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Towards the 21st Century:

Research and Operational Needs

(Paris, 22-26 March 1993)

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PREFACE

Approximately every six years, UNESCO and WMO jointly convene an international conference to co-ordinate their hydrology and water resources activities. In view of the increasingly important role being played by non-governmental scientific and technical organizations in this field, the two conference convenors were joined by ICSU for this, the fourth such conference in the series.

The UNESCO/WMO/ICSU International Conference on Hydrology - Towards the 21st Century: Research and Operational Needs, was opened in UNESCO, Paris, on Monday, 22 March, the day that the *World Day for Water* was celebrated for the first time.

The purpose of the conference was:

- To follow-up on UNCED (United Nations Conference on Environment and Development, Rio de Janeiro, June 1992) and its Agenda 21.
- To offer a forum for the free exchange of views on the current status and future direction of hydrological sciences, operational hydrology, interdisciplinary activities involving hydrology, and related education, training and capacity building activities.
- To encourage the development of innovative proposals for future activities under international programmes in hydrology.
- To review past activities and propose long-term priorities in order to help draw up the agenda for the hydrological programmes of UNESCO and WMO and related activities under ICSU, as an aid to the co-ordination of the relevant programmes of the three bodies.

The Conference treated four themes: Hydrological Research, Operational Hydrology, Interdisciplinary Activities, and Education, Training and Capacity Building. Each theme was introduced by keynote speakers and, after a brief discussion in the plenary session, participants worked in eleven smaller groups to formulate their views. Reports from each group on the themes were synthesized into four main theme reports, which form the core of the Conference Report presented here.

On its final day the Conference adopted the Paris Statement on Hydrology which summarizes the salient recommendations of the meeting.

P. Hubert
Chairman of the Conference

WORLD DAY FOR WATER

Recalling the relevant provisions of chapter 18 of Agenda 21, the General Assembly decided to declare 22 March of each year as World Day for Water to be observed starting in 1993. The General Assembly invited States to devote the Day, as appropriate in the national context, to concrete activities such as the promotion of public awareness through the publication and diffusion of documentaries, the organization of conferences, round tables, seminars and expositions related to the conservation and the development of water resources and the implementation of the recommendations of Agenda 21.

(text adopted by the forty-seventh session of the United Nations General Assembly)

THE PARIS STATEMENT ON HYDROLOGY

The World's water resources are coming under increasing stress; indeed in some countries a crisis has already been reached. Accelerating demand due to a rising population and growing water consumption per head, as affluence increases, is the chief cause. But the growing volume of pollution is a further factor and droughts intensify the difficulties. Hydrology, the science of the world's fresh waters, offers opportunities to overcome these problems and those of floods and other water-related natural disasters.

At the same time, many nations lack the capability to apply hydrology to their problems and to undertake the research needed. Their institutions are weak and fragmented and they have few educational and training facilities, often because governments have cut funding and staff. At the root of these difficulties is a lack of awareness amongst politicians and the general public and an appreciation of the gravity of the situation.

The participants at the UNESCO/WMO/ICSU International Conference on Hydrology meeting in Paris from 22 to 26 March 1993 building on the results of the International Conference on Water and the Environment and the United Nations Conference on Environment and Development made a number of recommendations for action, based on their discussions on hydrological research, operational hydrology, inter-disciplinary studies and capacity building, training and education. These recommendations are:

1. **To increase awareness of the value of water and information about water, on the part of decision-makers and the community at large.**

2. **To improve the contribution of hydrology and related water sciences**, by promoting interdisciplinary research focused on well defined projects of importance to society, by improving understanding of the hydrological cycle and by providing a scientific basis for the sustainable management of water.

3. **To increase the effectiveness of operational hydrology,** by better identifying and addressing users' needs, adopting modern management practices such as quality management, assessing and planning human resource requirements, and by closer co-ordination between scientific and operational hydrology programmes and those of other related disciplines.

4. **To further enhance the acquisition and transfer of technology and knowledge**, by sustaining research and educational programmes and capacity building in developing countries, the effective use of international training courses, and the development and dissemination of appropriate technology.

5. **To invite UNESCO and WMO to continue their programmes in hydrology and water resources** during the remainder of the Century and to set up a task group to consider with ICSU how closer co-operation should be effected at the national and international levels between their programmes and those of other UN agencies and Non-Governmental Organizations.

Paris, 26 March 1993

ACRONYMS

Agenda 21	The action programme of UNCED
CHy	Commission for Hydrology of WMO
COWAR	Committee on Water Research (A joint body of ICSU and UATI)
Delft Declaration	Declaration of the UNDP Symposium on a Strategy for Water Resources Capacity Building, Delft, June, 1991
Dublin Statement	Statement of the ICWE, Dublin, January, 1992
HOMS	Hydrological Operational Multipurpose System
ICSU	International Council of Scientific Unions
ICWE	International Conference on Water and the Environment, Dublin, January, 1992
IGBP	International Geosphere-Biosphere Programme of ICSU
IHD	International Hydrological Decade (1965 - 1974) of UNESCO
IHP	International Hydrological Programme of UNESCO
IHP-III	Third phase of IHP (1984 - 1989)
IHP-IV	Fourth phase of IHP (1990 - 1995)
Mar del Plata Action Plan	Action Plan of the UN Water Conference, Mar del Plata, 1977
New Delhi Statement	Statement issued by the participants of the International Consultation on Save Water and Sanitation for the 1990s, New Delhi, 1990
NGO	Non-Governmental Organization
OHP	Operational Hydrology Programme of WMO
UATI	Union of International Technical Associations and Organizations
UNCED	United Nations Conference on Environment and Development, Rio de Janeiro, June, 1992
UNESCO	United Nations Educational, Scientific and Cultural Organization
WCRP	World Climate Research Programme
WMO	World Meteorological Organization

REPORT OF THE CONFERENCE

INTRODUCTION

1.1 Jointly convened by the United Nations Educational, Cultural and Scientific Organization (UNESCO), the World Meteorological Organization (WMO) and the International Council of Scientific Unions (ICSU), the International Conference on Hydrology: " Towards the 21st Century: Research and Operational Needs", was held in UNESCO Headquaters, Paris, from 22 to 26 March 1993.

1.2 The opening session was addressed by Mr. Federico Mayor, Director-General of UNESCO, Mr. G.O.P. Obasi, Secretary-General of WMO and Mr. M.G.K. Menon, President of ICSU.

1.3 The 22nd of March 1993, the first day of the Conference, coincided with the first **"World Day for Water"**, declared by the United Nations General Assembly at its 47th session (November 1992). A World Day for Water ceremony was organized with the contribution of the French Ministry of Environment, whose representative, Mr. J.C. Laurent, highlighted in his statement the key importance of water for humankind. The ceremony continued outdoors with the launching of the hot-air ballon "The Drop of Hope", contribution of the International Secretariat of Water and Environment Development Action in the Third World.

1.4 The objectives of the Conference were to provide a forum for the free exchange of views on the current status and future directions in hydrology, and to review the respective activities of UNESCO, WMO and ICSU in order to help co-ordinate their relevant programmes. A total of 159 participants attended representing 55 countries, 7 UN Agencies and Regional Organizations and 5 non-governmental organizations.

1.5 The debates were conducted under the Chairmanship of Mr. P. Hubert, Chairman of the French IHP/OHP National Committee with four Vice-Chairmen, one for each scientific session: I. Shiklomanov (Russia), Chairman of the Intergovernmental Council for the International Hydrological Programme of UNESCO, Mr. K. Hofius (Germany), President of the Commission for Hydrology of WMO, Mr. U. Shamir (Israel), President of the International Association of Hydrological Sciences and Mr. Liang Ruiju (China), Vice-Chairman of the Intergovernmental Council for IHP.

1.6 The proceedings of the Conference were organized through several activities unfolded in plenary sessions and through 10 working groups. This permitted a thorough discussion of the four main themes of the Conference:

- **Hydrological Research**
- **Operational Hydrology**
- **Interdisciplinary Activities**
- **Capacity Building, Training and Education.**

The main conclusions of the different plenary and working group sessions were presented in the form of four session reports along the above themes. The theme rapporteurs were Mr. J. Fischer (USA) for hydrological research, Mr. P.M. Mosley (New Zealand) for operational hydrology, Mr. L. Veiga da Cunha (NATO) for interdisciplinary activities and Mr. A. Salih (Sudan) for capacity building, training and education.

1.7 On the final day the participants adopted the "Paris Statement on Hydrology" which highlights the five main recommendations of the Conference.

1.8 The Conference was closed by Mr. A. Badran, Assistant Director-General for Science, UNESCO.

2. HYDROLOGICAL RESEARCH

2.1 Hydrological research is a fundamental element of any successful operational hydrological organization. It provides the technical underpinnings upon which are based the understanding of natural processes in the field. Without technical understanding and an institutional mechanism to maintain and enhance this understanding, operational programmes are unlikely to succeed. This is particularly true in a fast developing science such as hydrology.

2.2 Hydrological research encompasses activity at all field scales and in the laboratory. It contributes to the understanding of the quantity and quality of water in its natural state and to the development of methods and tools, such as digital computer models and geographic information systems, to conduct the science. It is multidisciplinary in nature, requiring co-operation with the related sciences of meteorology, chemistry, biology, physics and many others. The value of a hydrological research team within a water-resource organization is not only to make technical advances to ensure technical adequacy but also to invigorate the atmosphere in which the science is accomplished.

Past achievements

2.3 The hydrology programmes of UNESCO and WMO have made many important contributions to the advancement of the science of hydrology. One of these contributions is providing an international focus for hydrological research. This support has contributed to notable technical advances in the science of hydrology, including the coupling of ground and surface water models, innovations in isotope hydrology, the incorporation of geographical information systems, and improved understanding of the relationship between the atmosphere, land surface, and hydrological systems, vital to the understanding of global change. Moreover, the support for hydrology provided by UNESCO and WMO has contributed directly to the development of sound basic data, a fundamental element in understanding hydrological systems. The activities of the organizations have also had the benefit of facilitating the transfer of hydrological knowledge and understanding between nations.

2.4 Naturally, difficulties have been encountered along the way, associated more with the science and practice of hydrology than with the programmes themselves. One difficulty is associated with data and is universal. Sufficient data to analyse the hydrological problems with which we are faced are not readily available. Not only are data commonly scarce but too often their quality is unreliable. Moreover, data are seldom collected with sufficient attention to protocol and are not stored in such a way as to facilitate retrieval by subsequent users. These are issues which all organizations funding hydrological research must work to remedy.

2.5 A second hindrance to effective hydrological research has been inadequate interaction between scientists in related fields. An example is hydrologists working on the problem of water quality in a stream without the close co-operation of biologists. This problem is not unique to international funding organizations, and along with the rest of the hydrological community UNESCO and WMO are moving swiftly to make the execution of hydrological research a true multidisciplinary exercise. The emergence of interdisciplinary issues such as global change has served to increase such co-operation, as has the recognition that surface water quality investigations can be carried out more economically and with significantly improved insight with the help of aquatic biologists.

2.6 Another problem concerns progress in modelling which, although technically important, may have outpaced both theoretical and field validation. In fact, there has been a proliferation of more complicated mathematical formulations which have not been particularly useful to the advance of scientific understanding or to practical application in the field.

The present situation

The key considerations

2.7 The pressure on the availability of fresh water for many nations of the world is accelerating and in many areas has reached or will reach crisis level in our lifetime.

2.8 It is within this reality that international organizations are attempting to promote and support hydrological research. It is obvious to those in the science that the information that we develop in our daily work is vital to the resolution of many serious water problems. Unfortunately, that fact is not so clear to many of those in leadership positions who, when faced with difficult budget situations, make decisions to curtail hydrological programmes fundamental to the effective management of their water resources. It is clear that hydrologists must do a better job of acquainting national leaders with the contribution which long-term hydrological records and their interpretation can make to the well-being of the people. We may have been too content to publish in the professional literature, forgetting to inform and educate the general public as to the use and benefits of our information. The unfortunate result has been that, although water resources issues are quite visible to our leaders, the science of hydrology is much less so.

Financial considerations

2.9 An aspect of the reality within which international organizations must deal is the insufficiency of funds available for the purpose of supporting hydrological research. Although funding for research has never been plentiful, the decrease in recent years has had a particularly negative effect on the ability of the hydrological community to support field studies. More painful, perhaps, has been the degradation in hydrological gauging networks brought about by the insufficiency of funds to maintain the number of stations or to repair stations after damage by storm, simple wear and tear, or vandalism. It is difficult and sometimes impossible to compensate for the loss.

2.10 The most basic result of the curtailment of funds, of course, is the decrease in ability to support basic hydrological research and study around the globe. This is reflected in the curtailment of many experimental catchment programmes since the 1980s. The research products from programmes such as these rank among the most important achievements of the IHD/IHP. It is tragic that funding support for such activities is decreasing at a time when we are becoming aware that the earth is a single system and that ecological catastrophes on one continent could have a catastrophic effect on other continents as well. There is a clear and serious need for improved understanding of hydrological processes everywhere in the world but particularly in nations of the "South".

Organizational considerations

2.11 There is a question regarding the number of international organizations involved in hydrological research, specifically whether that number might be reduced without losing effectiveness and perhaps even improving the situation. The question is an interesting one in that it also pertains to the number of organizations in individual nations.

2.12 Most countries are burdened with badly fragmented water programmes: some measure, perhaps, of the universal importance of the resource. It is possible that reducing the number of organizations, through combining one or more (leaving total funding intact) would provide a larger, more visible entity, capable of achieving greater financial and programmatic support.

The future

The most pressing needs

2.13 The need for additional hydrological research, basic as well as applied, is substantial. The issue of resource *vulnerability* is fundamental to the concept of sustainability. Without a reliable water supply and safe sanitation, it is highly unlikely that developing nations can continue to progress.

2.14 An area within which a great deal remains to be accomplished concerns *ground water in both the unsaturated and saturated zones*, these areas having been less intensively studied in comparison to surface water. Such interactions are particularly crucial to the improved understanding of groundwater quality and again to the issue of vulnerability. Our groundwater resources are at risk and the fact that they do not recover easily or quickly from over-exploitation or from the introduction of contaminants means that, in many cases, human beings millennia from now will be living with the consequences of our action or inaction in dealing with this element of our water resource.

2.15 One of the greatest needs in the hydrological community is to communicate the importance of our potential contribution to the leaders of nations. So far, we have not been effective in that regard and this ineffectiveness has resulted in a lack of understanding of our relationship to relevant social issues and a consequent lack of support in the budget process. It is frustrating to see a crisis in the making, to have the skills that could be useful in managing the crisis, and to be unable to bring these skills to bear.

2.16 We must work harder and be more effective in communicating with non-technical audiences. One way to accomplish this objective is to publish in a wider range of journals with an increased focus on those less technical.

2.17 There is a need for a better integration of related sciences in our hydrological models in order to present a way of understanding the broader environmental system within which water exists. The issue of scales and how to move from one to another needs to be resolved.

2.18 The issue of buffering in natural environments relates to the ability of a terrain to accept a certain amount of contamination and, through processes such as biodegradation, withstand the introduction without presenting an immediate or long-term health risk to living organisms. This "natural remediation", particularly in groundwater systems, is a promising area for hydrological research.

2.19 There is a need to address more effectively the issues of non-stationarity in hydrological time series and the development of regionalization methods. Addressing the latter could also help to address the problem of technology transfer of humid-temperate research results to the "South".

2.20 Research emphases should be given to scale problems, issues related to ecohydrology, connections between hydrology and climate, and the vulnerability of the water resource.

2.21 In addition to these specific areas, others supportive of them exist. Among those are:

- Revitalization of experimental field sites and studies;
- Hydrology studies to improve the understanding of physical processes;
- Support for sustained hydrological research in developing countries, particularly those in the humid, semi-arid, and arid parts of the tropical world; and
- Development of integrated models that take into account the atmospheric-hydrological and ecological processes in different landscapes and at different scales.

2.22 An issue which must be faced by all international organizations and national governments is the disparity between developed and developing countries in the ability to deal with water resource issues. In many developing countries, sufficient funds are not available to support either hydrological research or adequate data collection, and yet it is often in these countries that water resources are under the most pressure.

2.23 If one accepts the concept of global sustainability and the intercontinental links of global change, then it is clear that we are all equally responsible and funds to support the understanding and wise management of the water resources of all the nations of the world must be found.

Institutional changes

2.24 The question has been raised as to what if any institutional changes, nationally and internationally, might contribute to improvement in the environment for hydrological research. It is clear that many organizations at all levels of government,

currently have responsibility for some aspect of hydrology and, as a result, the focus for hydrological research is unclear. Such a fact suggests either that the responsibilities of several agencies be folded into one or that greater importance be placed on communication and co-ordination between agencies. The issues of consolidation are complex and beyond the scope of this Conference. If the co-ordination option is followed it should be pursued vigorously within and between research and operational organizations to include programmes from conception to conclusion, publications, meeting and conferences, research strategies, etc.

2.25 What are the most urgent issues facing international agencies related to the support of hydrological research? There are several, each addressed in varying detail earlier in this section.

- One of the most important is to work more closely together, avoiding duplication of activities so as to optimize the use of limited resources and to derive benefits from cross-fertilization;

- The next is to provide funds and leadership to assist developing nations in establishing and maintaining long-term water data networks to support the wise management of the water resource;

- Another is to encourage the hydrological community in improving its ability to carry not only the message of the importance and vulnerability of the water resource, but also the necessity and importance of hydrological research to those in leadership positions and to the general public;

- And finally, perhaps the most urgent need of all is to support staunchly hydrological programmes in the developing nations in recognition of the fact that their fate will not be divorced from that of all nations.

3. OPERATIONAL HYDROLOGY

3.1 Operational hydrology is fundamental to the management, assessment and forecasting the quantity and quality of water, and providing the information needed to mitigate floods, droughts, pollution incidents, and similar water-related hazards.

3.2 Operational hydrology is a technical discipline. Its scope includes:

- Collecting, analysing, and supplying information about the quantity, quality and bio-chemical characteristics of both surface water and ground water;

- Developing and applying technology, including instrumentation, observing systems, standards, data processing and archiving systems, forecasting and water resources management.

3.3 International effort in operational hydrology aims to ensure that all countries have these capabilities, by transferring technology and providing appropriate technical assistance.

3.4 Operational hydrologists call upon many other disciplines, including meteorology, microbiology and physics, and experts in such areas as electronics, engineering and analytical chemistry. Their customers include planners, resource managers, civil defence workers, indeed, all sectors of society and the general public. Operational hydrologists are responsible for providing decision-makers with the information they require, when and where it is needed, and in an easily usable form. Operational hydrology must respond to a rapidly changing world.

Past Achievements

3.5 Operational hydrologists in the developed world now have a very sophisticated ability to collect, store and analyse water-related information, and to supply it to their customers. To do this, they make use of advanced instrumentation and remote-sensing technology, data transmission systems such as radio and satellites, computer hardware and software, and highly developed sets of procedures for data collection and quality assurance. This ability has been applied in many countries:

- To assemble data-banks of historical information as a basis for project design;
- To provide real-time information for water resource management;
- To forecast conditions, enabling the impacts of water-related hazards to be reduced or avoided.

3.6 Operational hydrology has enabled the construction and operation of a great range of water-related projects; such as those for irrigation, hydro-electricity, water supply and waste disposal, and water transport.

3.7 Nevertheless, not all countries have been able to develop this capability themselves, and the status of water resources on the global scale is still only approximately known. A key role of the international organizations with water-related responsibilities has therefore been to arrange technology transfer and technical assistance to those countries which need it. Notable achievements in this process include the preparation of guidance materials, instruction manuals and other documents; the provision of training courses and higher education to hydrological personnel, technology transfer, intercomparison, and demonstration projects, the establishment of international databases to support projects on regional and global scales.

3.8 Even now, however, many developing countries still have poorly equipped and ineffective hydrological services. Obstacles have included:

- Competition for scarce financial resources, in countries which are still struggling to provide the basic amenities of life to their people, as operational hydrology often has not been recognized as a priority;
- Disorganization, where operational hydrology is carried out in several agencies with little or no co-ordination;
- Inability to benefit from available technology, because of language difficulties or lack of knowledge of what is available;
- Pressure on water resources from the rapid growth in population, which has outstripped the ability to provide the necessary hydrological information;
- Deficient information on, in particular, ground-water, water quality, and aquatic biology, because of a limited view of what types of water-related information are required;
- Inability to access data from other sources;
- Lack of trained technical and managerial staff, and the "brain drain" to other organizations and countries where career prospects are better.

In some countries, such gains as there have been are threatened by adverse economic conditions.

The present situation

The key considerations

3.9 There are four key considerations:

- The climate is highly variable, and may be progressively changing in response to both natural and man-induced processes, with consequent impacts on water resources;
- The most severe resource management issues exist under extreme conditions: in time, during floods and droughts; in space, in arid, semi-arid, and tropical areas, and in coastal areas;
- Global environmental issues must be faced; the environment is increasingly seen as a unity; natural resources including water must be managed in an integrated, holistic way, and in the context of social and economic systems;
- Operational hydrologists must see their role in this context, and be ready to extend their activities beyond current boundaries. They should recognize that the resources available to pay for environmental (including water) information may well not increase significantly, but will be spread across a widening range of variables.

Financial and organizational considerations

3.10 Obstacles which have prevented the satisfactory development of operational hydrology are almost all, in the end, financial or organizational in nature. The funds available are limited, both to develop technology and - perhaps more importantly - to attract and retain staff who are able to make the most effective use of the available resources. There are a number of specific consequences of limited funds, at the country level.

3.11 Firstly, observation networks for "traditional" hydrological variables, precipitation and streamflow, are inadequate in many areas. Hydrological observation networks are in decline in many developing countries. Other types of hydrological information needed for resource management, such as on ground water, water quality, soil moisture, and evaporation, are scarce in most developing and in some developed countries. Related types of information, for example, water use or fresh-water fisheries, or aquatic ecosystems, may be entirely lacking, because their need has not been recognized or skills are not available to collect them.

3.12 Secondly, new technologies may not be accessible to those countries which most need them, because of their high initial cost, lack of the high-level skills needed to operate them, and the difficulty of ensuring ongoing maintenance. The new technologies including remote-sensing from satellites, telemetry of data, weather radar, solid-state data loggers which can be downloaded directly into computers, and state-of-the-art computer software provide opportunities for acquiring information more cheaply and efficiently, and to higher standards of quality. On the other hand the very latest technologies may not be appropriate or sustainable, and premature adoption may result in wasted resources and loss of data.

3.13 Thirdly, inexperienced management and unpredictable resources may introduce major inefficiencies. Inefficiencies are also likely to be present where several agencies have water-related responsibilities, and there is no provision for co-ordination between them. Apart from duplication of effort, there may be other undesirable effects, such as that data may not be readily transferable, or may be lost or discarded when their original purpose is served, even though another agency could use them.

3.14 A major financial and organizational issue which offers both opportunities and threats is the trend towards commercialization of hydrological services and products. Commercialization has many potential benefits, including the ability to adopt more entrepreneurial management methods; the opportunity to develop new sources of revenue; perhaps the ability to use pricing to manage demand.

3.15 The cost of commercialization is that it introduces the threat that, if misused, it can irreparably harm the integrity of long-term data collection programmes. It introduces many new requirements, such as the need to establish very close relationships with customers to ensure that all work relates to existing or reasonably foreseeable needs, an emphasis on careful costing of products and services, development of policies on charging for information which are appropriate to local circumstances, and the probable need to introduce new legal provisions. A crucial need is to establish the principle that hydrological information is a public good which benefits the whole community and, in particular, future generations.

3.16 At both national and international levels, the over-riding financial consideration is that funds are limited. Nevertheless, they are available in other related areas, for development projects, environment programmes, and through agencies whose particular responsibilities impinge on water issues. This, of course, raises the need for effective co-ordination among the 24 UN system bodies and agencies with responsibilities related to water.

The future

The most pressing needs

The following pressing needs have been identified:

3.17

(1) Hydrological data acquisition

- Adequate, purpose-driven and integrated observation networks, including water quality, soil moisture and other variables;
- Automated, reliable, accurate field stations, telemetered for real-time information, where appropriate;
- Simple, manual observation networks, where appropriate;
- Design methodologies for cost-effective, multi-purpose networks;
- Extended use of satellites for provision of hydrological data sensors;
- Areal estimation using remote sensing, especially of precipitation and soil moisture;
- Implementation of the World Hydrological Cycle Observing System (WHYCOS).

(2) Hydrological data banks

- Data quality control and assurance systems;
- Accessible, integrated (multi-agency and multi-variate) data banks, with full provision for long-term maintenance;
- Co-ordinated international databanks, with free exchange of data for international projects, enhanced capability to provide for analysis of data, and provision of analytical methods for use by member countries;
- Improved delivery of accurate, scientifically validated information to decision-makers.

(3) Forecasting and warning systems

- Improvement of forecasting system effectiveness, incorporating weather radar information;
- Enhancement of seasonal forecasting capability;
- Development of storm surge forecasting;
- Drought and low flow forecasting;
- Improved risk management practices.

(4) Technology transfer

- Enhancement, effective promotion, and wider use of HOMS, including more training courses;
- Wide promulgation of standard techniques and methods.

(5) Financial resources

- Development and use of methods for estimating the value of products and services;
- Running hydrological services on a full-cost basis, with carefully controlled commercialization of products where appropriate;
- Close links between hydrological services and customers;
- Availability of sufficient resources to maintain hydrological programmes on a long-term basis;
- Marketing hydrology to increase its visibility.

(6) Inter-agency collaboration

- More effective mechanisms for collaboration and data interchange between agencies with water-related functions;
- Integration of scientific and operational hydrology networks;
- Facilitating the assessment and management of water in shared river basins and aquifers.

Institutional changes

3.18 Recommendations for institutional change focus on enhancing collaboration and co-ordination:

- Providing effective mechanisms for co-ordination amongst agencies with environmental (including meteorology and water-related) responsibilities;
- Establishing a single hydrological or hydro-meteorological service, and/or a national hydrological archive;
- Close co-ordination of the national activities of IHP and OHP, and co-ordinating work with other relevant national actions;
- Joint planning meetings should be more frequent, and supplemented by regular meetings throughout the implementation phase of the IHP Bureau and the CHy Advisory Working Group;
- Establish joint UNESCO/WMO programmes for publications, meetings, and training (including HOMS).

4. INTERDISCIPLINARY ACTIVITIES IN HYDROLOGY

4.1 Interdisciplinary activities cut across hydrological research, operational hydrology and education, training and capacity building in hydrology. In fact it is clear that the research, operational and education components should, all three, involve a strong concern for interdisciplinarity.

4.2 The main issues to deal with in future water resources development and management are the following:

- Environmental and social consequences;
- Land-water linkages;
- Allocation of water among competing uses and users;
- Achieving effective implementation.

4.3 All these four issues imply clearly the need for interdisciplinarity at different levels. As an illustration of the disciplines which should be involved in the interdisciplinary effort in hydrology and water resources, reference is made to two important aspects:

- Development of integrated water resources planning and management;
- Development of new technologies for the management of water resource systems.

4.4 The development of integrated water resource management requires co-operation between hydrologists and other specialists such as meteorologists, climatologists, geologists, soil-scientists, biologists, physicists, chemists, ecologists, agricultural and forest experts, anthropologists, public health specialists, engineers of different backgrounds, economists, social scientists, demographers, lawyers, regional and urban planners and political scientists.

4.5 The development of new technologies for the management of water resource systems equally involves the co-operation of several types of experts such as operational researchers, systems analysts, statisticians, geographers, remote-sensing and GIS experts, and computer specialists.

4.6 Obviously the degree of interdisciplinarity changes with the scale of each particular water resources problem, from local through regional and continental to the global scale. For instance, in global scale problems the framework for interdisciplinary co-operation is defined in its wider perspective by including the wide range of specialists required to consider the interactions between the hydrosphere, geosphere, biosphere and atmosphere established through the global interrelationships set up by the hydrological cycle, the energy cycle and the biogeochemical cycles.

Past achievements

4.7 Joint study of hydrological phenomena started in the 1950s through the involvement of adjacent disciplines which are today accepted as part of the hydrological sciences. This work was initially designated as "multidisciplinarity" to indicate the addition of contributions from different disciplines, rather than "interdisciplinarity", indicating mutual influence, an approach which started being developed only at a later stage. Since then, an increasing tendency has developed among hydrologists to work interdisciplinarily.

4.8 In this initial period, a number of good examples of interdisciplinary activities can be mentioned, namely the preparation of the World Water Balance and the Hydrogeological Maps of Europe, as well as the efforts to bridge hydrology and chemistry, and terrestrial ecology and hydrogeology. In more recent times and in a broader perspective, important interdisciplinary initiatives were the creation of WCRP and IGBP as well as the organization of the Second World Climate Conference and the Dublin Conference on Water and the Environment. IHP started incorporating an interdisciplinary concern in IHP-III, and this was strengthened in IHP-IV.

4.9 Major regional and global programmes for environmental data collection and research, including water, are also co-ordinated through IGBP and other programmes under the aegis of ICSU. Efficient co-ordination is vital in deriving the maximum possible benefit from hydrological research and operational activities.

4.10 During this period of development of interdisciplinary activities, a number of difficulties were, nevertheless, encountered. In general, it can be stated that although interdisciplinarity was considered useful, there were no suitable frameworks or mechanisms to implement it in an efficient way. Consequently many disciplines with close links to hydrology have not developed co-operation. This was due to a number of reasons, including: cognitive barriers and protection of the traditional territories of some professions; insufficient co-ordination of water-related agencies at national or international levels; and university education or continuing education not normally encouraging an interdisciplinary attitude.

The present situation

4.11 It is generally recognized that the need for interdisciplinary efforts is growing, and that responding to this need has become an urgent matter. There is also growing awareness of the need for broad-based teams for project planning or environmental impact assessment studies. However, the response to the perceived needs for interdisciplinarity in hydrology and water resources is limited by funding and financing constraints, and by current organizational and institutional arrangements.

4.12 With regard to the financial constraints, there is a particularly severe problem in Third World countries where the situation has clearly worsened over the last ten years. In developed countries, where funding is ensured mainly by national institutions and by international grants, there is a need for better co-ordination in order to make the best possible use of the funds available. At the regional level the situation has, in some cases, improved, thanks to donors increasingly supporting regional studies, as with certain river basin work.

4.13 With regard to organizational and institutional arrangements, the problems of sectorization are reflected in co-ordination difficulties at both national and international levels. In the latter case overlaps and duplication of activities are very obvious. This is partially because countries are not always coherent in the views they convey to different international organizations.

The future

4.14 There is clearly an urgent need for an organized framework to achieve a more coherent approach to the study of water-related issues and the implementation of the most appropriate solutions. Emphasis should be placed on the most acute problems, such as escalating water scarcity due to rapid population growth, urbanization and increased drought and flood impacts as a result of human action. The possible impact of global environment changes, even though it may not have immediate consequences, should be taken seriously and continue to be studied, as its short- and long-term effects could be a source of great concern in certain regions, particularly when associated with demographic growth. The solution of all these problems clearly requires an inter-disciplinary approach. Finally, improvements in the decision-making processes are crucial, especially in terms of bridging the gap between scientists and decision-makers, integrating information to support the decision-making process, and facilitating the education of decision-makers.

4.15 To face the problems of the future, some institutional changes will be required both at national and international levels. In particular, it is important to ensure that professionals of different disciplines work together within each organization, and also that different organizations work together. Barriers between national governmental agencies and international organizations should be overcome. The establishment of international interdisciplinary teams to deal with integrated research topics can also be a useful measure.

4.16 In order to face the present difficulties, the necessary steps towards achieving an integration of the activities of IHP (UNESCO) and OHP (WMO) should be taken as a matter of urgency. An interdisciplinary perspective should prevail in this integration and, in particular, a coherent approach to water and land management on the international level should be sought. The long-term goal could be the establishment of a joint structure for both the IHP and the OHP.

4.17 Steps should also be taken in order to achieve a rationalization of the activities of the various UN agencies which have water-related activities and to provide an international forum, such as the "World Water Council" proposed at the ICWE, to enable international governmental views on global water issues to bear on the activities of the UN Water Agencies.

5. CAPACITY BUILDING, TRAINING AND EDUCATION

5.1 Capacity building consists of the following three basic elements:

- Creating an environment with the appropriate policy and legal frameworks;
- Institutional development, including community participation;
- Human resources development and strengthening of managerial systems.

5.2 The importance of capacity building in water resources as an essential input to sustainable development has been given increased recognition by many national and international bodies in the last two decades. The recommendations on public information, education, training and research suggested in the Mar del Plata Action Plan of 1977 represent an important landmark in that direction. It emphasized the need for world-wide efforts in developing these essential elements. These recommendations were consolidated through, amongst others, the New Delhi Statement (1990), the Delft Declaration (1991), the Dublin Statement (1992) and the Agenda 21 of UNCED (1992).

5.3 Many national and international bodies have contributed to capacity building. However, the deficiency in quantity and quality is so great that huge contributions are still needed to meet ever-increasing problems at local, regional and global levels. Many of these problems have been identified in the previous sections. It is worth mentioning here that considerable contributions have been made by many UN organizations such as the UNESCO (IHP) and WMO (OHP) programmes which have specifically been designed to meet certain parts of these requirements.

Past achievements

5.4 Hydrological education and training issues were less complicated in the past. It is considered that the following elements represent the most important past contributions:

- The IHD/IHP of UNESCO contributions towards education and training of professionals and technicians in hydrology;
- The excellent technical and popularized documents produced as a result of the various IHP projects;
- The technical publications, including teaching materials, that addressed issues directly relevant to developing countries;
- The WMO contributions through the HOMS programme.

The main drawbacks and difficulties encountered in the past included:

- Funds were in short supply;
- National committees and focal points were ineffective;
- Textbooks and courses were not relevant to local needs;
- Public awareness programmes were lacking, as were education programmes at primary school level;
- Trained staff in developing countries, in most cases, left the job for which they were trained after a relatively short period of employment;
- UNESCO publications were not translated into the languages of many countries;
- WMO efforts to survey needs were not successful and hence actual requirements were not identified.

The present situation

5.5 The developed world has tried to make the adjustments in the educational system to adapt to the increasingly rapid and unpredictable changes taking place in the world today: this is clearly reflected in the increasing variety and contents of training courses, improved training methods and the fact that wider sections of the population are addressed.

5.6 The situation is completely different in most developing countries where education is still conventional and emphasizes knowledge rather than developing skills and professional attitudes. In most countries inadequacy in staff and teaching facilities adds to the poor results attained from education and training courses. A common problem is that most institutes use textbooks or teaching materials primarily published for the developed world and which are, in many cases, irrelevant to local conditions.

5.7 The most important facts at the present time are as follows:

(1) The training opportunities and the documentation resulting from UNESCO (IHP) and WMO (OHP) programmes have greatly contributed to capacity building in many developing countries. However, it is felt that:

- The number and quality of qualified hydrologists and technicians is inedaquate;
- The "brain drain" effecting trained staff is too high;
- Technology is still unbalanced with the skills of the users;
- UNESCO and WMO publications do not reach sufficient end users.

(2) Pure hydrology first-degree courses are not as widely available as desired.

(3) In some countries there are insufficient jobs for hydrologists.

(4) The participation of women and young people in water-related education is poor.

5.8 Financing of capacity building activities is inedequate in many developing countries. However, in a few cases the constraints are related to poor co-ordination and implementation plans. The Conference strongly recommends that more funds be secured from donor agencies as well as UN bodies for capacity-building purposes.

5.9 The main organizational and institutional matters that require urgent consideration are:

- Effective co-ordination between UN agencies involved in the water field;
- Improved documentation elements of the HOMS programme.

5.10 Capacity-building programmes should be flexible in approach and give due consideration to differences between countries and their corr-esponding needs in time and space. Furthermore, the confusion in the definition of the terms that make up capacity building must be resolved and standardized to allow a universally accepted framework.

The future

The most pressing needs

5.11 Numerous needs have already been identified at various international meetings, especially the Mar del Plata Action Plan, the Dublin Statement and Agenda 21 of UNCED. However, the following complementary issues are suggested for consideration:

(1) Water should be viewed as an economic good, a concept which deserves to be stressed in the education and training programmes of the future.

(2) UNESCO and WMO should encourage and assist countries in performing regular surveys of their manpower situations and capacity-building needs and consequently prepare appropriate action programmes for meeting these needs.

(3) Education and training programmes should be drawn up and implemented with a better understanding and appreciation of the multi-disciplinary nature involved in water resource development and utilization.

(4) Special and well designed education and public awareness programmes should reach all citizens, including decision-makers, pupils in the schools, end users and the public at large.

5.12 The present UNESCO/WMO courses should be maintained, regularly evaluated and improved to meet new as well as local/regional conditions. New courses should be added, mainly in developing countries, if the above surveys identify new needs. The material of these courses should:

- Be adapted to local and regional conditions and needs;
- Address water resources management issues as well as hydrology;
- Be based on textbooks and notes that are relevant to the region;
- Include more field work, experimental and practical aspects.

5.13 To improve the efficiency of these courses it is suggested that:

- Regular support be provided for teaching facilities and staff development;
- Feedback from participants be incorporated in the system of evaluation;
- Short refresher courses be regularly offered at local levels;
- More emphasis be put on the training of technicians and water resources managers in developing countries;

- UNESCO/WMO publications be translated by local experts into the languages of the various countries.

Institutional changes

5.14 It was suggested that the following changes be considered:

- Effective co-ordination and linkage programmes should be provided between education and training institutes, the employers, the local professional societies and relevant environment disciplines (including meteorology);

- The IHP National Committee and OHP focal point should co-ordinate their efforts towards more action-oriented activities in the water field;

- Water-related teaching should be introduced into primary and secondary school curricula.

5.15 The following changes are suggested at international level:

- Linkages and academic exchange programmes between education and training institutes of the developed and developing world should be improved;

- The level of co-ordination between NGOs and UNESCO/WMO Secretariats should be raised for more effective results. The COWAR UNESCO/ WMO partnership sets a good example in this respect;

- Networking of education and training institutes and twinning of IHP National Committees should be encouraged;

- Fellowships from UNESCO, WMO and other donor bodies should reach potential users in good time.

PROGRAMME OF THE

UNESCO/WMO/ICSU
INTERNATIONAL CONFERENCE ON HYDROLOGY

TOWARDS THE 21st CENTURY:
RESEARCH AND OPERATIONAL NEEDS

Monday 22 March 1993

8.30:	Registration
10.30:	Opening Ceremony

Chairman: *P. Hubert*, Ecole Nationale Supérieure des Mines de Paris (France), President of the French IHP/OHP-National Committee

Welcoming address by:
F. Mayor, Director General of UNESCO
G.O.P. Obasi, Secretary General of WMO
M.G.K. Menon, President of ICSU

Address by:
J.-L. Laurent, Directeur de l'Eau, Ministère francais de l'Environment, on the occasion of the World Water Day

SESSION 1: INTRODUCTION TO THE WATER PROGRAMMES OF UNESCO, WMO AND ICSU AND PLANS FOR FUTURE ACTIVITIES

Chairman: *P. Hubert*

The method of work for the Conference: Introduction by the Secretariat

14.30:	International Hydrological Programme: A Response to International Hydrological Problems *A. Szöllösi-Nagy*, Director, Division of Water Sciences, UNESCO
15.00:	Framing the Hydrological Future *J. Rodda*, Director Hydrology and Water Resources Department, WMO
15.30:	Discussion
16.00 - 16.30:	Coffee Break
16.30:	ICSU and Global Water Issues *J.C.I. Dooge*, President Elect of ICSU
17.00:	Sustainable Water Resources Development - A Call for Action by the International Water Related Scientific and Engineering Associations *E. Plate*, Chairman of the Committee on Water Research (COWAR), University of Karlsruhe (Germany)
17.30:	Discussion
18.00:	Composition of the Groups
19.00:	Reception hosted by the French Ministry of Foreign Affairs

Tuesday 23 March 1993

SESSION 2: HYDROLOGICAL RESEARCH

Chairman: *I. Shiklomanov*, State Hydrological Institute, St. Petersburg (Russia) and Chairman of the IHP Council of UNESCO

Rapporteur: *J. Fischer*, US Geological Survey, Reston, Virginia (USA)

9.30: Where shall we go from here? - Hydrological research towards the 21st century
Z. Kundzewicz, Research Center for Agricultural and Forest Environment Studies, Academy of Sciences (Poland)

10.00: Hydrological Sciences: Present Status and Future Trends
S. Chander, Indian Institute of Technology, New Delhi (India)

10.30: Discussion in Plenary

11.00 - 11.30: Coffee Break

11.30: Discussion in Groups

13.00 - 15.00: Lunch Break

SESSION 3: OPERATIONAL HYDROLOGY

Chairman: *K. Hofius*, Federal Institute of Hydrology, Koblenz (Germany) and President of the Commission for Hydrology of WMO

Rapporteur: *P.M. Mosley*, National Institute of Water and Atmospheric Research, Wellington (New Zealand)

15.00: Future Directions for Operational Hydrology in the Developing Countries
C. Caponi, Information and Research on Environment, Caracas (Venezuela)

15.30: Future Directions for Operational Hydrology
A. Tollan, Commission of the European Communities, European Environment Agency - Task force, Brussels (Belgium)

16.00: Discussion in Plenary

16.30 - 16.45: Film: Working for the World's Water

16.45 - 17.00: Coffee Break

17.00 - 18.30: Discussion in Groups

Wednesday 24 March 1993

SESSION 4: INTER-DISCIPLINARY ACTIVITIES

Chairman: *U. Shamir*, The Technion, Haifa (Israel) and President of the International Association of Hydrological Sciences (IAHS)

Rapporteur: *L.Veiga da Cunha*, Scientific and Environmental Affairs Division, North Atlantic Treaty Organization (NATO), Brussels (Belgium)

9.30: Presentation by *P. Nachtnebel*, Universität für Bodenkultur (BOKU), Vienna (Austria)

10.00: Some Suggested Multidisciplinary Activities to Improve Water Resources Management
N.B. Ayibotele, Water Resources Research Institute, Accra (Ghana)

10.30: Discussion in Plenary

11.00 - 11.30: Coffee Break

11.30: Discussion in Groups

13.00 - 15.00: Lunch Break

SESSION 5: EDUCATION, TRAINING AND CAPACITY BUILDING

Chairman: *Liang Ruiju*, Hohai University, Nanjing (China)
Rapporteur: *M.A. Salih*, University of Khartoum (Sudan)

15.00: Education and Training Needs for Future Water Resources Management
A. Van der Beken, Laboratory of Hydrology, Vrije Universiteit, Brussels (Belgium),
B. Braga, Polytechnic School of the University Sao Paolo (Brazil)
15.30: Creating Capacity for Sustainable Development
L. Oyebande, University of Lagos (Nigeria),
W.A. Segeren, Infrastructure-Hydraulics-Environment (IHE), Delft (Netherlands)
16.00: Discussion in Plenary
16.30 - 17.00: Coffee Break
17.00 - 18.30: Discussion in Groups

Thursday 25 March 1993

SESSION 6: SUBMISSION OF GROUP CHAIRMEN CONCLUSIONS TO THE PLENARY

Chairman: *P. Hubert*

9.30 - 11.00: Submission of the conclusions related to:
Hydrological research
Operational Hydrology
Inter-disciplinary activities
Education, Training and Capacity Building
11.00 - 11.30: Coffee Break
11.30 - 13.00: Discussion in Plenary
13.00: Lunch Break
Afternoon: Topic Rapporteurs to prepare synthesis reports together with Group Rapporteurs

Friday 26 March 1993

SESSION 7: SYNTHESIS BY TOPIC RAPPORTEURS

Chairman: *P. Hubert*

9.30: Synthesis on Hydrological research
Rapporteur: *J. Fischer*
10.00: Discussion in Plenary
10.15: Synthesis of Operational Hydrology
Rapporteur: *P. Mosley*
10.45: Discussion in Plenary
11.00 - 11.30: Coffee Break
11.30: Synthesis of Inter-disciplinary activities
Rapporteur: *L.Veiga da Cunha*
12.00: Discussion in Plenary
12.15: Synthesis of Education, Training and Capacity Building
Rapporteur: *A. Salih*
12.45: Discussion in Plenary
13.00: Closure of the Conference by *A. Badran*, Assistant Director-General for Science, UNESCO