwater resources and ground truth data for global climate models. The initiative will be complementary to and build upon the activities of other water related international programmes in the UNESCO-IHP, WMO, WCRP (GEWEX, CLIVAR), GEMS/Water and IGBP-BAHC (see Section A.5 for more details).

The global extent and seriousness of future water scarcity and pollution problems will require the combined efforts of many countries throughout the world. It is therefore vital to build national capacities, especially in developing countries, both in terms of hydrological infrastructure and through education and training in hydrological techniques.

A.2 Policy issues

The vital importance of water in sustaining human and environmental health has been widely recognized in numerous national, international and global fora. All of the most recent water resource and water quality assessments and policy documents support the rising concerns and the urgent need for action to address global water management issues. Key policy issues relating to freshwater have been identified as follows:

A.2.1 Water use in providing food for a growing population

Current projections estimate that by 2025 most of the world's population may not have sufficient water to grow their basic food requirements. This enormous food gap seems unavoidable in water scarce regions unless more efficient use can be made of existing water resources. A major effort is therefore required to look at the technical and non-technical aspects of increasing the efficiency with which water is used in both rainfed and irrigated agriculture. To ensure that any consequent impacts on downstream (and/or upstream) water users is taken into account this work needs to be carried out within a catchment framework.

A.2.2 Competition for water and potential conflicts

Expanding populations in water scarce regions will inevitably lead to increased competition, both on a national and an international level, for the limited water available in rivers and aquifers. On the other hand, water also provides a powerful tool for cooperation and has often been the vector for parties in conflict to achieve agreement. Improved information on water resources is essential to address potential conflicts over water.

A.2.3 Water quality impacts on human health

Human health is still seriously at risk due to water quality problems, especially in developing countries. This problem is likely to increase as increasing population pressure leads to further water quality degradation. Globally, information on water quality is extremely scarce, yet this is essential if the risks to much of the world's population are to be properly assessed and addressed.

A.2.4 Environmental water needs

Wetlands and biodiversity are threatened by water withdrawals and water pollution. Some consistent quantitative basis for deciding on the effects of sub-optimal water supply need to be evolved as an objective means for apportioning limited water between environmental and human needs. The degree and extent of water pollution effects on ecosystems also need to be much more clearly identified, if this escalating problem is to be effectively managed.

A.2.5 Impacts of climate variability and change on water resources

The Intergovernmental Panel on Climate Change (IPCC) recently concluded that the increasing cost of climate change and variability, in terms of loss of human life and capital due to floods, storms and droughts, are the result of the lack of adjustment and response in society's policies and use of resources. This places the emphasis of the solution on water resource management, which needs to quantify and account for possible future changes in water resources due to climate change and variability.

A.2.6 Improved communication between hydrologists and society

Sustainable water resources management policies require both a sound understanding of hydrological processes and a proper understanding of the desires and constraints of the full suite of water users. New mechanisms are needed to improve the communication between technical experts in the field of hydrology and stakeholders such as farmers, water managers and policy makers, etc.. Ultimately hydrologists need not only to provide the technical information to comply with current legislation, but also the information required to formulate new water laws.

Policies +

A.3 Objectives

Existing international scientific programmes typically report on the state of the art in one particular aspect of the water sciences. The WHIPD programme is different from and complementary to these existing programmes since it aims to -

- acknowledge and respond to societal needs and incorporate involvement of stakeholders and relevant scientific disciplines;
- recognize population growth as the principle driver in future demands for freshwater;
- contain an explicit and flexible capacity building element. This will enable appropriate participation by both developed and developing world nations.

The WHIPD programme is expressly focused on providing the scientific basis for developing sound water policy and development. It will be strongly guided by the results of past and current hydrological studies, as well as the future scenarios being developed (e.g., in Vision 2000 and by the IPCC). The primary objective of the initiative is to provide the process understanding required to derive effective tools for improved land and water management within a drainage basin framework. This objective is fully in line with the concept of Integrated Water Resource Management (IWRM) which has been widely recognized as an important approach for meeting current and future challenges in the water sector.

WHIPD will also provide a means of applying existing knowledge in a range of environments and at a range of scales. It will also develop new scientific knowledge where significant gaps exist. For example, WHIPD could provide the data and models to improve current global assessments of freshwater resources and water quality. The initiative could also provide the much needed ground data for improving global scale climate models.

Further details of the scientific issues to be addressed by WHIPD are given in Section C.4.

A.4 Project design

The WHIPD programme is focused on establishing a global network of representative hydrological catchments covering key climatic, hydro-geological, biophysical, socio-economic and policy environments. The international network is likely to evolve according to priorities set by the participants, and financial possibilities. Different regions may have different priorities. An international steering committee could be formed to provide advice on baseline measurements, methods and ways of networking with other WHIPD participants. The programme is to be discussed and promoted at a range of international meetings and support will also be sought from national, international and global organizations.

It is envisaged that catchments within the WHIPD initiative should:

- cover a range of bioclimatic zones, socio-economic structures and cultural environments
- be representative of the surrounding area to allow generalization to a wider region
- preferably be part of existing international networks, e.g., FRIEND, ERB, WHYCOS, GTOS, etc.
- for some, be located within GEWEX and CLIVAR continental scale programmes (GAME, GCIP, etc.)
- preferably have been operational for a few decades allowing historical and/or proxy data to be analysed
- from the start of the WHIPD programme, be observed for at least 10-20 years but with the aim of being made permanent

After some time it is anticipated that worldwide there could be as many as 100 to 200 catchments in the network. The study design will be iterative, combining past, current and emerging issues with process understanding gained from data analysis. Appropriate consultations between stakeholders and scientists should be maintained throughout this iterative process.

A.5 Relation to existing programmes

The initiative will be complementary to and build upon the activities of other water related international programmes in the UNESCO-IHP, WMO, WCRP (GEWEX, CLIVAR), GEMS/Water and IGBP-BAHC. For example, the WHIPD programme could provide GEWEX and CLIVAR with the long term globally extensive ground-based measurements of the hydrological cycle required to test large scale models and remote sensing techniques. This link should also create a worldwide capability to interpret understanding of global processes directly into the water environment at a catchment scale where it is most relevant to human and environmental welfare. WHIPD would also expand existing hydrological research from data collection and the analysis of current status and trends, into scenario analysis and the compilation of robust land and water management strategies for the next millennium.

The GEMS/Water programme could be strengthened via links into a more extensive network of ground based global observations. In the IHP FRIEND the emphasis has been on the collection and analysis of river flow data measured at national network sites. The WHIPD programme would complement FRIEND by focusing on the understanding of the entire catchment water balance including water quality. Further links and discussion are required with existing programmes to ensure that the appropriate synergies are optimally exploited.

The next steps to be followed in progressing the WHIPD initiative are given in Section C.7.

B. REPORT OF THE MEETING

B.1 Background

The first International Hydrology Decade (IHD) ran from 1965 to 1974 and was established in response to the need for the systematic study of the hydrological environment. This was very successful and led to a series of follow-up programmes including the successive phases of the International Hydrology Programme (IHP) of UNESCO. To date there have been five phases of the IHP, and the sixth is currently being planned (more details later in this report). The idea for a new Experimental Hydrology Decade (EHD) emerged in 1998 when GEWEX proposed consideration of a second IHD by UNESCO. A number of informal discussions followed leading to a formal call in July 1998 from the British Hydrological Society (BHS) conference in Exeter. The Exeter Statement recommended that -

"*consideration be given to a Second IHD as a major project within the current framework of activities of UNESCO, WMO and others. It would recognize the existing world observation programmes in related sciences, and be targeted at providing those comprehensive datasets and interpretive science needed to lower the uncertainty in hydrological prediction in areas of environmental, economic and social importance. It could build upon time series, for the 2001-2011 period, of variables as diverse as*

- *global surface moisture,*
- *continental soil-vegetation-atmospheric transfers,*
- *digital water tables of regional aquifers, and*
- *city water input, loss and effluent time series.*"

Discussions followed between a number of interested parties and resulted in UNESCO convening an Expert Working Group meeting in November/December 1998 to consider the need for, and possible form of, any new EHD.

B.2 Location, participants and agenda

The meeting was held at the United Kingdom's Centre for Ecology and Hydrology's Institute of Hydrology at Wallingford, UK. Twenty people attended the two-day meeting from a range of organisations including UNESCO, WMO, IAHS, and the GWP. For a full listing of organisations, see Annex II. Day 1 was a series of background talks, short presentations of related initiatives, and key technical issues. Day 2 started with a summary of the key points from Day 1 and was followed by an open discussion on the need for, and possible form of, any new EHD. After lunch on Day 2, any remaining issues where tabled and the outline concept for a new EHD was formed. Section C, "*Concept for a World Hydrology Initiative for Policy and Development*" contains full details of this.

B.3 Presentations - Day 1

B.3.1 Background to a proposed EHD and purpose of the meeting - *Mike Bonnell*

Funding agencies/donors/policy makers

- Declining respect for science/scientists
- We know enough
- Too many international meetings with too little outcome
- Discipline scientists by allocation of funds
- Ask long-term questions, but deliver short-term funds

Scientists

- Science for the sake of science ! ?
- Need to shift towards societal needs
- Could be proactive in defining issues

Conclusion: Any proposal for scientific programme needs to:

- Include good science
- Address policy issues and questions

Related initiatives and related recent papers (see Annex IV) cover the full range of global water issues.

The major international water issues identified are:

- **Water quality**
  - ⇒ In many countries the reason for water scarcity
  - ⇒ Climate change impacts on water quality barely studied
- **Global hydrology**
  - ⇒ Connection between land and sea surface characteristics which may affect our weather
- **Water for expanding population**
  - ⇒ Water for food
  - ⇒ Water for industry
  - ⇒ Water for the environment
- **Others:** details in subsequent presentations.

To note: Understand water quality = understand processes. Water quality is inseparable from water quantity.

However, after working one's way through all these issues and documents, it is clear that no follow-up scientific programme of the necessary vision exists which:

- **addresses these issues in the field, and**
- **closely integrates policy and management needs.**

Scientific issues to be addressed

- Status of modelling far surpassed field testing
- Experimental hydrology focused on microscale, i.e., on-site management questions
- No field experiments to address process hydrology at mesoscale: far more interesting to managers
- Need to filter anthropogenic impacts from climate variability
- Interannual variability implies need for long-term experimental hydrology data sets to address extremes
- Declining support for long-term monitoring

This meeting to keep in mind:

- Consider the need for and feasibility of an EHD
- Brainstorming session without formal minutes
- Invitations on personal grounds, not representing governments/institutes/etc.
- Consideration for institutional context or funding is secondary at present
- Truly global proposal is wanted, including developing countries' perspectives
- Representatives from several scientific organisations

If we want to make progress, no single agenda can drive this programme. Linkages across scales and topics and between science and policy are needed.

B.3.2 The IHP FRIEND project - *Alan Gustard*

- The structure of FRIEND is a key to its success — issues are identified globally but approached and managed at a regional level. The key to the success of an EHD will depend on its structure.
- Like FRIEND, an EHD will need to put emphasis on participants.
- It is essential that participants understand the ethos behind an EHD and the links between it and other projects.
- In the 21st Century FRIEND will look at user issues, process understanding, decision support systems, capacity building, and user implementation.
- Any programme needs review procedures.

B.3.3 Summary of future UNESCO IHP VI programme - *Kuniyshi Takeuchi*

- IHP-VI (2002-2007) Water interactions: systems at risk and social challenges.
- Five themes -
  - ⇒ Global changes and water resources
  - ⇒ Integrated watershed dynamics
  - ⇒ Regional perspectives
  - ⇒ Water and society
  - ⇒ Knowledge, information, and technology transfer (KITT)
- IHP-VI is based on the basic principle that "freshwater is as essential to sustainable development as it is to life, and that water, beyond its geophysical, chemical, biological function in the hydrological cycle, has social, economic and environmental values that are inter-linked and mutually supportive."
- IHP-VI has well-developed performance criteria.

B.3.4 Summary of future WMO OHP and related programmes - *Johan Kuylenstierna*

- Good ideas such as an EHD will crash during the political process unless lobbied beforehand.
- A worldwide approach is difficult — if consensus is reached then any outputs may actually say nothing.
- Remember that what is decided here will impact for 40 years.
- An EHD must have well-defined:
  - ⇒ *purpose* - is a new project necessary?
  - ⇒ *scope* - concentrate on key topics
  - ⇒ *structure* - encouraging cooperation
  - ⇒ *actors* - beneficiaries and money
  - ⇒ *duration* - why 10 years?; why not longer?
  - ⇒ *communications* - need to be effective

B.3.5 International Isotope Hydrology decade and its links with IHP-VI - *Din Dayal Sood*

- Isotope hydrology provides the fingerprints of water, providing a means of tracking.
- There is now an MoU between WMO/IAEA re. Global Network of Isotopes in Precipitation (GNIP).
- There is a proposal for an Isotope Hydrology Information System (ISOHIS).
- There are moves to integrate isotope hydrology into mainstream hydrology.
- IHP-VI is keen to pursue and support this field.
- All isotope hydrology studies are transboundary.

B.3.6 GWP proposal for Water Quality Management - *Janusz Kindler*

- GWP focuses — there is no aim to work throughout the world as nothing would be achieved.
- It aims for integration within water related areas (and without), in non-water policy areas.
- The issue of scale is important, decisions are made at the meso rather than micro or macro level.
- Social scientists are used throughout GWP projects.

B.3.7 Global Water Quality Initiative - *Jake Peters*

- A framework for investigating water quality operates at four levels / basin sizes -
  - ⇒ Global ($> 10^7$ km^2)
  - ⇒ Regional surveys (10^5 - 106 km^2)
  - ⇒ Long-term monitoring and characterisation (10^2 - 10^3 km^2)
  - ⇒ Long-term ecological process research (< 1 - 10 km^2)
- Emerging issues are identified through interaction between monitoring, scientific understanding and policy and management.
- Collecting data should be done in a manner that allows us to compare like with like.
- Capacity building should be part of the planning and study design.

B.3.8 Future GEWEX programmes involving experimental hydrology - *Rick Lawford*

- The two (out of four) most relevant objectives of GEWEX to an EHD are -
  - ⇒ Modelling the global hydrological cycle and its impact on the atmosphere, oceans and land surface.
  - ⇒ Developing the ability to predict the variations of global and regional hydrological processes and water resources, and their response to environmental change.
- There are a number of hydrological questions facing GEWEX that an EHD could help address.
- GEWEX acknowledges that runoff is very important.
- Individual countries are hesitant to share their data — we must show them a programme that will benefit them.

B.3.9 Future NASA programmes involving experimental hydrology - *Eric Wood*

- Current focus is on fast hydrologic processes -
  - ⇒ Water and energy exchanges at the land surface
  - ⇒ Remote sensing, modelling and analyses
- NASA spends $1 billion on Earth Sciences but little on hydrology.
- Hydrology has not been properly recognized by meteorologists and climatologists.
- Four missions are currently proposed -
  - ⇒ Global rainfall mission

⇒ Global soil moisture mission
⇒ Snow and cold season processes
⇒ Surface water measurement

B.3.10 The Global Hydrology component of an EHD - *Jim Shuttleworth*

- Hydrological design and management is currently based on the hypothesis that the statistics of hydrological variables are entirely random and stationary.
- There is now evidence that hydrological statistics have a deterministic component which is related to identifiable global processes, e.g., El Nino.
- During the next decade there will be a massive investment in global research to identify and understand additional global phenomena that are likely to influence hydrological statistics at catchment scale, e.g., monsoon systems.
- The ready availability of global data sets via the Internet provides an unprecedented opportunity for hydrologists around the world to identify the deterministic component in hydrologic statistics.
- The first IHD established scientific hydrology, and it then propagated up-to-date hydrological methods and understanding worldwide.
- A new worldwide hydrology initiative could show governments and policy makers that many accepted hydrological practices are based on thinking and technology that is 20 years old — we must be proactive in breaking the paradigm.

B.3.11 UK plans for future catchment research facilities - *Dick Bradford*

- NICHE - National Infrastructure for Catchment Hydrology Experimentation.
- Looking to establish 8 international quality mesoscale experimental basins for the UK hydrological research community.
- NICHE has two subcomponents, LOCAR and CHASM.
- LOCAR - Lowland Catchment Research 1999 - 2004.
  ⇒ Looking at hydrological processes in permeable lowland catchments.
- CHASM - Catchment Research and Sustainable Management.
  ⇒ Looking at scaling issues in mesoscale catchments (~ 10 km^2).
- Funding being applied for is between £6M and £10M for LOCAR, £4M for NICHE.

B.3.12 Water scarcity and food security - *Malin Falkenmark*

- A "new India" is created every 10 years - i.e., population growth is at 80 million per year.
- Water for food production comes from soil moisture (green water) and rivers (blue water) etc..
- Many areas of the world are moving towards not being food self-sufficient.
- Competition for water may lead to damaging upstream-activities; therefore we need upstream/downstream considerations.
- What is needed is -
  ⇒ Knowledge preparedness
  ⇒ Data preparedness
  ⇒ Conceptual preparedness
- The key issue is land/water interaction - *ecohydrology*.

B.3.13 Water use in agriculture - *Jim Wallace*

- A 65% increase in population over the next 50 years is a virtual certainty.
- This will mean that the proportion of the world's population living in water-scarce areas will rise from 7% to 70%.
- The land areas available for crops, both irrigated and rainfed, can only potentially increase by about 15%.

- There is, therefore, a need to increase yield per unit area.
- The key is to increase the efficiency with which water is used in agriculture (rainfed or irrigated).
- Globally, only 15% of water is transpired (much less, about 5% in semi-arid areas).
- There is, therefore, a need to combine technical and non-technical skills to -
  ⇒ Increase the amount of water that is transpired.
  ⇒ Fix more C per unit of water transpired.
- There is a key role for hydrologists in this R&D agenda.

B.3.14 Integrated catchment management planning in Southern Africa - *Roland Schulze*

- South Africa is "the world in one country"; it has a diverse and high-risk landscape, a diverse developmental landscape, a diverse cultural landscape, and a diverse political history.
- In water terms it has unequal distribution and demands, and faces change: supply to demand driven, "land = water" to "water for all", "top down to stakeholder driven" and "environmentally marginal to environmentally central".
- Integrated Catchment Management is the philosophy, process, and practice of integrated water resources management.
- It has many potential national and international water-caused conflicts.
- There has been a degree of success for hydrologists in helping to shape water law in South Africa.

B.3.15 Regulatory and legal structures affecting water management - *Patricia Wouters*

- There are insufficient legislative and regulatory tools.
- There is a lack of appropriate institutional frameworks.
- There is a need for transboundary cooperation in shared water resources.
- There is a need for an integrated approach at a conceptual level.
- There is necessary complementarity between hydrology and water law.
- An EHD needs to have a comprehensive reach.

B.3.16 The Exeter Statement - *Frank Law*

- Hydrologists do not have a policy.
- They are not trying to persuade the world to do anything in particular.
- They are facilitators and are accommodating.
- They are, therefore, easily led.
- There has now come a time to be proactive and say "This is what should be done".

B.3.17 How can experimental hydrology help international hydrological sciences - *John Rodda*

- A new EHD will increase the visibility of hydrologists, increase their influence, and help attract funding.
- There is a need to overcome the scientific obstacles and institutional impediments to make it happen.
- There are a number of overlapping programmes — will these surrender components or contribute to let an EHD become reality.
- We need to encourage contacts, and small teams, and look to the EHD to be an umbrella for hydrological research.
- There are four possible options for an EHD -

⇒ Be separate - alongside IHP, OHP, IGBP, etc..
⇒ Be part of an existing programme.
⇒ Gather all existing programmes under one umbrella.
⇒ Not have an EHD at all.

B.4 Summary - Day 1

The day was summarized by Mike Bonnell, Jim Shuttleworth, Jim Wallace, and Brian Wilkinson. Three key areas were identified: principles for organising a future programme, issues with consensus, and issues requiring further discussion.

B.4.1 Principles for organising a future programme

Any future programme should be -
- guided by well-defined scientific questions and hypotheses over a range of scales - time and space, and
- be clearly focused.

The scientific issues should -
- have policy relevance at local, regional, and international levels,
- require a consistent, simultaneous network of catchment-oriented observations,
- demonstrate a unique approach within the framework, and
- be unable to be fully addressed within frameworks of existing programmes.

B.4.2 Issues with consensus

- Hydrological analysis/design based on historic datasets, collected over a few decades and treated as if totally random in origin, will not meet societal needs in the future (i.e., there is evidence for non-stationarity in hydrological time-series.
- Within hydrology, model development has surpassed the ability to validate and calibrate the models.
- Catchment hydrologic research should be done in the service of human welfare.

A future programme should -
- in its definition, acknowledge and respond to societal needs and incorporate involvement of stakeholders and relevant scientific disciplines,
- recognize population growth as the principle driver in future demands for freshwater, and
- contain a significant and flexible capacity-building element. This would enable appropriate participation by both developed and developing world nations.

Hydrologists should be -
- proactive in developing this programme but should also involve other earth science and social science disciplines,
- proactive in providing the information needed for changing laws as well as implementing them, e.g., as is the case in South Africa, and
- able to provide information to help resolve and avoid conflict over water resources.

B.4.3 Issues still needing further discussion

A future programme should -
- look ahead to changes that are on their way or seek to resolve existing hydrological and policy issues,
- take strong cognisance of current studies concerning future scenarios,
- take strong cognisance of current hydrological studies,
- adopt a "clinical trials" approach,

- include ecosystem/human health, and
- consider the impacts of extreme hydrological events on future population.

B.5 Policy and science - Day 2

B.5.1 Linking policy with scientific questions

In an attempt to identify the topics that should be covered in a future programme, each delegate was asked to formulate two questions and identify the policy areas that each addressed. Some questions / policy were duplicated. The list is not meant to be exhaustive but illustrative of the hydrological concerns of the scientific community.

Policy issues raised

1. Framework conventions, e.g., Commission for Sustainable Development, climate change, etc..
2. Population increase — the hydrological science needed to provide food and help avoid conflict over water.
3. Improve landscape resource management at a catchment scale.
4. Integrated water resource management.
5. Balance between the demands of the ecological and biological systems, and man.
6. Water policy - science or legally driven?
7. Water regulation - hindering or helping water development?
8. Environment at a regional scale - price - subsidies - incentives, international competition, maximize employment.
9. Prediction/science advice to the community — protect integrity.
10. Reconciling competing users of water (evolving responsibility).
11. Alleviation of world poverty. Water requirements of future food production (sustainability of resource base).
12. Optimum policy for design/management of water resource systems.
13. Public assurance given on health aspects of water.
14. Freedom of information to real-time data to improve warnings of hydrological events.
15. Long-term reliability of reservoirs for water supply.
16. Protection of coastal waters (e.g., coral reef).

The scientific questions (and policy relevance in brackets)

1. Can the effects of climate change be detected with certainty in the hydrological cycle? (1)
2. Can changes in the hydrological balance due to land-use change be detected over climate change? (2)
3. Can we maximize water resources (use water efficiently) whilst maintaining a balance between man/industry/energy and the ecosystem? (3, 11)
4. Can hydrological process understanding improve the productivity of agricultural land? (2, 11)
5. Can we improve downscaling of hydrological information from large-scale experiments to catchment scale? (3)
6. Can we improve understanding hydrological/biological processes at a catchment scale and then upscale? (3)
7. How do we apply our scientific knowledge in improving integrated water resources management? (4,11)
8. Can we better understand the hydrological processes in large catchments? (3,11)
9. What is the hydrological value for decision makers of forecasting a season ahead? (3,11)
10. How do we determine hydrological pathways — isotopes? (3)
11. How do we assess water resources in semi-arid regions? (3,11)

12. Can we improve upscaling from micro hydrological/biological processes to catchment scale?
13. Can we improve model testing under a range of data density?
14. What are the benefits of remote sensing in hydrology as distinct from earth observation science?
15. Can we predict biomass in a catchment using hydrological models driven by remote sensing and climate prediction? (1,4)
16. Do present institutional arrangements and water use patterns make society susceptible to climate change? (1,11)
17. What scientific indicators are needed to evolve results in relation to integrated water resource management? (10) (4)
18. What is man's impact on hydrological and bio-geochemical processes at a range of scales? (10)
19. What is the relative efficiency of water use in different elements within a catchment? (4,11)
20. What are the hydrological interactions between different elements of the catchment? (4,11)
21. Are local statistical hydrological variables influenced by global variability and change?
22. Can we know the total chemistry/biology of a water sample?
23. Could links to the web (sensors) allow public to make their own predictions?
24. Can we improve understanding of sediment pollution in manmade lakes? (15)
25. Can we improve understanding of land to sea fluxes — flow and pollution? (16)

B.6 Summary - Day 2

A lunchtime working group brought together the identified policy issues and questions and formulated a structure for an outline proposal for an EHD.

B.6.1 A proposed structure

- Define the policy issues.
- Define the background and scope of the proposal.
- Define the activities — e.g., management, processes, model/technique (not necessarily this order).
- Define what is new about this programme (policy, techniques, approach, leading).
- Define the players — the stakeholders.

B.6.2 Key policy issues

- Water-related global security -
  - ⇒ food,
  - ⇒ climate, and
  - ⇒ conflict resolution, poverty alleviation.
- Integrated land and water management.
- Water and health -
  - ⇒ human and
  - ⇒ environment.

B.6.3 Key science questions

The science questions identified in Section B.5.1 have been grouped into three broad categories as follows -

- Process / Trends
  - ⇒ Hydrologic (18, 8, 6, 20, 24, 25)
  - ⇒ Bio-geochemistry (6, 18, 25)
  - ⇒ Climate (1, 11, 21)
  - ⇒ Landscape (2, 4, 24)
- Techniques / Models
  - ⇒ upscaling / downscaling (5, 12)

- ⇒ model development and validation (3, 15)
- ⇒ analytical techniques - uncertainty/problems (10, 22)
- Management (IWRM, ICM)
  - ⇒ demonstration projects (7, 9, 14)
  - ⇒ water use efficiency (3, 19, 21)
  - ⇒ institutional arrangements / reconciling uses (including environmental requirements) (17, 16)
  - ⇒ information services (23)

B.6.4 A name for the programme

Experimental Hydrology Decade has been used as a working title. By consensus, the following title for a new programme was proposed -

World Hydrology Initiative for Policy and Development

With the subtitle -

Providing the scientific basis for improved land and water management through a global network of experimental basins.

B.6.5 Timeframe

Since it is envisaged that WHIPD would build largely on existing hydrological infrastructure, the historical timeframes will, therefore, be variable. The intention would be to continuously run these as they are, or in an enhanced form, in addition to any new catchment infrastructures which may be put in place directly as a result of WHIPD.

C. CONCEPT FOR A WORLD HYDROLOGY INITIATIVE FOR POLICY AND DEVELOPMENT

C.1 Introduction

The vital importance of water in sustaining human and environmental health has been widely recognized in numerous national and international fora. Several recent international conferences and policy documents make explicit reference to the need to make sustainable use of our limited freshwater resources. Many of these documents recognize the greatest pressure on freshwater resources to be the continued escalation of global population. The large number of additional people on the planet, along with associated socio-economic pressures on freshwater resources and general lack of sanitation and waste-treatment facilities in high-population areas, are placing increasing demands on available water. Water scarcity is further exacerbated by climate variability and by the likelihood of climate change. Furthermore, degradation in water quality causes a critical reduction in the amount of freshwater available for potable, agricultural, and industrial use.

The UN agencies have been encouraging water data collection and analysis for over four decades. All of their most recent assessments support these rising concerns and the urgent need for action to address the global water management issue. For example, the United Nations' Commission on Sustainable Development (CSD) documentation emphasizes the emerging issue of global water scarcity, partly in response to recommendations of the Rio Conference and Agenda 21. In 1994 the CSD called for *a comprehensive assessment of freshwater resources, with the aim to identify the availability of such resources, making projections of future needs, and problems to be considered.* Three years later, the "Comprehensive Assessment of the Freshwater Resources of the World" was presented to CSD 5 and the UN General Assembly Special Session (UNGASS). This document was prepared by a steering committee comprising all UN agencies involved in freshwater, and in cooperation with the Stockholm Environment Institute. A further important step towards realising the CSD objective will be the publication of the UNESCO-IHP monograph 'World Water Resources'. This will establish broad baseline information, but concludes *much is still to be achieved and many aspects need to be improved, in particular global hydrology networks and the collection and processing of data to ensure greater accuracy and reliability in water resources assessment.*

The European Commission has examined water issues across Europe (Freshwater: a challenge for innovation, 1998). This widely consulted document highlights water as a strategic resource, and recognizes that *even in areas with high precipitation and in major river basins, over-use and mismanagement of water resources have created severe constraints on supply. Such problems are widespread and will be made more acute by the growing demand on freshwater arising from increasing economic development.* A recent UNESCO-IHP international conference addresses the issue of *the looming world water crisis* and concluded that positive action was needed in a number of areas to avoid the worst disasters.

It is clear that global water issues are often mentioned on the international stage. However, existing international scientific programmes typically report on the state-of-the-art in one particular aspect of the water sciences. There is still a need for a complementary scientific programme which addresses key water resource management issues in the field and closely integrates policy and management needs. The WHIPD programme is, therefore, different from, and complementary to, these existing international programmes because it:

- acknowledges and responds to societal needs and incorporates the involvement of stakeholders and relevant scientific disciplines;
- recognizes population growth as the principle driver in future demands for freshwater;
- contains an explicit and flexible capacity-building element. This enables appropriate participation by both developed and developing world nations;

The WHIPD programme is focused expressly on providing the scientific basis for developing sound water policy for sustainable development. The next sector of this concept will, therefore, outline key global policy issues relating to freshwater.

C.2 Policy issues

C.2.1 Water use in providing food for a growing population

Today some 1 billion people in the world do not have access to enough food. Based on likely scenarios for population growth, it now appears that at least half of the world's population in 2025 will live in water-scarce regions where food self sufficiency will be extremely difficult to achieve. A substantial food gap seems unavoidable in these regions unless more efficient use can be made of existing water resources. Irrigated agriculture presently uses some 70% of the withdrawals of renewable freshwater. Water tables are falling and rivers are running dry in many food-producing areas due to over abstraction. In the past, focus on water resources for food production has largely been on water for irrigation. Little attention has been paid to how water is used in rainfed agriculture, which constitutes some 85% of the agricultural lands and produces two-thirds of the global food supply. A major effort is therefore required to look at the technical and non-technical aspects of increasing the efficiency with which water is used in both rainfed and irrigated agriculture.

C.2.2 Competition for water and potential conflicts

Expanding populations in water-scarce regions will inevitably lead to increased competition for the limited water available in rivers and aquifers. On a national level, competition will occur between urban and rural populations and between agriculture, households, and industry. Internationally, the risk for conflicts arising from food-driven water scarcity are substantial. However, water also provides a powerful tool for cooperation and has often been the vector for parties in conflict to achieve agreement. Water should therefore be seen as a major opportunity for .second-track diplomacy and conflict resolution, especially in the glóbe's 200 or so international river basins. WHIPD will provide a wide range of "test cases" for developing and testing methods for conflict resolution

C.2.3 Water quality impacts on human health

Human health is still at risk due to water quality problems. In 1992, 1.2 billion people (20% of the world population) did not have a safe supply of water, and about 50% of the population had inadequate sanitation. A recent UN report states that *more than 5 million people die annually just from diseases caused by unsafe drinking water and lack of sanitation and water for hygiene. According to the World Health Organisation (WHO), billions of people are at risk due to water-borne diseases.* An increasing population is leading to water quality degradation which may be more immediate and serious than the projected water resource impacts from other phenomena such as global climate change.

C.2.4 Environmental water needs

Wetlands and biodiversity are threatened by water withdrawals and water pollution. A balance must be found between the protection of crucial ecological services and human water requirements. Where there is insufficient water for both human and environmental needs, some consistent quantitative basis for deciding on the effects of suboptimal water supply needs to be evolved. The degree and extent of water pollution effects on ecosystems also need to be much more clearly identified, if this escalating problem is to be effectively managed.

C.2.5 Impact of climate variability and change on water resources

The effect of human activity on water resources are additional to the inherent stress on water resource systems that already result from natural climate variability and potential climate change. The impact of climate variability and change is therefore particularly important for human survival where water resources are already under great stress, such as in arid and semi-arid areas, but there is also likely to be major economic impact in more humid, well-developed areas of the world. The Intergovernmental Panel on Climate Change (IPCC) recently concluded that *the increasing cost of climate variability, in terms of loss of life and capital due to floods, storms and droughts, are the result of the lack of adjustment and response in society's policies and use of resources.* This places emphasis on the need to develop understanding and proven methods for improved water resource management that acknowledges that the locally-measured statistics of hydrological variables may have a deterministic component related to global phenomena, and which recognizes possible future changes in climate.

C.2.6 Improved communication between hydrologists and society

There is frequently a serious lack of communication between the scientific community, managers, planners and policy makers. Water-related issues are highly multidisciplinary and encompass a number of other environment and development issues such as links to land degradation, biodiversity, air and water pollution, agricultural development, rural and urban development, climate change and sea level fluctuations. The call for an integrated approach is often done in order to address these issues properly. Such an approach requires participation and communication. Following the increased recognition of the complexity of water resources issues there is therefore an urgent need for improved communication among and within the scientific communities, planners, managers and policy makers. There is a trend that more data, from different disciplines, are combined and that the exchange of data is increasing, but this does not mean that there is a common framework being developed on how to support a dialogue between the users and providers of data. The increasing amount of data and information is not necessarily of benefit to the users. What users need is often tailor made information that is specifically gathered and processed to suit their needs.

Future hydrological monitoring and data analysis needs to be carried-out with the involvement of principal stakeholders from the onset. This should mean that the type of hydrological information obtained in the future is more likely to be that which the water managers, planners and policy makers require. The necessary stakeholder consultation to ensure that this important link between science and policy is made in the WHIPD initiative needs to happen during the next stages of development of the proposal.

C.3 Objectives

To address the above policy issues, we need to understand important aspects of hydrological systems at a range of temporal and spatial scales and for a range of biophysical conditions. By focusing investigations on drainage basins with differing climatic, hydrogeological, and biophysical environments and facing the full range of pressures of population and economic development, global pictures of cause and effect relationships, and appropriate and robust basin management techniques can be formulated. Contrasting basin responses in similar climatic, hydrogeological and biophysical settings, but with differing resource management options, will provide the scientific information required to develop tools for improving water management.

The primary objective of the initiative is therefore to provide the process understanding and derived management tools within a drainage basin framework for improved land and water management. The initiative aims to establish a global network of representative catchments where consistent observations of key elements of the hydrological cycle will be made. The bioclimatic, geophysical, and management characteristics and regulatory frameworks of the catchments will also be determined. This network will be based as much as possible on existing monitoring sites.

Nomination of catchments for WHIPD will be voluntary, and selection criteria will be developed in collaboration with national organisations according to local requirements. To ensure maximum mutual benefit, mechanisms will be established that optimize exchange of data and process understanding between the scientists involved in research and monitoring carried out under WHIPD.

C.4 Scientific issues

Earth systems processes are intimately linked. The simple fact that water runs downhill provides the basis for evaluating human and natural influences on hydrological processes. These processes must be understood along water pathways in the landscape. A land management decision is thus also a water management decision, and upstream impacts on the water cycle affect downstream users. The most natural framework for the evaluation of water management issues is therefore the drainage basin. The key issues to be addressed in any given drainage basin will vary according to local climate, soils, land uses, and socio-economic conditions. However, some basic elements should be common to most/all catchments. First, the water balance and water quality impacts of the main elements of a catchment need to be determined. For example, a basin may contain forests and agriculture, and the water regimes of these need to be known along with their associated economic, social, and policy implications. Second, the interactions between each element in a landscape with others in the basin need to be known. For example, how much water and pollutant flows from an agricultural area to a forested area, or *vice versa*. This information is vital if rational decisions are to be made about the relative efficiency with which water is used in different parts of a catchment. In turn, this information is needed to make sound economic, social, and policy decisions on land and water management.

Modern data collection using remote sensing, and large-scale climate modelling has enabled estimates to be made of hydrological variables across the entire globe. However, these sources of proxy data need to be refined and carefully compared with more direct observations. These direct observations can never be realized over the entire globe; therefore, one objective of the WHIPD catchment network is to provide ground-truth test areas, covering key climatic/biome permutations where remote sensing techniques and global models can be tested.

Global data sets which monitor the status of the atmosphere, oceans and biosphere that make up the Earth's climate system are now readily available worldwide via the Internet. In the course of the next decade, there will be major investments in observing systems, modeling and process studies under WCRP and IGBP. These research initiatives promise better understanding and documentation of the Earth's energy and water cycles, and improved identification and prediction of the global and regional phenomena that give rise to fluctuations and long term change in these cycles. By complementing these global research programs with a distributed network of well-documented research catchments, WHIPD will create the worldwide capability to interpret understanding of global processes directly into the water environment at catchment scale where it has most relevance to human welfare.

It is recognized that -

- Catchment hydrological research should be done in the service of human welfare.
- Hydrological analysis/design based on historic datasets, collected over a few decades and treated as if totally random in origin, will not meet future societal needs.
- Experimental hydrology has focused mostly on microscale, i.e., on-site management questions with no field experiments, to address process hydrology at the mesoscale where the interest to managers lies.
- Within hydrology, model development has surpassed the ability to validate and calibrate the models with field observations.

- Interannual variability implies the need for long-term experimental hydrology data sets to address extremes, but there is declining support for long-term monitoring.

Specific questions to be answered by the programme follow.

C.4.1 Hydrological variability and change

Can changes in the hydrological cycle (quantity and quality) be detected and at what scale(s)? Can they be attributed to changes in water management, land-use change, climate change, or a combination of these?

C.4.2 Biophysical processes

Which hydrological processes are affected by land-use change and soil degradation? How can we use the understanding of them to improve the efficiency of agricultural water use? How do these processes affect catchment water balances? How can we generalize this knowledge to the catchment scale using global models/satellite observations?

C.4.3 Pathways and modelling

What are the hydrological interactions between different elements of the catchment? Do we understand the controlling process well enough to model complete catchment behavior. What is the impact of different data densities on the results of the models? Can the model outputs be used to simulate results of land and water management options on a catchment scale? Can isotopes be more fully exploited as a means of identifying hydrological pathways?

C.4.4 Applications of global models and remote sensing

Can we derive hydrological parameters at the catchment and regional scale using global-scale data? Can observations of the current status of the oceans, atmosphere and biosphere and predictive models of their future development be used to predict the climate and the hydrological response at the seasonal-to-interannual time scale? How can these predictions be made useful for water managers and the general public?

C.5 Project design

The initiative aims to establish a global network of representative hydrological catchments covering, key climatic, hydro-geological, biophysical, socio-economic and policy environments. WHIPD will be based as much as possible on existing monitoring sites, thereby capitalizing on current and historic hydrological knowledge. It will also develop new scientific knowledge where key gaps exist, for example to provide data and models for more accurate assessment of freshwater resources and ground truth data for global climate models.

It is envisaged that catchments would be nominated by local stakeholders, according to local management priorities. A multidisciplinary international steering committee could be formed to advise on baseline measurements, methods, and ways of networking with other WHIPD participants.

The study design will be iterative, combining past, current, and emerging issues with process understanding gained from data analysis. It is important to evaluate the transfer value of process understanding and related system modelling for basins within, and between, hydroclimatic zones. A suite of ongoing studies will therefore be selected for comparison and to provide contrast with basins targeted for 'new' data collection and analysis. The international network is likely to evolve according to financial possibilities and priorities set by the participants.

It is suggested that the *selected catchments* will:

- cover a range of bioclimatic zones, socio-economic activities, and cultural environments
- be representative of the surrounding area to be able to generalize findings to a wider region
- be part of existing international networks, e.g., ERB, GTOS, GWP, FRIEND, WHYCOS, etc.
- for some, be located within GEWEX continental scale programmes (GAME, GCIP, etc.)
- preferably have been operational for a few decades allowing historical and/or proxy data to be analysed
- from the start of the WHIPD programme, be observed for at least 10 years but with the aim to be made permanent
- after some time will number ~100 - 200 worldwide.

It is suggested that *observations* will be:

- an agreed range of basic hydrological, isotopic, land use, agricultural, biological, and socio-economic measures
- according to standard protocols for data collection and exchange, e.g., the WMO guidelines
- principally aimed at the study of the catchment water balance, its chemical regime, and hydrological processes
- starting early in the next decade to ensure maximum benefit from the interaction with complementary global research programmes.

The basis for the implementation of WHIPD is that it is a global network, the participants in which contribute something to the network as well as receiving something from it. The detailed guidelines and conditions for this to work are yet to be defined, but they could follow the very successful FRIEND model developed through the UNESCO IHP framework.

It is recognized that many developing countries will not be able to achieve the objectives of the initiative without substantial increase in their hydrological capacity. Capacity building will be required to collect, process and analyse the hydrological data needed by WHIPD. It is therefore a high-priority of this initiative to put in place the necessary training and human exchange programmes to build-up the hydrological expertise of developing countries. The physical infrastructure of catchments in developing countries is no less important and it will be a priority objective of WHIPD to ensure that funds are available to maintain the necessary measurements.

C.6 Relation to existing programmes

The proposed initiative is complementary to and would build on the activities of other international programmes, e.g., IHP, GEWEX, CLIVAR, GEMS/Water and GWP, and would continue to interface with them. However, this programme would expand the research from data collection and analysis of current status and trends to scenario analysis and a compilation of robust land and water management strategies for the future.

The GEMS/Water programme, to date the only international programme strictly devoted to water quality, has contributed significantly to a global appreciation of the current water quality status and trends by working with long-term fixed-station monitoring and by providing some synthesis at regional level. The IHP has contributed to understanding hydrological and ecological processes, but it needs to be strengthened via a more extensive network of global observations.

The IHP FRIEND project is complementary to the current initiative. FRIEND provides a near-global coverage of regional hydrological networks, and the emphasis has been on the collection and analysis of river flow data measured at national network sites. The WHIPD programme would complement

FRIEND by focusing on the understanding of the entire catchment water balance including water quality and links to socio-economic development issues.

In the context of the WHIPD initiative, the most relevant objectives of GEWEX are its modelling of the global hydrological cycle and its impact on the atmosphere, oceans, and land surface, and the development of the ability to predict the variations of global and regional hydrological processes and water resources as well as their response to environmental change. The WHIPD programme could provide GEWEX with the long-term globally extensive ground-based measurements of the hydrological cycle required to test large-scale models and remote-sensing techniques and, in return, contribute to efforts to communicate relevant information on water resources emanating from the GEWEX programmes to policy and decision makers.

C.7 Next steps

The next step is to put the proposal in its outline form to the Fifth Joint UNESCO/WMO International Conference on Hydrology to be held in Geneva from 8 - 12 February 1999. Acceptance of the proposal at that conference and the willingness of UNESCO to adopt WHIPD in support of the IHP VI will ensure a sound basis for further planning. This planning can be undertaken at various scientific meetings and refined to a state so that a definite proposal can be incorporated into UNESCO's future plans for the IHP which can be put to the next Intergovernmental Council of the IHP.

As the concept evolves, updates will be posted on the WWW at http://www.nwl.ac.uk/ih/whipd (this will be online in early 1999). We would particularly welcome suggestions on the focus of the programme and preliminary indications of catchments which could be included in the network.

D ANNEX I GLOSSARY OF ACRONYMS

BHS	British Hydrological Society
CEC	Commission of the European Communities
CHASM	Catchment Research and Sustainable Management
CLIVAR	Climate Variability Research Programme
CSD	Commission for Sustainable Development
EEA	European Environment Agency
EHD	Experimental Hydrology Decade
ERB	European Network of Experimental and Representative Basins
EU	European Union
FRIEND	Flow Regimes from International Experimental Network Data
GEWEX	Global Energy and Water Experiment
GNIP	Global Network of Isotopes in Precipitation
GWP	Global Water Partnership
IAEA	International Atomic Energy Authority
ICM	Integrated Catchment Management
IGBP	International Geosphere-Biosphere Programme
IHD	International Hydrology Decade
IHP	International Hydrology Programme
IPCC	Intergovernmental Panel on Climate Change
ISOHIS	Isotope Hydrology Information System
IWRM	Integrated Water Resource Management
KITT	Knowledge, Information and Technology Transfer
LOCAR	Lowland Catchment Research
NASA	National Aeronautics and Space Administration
NICHE	National Infrastructure for Catchment Hydrology Experimentation
OHP	Operational Hydrology Programme
UNESCO	United Nations Educational, Scientific and Cultural Organisation
WHIPD	World Hydrology Initiative for Policy and Development
WMO	World Meteorological Organisation
WWC	World Water Council

E. ANNEX II: MEETING PARTICIPANTS

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F. ANNEX III MEETING AGENDA

Monday 30 November 1998

09.15 - 09.30	Welcome and opening remarks	Jim Wallace
09.30 - 10.00	Background of the proposed EHD and purpose of the meeting	Mike Bonnell
10.00 - 1300	*Presentations of related initiatives:*	***Chair: J Wallace***
10.00 - 10.15	The IHP FRIEND project	Alan Gustard
10.15 - 10.30	Summary of future UNESCO IHP VI programme	Kuniyshi Takeuchi
10.30 - 10.45	Summary of future WMO OHP and related programmes	Johan Kuylenstierna
10.45 - 11.15	Coffee	
11.15 - 11.30	International Isotope Hydrology decade and its links with IHP VI	Din Dayal Sood
11.30 - 11.45	GWP proposal for Water Quality Management	Janusz Kindler
11.45 - 12.00	Global Water Quality Initiative	Jake Peters
12.00 - 12.15	Future GEWEX programmes involving experimental hydrology	Rick Lawford
12.15 - 12.30	Future NASA programmes involving experimental hydrology	Eric Wood
12.30 - 12.45	The Global Hydrology component of an EHD	Jim Shuttleworth
12.45 - 13.00	UK plans for future Catchment research facilities	Dick Bradford
13.00 - 14.00	Lunch	
14.00 - 15.00	*Presentations of related technical issues:*	***Chair: M Bonell***
14.00 - 14.15	Water scarcity and food security	Malin Falkenmark
14.15 - 14.30	Water use in Agriculture	Jim Wallace
14.30 - 14.45	Integrated catchment management planning in Southern Africa	Roland Schulze
14.45 - 15.00	Regulatory and legal structures affecting water management	Patricia Wouters
15.00 - 15.30	Tea	
15.30 - 16.00	*Introductions to the discussion*	
15.30 - 15.45	The Exeter statement	Frank Law
15.45 - 16.00	How can experimental hydrology help international hydrological sciences	John Rodda
16.00 - 17.00	*Discussion:* Are there key interactions between hydrological science and social, economic, political and legal structures which require an experimental hydrology approach within a drainage basin setting ?	

Tuesday 1 December 1998

09.00 - 09.30	Review of progress: should there be an EHD ?	Jim Shuttleworth
09.30 - 12.30	Steps towards implementation: • Which topics should be covered in EHD • Outline basic structure • Relationship of the EHD to other initiatives (IHP, OHP, GWP, ICSU activities) • Working plan • Immediate actions	*Co-Chairs:* *W B Wilkinson &* *K Takeuchi*
12.30 - 13.30	Lunch	
13.30 - 15.00	Remaining issues	*Chair: R Schulze*
15.0 - 15.30	Conclusions and closure	Mike Bonell

G. ANNEX IV: RELATED INITIATIVES AND RECENT PAPERS

Initiatives

No.	Author	Title
1	Unesco	A comprehensive global water quality initiative
2	GWP	Water quality management (proposal)
3	EEA/WHO	Monograph on water resources and human health in Europe
4	EU	Protocol on water and health (draft)
5	CEC	Fifth framework programme
6	CEC	Freshwater initiative: EU policy objectives
7	CSD	Strategic approach to freshwater management
8	Unesco	Water: a looming crisis?
9	WWC	Long term vision for water, life and the environment
10	CEC	Freshwater: a challenge for research and innovation
11	Shiklomanov	World Water Resources: 21sh Century
12	UNESCO	IHP-VI proposal
13	UNESCO	List of IHP-V projects
14	11 authors	Montreal statement
15	Conference	Exeter statement

Papers

Author	Title
Entekhabi *et al.*	An agenda for land-surface hydrology research and a call for the second International Hydrological Decade
Falkenmark *et al.*	Water scarcity as a key factor behind global food insecurity: round table discussion
SCOWAR	Water resources research: trends and needs in 1997

Centre for Ecology & Hydrology

Component Institutes
Institute of Freshwater Ecology
Institute of Hydrology
Institute of Terrestrial Ecology
Institute of Virology & Environmental Microbiology

Natural Environment Research Council