WMO/UNESCO

REPORT ON

WATER RESOURCES ASSESSMENT

UNESCO

Progress in the Implementation of the Mar del Plata Action Plan and a Strategy for the 1990s

WMO

1991

NOTE

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UNITED NATIONS

UNITED NATIONS
WATER CONFERENCE

Resolution I

Assessment of Water Resources

The United Nations Water Conference,

recognizing that for the plans of action adopted by the Conference for the intensification and improvement of water use and development in agriculture and for providing safe drinking water and sanitation for all human settlements by 1990, a proper assessment is necessary of water resources in all countries of the world, and in particular in developing countries, and

considering that this assessment can be achieved only if all countries strengthen and co-ordinate arrangements for the collection of data in accordance with the recommendations of the Conference,

resolves that:

a) all efforts should be undertaken at the national level to increase substantially financial resources for activities related to water resources assessment and to strengthen related institutions and operational services as necessary and appropriate at the national and regional levels;

b) training programmes and facilities for meteorologists, hydrologists and hydrogeologists should be established or strengthened;

c) national scientific infrastructure for water-assessment activities be strengthened or established, particularly in developing countries;

d) international co-operation aimed at the strengthening of water resources assessment, particularly within the International Hydrological Programme and Operational Hydrological Programme be keyed to the targets set by the United Nations Water Conference and appropriately supported by national and international governmental and non-governmental institutions.

From UN 1977, Mar del Plata Action Plan,
UN Water Conference, Argentina

Foreword

Water is vital to all forms of life on earth, from the simplest of living organisms to the most complex of human systems, such as conurbations like New York, Cairo and Bangkok. Lack of fresh water to drink, for use in industry and agriculture and for the multitude of other purposes where water is essential, is a limiting factor—perhaps the most important factor— hindering development in many parts of the globe. As populations increase, the demand for water grows. And, while the world's fresh-water resources are massive, they are not only unevenly distributed in both space and time but also have a finite limit in terms of practical utilization. Some shortages currently affecting many areas are likely to spread, becoming far more prevalent during the next century. In many regions these shortages are likely to be exacerbated by climate change.

In these circumstances, improving knowledge of the globe's water resources is indispensable for the well-being of mankind and for the protection of the environment. Reliable information on the state and trends of water resources is a prerequisite for sound decisions on their sustainable management. Information is required for water resource planning, design of projects, impact assessment, project operation, and for forecasting or warning of extreme events such as floods and droughts. Hence, water resources assessment (WRA) is a precondition for all other aspects of water resource development and management.

The 1977 Mar del Plata Action Plan (MPAP) identified a number of needs for improvements in WRA, in support of countries' sustainable resource management. The present report was prepared by the World Meteorological Organization (WMO) and the United Nations Educational, Scientific and Cultural Organization (UNESCO) under the aegis of the UN Administrative Co-ordination Committee–Intersecretariat Group for Water Resources, along with other reports by different agencies and with the support of UNDP. Its aim was to assess progress in implementing MPAP recommendations relating to WRA, establish the current state of WRA activities at a global, regional and national level, and identify key issues. It is intended to contribute to a comprehensive United Nations strategy for implementing the MPAP during the 1990s, to be submitted to the ECOSOC Committee on Natural Resources at its session.

WMO and UNESCO wish to express their appreciation of the help given by all those who contributed to the preparation of this report, in particular to the consultants who carried out the regional assessments, the national experts who prepared case-studies for their countries, and the UN agencies that provided information for, or supported the preparation of, the report.

There is today an even stronger case to be made for strengthening WRA programmes at the national level than there was in 1977 at Mar del Plata. WMO and UNESCO will continue to play their role in this regard at the international level, in co-operation with other relevant agencies in the UN system.

January 1991

G. O. P. Obasi, Secretary-General, WMO

F. Mayor, Director-General, UNESCO

Executive Summary

This report has been prepared by the World Meteorological Organization (WMO) and the United Nations Educational, Scientific and Cultural Organization (UNESCO) to establish the current state of water resources assessment activities globally, regionally and nationally. It was prepared in response to a request from the UN Economic and Social Council (ECOSOC) (Resolutions 1987/7 and 1989/7) under the aegis of the UN Administrative Co-ordination Committee–Intersecretariat Group for Water Resources (ACC ISGWR), along with several other reports by different agencies. The regional assessments, which were compiled with the support of UNDP, aim to establish progress made since the UN Water Conference in 1977 and the adoption of the Mar del Plata Action Plan (MPAP) (see reference 1), and identify key issues. They also provide the foundation for a UN strategy for water in the 1990s and beyond—a strategy on water resources assessment activities being one component.

F. Mattioli, FAO

Existing community water supply (Niger)

The need for Water Resources Assessment (WRA)

Government policies and plans must be based upon comprehensive, reliable water data and information if they are to succeed, and if sustainable water development is to proceed.

Water resources assessment (WRA) must be the very basis for sustainable development and management of the world's water resources. It is a prerequisite for the vast range of activities where water is involved. Indeed it is difficult to understand how irrigation schemes can be planned and urban water supplies developed without WRA. The very nature of the decisions based on WRA information, involving major capital investments with potentially massive environmental impacts, argues the value of these activities. So does the scope and impact of government policies and programmes that are necessary to ensure sustainable development, including sustainable water development, for the future. Furthermore, from an international perspective, problems related to the changing climate, toxic wastes, and acid precipitation have potentially devastating impacts on water, which cannot be addressed using the uncoordinated approaches which prevail in many regions.

Thus, both Resolution 1 (see page 4) and Recommendation A (see Appendix A) of the MPAP stressed the need for greater knowledge about the quantity and quality of surface and groundwater resources, and for comprehensive monitoring to guide the management of these resources.

Challenges for WRA agencies

A number of challenges face WRA agencies in the 1990s, which arise from technical, social and economic circumstances. These include:

- the demand for water is growing, which requires increasingly precise information to allocate this resource adequately amongst competing users;
- WRA is costly, particularly because the need for additional information is often greatest under circumstances which are most difficult to deal with;
- the need for WRA is often greatest where economic

resources are least, but it is often difficult to demonstrate the immediate value of WRA information, relative to other uses to which funds can be put;

- WRA is a long-term endeavour, and may be of particular benefit to future generations. Long-term trends, particularly those caused by human activity, can only be identified through long-term data collection programmes;
- water resources are often developed in the context of separate projects which are not integrated, and may even be competitive, so that assembly of integrated databases is not easy;
- many major river basins and aquifers lie within the territory of more than one nation.

Status of WRA capabilities—regional assessments

In the late seventies, there was evidence that countries were responding to the call to develop and strengthen their WRA programmes in line with the MPAP, by installing new instrument networks, investing in up-to-date data processing systems, and employing and training the necessary manpower. This trend however has reversed in recent years under pressure of economic stringency. In many areas of the globe, countries are suffering from economic difficulties, and many aspects of WRA have also been affected, in view of insufficient budgetary allocations for these purposes. At the same time greater and greater demands are made for more precise information about water resources, their availability, variability, reliability and quality.

The recent regional assessments of the situation, which have resulted in a notable concordance in identifying a number of key issues despite diversity of economic and physical conditions, give cause for concern that data collection and analysis are not keeping pace with present water development and management needs, not to mention the new demands being created by pressures for sustainable development.

The initial modest increase of the hydrological networks early 1980 in the **ECA** region has now given way to a rapid deterioration in operations and equipment. The number of precipitation and streamflow stations remain wholly inadequate for meaningful assessment, planning, or design purposes. The number of water quality stations is even less so. There is now also a marked decline, due to a lack of funds for even the most elementary operations. The importance of sediment and water quality observations is recognized, but network development and operation are hampered by the lack of equipment, logistic support and laboratory facilities. Groundwater data collection networks are found mostly in areas of urgent water demand, such as large cities and irrigation schemes, but not all countries have appreciated the need for systematic monitoring of the resource. Some countries have made progress in establishing national hydrological data banks, using new computer methods, but effective dissemination to users is difficult. Hydrological research and development is lacking in most countries, and indeed the basic training, development and retention of qualified WRA staff is acknowledged as a priority issue.

The evaluation of WRA in the **ESCWA** region and North Africa is similar to that in Sub-Saharan Africa. Particular regional problems comprise intermittent and ephemeral flow in wadis, salt water intrusion, overdevelopment and pollution of shallow aquifers and depletion of deep fossil groundwater resources. The utilization of intermittent flows for groundwater recharge offers one of the few remaining opportunities for surface water exploitation, but its assessment is extremely difficult. The issue of fresh and salt water mixing in coastal aquifers already threatens existing developments. Meteorological networks appear to be in a more satisfactory condition, and an improvement in hydrometric networks was also observed. However, a deterioration in operation and maintenance has also set in over this region. Data base management procedures are at a very low level and, consequently, the availability of water data and information is generally unsatisfactory.

In the **ESCAP** region, good progress has been made in collecting project-oriented water data, in establishing computerized data banks, and in preparing generalized

water resources information. A main concern is the diversity of the equipment used, and its operation and maintenance. Problems of co-ordination exist, due to the number and diversity of small countries in the region, which is also reflected in a diversity of agencies, policies, and programmes related to WRA. Human resources training has been identified as significant limitation in this region, reflecting the general lack of resources for WRA.

Overall coverage of hydrometeorological and surface water networks, in the **ECLAC** region, appears fairly well matched to development needs, but with little attempt at integration into a resource management system. Data collection is usually carried out on a project-specific basis, without any general plan, and this also reflects the diversity of agencies with interest and responsibilities related to water. Where there are national or international river basin authorities, their mandates, although often limited in scope, tend to include data collection, and consequently they give more systematic attention to assessment activities. Advanced technologies for data collection, transmission and analysis are a feature of this region. Groundwater, sediment and water quality monitoring lag behind the other components, but have been initiated in most of the countries—usually in relation to urban centres and major schemes.

The practice of WRA is most advanced in the **ECE** region, where a preponderance of developed economies exists. Networks are well established, and many different assessment and interpretative techniques are routinely applied. However, large parts of northern areas of the region have only rudimentary systems in place that cannot support advanced WRA. Modern hydrometric technology and data base management systems are also routinely applied. Within WRA agencies, emphasis is being placed upon integration policies, and some countries have recently overhauled their water legislation. Human resource planning and development programmes have also been established in most countries. The issue of greatest concern, however, is the increasing pressure for commercialization of WRA activities arising from economic policy and pre-occupation with environmental "hot spots". While forcing a renewed focus on clients and users, the potential exists for significant disruption of WRA even in these developed countries because the linkage between reliable data and effective water decision-making is not clear to many managers.

Key WRA issues

In summary and from a global perspective, a serious concern is the ability of WRA agencies to meet the growing needs for data and information, especially as these relate to sustainable development. Deterioration has set in already in many regions, ECA and ECLAC being the most seriously affected. The issue of financial resource allocation is uppermost in the minds of all WRA agencies, and recent cutbacks have taken their toll both in terms of the poor operation and maintenance of networks, and in the non-availability and lack of reliability of water information. A major cause for concern for the future lies in the obvious insufficiency of groundwater, water quality, and related data virtually everywhere, even in some parts of the ECE region. A theme common to many countries is that of problems in training and retaining water resources assessment personnel, and updating their abilities to manage more advanced technologies and equipment, with ECA, ESCWA and ESCAP regions being most affected. The technical and operational aspects of the work, and the fragmented nature of institutional arrangements, is recognized as an impediment to the establishment of national integrated data bases.

In many respects, Resolution 1 and Recommendation A of the Mar del Plata Action Plan are as relevant now as they were in 1977.

Strategy for the 1990's

Looking ahead to the coming years of this decade, the following four components of a strategy are proposed to implement those aspects of the MPAP which are still outstanding, expressed as a series of specific objectives:

- *Strategy component 1—Financial resources for WRA* to have all countries allocate to WRA the financial resources which are justified by the economic and social value of information about their water resources;
- *Strategy component 2—Institutional arrangements* to have all countries establish the institutional arrangements needed to ensure the efficient collection, processing, storage, retrieval and dissemination to users of information about the quantity and quality of available water resources in an integrated manner;
- *Strategy component 3—WRA technology transfer* to make available to all countries WRA technology which is appropriate to their needs, irrespective of their level of development;

- *Strategy component 4—Human resource development, education and training*
  to have sufficient numbers of appropriately qualified and capable staff recruited and retained by WRA agencies, and provided with the training and retraining they need to carry out their responsibilities successfully.

Action proposals

A wide number of actions have been proposed to implement the above components of the strategy, to be carried out by national agencies, regional and international organizations, and donor countries. Principal actions include:

- Cataloguing of available water resource information and definition of national requirements, taking particular account of the multiplying demands for water, expected impacts of climate change and variability and the world-wide trends towards integrated water resource management, and also the present capabilities of WRA agencies for meeting these requirements;
- Review of institutional arrangements for WRA paying special attention to the need for close co-ordination and communication, particularly between producers and users of data;
- Identification and implementation of new mechanisms for funding WRA, where these are required to provide adequate resources;
- Implementation of modern technologies for data collection, including water quality and groundwater, and of user-friendly data management systems;
- Establishment of comprehensive and accessible national data banks of water resources information;
- Development of technical assistance initiatives oriented towards assessment of water resources;
- Definition of human resource needs for WRA and provision of education and training programmes to meet those needs;
- Co-ordination of WRA related research and development on a regional basis, employing local resources more fully and also the creation of avenues for publishing the research being carried out in the developing countries as an encouragement;
- Promotion of co-operation and information exchange at the national and international scale.

Conclusion

The primary responsibility for achieving the objectives of WRA rests with the hydrological services and other agencies of national governments, and the governments themselves. However, support of regional organizations, such as river basin commissions, and international organizations will also be required to assist countries in rebuilding and strengthening WRA capabilities.

Many of the actions required in the 1990's are similar to those identified as needed in the MPAP, and are already being addressed by programmes of international organizations, particularly those of WMO and UNESCO, with other agencies of the UN system. However the need, if anything, is greater now than in 1977.

WRA is a continuous, long-term activity, as it must be to support water resources management that is sustainable into the future. Particularly with the growing recognition of such issues as the possibility of global climate change and the environmental impacts of human activities, there is an increasing need for reliable information. This implies that present and future generations will benefit from decisions made today, and from the information produced by today's WRA activities.

> *If "sustainable development" is to mean anything, such development must be based on an appropriate understanding of the environment—an environment where knowledge of water resources is basic to virtually all of man's endeavours.*

1

Introduction to Water Resources Assessment

Water is, like the air we breathe, a basic requirement for all life on earth—plants, animals and humankind. It is vital for many aspects of economic and social development—for energy production, agriculture, domestic and industrial water supply—and it is a critical component of the global environment. There is growing awareness that development, including development of water resources, must be sustainable, which implies that the world's natural resources must be managed and conserved in such a way as to meet the needs for present and future generations.

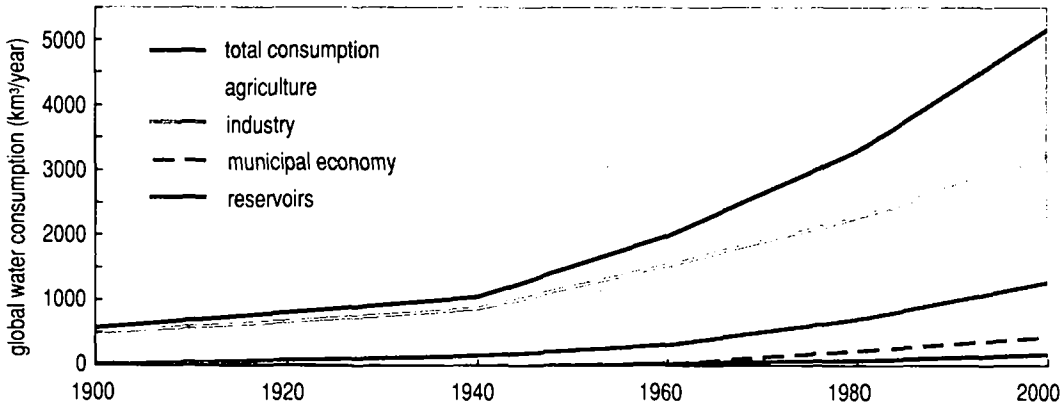
The need for Water Resources Assessment

Water Resources Assessment (WRA) is the determination of the sources, extent, dependability, and quality of water resources, on which is based an evaluation of the possibilities for their utilization and control.

Water Resources Assessment (WRA) (see reference 2) is of critical importance to wise and sustainable management of the world's water resources. Several reasons

Evolution of world water consumption

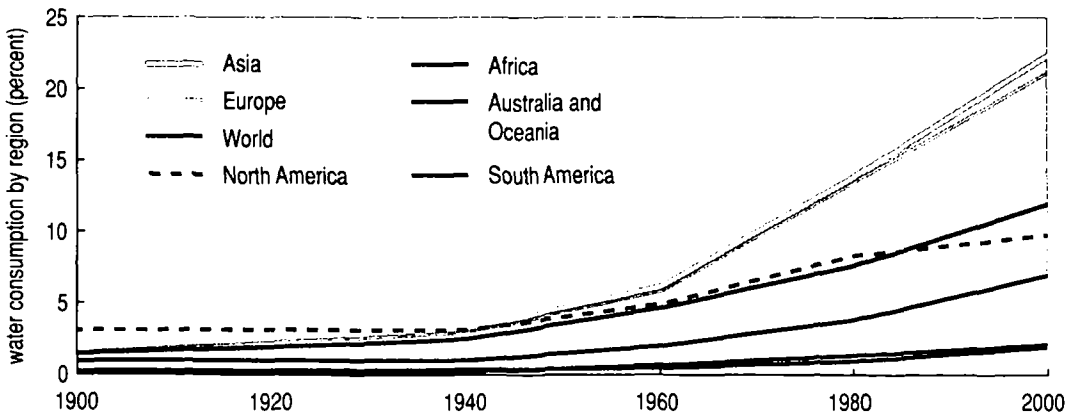
Source: Investigations of land water resorces: results, problems and prospects. A. Shiklomanov, Leningrad, 1988 (see reference 3)



This graph shows the evolution of world water consumption from 1900 to the year 2000. Globally, consumption has increased ten-fold and, by the year 2000, almost half of available water supplies will be in use.

Agriculture, and particularly irrigation, remains the thirstiest consumer despite a continuing fall in the amount of water it uses—from 90.5 per cent of available supplies in 1900 to 62.6 per cent in 2000.

During the same period, the portion used by industry will have passed from 6.4 per cent to 24.7 per cent, with cities sharing the same rate of growth, climbing from 2.8 per cent in 1900 to 8.5 per cent in 2000.

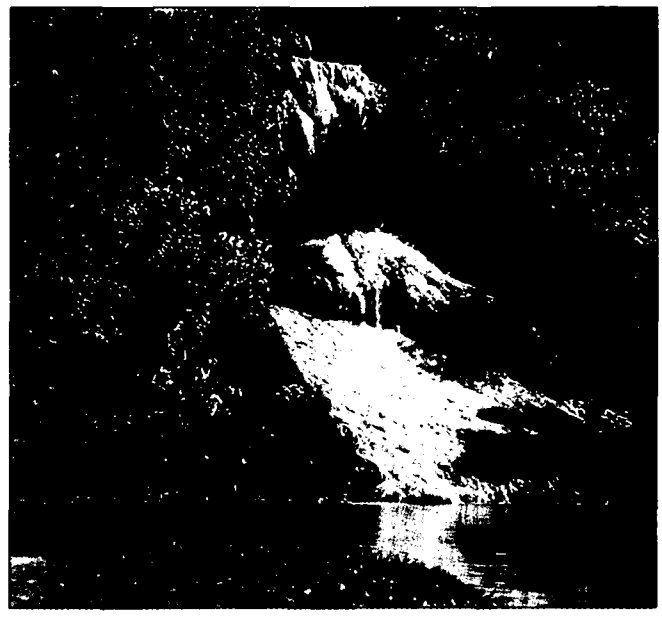


Still looking across the 20th century, how has water consumption compared to available resources in each of the world's major regions? This graph answers the question with the help of percentages calculated on the basis of theoretical resources, i.e. the amount of water flow in rivers.

According to these calculations, Europe and Asia are clearly much greedier than North America, Africa, and more particularly South America and Australia–Oceania. It is also clear that Europe and Asia have the highest growth in consumption, except for South America, where the increase is offset by plentiful reserves of water.

may be cited, including:

- the world's expanding population is placing increasing demands on water for drinking, food production, sanitation, and other basic social and economic needs; but the world's water resources are finite. The rising demand has reached this limit in some areas. It is going to reach the limit in many other areas within the next two decades, while before the end of the next century, the world's water resources will be fully utilized should present trends continue;
- human activities are becoming increasingly intensive and diverse, and are having an ever-growing and more evident impact on natural resources, through depletion and pollution. This is particularly the case for water, whose quality for many purposes can be severely degraded by pollution by a wide range of chemicals, micro-organisms, radioactive materials and sediments and by other physical changes;
- water-related natural hazards—floods, droughts, tropical cyclones—are among the most destructive of human life and property, and have been responsible for death and widespread misery of countless millions during the course of history. Deforestation and urbanization in particular have exacerbated flood hazards by increasing the magnitude and frequency of floods;
- there is growing realization that the world's climate is not constant, and indeed may well be changing in response to human activity (see graph below and box page 12). While the postulated rise in global temperature due to greenhouse gas induced warming has been widely publicized, the more important effects are likely to be on the distribution of rainfall, runoff, and groundwater recharge: it cannot be assumed that the future patterns of these hydrological phenomena will continue to be as they were in the past.



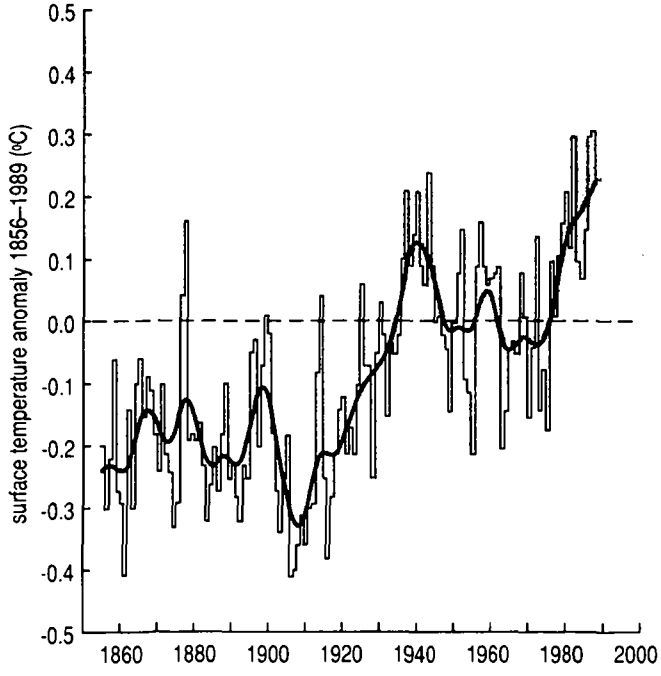
D. Kraemer, WMO

Available water resources (Mexico)

Only with reliable data and information on the status and trends of the water resource—including quantity, quality, statistics on such events as floods, and use (for human purposes)—can wise decisions be made on how best to manage water. To a large extent, then, water resources assessment is a prerequisite for all aspects of water resource development and management.

Annual surface temperature of the world

Source: P. Jones, University of East Anglia, UK (see reference 4)



Challenges for Water Resources Assessment agencies

A variety of challenges face water resources assessment agencies during the 1990s. Some of these are technical, but others arise from the socio-economic environment in which they operate:

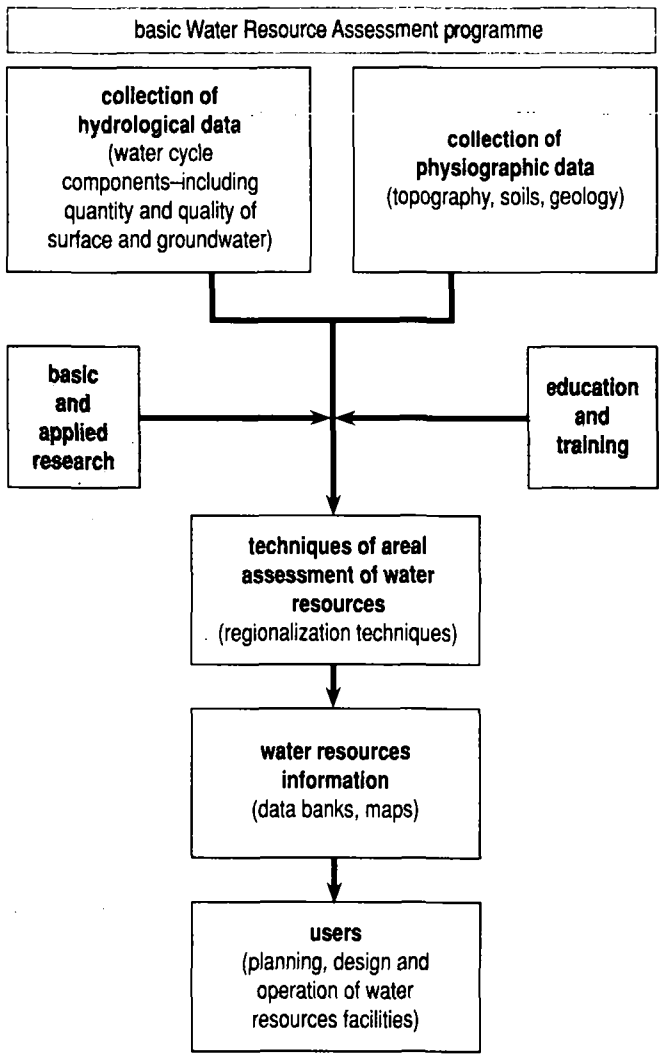
- *Stress on water and the need for more precise information*

  Global water resources are under increasing stress. As the balance between demand for and availability of water becomes more finely tuned, the need for more precise and reliable assessments of the status and trends of the resource increases rapidly;

- *The cost of WRA*
  The need for reliable information on water resources is often greatest where information is most difficult and expensive to acquire—during infrequent and extreme events such as floods and droughts; in rugged and inaccessible headwater catchment areas; in circumstances where those attributes of water which are most difficult to measure successfully, such as chemical quality, are of greatest concern;
- *The need for WRA is greatest where economic resources are least*
  The need seems to be greatest in those areas of the world which can least afford to invest in WRA—in the basins which provide sources of water for the growing cities of the developing countries, in irrigated areas where salinization has already damaged productivity and cashflows, in drought-hit areas of the tropics where populations are already impoverished;

Components of a WRA programme

(Source: reference 2)



Statement adopted by the Second World Climate Conference

"Among the most important impacts of climate change will be its effects on the hydrological cycle and water management systems. Increases in incidence of extremes, such as floods and droughts, would cause increased frequency and severity of disasters.

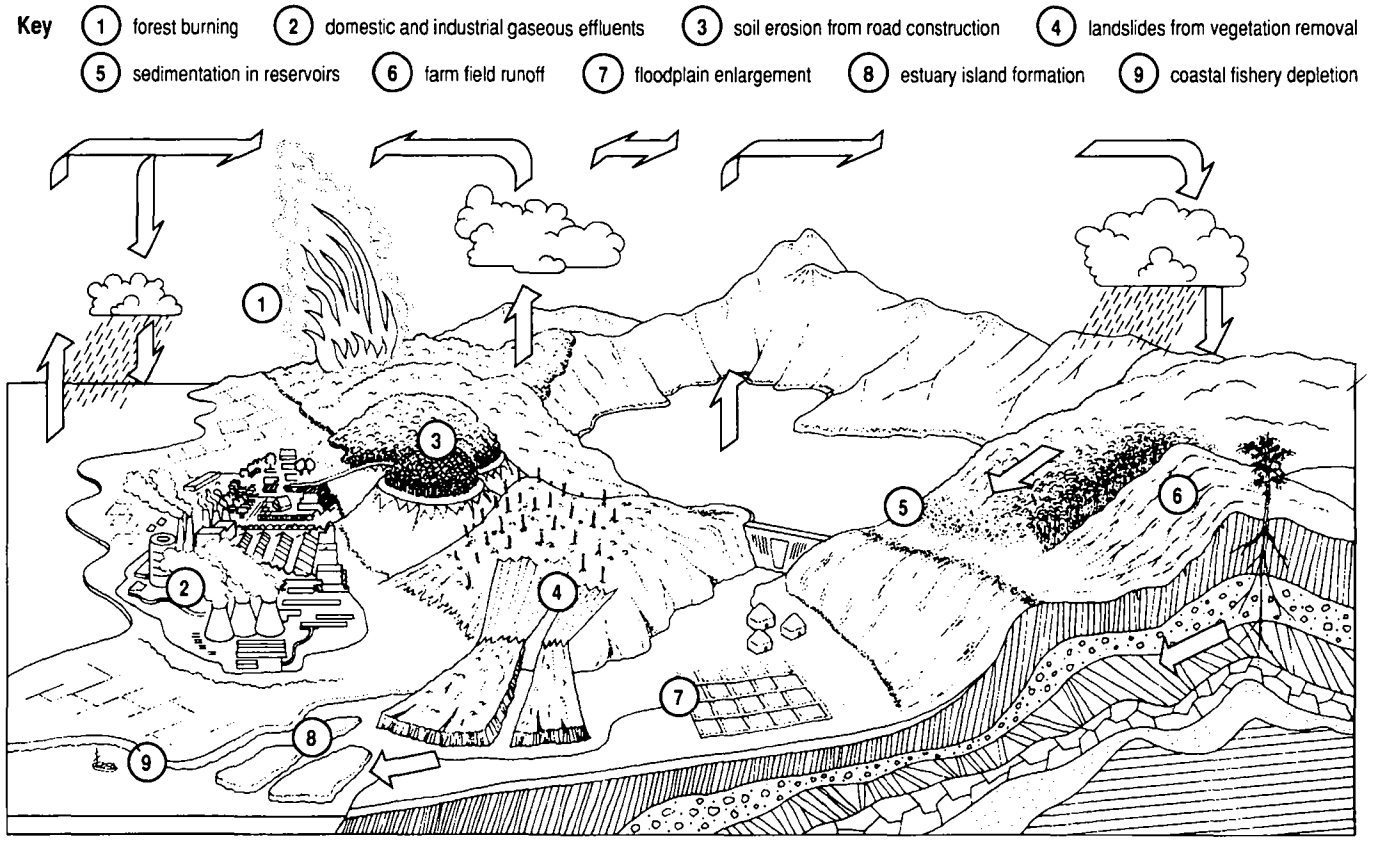
The design of many costly structures to store and convey water, from large dams to small drainage facilities, is based on analyses of past records of climatic and hydrological parameters. Some of these structures are designed to last 50-100 years or even longer. Records of past climate and hydrological conditions may no longer be a reliable guide to the future. Engineers should allow for the possible effects of climate change in the design and management of water resource systems.

Data systems and research must be strengthened to predict water resources impacts, detect hydrological changes, and improve hydrological parameterization in global climate models."

From the scientific and technical sessions of the Second World Climate Conference, convened in Geneva from 29 October through 7 November 1990, under the sponsorship of WMO, UNEP, UNESCO, FAO and ICSU (see reference 5).

- *The need to demonstrate the value of WRA information*
  At a time when the need for information is greatest, and WRA technology is becoming better able to provide it, funds are increasingly difficult to obtain for investment in WRA programmes. WRA agencies seem to experience great difficulty in demonstrating the value of their products to decision-makers, as related to other uses to which scarce resources could be put;
- *The long-term nature of WRA*
  Useful water resources information often takes many years to collect, because a key aspect of the water cycle is its variability with the passage of time. On the other hand, possible future needs for WRA information are hard to predict, so general data collection programmes need to be established early to improve the understanding of the hydrological cycle and to provide information which can be used for the design of a variety of different projects;
- *Lack of integration of WRA and development*
  Water resources are often developed in the context of separate projects which are not integrated, although the water cycle is itself an outstanding example of a single, integrated, natural system. Indeed, users of

Impacting the water cycle : *precipitation–percolation– transpiration–evaporation–transportation–precipitation (source: reference 6)*



water are increasingly competing with each other for scarce resources. In these circumstances, it is difficult not only to manage water wisely, but also to measure its availability and the effects which usage is having on the resource;

- *The special challenges of international water resources*
  Many of the world's major river basins lie within the territory of more than one nation. WRA and management is carried out in some international river basins in a fully co-operative fashion, with free exchange of information and use of common standards, but in many others there is little co-operation. Indeed, in some, information on water is regarded as a matter of national security, and is witheld for political or economic reasons;
- *The effect of human activity and climate change on water resources*
  The hydrological cycle is being modified quantitatively and/or qualitatively in most river basins, by human activities such as land use change, water storage, inter-basin transfers, irrigation and drainage (see figure above). It is possible, too, that global climate change may have an impact on water resources throughout the world. Thus, it can no longer be assumed that information collected in the past is a sufficient or reliable indicator of recent or future conditions.

The Mar del Plata Action Plan

The concern for sustainable development is not new. The United Nations Water Conference, convened in 1977 in Mar del Plata, Argentina, addressed the needs for wise management and development of water resources, as a prerequisite for improving economic and social conditions, particularly in developing countries (reference 1).

The Conference was the first global meeting of its kind on water, at a high policy-making level. It was attended by representatives of 116 States, 21 UN Organizations and Specialized Agencies, and over 80 intergovernmental and non-governmental organizations. Its recommendations covered eight major areas: assessment of water resources (see Appendix A); water use and efficiency; environment, health, and pollution control; policy, planning, and management; natural hazards; public information, education, training, and research; regional co-operation; and international co-operation. Ten resolutions were agreed by the Conference, which were based on these recommendations. Participants declared the

recommendations of the Conference to be known as the Mar del Plata Action Plan (MPAP), and urged strongly that they be effectively implemented by all States.

Assessment of progress of MPAP implementation

The Committee on Natural Resources (CNR) of the UN Economic and Social Council (ECOSOC) has, at its biennial meetings, reviewed progress in implementing the Mar del Plata Action Plan. While the Plan is seen as having contributed significantly to progress in water resources management, there is clearly opportunity for yet further progress. Following the 10th Session of the CNR in 1987, ECOSOC requested the Secretary-General (Resolution 1987/7) to undertake the following:

"In consultation with the Regional Commissions and Organizations of the United Nations System, to report to the Committee on Natural Resources at its 11th Session on progress in formulating proposals for a comprehensive strategy to implement the MPAP during the decade 1991-2000, and to include an assessment of these proposals as they relate to the action of the United Nations System".

A meeting of a panel of experts was convened in 1989 by the Administrative Committee on Co-ordination, Intersecretariat Group on Water Resources (ACC-ISGWR), to advise on a strategy. Its recommendations were duly reported to CNR and ECOSOC, which requested that proposals for a strategy for the MPAP during the 1990s be submitted to the Committee's 12th session in 1991 (reference 7).

Progress since 1977 in tackling the different needs, as conceived in the MPAP, has been assessed by the several agencies of the United Nations system. This was done by means of a series of in-depth assessments undertaken under the aegis of an ACC ISGWR project funded by UNDP. WMO and UNESCO have been responsible for reporting on progress and issues with regard to water resources assessment. Agricultural water use has been considered by FAO, water quality issues by WHO, and economic aspects by the UN. The results of these assessments have been utilized for the formulation of action proposals at the national, regional and global levels, having been reviewed by the ACC ISGWR at its eleventh session (Geneva, October 1990) (reference 8).

The Committee on Development Planning has recommended that the United Nations Conference on Environment and Development (UNCED), [Brazil, 1992], should include on its agenda the topic of sustainable development and utilization of water resources, and should take into account the strategy for implementing the Mar del Plata Action Plan during the 1990s. Towards this end, the ISGWR is planning an International Conference on Water and the Environment (Dublin, 1992) whose findings will feature this report on WRA as part of the main input to UNCED.

Joint WMO/UNESCO WRA project

In 1978, as a follow-up to the UN Water Conference, WMO and UNESCO, with the endorsement of ECOSOC, initiated a project which was designed to increase the capability of countries to evaluate their achievements in WRA and to provide a general framework for determining their needs for technical assistance in this field.

The first stage in the project was the preparation of a Handbook which could be used by countries to determine for themselves the adequacy of their national WRA programme. A draft of this "Handbook for National Evaluation" (reference 2) was prepared in the early 1980s and tested in pilot projects in Australia, Federal Republic of Germany, Ghana, Malaysia, Panama, Romania and Sweden. It was reviewed at regional meetings of experts in Africa, Asia and Latin America in 1984 and 1985 and, after due revision, was published in English; the French and Spanish versions are currently being processed for this purpose.

The Handbook illustrates the full range of topics and activities which are included in a water-resource assessment programme. It contains detailed check-lists under each heading and offers explicit advice as to how each activity might be evaluated, in most cases in quantifiable terms.

The second stage of the project, which was initiated in 1988, is currently underway. The Handbook is being distributed to Member States, who are encouraged and supported to make use of it in evaluating their own WRA activities. This includes the convening of workshops where the methodology for national evaluation is presented to those in a position to use it.

Progress on Water Resources Assessment

The objectives of this report are:

- to assess progress in implementing Recommendation A, paragraphs 3 and 4, of the Mar del Plata Action Plan, which relate to WRA (reproduced in Appendix A);
- to identify key issues which must be dealt with in defining a strategy for the 1990s, at the national, regional, and international level;

- to make recommendations for components of a strategy for implementing the Mar del Plata Action Plan during the 1990s.

The overall global assessment in this report is an amalgamation of regional evaluations for each of the five UN Economic Regions. More detailed assessments in the form of case studies were made for a number of selected countries* around the world in order to provide an in-depth review of progress and current status under a wide range of socio-economic circumstances. The case studies were based on the methodology described in the UNESCO-WMO publication: "Water resources assessment activities: Handbook for national evaluation" (see box page 14 and reference 2). In addition, brief reports were prepared for many of the other countries in each region, by a total of eight WRA regional consultants.

Each of these consultants prepared a regional report, using information collected during visits to selected countries and regional organizations; from publications, from files and other documents of the UN and other UN organizations; and from personal knowledge. The consultants and the regions they covered were as follows:

ECA	N.B. Ayibotele (Ghana)
	[English speaking countries]
	J.J. Peters (Belgium)
	[French speaking countries]
ECE	K. Hofius (Germany)
	A. Becker (Germany)
ECLAC	T. Palas (Uruguay)
ESCAP	P. Mosley (New Zealand)
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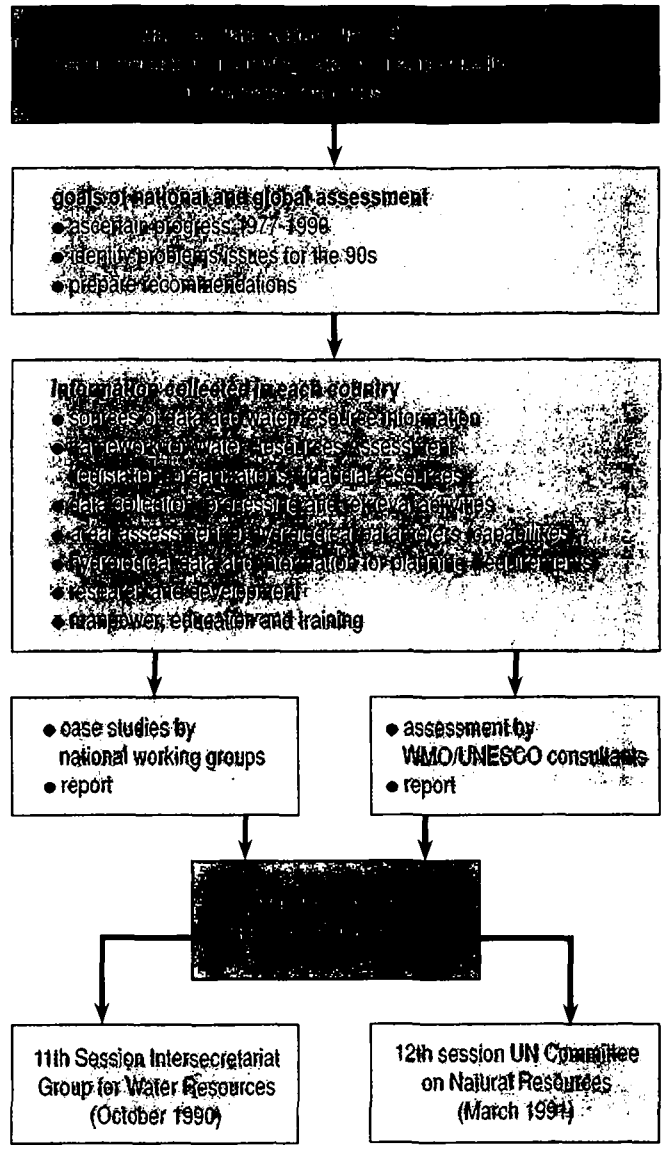
ESCWA	J. Khouri (Syria)

This material was brought together, appraised and synthesized by the consultants, at a meeting in July 1990 in the WMO Headquarters, in which representatives of UNESCO, WHO, the UN Department of International Economic and Social Affairs (UN-DIESA) and the ECE also participated. The material for this report was then compiled by P. Mosley (New Zealand) and subsequently reviewed by O. Starosolszky (Hungary) and A. Perks (Canada). The statistical analysis of networks was carried out by A. Afouda (Benin). The figure on the right illustrates the overall procedure used in this project.

Summarized flow chart of the WMO/UNESCO project components



* Côte d'Ivoire, Ghana, Hungary, India, Malawi, New Zealand, Papua New Guinea, Sweden, Venezuela, Yugoslavia

2

Water Resources Information

Accurate information on the condition and trends of a country's water resource—surface and groundwater, quantity and quality—is required as a basis for economic and social development, and for maintenance of environmental quality through a proper perception of the physical processes controlling the hydrological cycle in time and space. Uses of information about the water resource are many and varied; almost every sector of a nation's economy has some requirement for water information, for planning, development, or operational purposes.

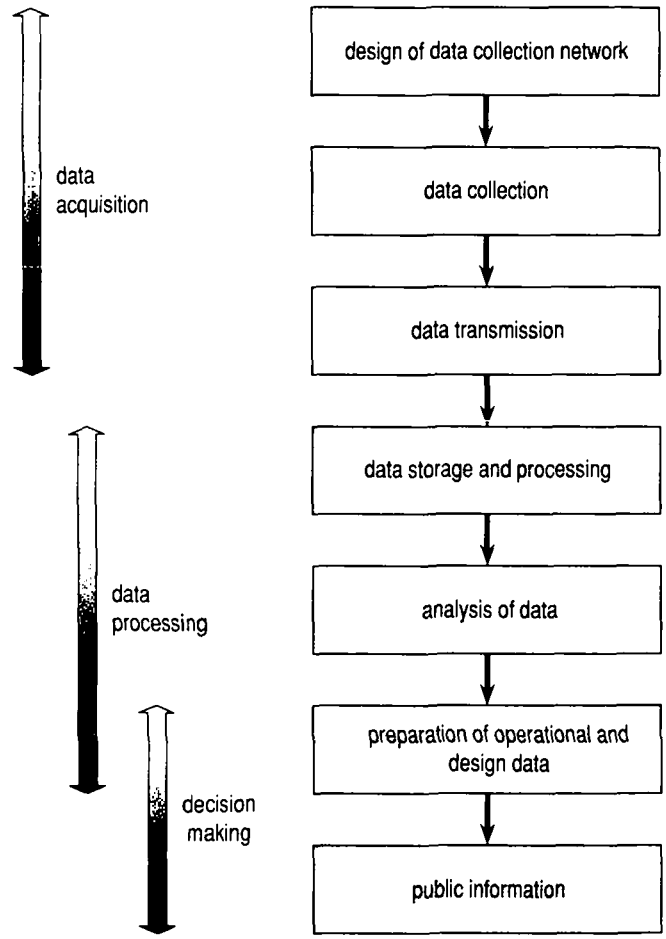
Uses of water resources information

Hydrological or Hydrometeorological Services or related agencies have been established in countries for systematic water resources data collection, archiving and dissemination. Their primary role is, in principle, to provide information to decision-makers on the status and trend of water resources. Such information may be required for the purposes of:

- assessing a country's water resources (quantity, quality, distribution in time and space), the potential for water-related development, and the ability of the supply to meet actual or foreseeable demand;
- planning, designing, and operating water projects;
- assessing the environmental, economic, and social impacts of water resource management practices, existing and proposed, and planning sound management strategies;
- assessing the response of water resources to other, non-water sector activities, such as urbanization or forest harvesting;
- providing security for people and property against water-related hazards, particularly floods and droughts.

Most frequently, water resources information has been collected for a specific purpose, such as the design of a hydro-electricity scheme. However, increasingly, competition amongst users for scarce water requires that resources are managed in an integrated fashion, so that the interactions amongst several projects and users may be understood and planned for. This places a much greater burden on suppliers of water resources information, because a variety of different types of information is simultaneously needed—on water quantity and quality, both above ground and below—and it has to be presented in different forms for different users. This makes

Activities of a hydrological service



Hydrological information required for water resources projects

Water projects	water levels			river flow			sediment			water quality*		
	time series	max	min	time series	max	min	time series	max	min	time series	max	min
redistribution of water (diversions, lakes, canals)	M	M	M	H	H	H	H	M	M	H	M	M
redistribution of water in time (reservoirs)	M	M	M	H	H	H	H	M	M	H	M	M
energy production (hydropower, waste heat disposal)	H	M	M	H	M	H	H	M	M	M	M	M
water conservers (dams, floodbanks)	H	H	M	M	H	M	M	M	M	M	M	M
water relievers (spillways)	M	H	M	H	H		M			M		
quality improvements (water and sewage treatment)				H	M	H	M	M	M	H	H	H
zoning (flood plain, coastal zones)	H	H	M	M	H	M	M					
insurance (flood damage, water quality damage)		H	H		H	H				H	H	
flow and level forecasts (flood control, reservoir operation)	H	H	H	H	H	H						
standards and legislation (water quality)	M	H	H	M	H	H				H	H	H

H = High level of priority M = medium level of priority * water quality parameters are diverse depending on the project

it essential that WRA agencies understand the needs of all their users, not just those with which they have traditionally dealt. Even more demanding is the need to look ahead to the possible needs of future users of data and to commence collecting the information before an actual demand can be demonstrated with certainty.

It is therefore necessary that the design and up-dating of data collection networks, especially the principal stations be co-ordinated to ensure that stations for monitoring the different elements of the water cycle are sufficiently related, both in number and location, to achieve an integrated network. Such an approach would enhance the information content of the data sets for present and unforeseen future needs.

With the growing recognition of such issues as the possibility of global climatic change, and the environmental impacts of human activities such as urbanization, there is an increasing emphasis upon the information required as a foundation for sustainable development and management of water resources. This implies that present and future generations will be beneficiaries of decisions made today, and of the information on which these decisions are based.

Types of water resources information

The diversity of possible uses of water resources information implies that there is a considerable range of types of data. Conventional water resources information comprises the statistics of a variety of meteorological and hydrological elements.

The elements include:

- precipitation (rainfall, snow, and fog-drip);

D. Kraemer, WMO

Plot under irrigation (Guatemala)

- river levels and flows, and lake or reservoir levels;
- groundwater levels;
- evapotranspiration;
- sediment concentrations and loads in rivers;
- water quality (bacteriological, chemical, and physical) of surface water and groundwater.

The statistics include:

- mean annual, monthly, or seasonal values;
- maxima and minima, and selected percentiles;
- measures of variability, such as standard deviation;
- continuous records in the form, for example, of a river flow hydrograph.

There is a requirement for both historical and real-time data, to cater for the full range of needs, from project design through to flood warning. Flood or drought forecasting requires data to be synthesized for the future, using numerical flow routing models.

The UNESCO/WMO Handbook for National Evaluation of Water Resource Assessment Activities (see reference 2) recognizes a number of types of water resource projects, for which hydrological information is required, given in the table on page 17.

In addition to the more conventional measurements (given above and in the table on the previous page), there is a growing recognition of the need to measure other aspects of the freshwater environment, and of the wider environment in which freshwater is only a single component. These include:

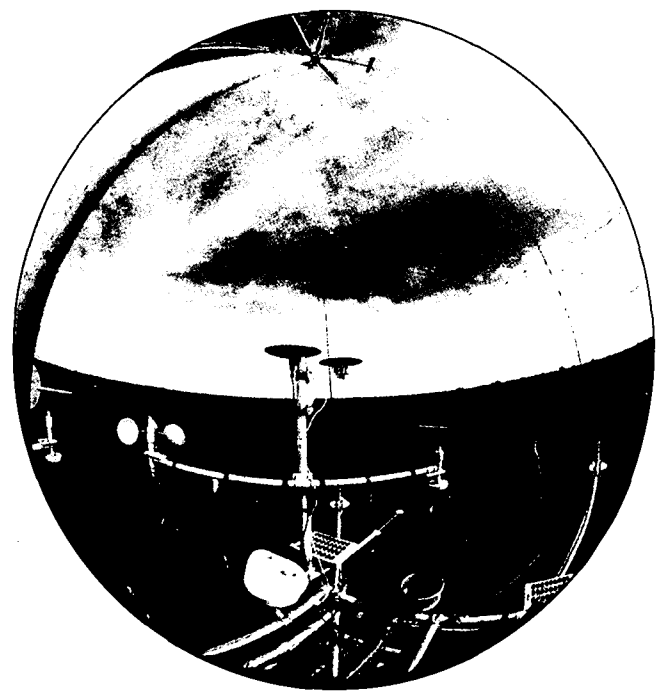
- the volumes of water needed for industrial, domestic, and agricultural use, and for navigation. These are now a significant modifier of the hydrological cycle in many basins;
- attributes of rivers related to instream uses such as freshwater fishery habitats or recreation;
- watershed characteristics which may be related to hydrology, such as vegetation patterns, soil moisture, topography, and aquifer characteristics like permeability;
- environmental concerns (eutrophication of lakes, damage to natural freshwater and estuarine ecosystems).

Together, these imply a vast range of water-related data and information that the Hydrological Service and other related agencies may be required to collect and archive. Different countries have different priorities, depending on their level of economic and social development, the sensitivity of the natural environment to disturbance by human activity, and the nature of the physical environment itself (climate, topography, the abundance or otherwise of water, and so on).

There are several critical requirements for an effective WRA programme:

- high quality data must be collected to permit confident statistical analysis;
- the data and information it provides must be carefully targeted to the users' requirements;
- an integrated observation programme, in which measurements of several variables are made simultaneously, is required to provide the greatest total value;
- other forms of information should be available which

Studying evapotranspiration from tropical rain forests (Brazil)



Institute of Hydrology, Wallingford
United Kingdom

are compatible with, and can be analysed with, water resources information;

- an effective system is needed for archiving and disseminating data to ensure that they are not lost or corrupted, and are made available in a form that enables analysis.

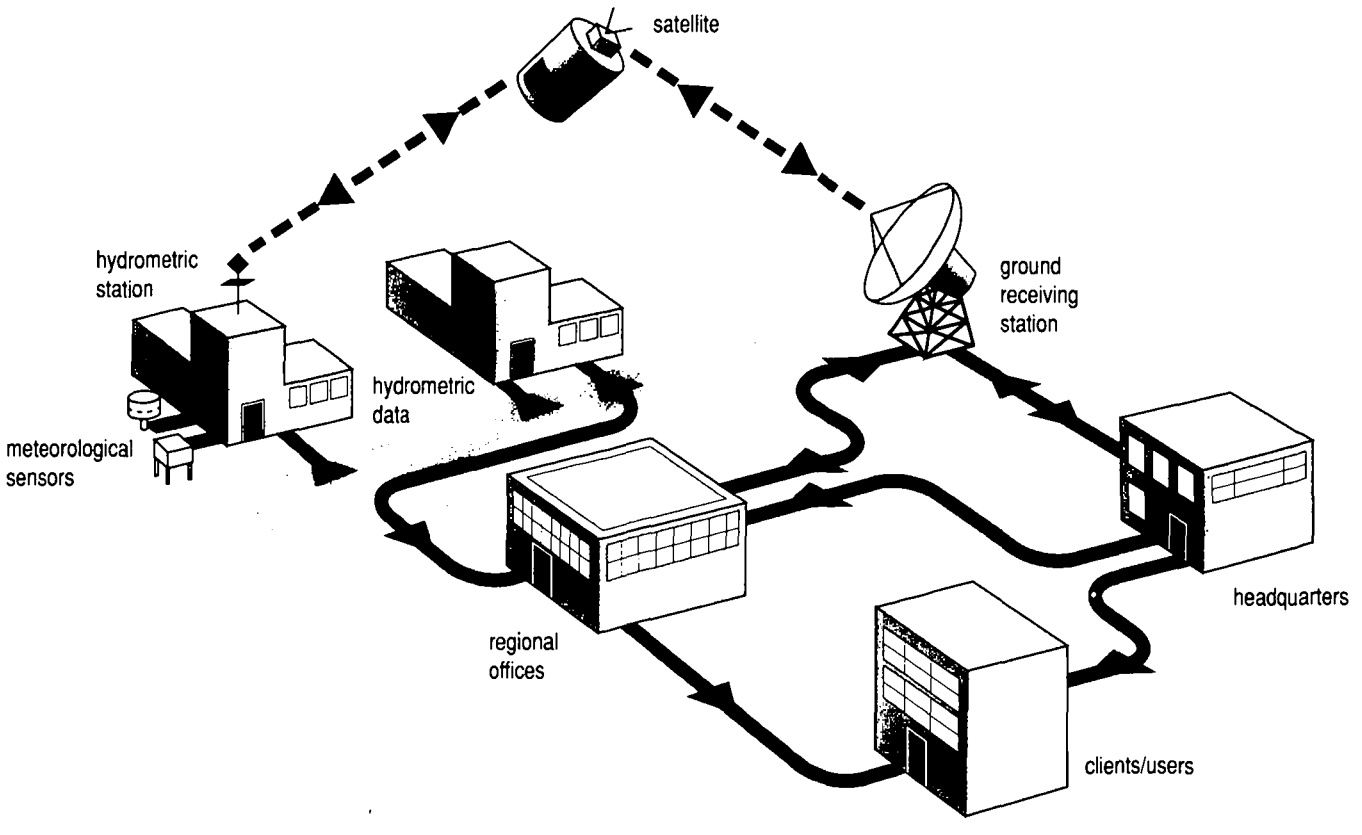
The above requirements can increasingly be met by application of new technology such as telemetry, to make data available in near-real time, archiving and processing data by personal computers, remote sensing to more effectively collect areal information, geographical information systems (GIS) to provide a means of analysing spatial data. At the same time, new micro-computer storage devices (i.e. optical disks) make the data more easily available. Nevertheless, technology is not the only requirement; a trained and well-managed staff is of even more fundamental importance. As financial resources become increasingly limited in many countries, it becomes ever more vital that effective organizational structures are in place to ensure that those resources are used most efficiently.

The value of water data

The nature and variety of the users of water data and information provide considerable insight into the importance of that data to a country's environment and economy, and consequently into the value of that data and information. With increasing pressure to properly justify the cost of hydrological data collection programmes, it is very important that countries demonstrate the value of hydrological data, in cost-benefit terms. In this context, during the recent WMO Technical Conference on Economic and Social Benefits of Meteorological and Hydrological Services (Geneva, 1990) (reference 9), ratios of benefit/cost of up to 40 to 1 were cited. That is, the value of the information in more cost-effective decision-making or design is forty times greater than its cost of collection. Benefit/cost ratios in the range 5 to 10 seem to be normal, with figures of 9.3 and 6.4 being found in studies in Canada and Australia (references 10 and 11).

It is a widely held view among water managers and data users alike that water data collection programmes cost but a small fraction of the benefits they provide to a country.

Telemetric data handling system



Organizational patterns

There is a great diversity in the types of legal and organizational arrangements that have been adopted for WRA. However, there does not seem to be a strong correlation between the type of organization adopted and the apparent effectiveness of WRA in a particular country.

As regards meteorological and climatological data, these are usually collected by a single national Meteorological Service. In some countries, particularly in central and eastern Europe, a national Hydrometeorological Service has been set up which has responsibility for collecting, archiving and using both meteorological and hydrological data (in several countries only for surface quantity data). However, historically, water resources have been developed and managed for a variety of purposes—irrigation, hydro-electricity, drinking water—in a rather unco-ordinated way. Since in many countries these various functions have been the responsibilities of different government departments, water resources management has tended to be carried out by a number of agencies—over thirty in one southeast Asian country. Frequently such agencies have also carried out WRA for their own purposes. Many countries, as a consequence, have several data collection networks, and several hydrological archives. The following table, extracted from WMO's INFOHYDRO data base (1987) (reference 12), illustrates this point.

The effectiveness of these individual programmes is attested to by the number of successfully completed projects, but unco-ordinated programmes can give rise to significant difficulties in both WRA and management.

Agencies collecting WRA data

region	countries collecting data	surface water quantity	ground water	climate	sediment	water quality
ECA	34	56	30	54	31	30
ECE	33	62	54	69	45	62
ECLAC	27	73	34	64	28	33
ESCAP	27	59	35	58	37	49
ESCWA	18	80	54	17	8	13
total	139	330	207	264	149	187

Note: figures for ESCWA Region taken from reference 13

These include, at times, serious conflicts between the goals of different agencies; for example, an irrigation scheme which successfully enables new farmland to be brought into production may, by reducing river flows or introducing low quality return flows to the river, adversely affect another agency's programme to develop aquaculture or manage a freshwater fishery.

Furthermore, the consequences of lack of co-ordination amongst WRA agencies may include duplication of activities because one agency does not know that another already has collected the data it requires, or gaps in coverage or willful duplication because of interdepartamental rivalry, inconsistent standards of data collection, incompatible data processing and archiving, and outright competition for resources.

Almost all countries agree that it is desirable to maximize communication and co-operation between agencies with water related responsibilities, where there is more than one, and to ensure that data are easily accessible and the possibilities of duplication are avoided.

As these difficulties have been recognized, new structures have been established in many countries. These include setting up co-ordinating bodies, such as the Australian Water Resources Council; providing organizations which have national responsibility for water resources assessment and management, such as Environment Canada and the British National Rivers Authority; or assigning overall responsibility for water resources management to one pre-existing agency, such as the Bureau of Water Resources of Papua New Guinea or the National Water Commission of Mexico.

Nevertheless, many countries still have no unified infrastructure for WRA; indeed, New Zealand has recently dispensed with its National Water and Soil Conservation Authority and the government department which serviced it, turning over all responsibility for WRA and management to regional bodies.

3

Water Resources: availability of information and status of assessment capabilities

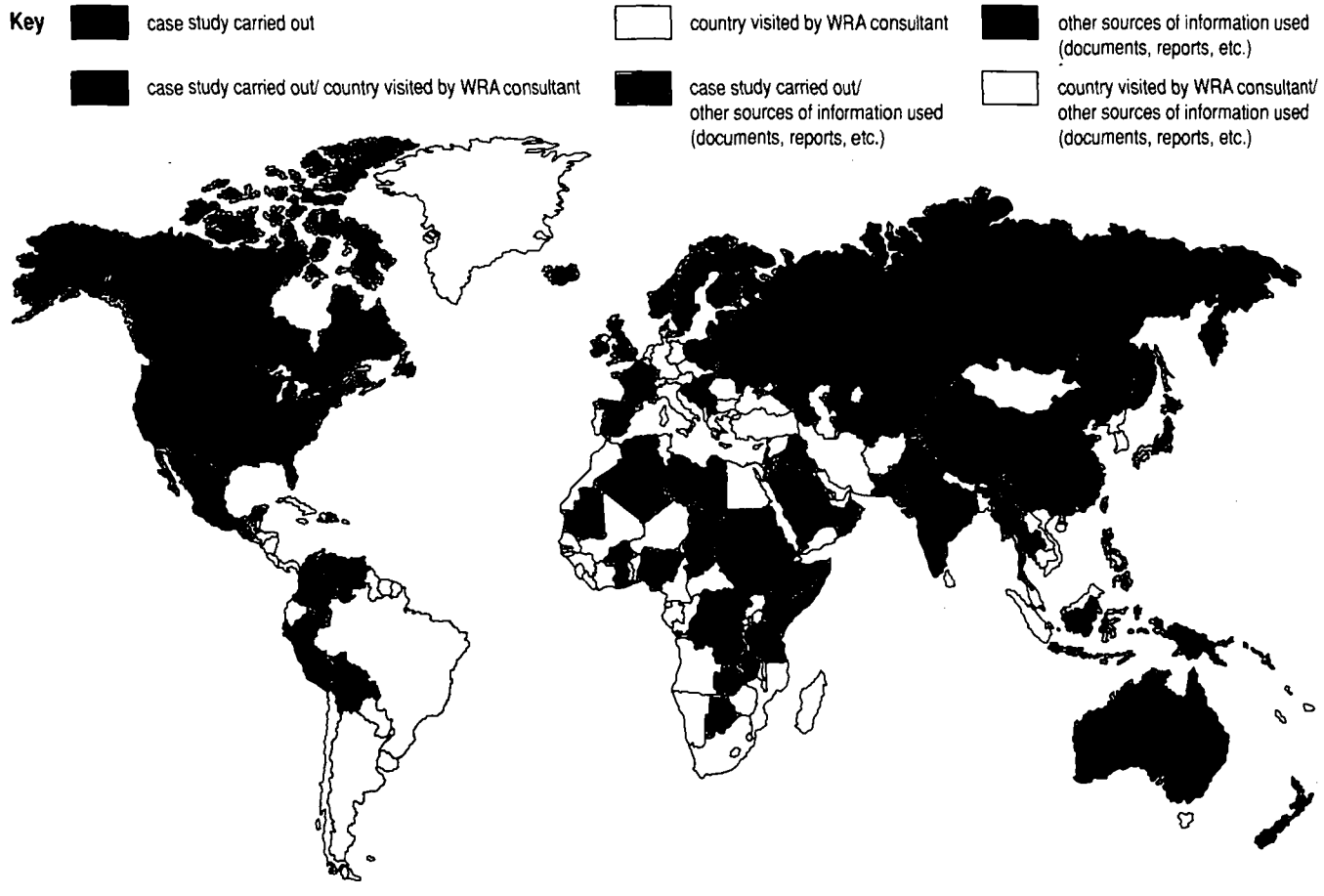
A wealth of information is available on the status of WRA capabilities around the world, but it requires collection and analysis. Because the countries of each Region are very diverse in their economic development, climate, water resources, and so on, it is difficult to generalize about their capabilities. But nevertheless it is important to do so, so that recurrent issues can be identified and dealt with in a structured way. The reports on the status of WRA in each of the Economic and Social Regions (references 14 to 18), prepared as part of the in-depth assessments, provide the basis for this chapter; and, after drawing out the main conclusions for each Region, general issues are identified. It is probably true to say that most of the conclusions drawn for any one Region apply to a greater or lesser extent to the others.

Africa (ECA)

Availability of data and water resources information

Data collection networks are satisfactory only in some of the more developed areas of the Region. They are deficient in arid, semi-arid, or remote areas except for some

Sources of information on WRA activities



Hydrogeology project, UNDP/WMO

Staff gauges in need of repair (Africa)

areas as the Sahel where efforts have been made to develop meteorological networks. There is a general lack of equipment, laboratories and other components of the infrastructure, while sediment and water quality data collection are largely ad hoc in nature. Furthermore, because of adverse economic conditions, observational networks and the state of repair of the equipment have been rapidly deteriorating. Programmes for collecting groundwater information are often inadequate, despite the many boreholes installed during the 1980s.

Data processing, archiving, and dissemination have improved in some respects, particularly for meteorological data. Hydrological data are still often processed manually, and disseminated with long delays, because of shortages of funds for equipment and printing. There is a trend towards equipping WRA agencies with personal computers, and some have very advanced equipment, the maintenance of which however will depend on adequate funds.

In only a few countries are reasonably comprehensive time-series data available for rainfall, water level and sediment load, and then usually only since the 1950's. Rainfall data are normally the most readily available, while water quality and sediment data are generally scarce. Much groundwater data were generated by drilling programmes during the 1980s, but there has been a failure to establish ongoing programmes of groundwater observations to make use of these bores.

Many countries have maps of various hydrometeorological statistics, such as mean annual rainfall or extreme river flows, and hydrogeological maps; other types of data, such as land use or topographic information, are generally not available in the quantities and with the coverage required, except in a few areas where significant international assistance has been provided. With the consequences of climatic variability and the trends so evident in Africa, the need for all types of data to monitor and manage all natural resources is clear, but has not been achieved.

Methods of extrapolating data, such as hydrological modeling, are available in some countries, but in many the resources are not even available to maintain the necessary data collection programmes. There is a large gap between those countries which have received such technology, and those which have not.

- In conclusion, due to the general shortfall in financial resources, the needs for improvement in WRA technology are obvious and wide-ranging. Numerous specific needs can be identified, such as for the development of groundwater monitoring networks (quantity and quality), for improved and appropriate methods and technology for river flow gauging under difficult conditions, application of remote sensing techniques for acquiring meteorological data, hydrogeological characteristics, physiographic information (land use, soils, geomorphology in particular), and data on river behaviour and form, particularly where there is a significant human influence on the hydrological regime. Even more basic is the need for current meter rating tanks, as these facilities are lacking in many countries, giving rise to concern for the reliability of river flow records. Indeed, there is a general and immediate need for more effort to be put into virtually all aspects of WRA.

Infrastructure for WRA

There are several types of institutional arrangement for WRA. Not enough countries have integrated policies for WRA, or co-ordinated water resources management, but there is a tendency for WRA to be concentrated in a few agencies. There is a general lack of relevant legislation, particularly relating to water quality, but there have been some improvements. Efforts have tended to focus on particular areas of water resource development, especially for drinking water and agriculture, so that comprehensive WRA commonly has not been carried out.

The World Bank/UNDP Sub-Saharan Hydrological Assessment Project, which was started in 1987 and had covered the IGADD and SADCC countries by the end of 1990 has, among others, demonstrated very clearly the generally poor institutional arrangements for WRA in these countries.

- Several areas of particular opportunity for improvement may be identified, including improved co-ordination of water agencies; comprehensive legislation to provide a basis for defining responsibilities for water resources management and assessment; establishment of more effective structures for activities at regional and local levels; and integration of water issues with those of a broader environmental nature. The impetus which was present during the early 1980s has been lost, and a determined effort will be required to regain it.

International programmes

Although international assistance has brought an improvement in WRA in a number of countries, the adverse economic conditions during the latter half of the 1980s have led to a loss of ground in many of these, and only increasing international aid can prevent a continued backward slide. The International Hydrology Programme (IHP) of UNESCO and the Operational Hydrology Programme (OHP) of WMO are vehicles for this aid, to varying degrees. Often the involvement of a particular country depends heavily on the interests of only one or a few people or agencies, and others are not kept informed of the programmes.

However, international assistance has brought a number of problems, or has not helped as much as it might. Assessments of regional needs by overseas consultants are not always perceived to be objective or well conceived, and over-reliance on international consultants, who frequently are not enthusiastic about transferring their knowledge to national counterparts, has a demoralizing effect on nationals who are qualified (or could easily be trained) to do the work, and would appreciate the opportunity to do so. Because of inadequate training of nationals during project implementation, there has frequently been a lack of ability to sustain a project after it has been handed over. There is a perception that developing countries are used as test laboratories for agencies in donor countries to obtain experience using donor funds, and there is insufficient consideration given to the sustainability of projects after external assistance ceases.

Co-operation in international river basins has been beneficial in several cases, but unfortunately shared waters in some international river basins have been a source of tension and dispute in other cases.

Research and development

Research and development is lacking in most countries; the potential capability is under-employed, because of poor planning, a lack of policies to direct research, and a lack of financial resources. Only a few centres have developed co-ordinated R & D programmes of a good standard, mostly with foreign assistance.

Human resources and training

Some ECA countries have achieved a good degree of training of WRA staff (both in number and level), but there are large differences, and only in a few countries is the education and training infrastructure adequate. The situation has improved in some countries particularly for engineers and professionals up to first degree level, and to a lesser extent for senior technicians. However, environmental subjects, planning, and resource management require more attention, and there is a need for greater integration of training in the various sub-areas of water.

Planning of special education programmes at the national level is difficult, because of the lack of resources and of national human resource planning at the broader scale. Essentially, there seems to be an inability to mobilize the existing educational resources to develop courses which are relevant to changing needs.

In several countries, there is a "brain drain" of experienced staff, because of poor conditions of service and remuneration, both to private sector employment and to better paid posts abroad.

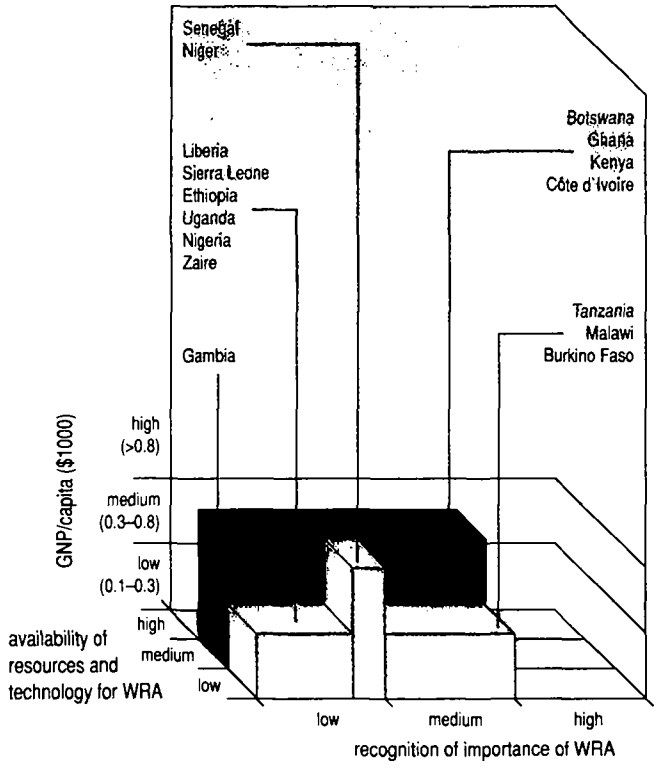
- Primary needs include the continual strengthening and reorientation of education programmes, the development of the potential which several universities and institutes offer for post-graduate and senior technician training, in-service training for junior technicians and observers, the teachers and materials needed for these areas, and the integration and broadening of water-related education and training.

Key issues

The key issues which must be dealt with in developing WRA in the ECA Region are:

- *Resources availability.* Inadequate funds are allocated to WRA, because priority has been given to other sectors in the economic crisis in which many African countries find themselves, and because of the effects of drought and population growth, which reduce available resources and require that they be spread more widely. However, available resources are not always well used, because of deficient planning, lack of managerial skills, inadequate advice, political instability, and disruption by military activity and other sources of tension.
- *Integration.* All aspects of water resources activities are generally poorly integrated, especially in environ-

ECA region countries classified according to resources available for WRA, recognition of WRA importance and per capita GNP



Note: Only countries for which up-dated information was available are shown.

mental matters. Often there are fragmented or no policies or legislation, absence of policy-making or co-ordinating body, and overlapping or conflicting responsibilities. Responsibilities and structures are particularly required at the district and local levels.

- *Data acquisition.* Data collection networks are inadequate, and deteriorating, for almost all parameters. Resources are urgently needed for rehabilitation, and for extension of networks to cater for water quality, sediment transport, and groundwater data. In addition, equipment, servicing facilities, and laboratories are deficient. A major need is to ensure that national agencies are able to maintain projects after they are handed over by international or donor agencies.
- *Human resources.* The lack of specialists in planning, systems analysis, and modeling needs addressing. Staff motivation tends to be low because of poor conditions of employment and irregular payment; over-reliance on consultants has had a demoralizing effect on trained staff. The existing education and training infrastructure and human resources must be fully utilized, and targeted to changing needs, particularly for the broadly-based training of technical staff.
- *International activities.* There is great need for enhanced co-operation amongst African nations which share river basins and aquifers, in data collection, training, and research into topics of common concern, like environmental degradation. International organizations can provide assistance in a wide variety of ways, including technology transfer, assistance with mobilization of the educational and training infrastructure, provision of financial and logistic support, and facilitation of regional co-operation. Donor countries could enhance the long-term value of their assistance by such measures as formal development of strategies, linking funding to necessary restructuring, ensuring suitable terms of reference in projects, including social and environmental impact assessments in projects, and promoting inclusion of the recipient countries' own expertise, as a means of further developing skills.

The Arab States (ESCWA)

Availability of data and water resources information

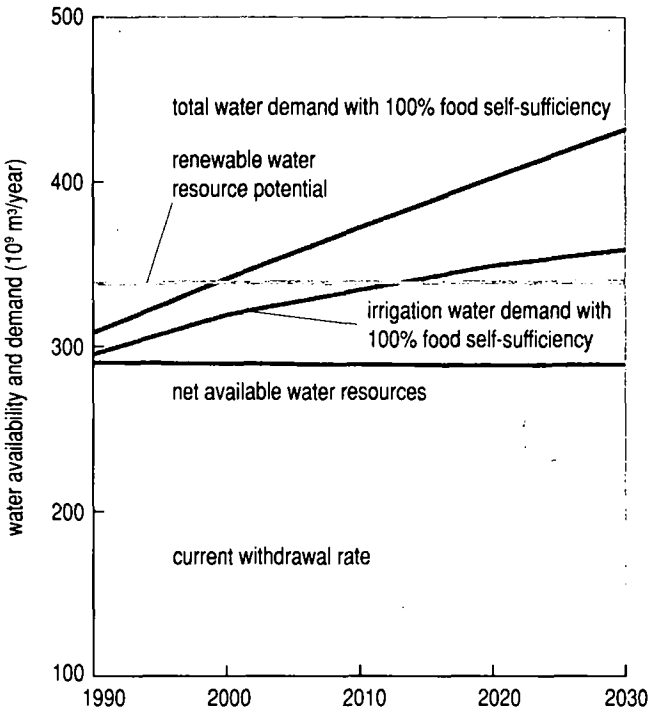
Meteorological networks in the Region are fairly satisfactory, although needs include standardization of techniques and equipment, optimization of networks, and application of remote sensing and automatic data collection procedures. There was a noticeable improvement in the extent of hydrometric networks during the early 1980s, but since the middle of the decade there has been a deterioration in their operation and maintenance. The greatest emphasis is placed on water quantity data, but water quality is neglected; data collection programmes for ephemeral rivers are far from adequate, and programmes for groundwater are the least adequate of all.

Facilities for data processing and archiving are inadequate in most countries, despite some progress, and there is only modest use of hydrological models and other advanced technology, because of a shortage of software, hardware, and qualified personnel. In general, data archiving and dissemination is deficient, and with the exception of meteorological data it is often difficult to obtain information.

There is considerable variation in the availability of information and data, but generally it is unsatisfactory for reliable planning. Meteorological data tend to be the most satisfactory, and surface water data are fairly satisfactory for perennial watercourses. Hydrogeological information is least satisfactory, although there has been some progress in its provision; physiographic information is fairly adequate, but soil, land use, and vegetation maps are needed, or need updating.

Water availability and demand in the Arab region

(Source: reference 15)



- Major areas of need include improved measurement techniques for ephemeral rivers, groundwater levels and quality, and rainfall characteristics, with an emphasis on automatic, real-time, or remote sensing technology. A need is recognized for improved and more specific standards for data accuracy. Specific topic areas in which improved information is required include river sediment loads, water quality, river mechanics, and urban hydrology. Particular effort is needed on database management systems, and systems for data dissemination and exchange, including geographical information systems and the more sophisticated computer applications. National plans and priorities for research and development, and co-ordination between government and the private sector, are needed to identify further research needs and promote application of results.

Infrastructure for WRA

WRA has mostly been geared to the development of irrigation and urban water supply, rather than to integrated water management, and therefore has commonly been the responsibility of agricultural or municipal departments. Few countries have established agencies for the overall management of water resources, and lack of co-ordination is a major issue for most countries. Co-ordinating bodies which have been established have not been very effective, but the present trend is to merge agencies.

Many countries have or are considering new legislation, including provisions for charging, and for the rights and responsibilities of water users and producers of WRA information. Water is considered a national security issue, related to food security. International river basins and aquifers need more exchange of information, but this is not always forthcoming.

International programmes

There have been some successful projects at the regional level, particularly related to shared aquifers, and most of the less developed countries have benefitted. However, international programmes have tended not to be based on well defined needs and priorities, but on the views of a few people in a specific agency.

- The greatest needs relate to shared aquifers and river basins, where information exchange is highly desirable, and where introduction of new technology for improving data aquisition and analysis, will require assistance at the international and regional level.

Research and development

In general, countries have national policies and plans for research and development, so that work by universities, consultants, research institutes, and WRA agencies tends to be fragmented and unco-ordinated.

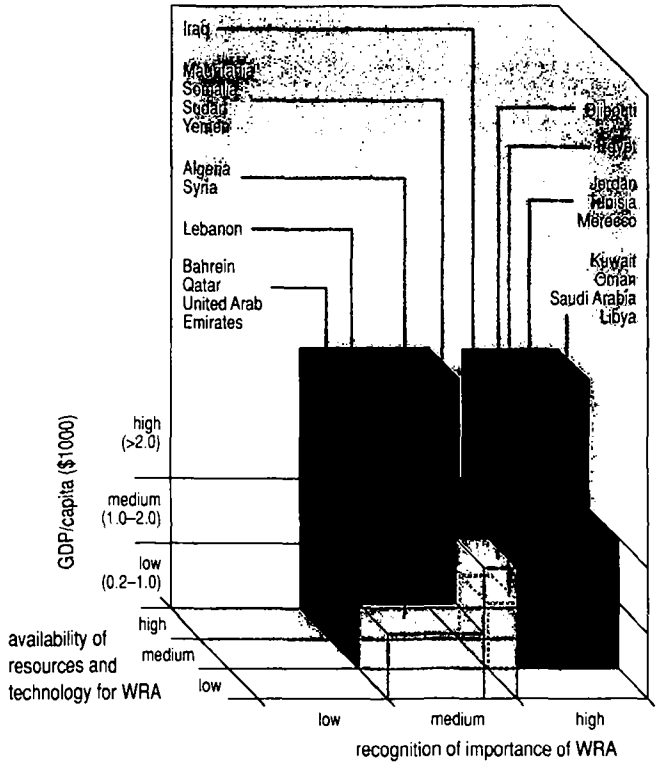
Human resources and training

All countries lack policies or plans for future needs, so that workable plans for training and human resource development are available in only a few. There has been considerable improvement at university and postgraduate level in the number of trained staff, but there is a great shortage of facilities for training technical staff. In-service training for observers and technicians is also inadequate, and planners, managers, and policy-makers are not generally considered in developing plans for education and training.

In general, there is a lack of technical and management skills at all levels. Adverse working conditions, poor terms of employment, and lack of incentives or career opportunities make staff recruitment and retention difficult.

- The needs in the area of human resources development and training follow fairly clearly from the preceding paragraphs. They include national policies for human resource development, sufficient resources for training and educational institutions, improved

ESCWA region countries classified according to resources available for WRA, recognition of WRA importance and per capita GDP



Note: Only countries for which up-dated information was available are shown.

terms of employment, and more training for managerial staff.

Key issues

Despite some progress in WRA in the ESCWA Region, a number of issues need addressing, including:

- *National policies and legislation.* There is a need for national policies in most aspects of water resources management and assessment, including water resource management policies (which would help resource managers in deciding the types of data required), research and development, and education and training.
- *Co-ordination and integration.* This is a need at all levels—international (particularly in shared river basins and aquifers), regional, and national—and in all aspects of WRA and management. The particular need is to promote information exchange, eliminate duplication, and ensure that data acquisition and dissemination are as efficient as possible.
- *Financial resource availability.* Reversal of the present deterioration in the status of WRA requires that more resources be made available, and also that those which are already available are fully used. The need extends from data collection programmes, through archiving and disseminating data, through to analysis and computer modeling. Resources are required particularly to enable application of modern technology such as computers, geographical information systems (GIS), real-time data collection, and remote sensing.
- *Education and training, and human resources.* Substantial effort is needed in all areas, to ensure that staff are recruited and retained at all levels who are equipped to carry out their duties. Particular attention needs to be paid to staff management, including such aspects as motivation and conditions of employment.

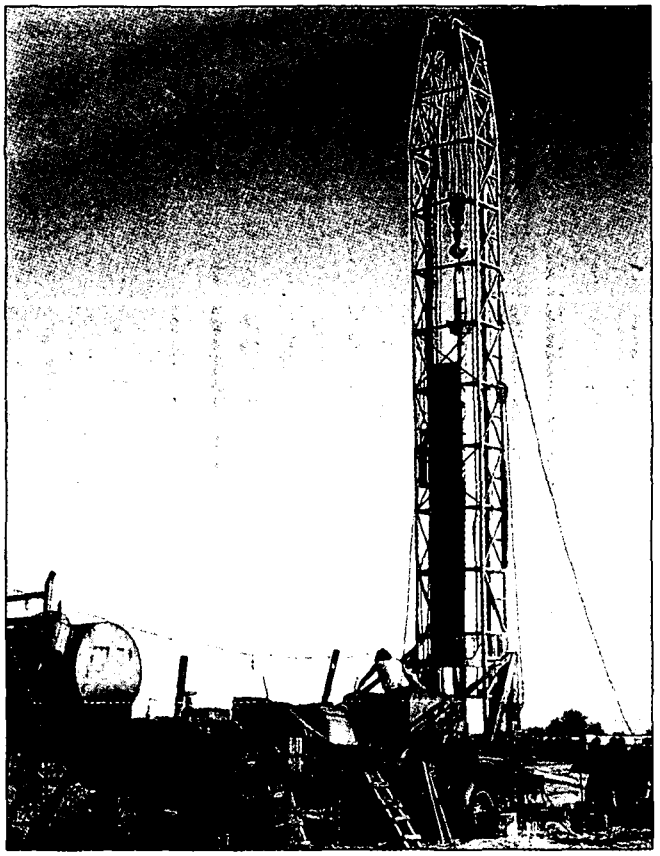
Latin America and the Caribbean (ECLAC)

Availability of data and water resources information

Economic circumstances in Latin America, particularly since about 1983, have severely limited the financial resources available for WRA. Although water resources management agencies have generally been able to justify allocating resources to project-based data collection, hydrometeorological agencies have suffered most from the economic conditions. A general deterioration in data collection programmes has resulted, particularly at the level of national rather than project-based monitoring. Extensive areas have little or no monitoring, in view of difficult conditions of access and very low levels of social and economical development, which make it necessary to conduct WRA at the basin (or sub-basin) level. Groundwater observations are practically non-existent in many countries, and water quality data collection is also lacking.

Meteorological information is generally available, in the form of maps and atlases, but this is not the case for hydrology, and particularly not for water quality or groundwater data. However, UNESCO projects on the surface water balance and hydrogeological mapping have been instrumental in providing coverage.

Despite considerable advances in data processing and the availability of computers, data are frequently difficult to access. Data of different types are commonly available from different agencies, or in different political jurisdictions. There is a considerable backlog in data archiving in many countries, and delays in secondary processing, such as that needed to establish stage-discharge rating curves.



D. Kraemer, WMO

Drilling for groundwater observations (Mexico)

Commonly, users employ what data are available, rather than expecting to be able to specify their requirements and have them met. There tends to be poor communication between users and producers of information, with no clear guidelines as to what is required, particularly with respect to data quality.

There is little use of special techniques for areal assessment of water resources, and few developments and routine application of hydrological models.

- ❑ In conclusion, the primary need in this area seems to be funding for all aspects of WRA technology.

Infrastructure for WRA

There is a general lack of national plans for the management of water, although some countries have introduced water-related legislation. There is commonly poor co-ordination amongst agencies with responsibilities for water management, and there is not normally a national WRA agency. International river basin projects have made substantial progress, including those on the Amazon and Rio de la Plata, and provide a possible solution to national deficiencies. National agencies with water resource management responsibilities commonly have an in-house WRA capability to meet their own information needs, and are able to justify allocating resources to WRA and related analysis, research and development. Hydrometeorological agencies generally have a low status in the government hierarchy, and are poorly funded except during periods when water-related natural disasters focus attention on the importance of water.

- ❑ Broadly, the main areas of need are: better co-ordination amongst agencies with water-related responsibilities, improved communication amongst data producers and users, and enhanced resources.

International programmes

Many countries have benefitted from the programmes of international agencies, for example through the UNESCO regional projects on hydrogeological mapping and surface water balance. However, international agencies have not had as much impact on WRA as would been hoped. The UNESCO-WMO Handbook for National Evaluation of WRA Activities is neither widely known nor used in Latin America, primarily because the Spanish language version is not yet available. It appears that the follow-up to the MPAP has not been effective.

- ❑ There are several areas in which the international agencies could assist with WRA, including helping countries with WRA (through training in the use of the Handbook), assisting in preparation of national water resources plans, and facilitating co-ordination amongst countries and agencies at the level of shared river basins.

Research and development

National WRA agencies do not dedicate enough time to research and development. With the problems of personnel shortage, and pressing daily routine work, there are very few agencies engaged in R & D activities. However, the computer boom, the proliferation of software, and help from international organizations has transformed several routine processing tasks into simple applied research.

Subcontracting R & D studies to universities and other institutes appears to be, in many cases, a way out. Sometimes users contract directly with universities and the national service provides only the rough data required.

It is easily seen that, in the Region, the majority of the countries conduct their R & D activities with no general plan, but according to the desires of the user who pays the bill. After studies are completed, results are not as

well applied as they could be. The lack of adequate institutional frameworks found in the Region is also reflected in the lack of a national policy related to R & D.

The Region suffers from the lack of technical information (books, professional journals, society membership) due to the economic constraints already mentioned.

- In spite of these factors, there are activities on applied research in the Region covering several aspects of WRA. Some of these research centres have been established on the basis of international co-operation programmes, and with the appropriate personnel.

Human resources and training

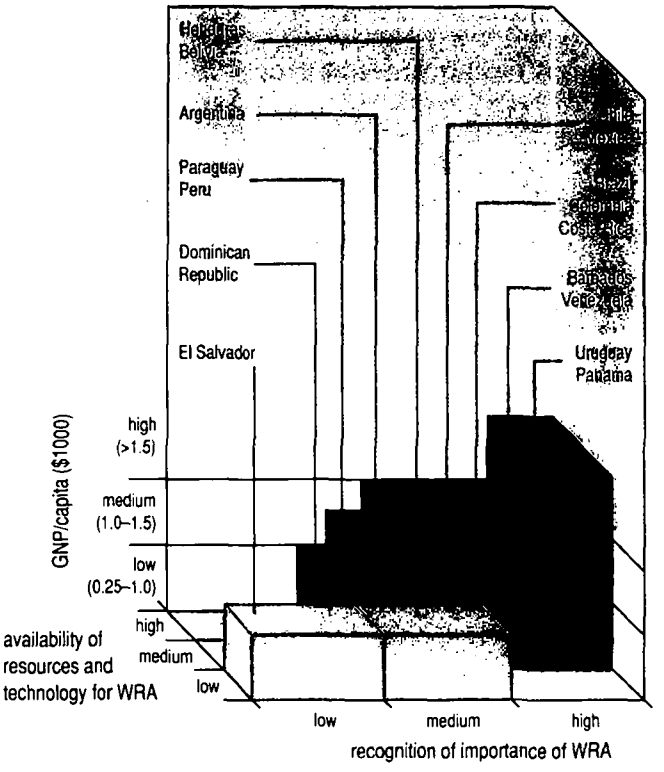
The common lack of a national water plan makes difficult the assessment of human resource requirements for WRA. Economic constraints have aggravated an unfavourable situation, and there is a shortage of staff at all levels of WRA. All manner of arrangements are made to obtain rainfall and staff gauge observations on rivers, such as by enlisting the services of local school teachers, but poor pay, conditions of employment, and career prospects generally result in poor quality staff, and the inability to recruit or retain staff.

Provision of training for meteorologists is generally satisfactory, but in-service training for hydrological technicians is generally deficient, and there is a need for refresher courses for professional hydrologists. The tendency to sub-contract R & D to other agencies prevents the agencies' own hydrological staff from developing their skills.

Key issues

- *Financial resources.* The fundamental issue is a lack of financial resources for WRA, occasioned by adverse economic conditions in Latin America. This has affected in particular the salaries paid to staff, and has created difficulties for their recruitment and retention. In turn, this has limited the possibility of doing anything other than routine work, but it has also led to a deterioration in the extent and standard of monitoring networks, to backlogs of unprocessed data, and to a lack of the necessary R & D.
- *Co-ordination and integration.* There is a general lack of: i) a national body responsible for WRA; or ii) inadequate co-ordination between producers of different types of data, as well as between the producers and users of hydrological information. This prevents the full utilization of available information and capitalization upon non-traditional techniques, such as hydrological modeling using physiographic information. Indeed, it is common that access to data is rather difficult, because data are held by multiple agencies or under different jurisdictions. Some progress has, however, been made in international river basins, and international agencies—particularly UNESCO—have assisted in regional scale collaboration.
- *WRA evaluation.* The practice of evaluating WRA activities appears to be poorly developed in Latin America, particularly because the UNESCO-WMO methodology has not been widely adopted, and there is a pressing need to promote such assessments and provide assistance for such activities. There is a lack of information on the MPAP in the Region, and the follow-up does not appear to have been effective. In addition, due to the existence of extensive areas without development, and difficulties of access, WRA needs to be undertaken at the basin level.

ECLAC region countries classified according to resources available for WRA, recognition of WRA importance and per capita GNP



Note: Only countries for which up-dated information was available are shown.

North America and Europe (ECE)

In general, the status of WRA in the ECE Region is satisfactory, and the Region to an extent provides the source

for much—but not all—of the technology used in other regions. There has been widespread introduction of integrated water management and co-ordinated approaches, and attention to restoration and protection of aquatic ecosystems. New administrative and regulatory provisions, including the growing use of economic incentives, such as charging for information and services, are having a significant impact on WRA.

Availability of data and water resources information

Meteorological and water quantity data are generally sufficient for WRA, planning, and project design, except in the less populated areas of northern Canada and Europe. Water quality data, particularly for groundwater, and especially in central and eastern Europe, are still insufficient; evapotranspiration and soil moisture data are also inadequate.

The rate of development and adoption of computer technology has facilitated rapid data dissemination, and direct access to both real-time and historical data is becoming increasingly easy. Integration of data processing allows simultaneous analysis of all types of information—water quantity and quality, surface and groundwater, demand and supply, land and water resources.

Much of the technology presently available for WRA—instrumentation, methods, data processing and archiving software, hydrological models, methods for areal assessment and data extrapolation, remote sensing and data transmission equipment, textbooks—has been developed in countries of the ECE Region, so there is no shortage of such technology. Because the ECE is generally densely populated and economically well-developed, there is a relatively high awareness of the need for and value of good water resources information, and so there is less difficulty than in other regions in obtaining adequate resources for the necessary infrastructure.

Areal assessments of water resources are well developed in most ECE countries; there are many "working" maps, sometimes published as hydrological atlases, while hydrogeological maps are available for much of the Region. There is much detailed information for a large number of river basins, sometimes at large scale.

- ❑ Nevertheless, there are still areas of need, and many techniques have barely reached the stage of routine application. Particular areas of need which might be mentioned include those relating to the effects of changing climate and land use, making measurements under adverse conditions, accuracy of estimation and extrapolation of hydrological parameters, and more cost-effective methods of making surface water, groundwater and water quality observations.

Infrastructure for WRA

With growing emphasis on the need for integrated water management, infrastructures for management and assessment have been progressively developed in many ECE countries, often in the context of overhauled water legislation. Mechanisms vary, with water commonly managed at a provincial/state/district level; WRA is frequently carried out also at the district level, but with a national oversight, or with a national agency having responsibility for data collection and/or archiving. Nevertheless, despite efforts to integrate WRA activities or to focus them on one or a small number of agencies, some countries still have several or many agencies involved. Modern computer technology and new approaches to data archiving and cataloguing facilitate data exchange between agencies, when necessary.

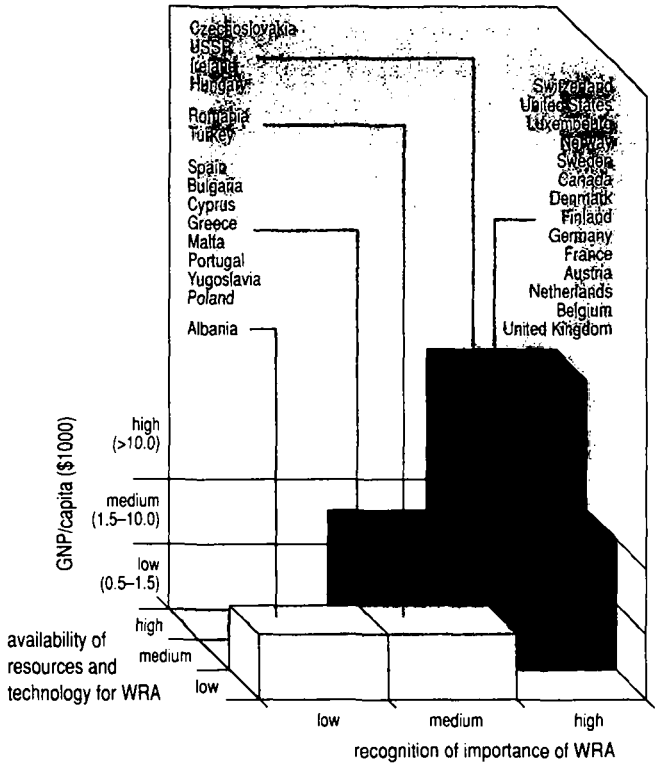
The countries of the ECE are, by and large, fortunate in having the resources—financial, technological, and human—that they require for effective WRA, although they are not impervious to demands for increased efficiency or recovery of costs. Perhaps the major issue at present, because it is the least familiar and the one that may require most careful response, is the increasing tendency for governments to require water agencies to operate on a commercial or semi-commercial footing. This is introducing a much enhanced orientation towards users and customers, and a greater premium being placed on the use of automated and other technology to reduce staff needs or, more likely, to give the existing staff complement the capability of being even more productive and efficient.

Commercial operation provides an opportunity to target operations on those areas for which the demand is greatest, and to generate resources for expansion which might not otherwise be available. All the same, experience seems to indicate that water agencies find difficulty in operating at a level of greater than 40 to 50% recovery of costs from users, which indicates that public funding will continue to be required. Since many of the concerns which relate to water management involve the public good attributes of the natural environment, continued government funding seems to be inevitable.

International programmes

The ECE countries do not, in general, require assistance through international programmes, but are more frequently the source of technology transfer, consultancies, and overseas development assistance. However, they do participate to a significant extent in international activities, in the context of the water-related programmes of UNESCO, WMO, and other agencies, for example through the FREND project of UNESCO IHP-III, and in

ECE region countries classified according to resources available for WRA, recognition of WRA importance and per capita GNP



Note: Only countries for which up-dated information was available are shown.

the WMO Global Runoff Data Centre in Koblenz (Federal Republic of Germany). Much of this type of activity is oriented towards research, rather than to operational hydrology, and to the development of increasingly sophisticated technology for WRA.

International co-operation is essential in shared river basins and aquifers, and has reached a high standard of effectiveness in basins such as the Rhine, Danube, and others in North America and Scandinavia. The approaches used, such as the special river basin commissions, provide possible models for evaluation in other parts of the world.

Research and development

There is a large R & D investment in many countries, which includes WRA agencies themselves, universities, and the private sector. Integrated water management and WRA make heavy demands on R & D resources, particularly with the widespread adoption of an ecosystem-oriented approach which requires attention also to land use planning, environmental impacts, ecosystem restoration, and so on.

Human resources and training

Because of the number of WRA and R & D institutions, it is difficult to obtain comprehensive data on the numbers of staff engaged in WRA. Increasing information requirements for water management tend to bring increased demands for staff, but on the other hand rationalization of data acquisition and automation of many aspects of data collection and processing may reduce such demands.

The ECE has a very well established system for education and training at all levels, from post-graduate to technician. Professional training is available in many universities in all aspects of water management, and there are many other mechanisms available, including correspondence courses, training courses, seminars, and on the job training, organized by universities, professional organizations, and water agencies themselves.

Key issues

- *Commercialization*. The pressure for commercialization is a symptom of the economic restraints felt in a number of countries, and an increasing preoccupation with environmental "hot spots", with the consequent re-direction of resources to such current and highly visible problems as toxic spills, hazardous wastes, and other environmental emergencies. The potential exists, therefore, for a significant disruption in WRA, even in these developed countries, because the linkage between reliable data and effective water decision-making is not clear to many managers.
- In addition, the recent changes in central and eastern European countries are having an important and rapid effect on budgets and economies. There is little doubt that this area is losing WRA capacity, while at the same time appalling water resource problems are surfacing.

Asia and the Pacific (ESCAP)

The ESCAP Region contains perhaps the greatest diversity of countries and conditions of any of the regions, and so generalizations are even more difficult to develop at the regional scale.

Availability of data and water resources information

Much available data has been collected for project purposes, particularly hydro-power and irrigation; such data can provide a sound basis for WRA, if they are readily accessible. Attention has traditionally been focussed on

precipitation and surface water data, and the availability of groundwater, water quality, and other types of data are very unsatisfactory at the regional scale. There has been little interest in integrated water resources management or WRA, so that complementary types of data which could be analysed together are frequently lacking.

A great diversity of technology, from many places including ESCAP countries themselves, is used in the ESCAP Region countries. There is a strong move towards adopting modern technology for data acquisition, including solid-state data-loggers and telemetry, while computers are also being widely adopted for data processing and archiving. However, problems are experienced in some countries which have limited foreign exchange, in purchasing spare parts for aging instruments; an associated problem is found in countries which have accepted tied aid from a series of donors, which has left them with an inconvenient diversity of equipment.

Good progress is being made in many countries in setting up computerized data archives, but only in a few are there integrated national archives which facilitate access to data. Particularly urgent needs are those relating to data security—ensuring that existing data are not lost—and data accessibility—ensuring that data can be readily obtained by users, without the need to approach multiple agencies. A longer term requirement is to provide data relating to the full range of information requirements of resource managers, particularly those relating to groundwater and water quality, but more generally also to physiography and land cover.

Availability of water resources information is generally good throughout the Region, particularly for surface water resources. Water resources data are available in map or atlas form in a number of countries, including the ASEAN climate atlas—a good example of sub-regional co-operation. Commonly, data are available in year-book form, although there is increasing reliance on computerized data banks from which data are directly obtained when necessary. On the other hand, a number of small Pacific island countries do not have much information; their water resources are frequently restricted to the freshwater lenses on low coral atolls, so that there is limited need for information.

Technology for areal assessment—hydrological models and extrapolation procedures—is relatively poorly developed in the Region, although several countries have developed their own models, or have modified existing ones when the need arose. In general, it seems that WRA has been directed at providing information for specific projects, so that these techniques have not been of great concern. The most common use of modeling appears to be for flow and flood forecasting purposes.

In general, the technology required in the ESCAP Region is already available or could be obtained by modifying existing technology; the greatest need is for financial resources to obtain it. To avoid the problems associated with foreign exchange, a particularly useful strategy already being adopted is to manufacture spare parts and, in some cases, entire instruments locally. This could be promoted by development of a complete set of modular equipment for all phases of data acquisition, emphasizing user-friendly characteristics, robustness, ease of servicing, and simplicity of manufacture in developing countries. This would also provide a solution to the multiplicity of instruments and software that may result from a succession of tied aid projects, if donors can be persuaded to relax the provisions.

Infrastructure for WRA

There is a wide diversity of arrangements for WRA, but a state/provincial/district set-up, with a federal/national agency to provide oversight or co-ordination is common. However, because much water resources development has been related to specific projects, undertaken by a variety of government agencies, there is frequently a multiplicity of agencies—more than 30 in one country. Hence, national Hydrological Services are uncommon, and so concurrent data collection programmes are frequently found. In some cases, a particular use of water, such as for irrigation, is of dominant concern, and the agency responsible has been given responsibility for playing a leading role.

Water legislation is being upgraded in many ESCAP countries, reflecting the importance attached to water resources in the region. Nevertheless, in only a few countries is there an integrated approach to water resources management—as opposed to development—and this has been adopted, primarily in those with the highest levels of economic development.

There is no clear relationship between the success of a country's WRA programme and its organization; availability of adequate funding appears to be more important.

International programmes

Many ESCAP countries are island nations, with no need for direct international collaboration, but the Region also contains several important international river basins. The Mekong is an encouraging example of effective collaboration in WRA and management, under adverse circumstances; on the other hand, there are several basins where information on water is regarded as a national security issue, and is restricted or not available.

Many ESCAP countries have benefitted from interna-

tional assistance, either through donor or colonial aid, or through agencies of the UN System. Many water resources projects have been funded, particularly in the Indian and southeast Asian sub-continents, and have frequently included substantial incorporation of WRA, particularly with a groundwater element. The training and technology transfer aspects of the WMO's OHP and UNESCO's IHP have been used to a significant degree, within the limits of available resources; however, there are several countries, particularly the least developed, that participate to a limited or negligible degree.

Research and development

Less than a handful of ESCAP Region states have any formal national policy on water R & D—or indeed for R & D as a whole. Research and development in WRA in the ESCAP Region is relatively restricted, because many of the countries are too small to devote resources to R & D. Several countries do, however, have R & D programmes which are of world class, while others have domestic capabilities which meet their needs for development of technology for application to water resources management issues.

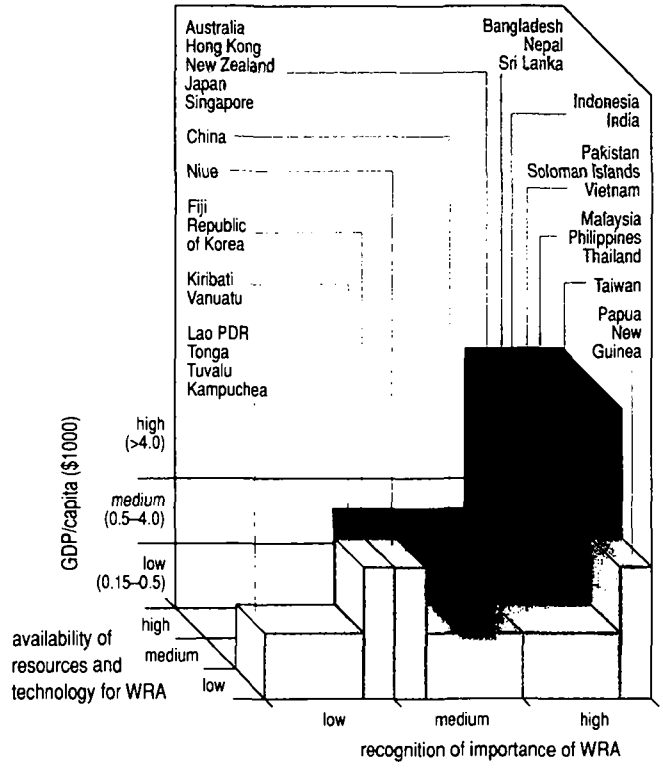
To an extent, though, R & D is unnecessary in most of the ESCAP Region countries, because the state of WRA and water resources management is such that readily available knowledge is sufficient to deal with most circumstances. Effective technology transfer and adaptation, rather than development of entirely new technology, is what is required. However, several countries have very limited access to technical literature, because of language difficulties or the lack of funds to purchase textbooks. Only a few ESCAP countries have a well-developed information system, comprising libraries, access to computer databases, and current awareness services. The publishing programmes of WMO and UNESCO are a significant contributor in disseminating technical information, and in several countries are referred to as the predominant source of such information.

Human resources and training

The availability of trained staff is a significant limitation on WRA throughout the Region, and the lack of resources— trained educators, training equipment, syllabuses, and training institutes themselves—an even more basic need. A common problem is the difficulty of recruiting and retaining staff, in the face of competition from the private sector for skilled technical people.

Nevertheless, several ESCAP countries have developed a good training and education capability for WRA staff, which in several cases provides training opportunities for other nationals. A large number of countries

ESCAP region countries classified according to resources available for WRA, recognition of WRA importance and per capita GDP



Note: Only countries for which up-dated information was available are shown.

make good use of training provided through the UN System, particularly courses organized through ESCAP, WMO and UNESCO.

In general, it appears that the ESCAP Region countries recognize the deficiencies in their training programmes, particularly in technical areas, and are taking steps to rectify them, within the limits of their resources. However, a particular need is for improved managerial and supervisory skills for senior WRA staff, who must make the best use of increasingly limited resources, and find ways of obtaining more.

Key issues

- *Financial resources.* WRA cannot be carried out effectively without commitment of financial and human resources to it. Of the 51 countries in the ESCAP region, 25% have a high level of resources committed to or available for WRA, and 20% have a medium level of resources and medium to high government recognition of the importance of WRA. For a number—perhaps 20%—WRA is a very low priority,

because the water resource is limited, easily defined, and/or not at present a constraint on social/national development. This is particularly the case with the numerous Pacific island nations. The remaining one third of ESCAP Region countries, with limited financial resources and/or governmental recognition of the importance of WRA as a basis for national development, are those where there is the greatest scope for progress to be made.

- *Integration and co-ordination*. Water resources management and assessment has commonly been uncoordinated and project-based, with consequent problems for access to data, overlapping of responsibilities, and a generally unsatisfactory situation from the perspective of integrated water management. Data collection for project purposes has been successful in providing, in an ad hoc fashion, a valuable data base, but it is important that such data are known about, easily accessible and, even more important, not lost in their entirety. Provision for co-ordinating data collection, archiving, and dissemination is therefore of great importance in most ESCAP countries. Such mechanisms are required as developing database directories, making legal provision for water permit holders to lodge data in a national archive, and ensuring that all historical data have been "rescued" and put into a form that assures future accessibility.
- *Meeting user needs*. Increasing pressure on water resources requires a greater range of information, particularly on new water sources (especially groundwater) and water quality (which is a growing constraint on the usability of water in many countries). In addition, water information needs to be put alongside other types of information, including land use, physiographic, and water demand/use data. WRA staff need a full understanding of the requirements of all their users, so that they can ensure that their product is what is required, and that it is modified to meet evolving needs.
- *Technology*. While many needs for technology can be readily met, given the available funds, a major need is for appropriate technology. This is particularly the case in developing countries with limited foreign exchange to purchase spares, and whose technical staff may not yet have all the skills needed to use highly sophisticated equipment. International organizations can assist by carrying out comparisons and evaluation of instruments, software, and other technology, assisting in technology transfer, and by placing particular emphasis on providing training in new technologies. An extension of this would be to commission the design and construction of a complete system for acquiring and archiving hydrometeorological data. Donor countries could assist by relaxing "tied aid" provisions to ensure that recipients acquire technology that is consistent with their long-term needs.

Global overview

Based upon the foregoing assessments of regional needs, the current status and trends of hydrological data collection activities, the main key water resource assessment issues of global relevance, and regional recommendations, are summarized below.

Hydrological networks and data banks

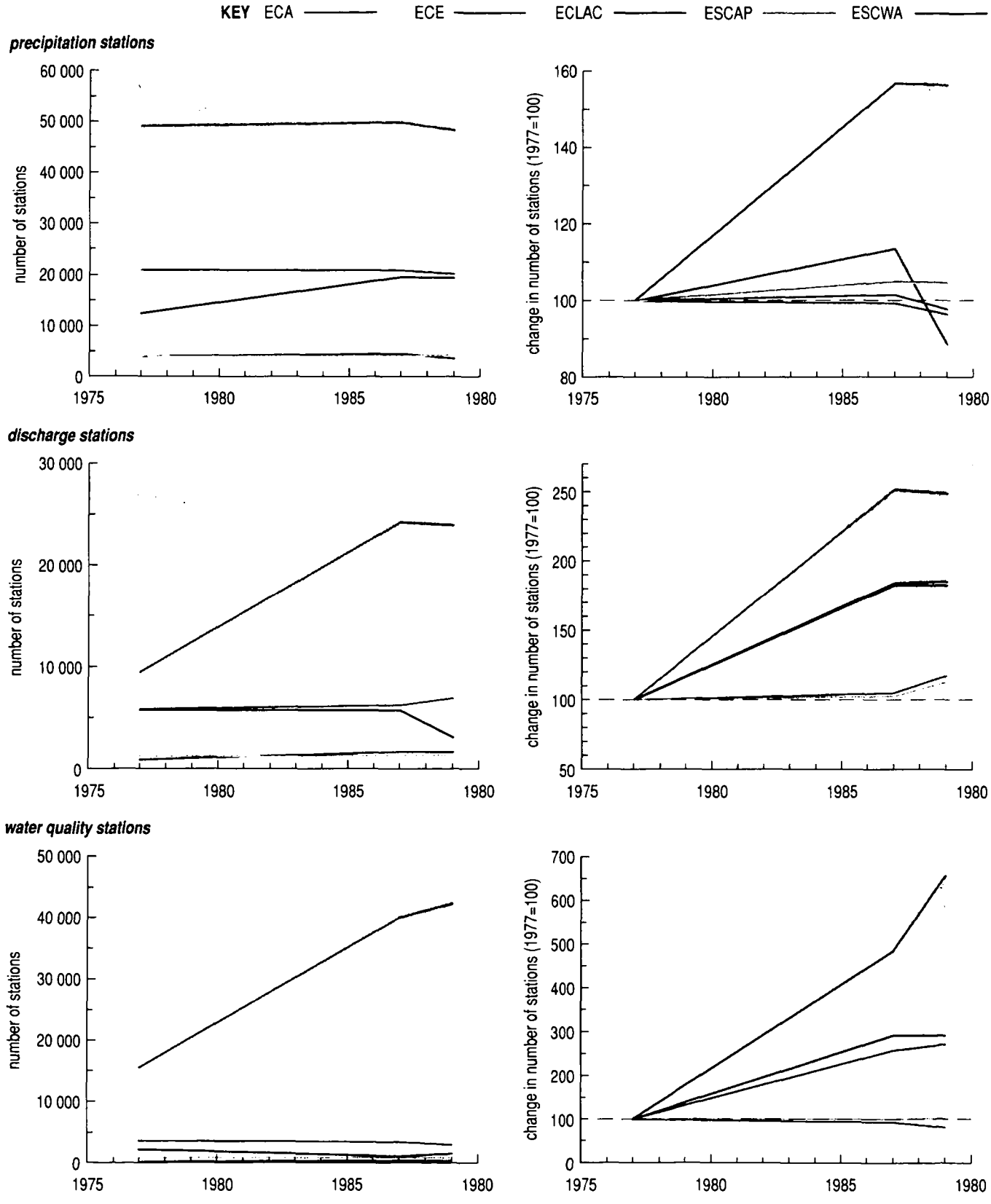
Following the adoption of the MPAP in 1977, an expansion of the world's hydrological networks did occur. An assessment of the trends was made using data from WMO's INFOHYDRO data base (reference 12) for the years 1977, 1987 and 1989. The analysis was made on the basis of the UN's Economic Regions, and was confirmed against the same data for WMO's regional associations. In most cases, the results can be considered as representative samples of countries in each Region, since a number of other countries had not reported consistent data over the time period analyzed and were therefore excluded. Where a large industrialized country tended to significantly skew the totals for a Region, these data were also excluded from the totals (i.e. Australia and Japan).

Precipitation stations. In 1977, there were some 90 694 precipitation stations in the countries surveyed, which increased to 99 668 stations over the 10 year period to 1987. This increase appears to have occurred mainly in the ECLAC Region, with other areas showing only modest increases or no changes (see figure page 35). However, between 1987 and 1989 a general decrease in the number of stations has occurred, especially in the ECA, ECE and ESCAP Regions.

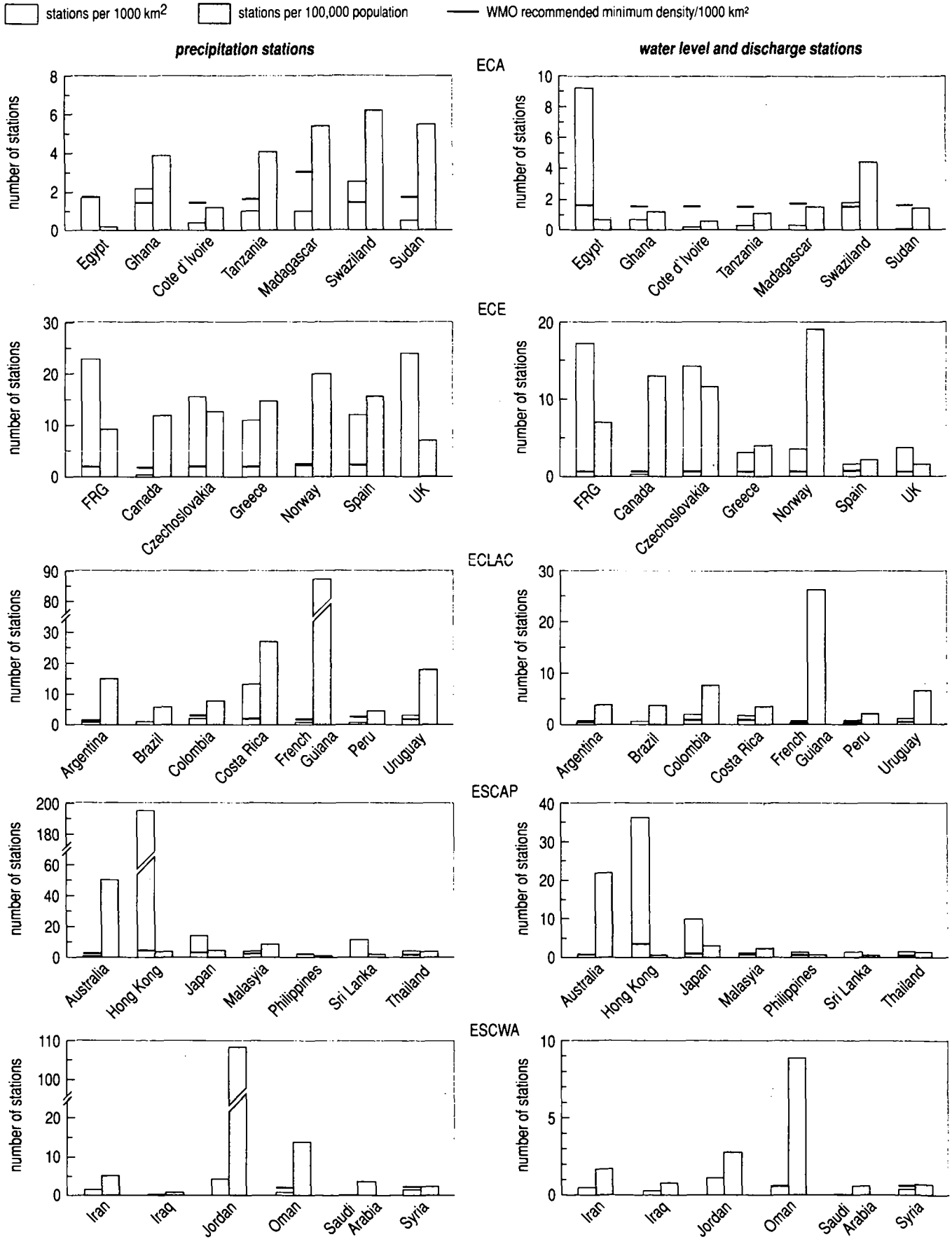
Number of precipitation stations

	1977	*1987*	*1989*
ECA	4047	4636	3596
ECE	49 240	50 167	48 507
ECLAC	12 409	19 590	19 531
ESCAP	20 980	21 027	20 422
ESCWA	4018	4248	4240
totals	90 694	99 668	96 296

Hydrological stations 1977-1981 by UN region



Selected national precipitation and stream-gauging networks expressed in densities and by population

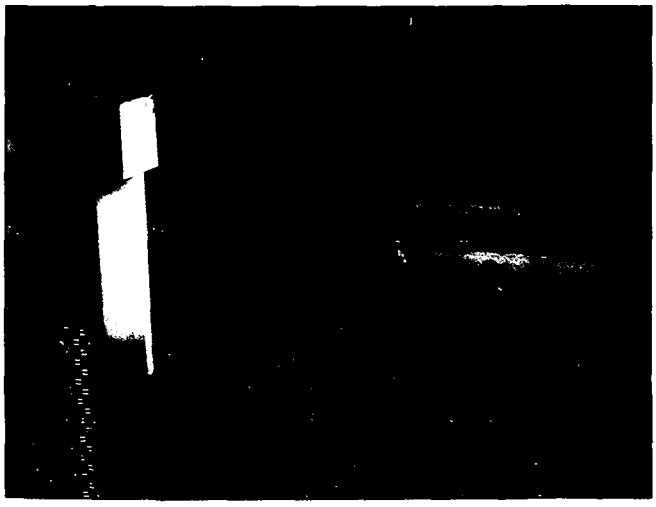


The same trends can be found when examining only the data for recording precipitation stations, except that the number of these stations continued to increase in the ESCAP Region.

The figure on page 36 includes the pattern of precipitation networks expressed as densities and per capita in 1989 for selected countries of each UN Economic Region. Comparing the network densities with respect to the minimum density requirements established by WMO (see reference 19), the precipitation station densities appear to be adequate throughout the whole of the ECE except Canada whose overall density reflects the very low distribution of the network in its northern territories. Only half of the ECA countries may be said to have adequate precipitation network density. For the ECLAC countries the densities are adequate for more than half of the sampled countries if low-land conditions are assumed, but grossly inadequate in mountainous areas of the Region. All ESCAP countries except, understandably, Australia, have adequate precipitation networks. The situation of ESCWA countries is somewhat less satisfactory, in view of the greater variability of the precipitation distribution in time and space within much of the Region.

Discharge stations. Between 1977 and 1987, the total number of discharge stations (recording and non-recording) showed a marked increase from 20 698 to 39 196, but has remained approximately the same over the last two years (see figure page 35). Within this total, however, the use of recording stations continues to increase. Nevertheless the non-recording stations in use in the ECA Region remains very small. The large increase in recording stations in the ECE Region tends to overshadow the modest increase in all other regions.

Stream gauging station near Rabat, Morocco



D. Kraemer, WMO

Number of discharge stations

	1977	1987	1989
ECA	918	1694	1695
ECE	9549	24 2288	23 [illegible]
ECLAC	3086	5730	5762
ESCAP	5923	6282	7026
ESCWA	1222	1262	1360
totals	20 698	39 196	39 869

In the figure on page 36, densities and per capita water level and discharge stations are depicted. The patterns revealed follow closely those of precipitation networks.

Water quality stations. The number of reported water quality stations in operation has increased almost two and a half times since 1977, reflecting the increased concern worldwide on water quality issues (see figure page 35). However, the rate of increase has dropped significantly since 1987. Once again, most of the increases occurred in the ECE Region. The number of stations in all other regions remains very small, and a decrease has evidently occurred in the ESCAP Region.

Number of water quality stations

	1977	1987	1989
ECA	123	361	361
ECE	15 509	40 030	42 [illegible]
ECLAC	218	1059	1[illegible]
ESCAP	3533	3314	2[illegible]
ESCWA	801	801	8[illegible]
totals	20 184	45 565	47 837

Hydrological data banks. The number of data banks operated, especially those using computers, is a good indication of WRA activity in each Region. These have shown a steady increase since 1977 probably reflecting, as well, the implementation of low-cost micro-computer technology. For example, in 1977, 65 computer data bases were reported, and the number has grown steadily to 97 in 1989. In fact, the rate of increase is larger between 1987 and 1989, although the sample size is relatively small. Thus it appears that more efforts are being devoted towards establishing new banks with the data that exists.

Hydrological data banks using computers

	1977	*1987*	*1989*
ECA	17	23	25
ECE	23	28	28
ECLAC	16	18	21
ESCAP	12	20	23
totals	68	89	97

Note: comparable data for ESCWA Region not available

In summary, clearly the increase in hydrological networks that occurred after the MPAP must be viewed with both encouragement and as a source of concern. The efforts of WRA agencies and international agencies focussed attention on the problem of the scarcity of data for water resource decision-making. However, the growth that did occur took place disproportionately in the highly developed regions of the world. More modest growth took place in developing regions, and the total number of stations remains very low. In fact, most countries fall below the minimum density guidelines established by WMO (reference 19). The fact is that in many of these countries where data are needed the most, the networks are static or declining from already low numbers of stations. Attention must be re-focussed on these regions, for without sufficient basic data networks in operation, WRA activities cannot be carried out, and the concept of sustainable development will remain illusory.

In terms of specific network and data collection improvements, a number of suggestions can be made from this review:

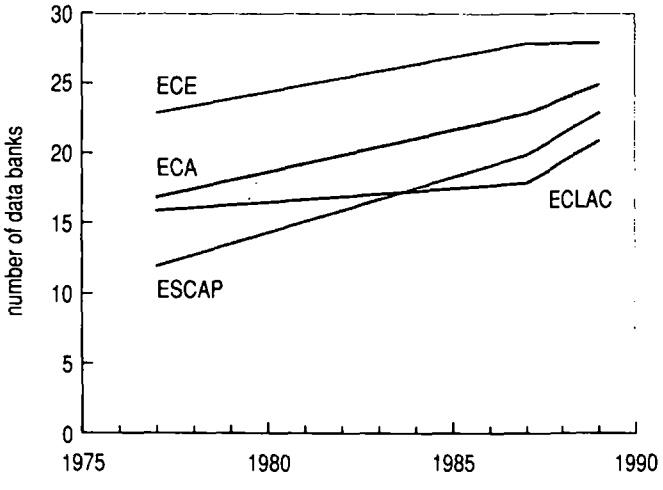
- hydrometric networks need to be expanded, especially in tropical and arid regions;
- there is a particular shortage of data from small basins, such as wadi systems, urban basins, and agricultural areas frequently subject to development pressures;
- networks of precipitation, groundwater and water quality stations are urgently needed, especially in the ECA, ECLAC, and ESCWA Regions, and these should be planned and co-ordinated with the hydrometric networks;
- the growth of computerized data banks provides an opportunity to assemble regional data bases, using new microcomputer technology such as optical disks, that would be extremely useful for WRA purposes;
- there are some very large basins with inadequate or incomplete data because of the lack of co-ordination, planning and data exchange in some regions.

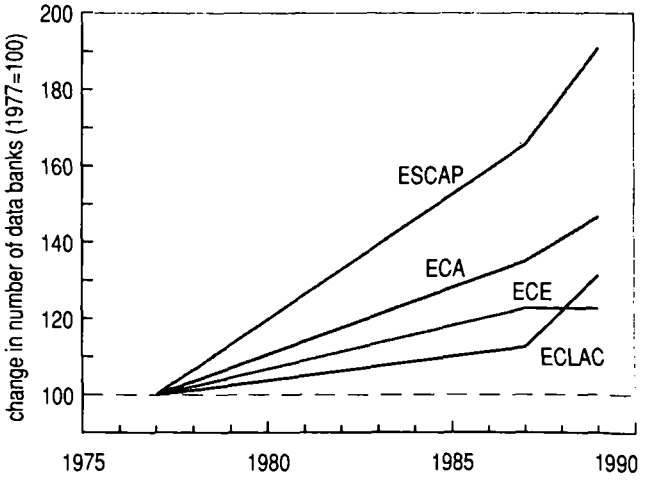
Summary key WRA issues of global relevance

It is striking how similar are the reports from the several regions, the ECE and to a lesser extent ESCAP excepted. The same key issues were referred to by several of the regional reports, and this is not an artifact of the procedures used, but of the situation as the regional experts found it. It is unnecessary to summarize at length but the key points which seem to have global relevance include:

- The need for good legislation, co-ordination, and integration in water resources management and assessment.
- The over-riding influence of the availability of financial resources as a control on the effectiveness of WRA programmes, and the deteriorating situation in many countries during the 1980s.

Hydrological data banks 1977-1989 by UN region





- The lack of data and data collection networks for variables other than rainfall and surface water—water quality, groundwater, sediment, water use, and associated information such as physiography and land use.
- The importance of specific purpose, project data as an information resource which tends to be neglected, and in many countries is in danger of being lost.
- The success of some international river basin programmes in promoting collaboration and information exchange, and the failure of others.
- The increasingly critical part played by modern data processing systems in ensuring delivery of data to the end-user in a suitable and timely fashion.
- The practicular need for transfer of existing technology, supplemented by applied R & D to deal with specific circumstances and issues, such as flow measurements under difficult circumstances (e.g. wadis, etc.).
- The severe difficulties experienced by WRA agencies in recruiting and retaining staff, because of unfavourable conditions of employment.
- The generally good progress made in education and training at university and senior technician level, and the poorer progress at junior technician and observer level.
- The need to make full use of available training opportunities by proper planning, and the effect of lack of resources, training materials, and capable educators in some areas, particularly technician training.
- The beneficial impact of international and bilateral programmes in many areas, but also the large number of aspects which are undesirable or reduce their value below the potential.

Summary of regional recommendations

The recommendations arising from the regional assessment reports are numerous and wide-ranging. Key regional recommendations that appear in several reports include the need for:

Recording precipitation and discharge stations with 30 years of record

(Source: Infohydro Manual, reference 12)

Summary of regional recommendations

	ECA	ECE	ECLAC	ESCAP	ESCWA
institutional framework					
develop single WRA institution	•	•	•		•
allocate more WRA funds	•		•		•
increase co-ordination WRA activities	•		•	•	•
more data/information exchange			•	•	•
prepare guidance material for WRA			•	•	
data collection, processing and retrieval					
increase financial resources	•		•		•
expand networks including groundwater and water quality	•		•		•
develop/implement/standardize new technology	•		•	•	•
more dialogue with users			•		•
define needs for WRA information			•	•	•
prepare directories of available data				•	
rescue available data	•			•	
improve data quality and reliability	•		•	•	•
areal assessment of hydrological parameters					
carry out WRA activities	•	•	•		•
develop new techniques for WRA		•			•
technology transfer for WRA	•		•		
hydrological data/information for planning					
appraise/improve data accuracy	•		•		•
more groundwater/water quality data	•	•	•		
develop environmental impact procedures		•			•
improve network design procedures					•
develop integrated planning concepts	•	•	•		•
develop interpolation methods		•	•		•
research and development					
more financial resources	•		•		•
better collaboration amongst institutes	•		•		•
involve local experts	•				
develop regional WRA groups	•				
use multidisciplinary approach	•		•		•
identify R&D gaps and needs		•			•
research topics suggested		•	•		•
manpower, education and training					
staff training programmes	•		•	•	•
improve public WRA awareness	•	•	•	•	•
better WRA employment conditions			•	•	•
strengthen WRA technical training	•		•		•
more training in automated equipment				•	•
more co-operation in training	•			•	•
improve management skills of staff	•				•

Note: • represents a recommendation made in the regional reports based upon the concern of a number of countries in the corresponding Region

- Co-ordinating/streamlining national WRA agencies;
- Allocating increased funds to WRA;
- Co-ordinating WRA activities within countries;
- Developing and harmonizing new technology;
- Promoting dialogue with data users;
- Assembling/rescuing available data;
- Transferring WRA techniques;
- Improving data reliability;
- Promoting integrated network planning;
- Formulating staff training programmes;
- Creating better employment conditions;
- Developing managerial skills;
- Promoting the value of hydrological services;
- Collaboration in research;
- Ensuring involvement of local experts.

The key recommendations in the regional reports are summarized in the table on the left, which provides a general overview of the areas of greatest concern.

The regional recommendations that appear to be of greatest importance to WRA would include

- *The allocation of increased WRA funding;*
- *Increased co-operation and co-ordination among agencies;*
- *Implementation of standardized and appropriate technology on a regional basis; and*
- *The training, development and motivation of WRA staff.*

4

Needs and Constraints During the 1990s

Hydrological data have great intrinsic value in the information they contain on the natural environment. However, they have economic value only if they influence decisions which are important for the social and economic development of a country, the safety of its population, or the quality of its environment, in the short and long-term.

Although water managers, scientists, and engineers recognize the value of water resources information as a foundation for sustainable resource management, it is frequently difficult to persuade decision-makers to allocate resources to WRA. The present assessment of the global status of WRA demonstrates a direct relationship between a given country's economic condition, indicated by GDP per capita, and the resources allocated to WRA. For instance, the results for some regions (ESCAP and ECLAC) indicated that countries with a GDP per capita in excess of US$ 800 have adequate WRA capabilities, and those below do not. This is perhaps not surprising; with the deterioration in economic conditions in many countries during the 1980s, resources have become increasingly scarce, and have inevitably been allocated to immediate needs—public health, general education, investment in agriculture and armaments—rather than being invested in activities like WRA which have a long-term value.

The decision to allocate resources to WRA rather than to some competing use is essentially an economic one—to maximize the net benefit to society. It is a relatively straightforward matter, at least in principle, to demonstrate the value of hydrological information when the design of a major project is being considered; the cost of failure of a dam because a spillway was underdesigned, or of money wasted on a major irrigation scheme for which there proves to be insufficient water to supply each landholding, are reasonably obvious. In general, then, resources for WRA which relates to specific projects have more frequently been forthcoming.

However, there is an increasing awareness that development projects may not be sustainable in the longer term because of unanticipated effects, such as waterlogging and salinization, or loss of downstream subsistence fisheries. Reservoirs are silting up in many regions, while deltas and estuaries in the lower reaches of their basins disappear. Wet lands are drained and the buffer they previously offered to the spread of pollutants has been lost. Apparently, decisions have not always been made on the basis of complete information or understanding. In the industrialized or densely populated countries, these so-called external effects are becoming more obvious, and are leading to a recognition of the need to collect information on water resources which goes beyond that required simply to design projects. More generally, the complexity of the water systems requires an increasingly multidisciplinary approach.

This is leading to increasing emphasis on collecting data in addition to the traditional rainfall and streamflow—water quality, sediment loads, biological and ecological indicators, and so on. To avoid unintended effects of one project upon other water users, integrated water resources management is increasingly adopted, in which all aspects of the hydrological cycle in a river basin are simultaneously examined, and alternative uses (and non-uses) of the water resource are weighed up. Such an approach needs information not just on the quantity and quality of water—both above ground and below—but on other aspects of the river basin—physiography, land use, and vegetation types in particular. The human influence on the hydrological cycle is increasingly strong in many river basins, affecting the quantity, timing, and quality of river flows, the size of lakes, infiltration into groundwater and aquifers, and even the climate itself. To fully understand the resource and the consequences of management, appropriate information is needed.

Increasing awareness of the value of WRA

Hydrologists have had rather limited success in persuading decision-makers that the value of more and better water resources information justifies increased investment.

To increase acceptance of the value of WRA, it will inevitably be necessary to demonstrate that the value of the information it provides, in terms of improved decision-making, well exceeds its cost. It will also be necessary to show that resources invested in WRA produce a greater return (perhaps a political return) than some alternative use of those resources, given that there are never enough resources for every desired purpose.

Information is increasingly seen as a valuable commodity; indeed, many WRA agencies are now required to charge for the information and for the services that they provide. Application of economic principles could be a powerful means of demonstrating the value and importance of the products of WRA, particularly where the true costs of unwise and uninformed resource management—such as water pollution, sedimentation, water losses, seawater intrusion into coastal aquifers, or waterlogging of irrigated farmland—can be observed and quantified. A major area of need, then, is further development of the techniques for analysing the economics of water resources information. However, it is unlikely that rigorous analysis of the value of information will be feasible in all—or even many—circumstances.

WRA agencies need to be able to demonstrate in more quantitative terms the value of and need for water resources information. All sectors of the community, not simply the decision-makers and politicians, must be addressed, at the level of international organizations, national governments, local authorities, and the general public.

One means is the use of informative material, which is adaptable to particular socio-economic conditions and which can be conveyed using a variety of media. Such material, emphasizing the importance of water in everyday life and explaining the links between the availability of water and standards of living, may be used by national and local agencies to inform and persuade decision-makers and the general public. It may be disseminated through:

- publications addressed to different readers: the lay public, decision-makers and politicians, other professionals;
- films, videos, computer demonstrations;
- celebrations and events such as the World Meteorological Day, Environment Day or the UN International Decade for Natural Disaster Reduction (IDNDR) Day;
- press releases and radio or television interviews; and
- discussions with non-governmental organizations and consumer groups.

The public information media—newspapers, magazines, television, radio—are in most countries the primary means of reaching the greatest number of people. Professionals in this industry are normally very aware of what issues concern the public, or will attract public attention, and know how to present information in an effective and persuasive way.

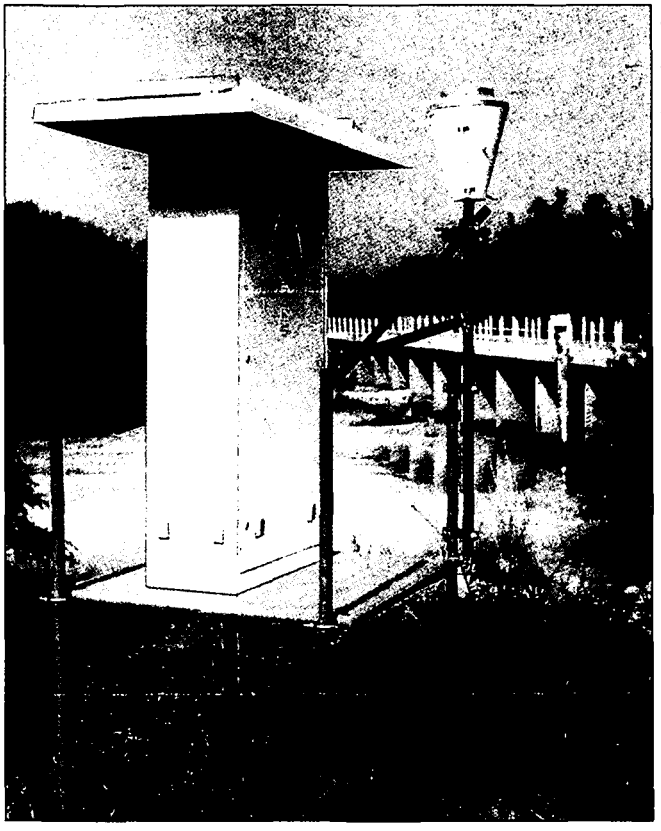
To a large extent, the media shape public opinion, as well as reflecting public concerns. It is important, then, that media professionals themselves are persuaded of the importance of WRA, and that it can be presented in a light that will attract public attention. At a time when environmental issues are of widespread concern, this should be possible.

Non-governmental organizations, particularly in the environmental field, are becoming increasingly influential, and able to mobilize public opinion in persuading decision-makers of the value of particular courses of action. It is important, then, to demonstrate the links between WRA, sustainable resource management, and more specific environmental issues, to promote the collaboration of such non-governmental organizations.

Perhaps the most important need is for the staff of WRA agencies to work closely with their customers, the users of their information. They must understand users' needs, and inform and advise users about the products that they can offer, and what their benefits would be.

Information and databases

Considerable progress has been made in scientific and operational hydrology since the Mar del Plata Action Plan was adopted in 1977. There have been significant advances in instrumentation; in technology for data transmission, processing and archiving; in application of such methods as remote sensing from, and data transmission through satellites; and in the analysis and presentation of data, using computer models and Geographical Information Systems (GIS). There has been a general move towards making data more accessible and useful to a greater range of clients.



Hydroniger project, UNDP/WMO

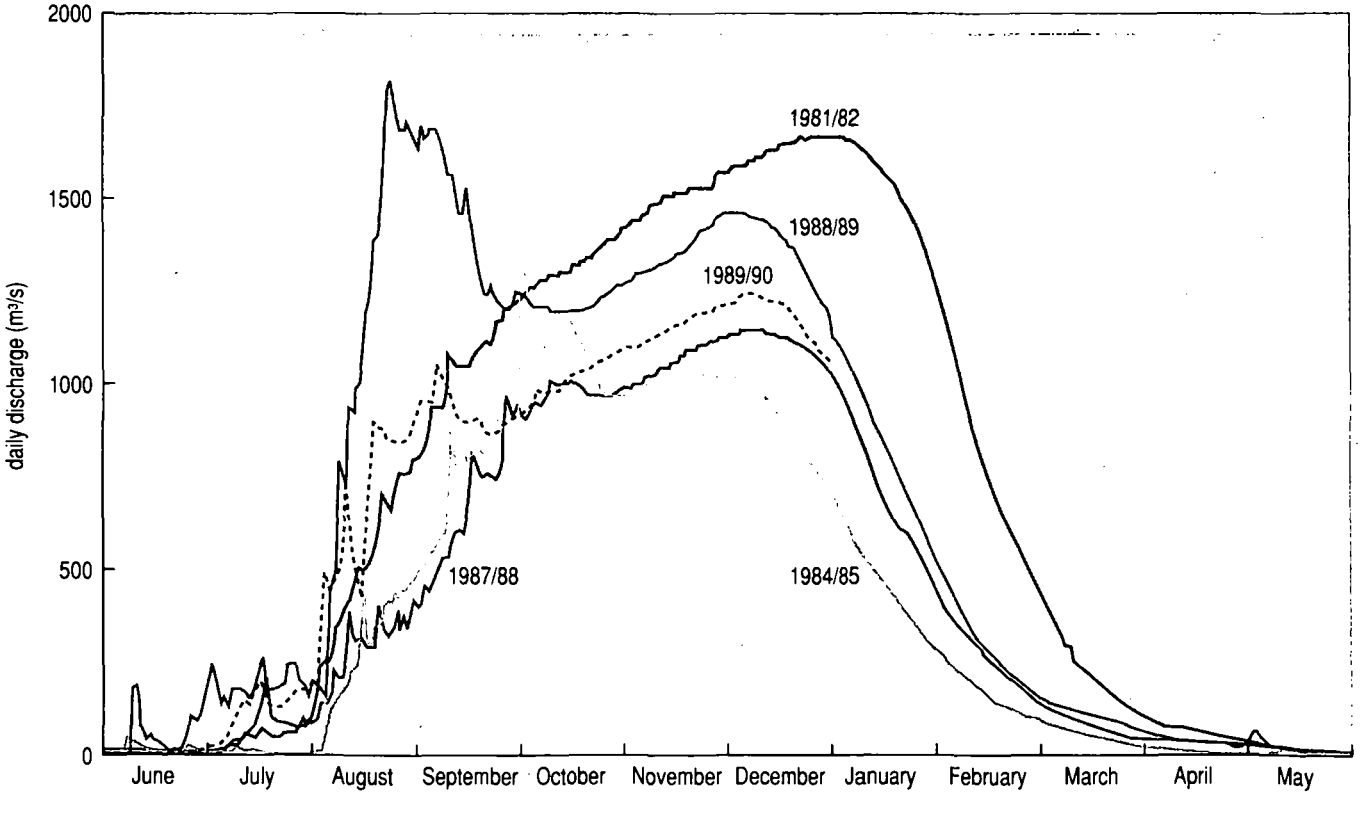
Data collection platform (DCP) with raingauge (Hydroniger project)

The general progress hides regional differences. In many areas of the globe, countries are suffering from economic difficulties, and many aspects of water resources assessment have also suffered. Human and financial resources are often inadequate to maintain effective data collection networks, which are rapidly deteriorating, so that new data are not being collected or that data are becoming unreliable.

Even such basic requirements as the proper calibration of current meters, needed to ensure the reliability of discharge data, is not being attended to. Deficiencies are widespread in the acquisition of certain types of information which are crucial to wise resource management on a sustainable basis. These include information on the quantity and quality of groundwaters, aquifer characteristics, and the quality of surface waters, especially in relation to accidental spillages, diffuse sources of pollutants, and irrigation returnflows. A serious and growing need is for improved monitoring of groundwater levels and water quality in irrigated areas, where waterlogging and salinization are causing huge losses in productivity. And a critically important area is information on those groundwater aquifers which are non renewable on a human time-scale, and are presently being "mined".

Annual hydrographs of mean daily discharge for the Niger river at Niamey

(Source: Hydrometer Project RAF/8/D82)



Unrestricted access to and exchange of hydrological data and information is necessary for effective resource management, particularly in international river basins, including their lakes and aquifers.

Information is increasingly seen as a valuable commodity which can be bought and sold, and the high costs of information exchange and the general co-operation that this demands are also being more widely recognized. Thus, although there is general agreement about the desirability of information exchange and co-operation, they become less likely, and need more effort to arrange.

In assessing the status and trend of water resources, a complete picture can only be obtained when reliable data are available for water use. This is because, in an ever-growing number of river basins and groundwater systems, man-made modification is an increasingly dominant aspect of their hydrological regimes, and less conventional sources of water such as recycling or desalination become more significant. Efforts simply to encourage the private sector to supply information to public management agencies are generally unsuccessful; even legal monitoring requirements, attached to water use or waste discharge permits, are successful only in those countries where the legislation is firmly administered. Data collected in the past, often for project design purposes, provides a wealth of information, which in all too many countries is being lost. This is because the data which are often held by a variety of agencies or private sector consultants, have never been catalogued, or are held in obsolete formats.

A major need is a "data rescue" operation such as has been mounted for climatological information, designed to catalogue the whereabouts of all data and, preferably, assemble them in a national archive in a permanent form. Such catalogues and archives would ensure not only that valuable data remain accessible, but that international organizations, donor countries, consultants, and governments can avoid repetition of work that has already been carried out.

Institutional arrangements

Institutional arrangements for water resources assessment exist in almost all countries, but they take a wide variety of forms, and are of variable effectiveness. In some countries, national hydrological or hydrometeorological services have full responsibility for systematic data collection, archiving and dissemination, and assessment. In others, WRA may be carried out by a number of agencies which either have regional responsibilities, or responsibility for particular sectors such as irrigation or hydropower. However, in many cases, divided responsibilities result in unco-ordinated WRA activities, incompatible or inaccessible data, and a lack of awareness on the part of users of the need for, existence of, or means of obtaining data.

Countries which have effective WRA programmes differ widely in their institutional arrangements, and in the degree of co-ordination between sectoral and regional agencies. It is difficult, then, to point to a particular type of arrangement that is most effective in any particular set of circumstances. The greatest need however is to ensure unrestricted flow of information from producers to users; in most circumstances, formal co-ordination facilitates this flow, and appropriate mechanisms are therefore required. Central bodies have been established to co-ordinate ministries, departments, and other agencies which have responsibilities in the water resource area. Their functions, responsibilities and effectiveness vary from country to country. However, most developing countries, and to a lesser extent developed countries, continue to have difficulty in co-ordinating WRA, particularly from the perspective of integrated water resource management.

While most WRA agencies are governmental, a few are now required to operate on at least a partly commercial basis, while many private sector organizations, such as power companies, collect information for operational purposes. In other cases, recipients of water use or discharge permits may be required to monitor their performance, and to provide data to the water management agency. Because a market approach to water resource information is presently unfamiliar to most WRA professionals, there may be a need for guidance on using appropriate market mechanisms to ensure an adequate level of investment in WRA.

Many WRA agencies are increasingly subjected to unfamiliar and changing conditions, brought about by budgetary pressures, technological change (computers, telecommunications, remote sensing), demands for new types of information, and the evolution of economic and political systems. They must therefore be prepared to anticipate, rather than merely respond to, changing needs and opportunities.

Human resources development and training

J. L. Bassier, WMO

Training for sediment transport measurements (China)

The world's greatest resource is its people. A staff well trained in all aspects of the work is the guarantee of a successful programme of activities. Water resources assessment activities are no exception.

Good progress has been made in many countries in providing training at all levels, but there are nevertheless several areas of concern:

- recruitment or retention of staff, particularly trained staff, is often difficult, in the face of the competition from the better conditions of employment in industry, or even in other countries;
- staff responsible for management of WRA programmes commonly often have technical backgrounds and little formal training in management; they are therefore not always able to make optimum use of available resources, or argue for increased resources;
- training programmes at all levels are too often hindered by a lack of well qualified educators, suitable syllabi or educational equipment and materials which are appropriate (e.g. in the right language);
- technical training must be founded on an adequate level of secondary education, but even this cannot be provided in all countries. Increasingly, training in mathematics, physics and computing will be required, even at technician level, to make full use of available technology;
- training must be recognized as a continuous process, with staff requiring regular refresher courses to ensure their familiarity with developing technology.

The primary constraint, then, is not the availability of people with the ability to work in WRA, but the resources needed to attract and retain them, and to provide them with adequate training. The international agencies are playing a significant role in the second aspect, through the provision of training courses, seminars, and other opportunities for skills' transfer.

Because training needs are so often dependent on conditions in a particular country, the most successful forms of training have often found to be in-country training on-the-job, roving seminars which are addressed to nationals of only one or two countries, and similar, highly focussed approaches. Bilateral assistance and co-operation between countries with similar characteristics are also found to be particularly effective approaches to meeting training needs, almost on a self-help basis.

Major areas of need in human resource development continue to be:

- technician training, particularly in new and evolving technology;
- training of professionals, and provision of satisfactory terms of employment, incentives, and career development structures which attract and retain capable and marketable people;
- managerial skills development for senior and supervisory staff;
- training of trainers and educators themselves, and provision of the resources they need.

Technology development and transfer

At the global scale, technology for WRA is being developed very much more rapidly than the global community is able to disseminate it and apply it.

Technology for data acquisition, processing, archiving, analysis and presentation has undergone a revolution during the 1980s, with the introduction of solid-state dataloggers, powerful and cheap personal computers, and software such as that needed to drive geographical information systems. However, although such technology is generally applicable to a wide range of conditions, there is still a need for research and development in subject

areas which are specific to certain needs and to certain countries or regions. These include measurement methods for non-perennial water courses (wadis), flash floods, very large rivers, and those with mobile beds; for groundwater and surface water quality; for areal assessment of hydrological elements which vary greatly from place to place and are difficult to measure, such as soil moisture or the water content of a snowpack. Even measurements of some of the basic hydrological variables are still in doubt—the measurement of rainfall is one example where it is widely assumed that observations are accurate, when in fact they are subject to a serious systematic error and a number of additional ones.

Nevertheless, the primary need is for applied research and development, to extend available technology to a particular country, district, or river basin. Arrangements are needed to promote technology transfer, as an integral aspect of the many consultancies administered through international and bilateral assistance programmes. The value of many consultancies would be improved by placing greater emphasis on assisting staff of the host countries to develop their skills. Indeed, more opportunities for trained national staff to gain practical experience would improve morale and thereby help many WRA agencies to retain skilled staff.

Many developed and developing countries are benefitting from new technology, but many others, which lack financial resources, have not yet been able to do so.

There is a need for guidelines on the use of already available techniques and methods, especially in cases at the border of current knowledge. The international organizations play a major role in preparing technical material, but its dissemination to users should be continuously improved: resources are simply not sufficient to provide copies to every WRA office in every country. A major need is to develop ways of disseminating available information and knowledge to all that could use it, and to define and eliminate the bottlenecks which presently prevent this from happening.

In some countries, a shortage of foreign exchange hinders access to technical information, conveyed through journals, textbooks, current awareness services, computer databases of bibliographic information, participation in international organizations, attendance at professional and scientific meetings, and so on. A particular concern in some countries is their inability even to pay affiliation fees to the various international organizations both governmental and non governmental. These hindrances are of course a serious handicap to WRA agencies in the countries affected, which include the least developed ones. Similarly, acquisition of new instruments and data processing equipment, repair of existing instruments, and maintenance of data archives and information systems is increasingly costly, and difficult for countries with limited foreign exchange. The primary need, then, is for financial resources to be made available to pay for technology transfer. Besides, initiatives should be taken to encourage manufacturers to develop instrumentation better adapted to local conditions and easier to maintain locally.

Technology must always be appropriate to the country's needs and circumstances, ability to maintain it in an operational state, and the level of education and training of the staff who will use it. In many countries, such technology—particularly that which could be fabricated and maintained locally, and which is robust—is most appropriate. There is a great need for development of such appropriate technology, and also for guidance on ways of selecting the most cost-effective mixture of conventional and new technology.

New instruments or systems must be operated and maintained properly. A particular need is training in trouble-shooting, maintenance, and repair of new technology, as well as in its use under normal or ideal operating conditions. A real need is to aim, as far as possible, for harmonization of technology at the national and even regional level.

Resource strategies

Inadequate financial resources are, in all regions which encompass developing countries, either the most serious or one of the most serious constraints to effective WRA.

It would be desirable for governments, international organizations, and aid donors to recognize the value of water resources information, and allocate resources accordingly. However, WRA agencies need to assist the process, by developing strategies to augment their financial allocations. This should include:

- ensuring that their products meet the needs of information users;
- promoting the value and applications of water resources data among planners and resource managers;

- making delivery to the users as easy and cheap as possible, by developing communication and data transfer systems;
- maximizing the use of data, in order to spread costs as widely as possible, and minimize the cost to any one user, or the government.

It is significant that communication is central to three of the four above elements. WRA agencies must ensure that they maintain close contact with their clients. International agencies have an important role in assisting WRA agencies, particularly in developing countries, to develop skills in these relatively unfamiliar areas.

All hydrological data production requires financial resources. A charge for supplying these data to users could be envisaged to supplement budgetary allocations available to WRA agencies.

Cost recovery provides a means of supplementing the financial resources available, if this is considered appropriate within a national context. Nevertheless, regardless of how successful efforts might be to increase the availability of financial resources for WRA activities, it is probable that their scarcity will continue to be a major constraint, particularly in developing countries. WRA agencies must therefore strive to increase their efficiency and effectiveness by using available resources to the best advantage.

A particularly effective means of doing this is by improving co-ordination among WRA agencies, in order to minimize duplication and maximize the flow of information.

There are many ways in which efficiency and effectiveness can be continually improved, for example by regularly reviewing and optimizing data collection networks, revising priorities for data collection, monitoring technological developments, by continually training and motivating staff, and by developing new and easy to apply data and information products that will appeal to the widest possible spectrum of users.

5

A Strategy for the 1990s

The primary goal of Water Resources Assessment is to ensure the assessment and forecasting of the quantity and quality of water resources, in order to meet the needs of all sectors of society, to enable mitigation of water-related hazards, and to maintain or enhance the condition of the global environment (reference 20).

Globally, there has been significant progress towards enabling national WRA agencies to achieve this goal since the UN Water Conference, but as the preceding sections show, except in the ECE Region, there is still very substantial room for improvement. Indeed, in many respects, Recommendation A of the Mar del Plata Action Plan is as relevant now as it was in 1977. Many of the key issues identified in the Plan were raised again in the present review; it has to be admitted that progress on implementing the Plan fell short of expectations.

The regional assessments dealt with six main WRA functions, and identified key issues, needs and related recommendations for each Region, for which actions required were then derived. These have been summarized in the table on the following page.

Strategy components

Looking ahead to the 1990s, a strategy is required to implement those aspects of the MPAP which are still outstanding. The findings of the regional assessments provide a good basis to identify four components of a key strategy to achieve the above mentioned primary goal:

- *Strategy component 1—financial resources for WRA*
  to have all countries allocate to WRA the financial resources which are justified by the economic and social value of information about their water resources;

- *Strategy component 2—institutional arrangements*
  to have all countries establish the institutional arrangements needed to ensure the efficient collection, processing, storage, retrieval and dissemination to users of information about quantity and quality of available water resources;

- *Strategy component 3—WRA technology transfer*
  to make available to all countries WRA technology which is appropriate to their needs, irrespective of their level of development;

- *Strategy component 4—human resource development, education and training*
  to have sufficient numbers of appropriately qualified and capable staff recruited and retained by WRA agencies, and provided with the training and retraining they need to carry out their responsibilities successfully.

The primary responsibility for achieving the goal and objectives of WRA rests with Hydrological Services and other agencies of national governments, and the governments themselves. However, many countries will require support by regional organizations such as river basin commissions, and international organizations.

Storage dam in Alps (Switzerland)

D. Kraemer, WMO

Action proposals

Water resources assessment is a continuous activity, as it must be to support water resources management that is sustainable into the future. Sufficient information must be continuously collected, particularly as the global environment responds to human activity, and as new issues are recognized.

In a number of instances and in addition to those identified in the MPAP, recommendations are already being addressed by programmes of international organizations such as the Economic and Social Commissions, WMO, UNDP, and UNESCO. They also reflect or amplify recommendations of other events, such as the UNESCO-UNEP International Colloquium on the Development of Hydrology and Water Management Strategies in the Humid Tropics. It is encouraging that there is such a high level of agreement on necessary actions for the future.

In order to implement the four elements of the strategy identified above, a number of action proposals described below must be taken by national agencies.

WRA overview: key issues, needs and actions for the 1990s

WRA element	institutional framework	data collection, processing and retrieval	areal assessment	data and information for planning	manpower, education and training	research and development
issues						
	• fragmentation of WRA responsibilities • lack of resources • poor co-ordination • lack of technical guidance	• inadequate networks • incompatible technologies • little user interaction • poor data accessibility	• lack of technology transfer	• poor network design • need for other data (groundwater, water quality) and integrated networks • no interpolation methods	• lack of human resource planning • poor terms of employment • no public awareness • lack of training	• poor co-ordination • few needs identified • underutilized local/ regional resources
needs						
	• to rely primarily upon methods of improved co-ordination at national and regional levels, while seeking new opportunities to increase WRA allocations	• to develop and implement standard appropriate technology that will contribute to effective data exchange and dissemination	• to implement existing methods in regions lacking experience and resources for areal assessment	• to maximize information available by means of integrated network planning and dissemination of interpolation techniques among users	• to increase the development and motivation of WRA staff through training and, where possible, improved employment opportunities	• to improve the effectiveness of regional R & D efforts, taking advantage of existing resources and facilities
recommendations						
	• review existing legislative, regulatory and institutional arrangements with respect to WRA • co-ordinate WRA projects on national/ regional basis • Identify new/ innovative funding mechanisms • assess benefits/costs of WRA programmes allocate sufficient resources • promote WRA activities • internalize WRA costs in water projects	• define national needs for WRA data/ information • catalogue available data resources • establish national archives for all data • promote co-operation and exchange of data/ information • improve data collection with respect to groundwater, water quality and environmental assessment • review and optimize networks	• prepare national/ regional WRA plans • provide technical assistance for WRA on a regional basis	• improve dialogue with users • develop better interpolation techniques • disseminate WRA technology more widely	• develop human resources plans on an agency basis • improve terms of employment for WRA staff • use available local/ regional training facilities • prepare improved WRA training material • incorporate training needs in project activities	• improve R & D co-ordination on a regional basis • use local/regional resources more fully

Strategy component 1—financial resources for WRA

The resources allocated to WRA have been declining in many countries since the mid-1980s—in most developing countries, from an already insufficient level. At the same time, multiplying demands on water resources and a growing awareness of environmental issues require more and better information on a wider range of variables.

Action by national agencies

- Define national requirements for water resources information, taking particular account of the often unexpected side effects of water resource development projects, multiplying demands for water, and the world-wide need towards integrated water resource management;
- catalogue water resources information that is already available, from all sources, and evaluate the present capabilities of WRA agencies for meeting the defined information requirements;
- estimate the economic and social value of water resources data and information, and thereby estimate the financial resources that can be justified for investment in WRA;
- explore novel ways of providing funding, such as fees for water permit monitoring, recovery from private sector enterprises of the full costs of providing information, and transfer charging between government agencies;
- allocate the budgetary resources estimated to be necessary for WRA, and avoid the reduction of funding to meet short-term financial stringencies;
- advise and inform managers and the public about the importance of water resources to economic and social development, and of the part that WRA plays in sustainable water resource management.

Action by international organizations

The UNESCO-WMO methodology for evaluating WRA capability provides a good basis for the above actions, and has already been used in several countries. It has not been universally adopted or applied, because of language difficulties, the need for training, and so on. Methodologies for economic analysis are still needed for assessing the value of information on water resources, and the investment which should be made in WRA. Further exploration is also required of economic instruments which are appropriate for funding water resources management and assessment, particularly in developing countries. The role of international agencies concerned should therefore be geared to:

- widely disseminate and assist in the application of the UNESCO-WMO methodology for evaluating WRA capability, providing technical assistance and training at regional and country level where required;
- develop and disseminate practical methodologies for estimating benefits of WRA in different economies and societies, and assist countries to apply them;
- prepare and disseminate informative material, usable for a wide range of audiences and using a wide range of media, on the value and importance of WRA to national socio-economic well-being and sustainable water resource management;
- ensure that, as an integral component of any water-related project, sufficient financial means are allocated for WRA to provide the amount of information required for project design and subsequent management.

Strategy component 2—institutional arrangements

It appears that different institutional arrangements can all support effective WRA programmes. However, the effective application of water resources information, and information exchange amongst producers and users, is likely to be facilitated by good inter-agency communication and co-ordination. Moreover, the growing need for integrated water resource management points to the desirability of increased levels of co-ordination.

Action by national agencies

- Review the legislative or regulatory basis for WRA, and make provisions appropriate to needs, paying due regard to such matters as the addition to national archives of information collected by private enterprise, or the requirements for water use and water permit data to be made available to a central agency;
- review institutional arrangements for WRA, paying particular regard to the need for close collaboration and easy communication amongst agencies with water sector responsibilities, and particularly between information producers and information users;
- prepare comprehensive catalogues of water resources information held by government agencies, private enterprise, international consultants and organizations, educational institutions, and others;
- implement "data rescue" operations, e.g. establish national archives of water resources information, where existing archives are too fragmented to allow easy access to data, and ensure that all historical data,

from whatever source, are held on at least one secure archive which will be maintained long-term;
- ensure that all water projects are fully co-ordinated, particularly from the perspective of WRA.

Action by international organizations

For all the above actions, collaboration, guidance, and in many cases direct assistance will be required from regional and international organizations. This is particularly the case in shared river basins and aquifers; the successful examples of river basin commissions and regional organizations, such as the Interim Mekong Committee, the Danube Commission, the International Joint Commission, or ASEAN, show the advantages to be derived from collaboration amongst countries at the regional scale. There are many other examples of successful co-operation in WRA arranged through the international organizations—the World Weather Watch (WWW) of WMO being perhaps the most striking example of what is possible when countries work together in one field, such as meteorology. On the other hand, there seem to be some cases where several international organizations or donor countries have provided assistance, apparently in ignorance of what has already been done and what information is already available. Regional and international organizations, then, have a very clear role to:

- promote and facilitate co-operation and information exchange amongst countries, particularly at the scale of the sub-region and the shared river basin or aquifer. It is desirable for regional bodies such as river basin commissions to support and co-ordinate national WRA agencies, rather than replace them;
- closely co-ordinate water-related projects, and freely exchange information both about the projects and about the water resources themselves. This may require development of new or improved mechanisms for co- ordination and communication between international and regional organizations.

Strategy component 3—WRA technology transfer

There is no shortage, internationally, of up-to-date WRA technology (instruments, methods, computer hardware and software), although it is increasingly sophisticated, expensive, and demanding of a high level of skill in its users. It also tends nowadays to become rapidly obsolete. There are many opportunities to improve the development and delivery of technology to developing countries with limited foreign exchange, especially where tied aid from multiple donors has resulted in a variety of different instrument types, difficulties with spare parts, incompatible data outputs, complex training needs, and so on.

The primary limitation on technology transfer appears to be the availability of funds. Strategies to deal with this must be developed simultaneously by national governments and their WRA agencies, international organizations, and donor countries. Because WRA is inherently a long-term, continuous function, it is particularly necessary to develop plans which provide consistency and stability over a period of years, and avoid ad hoc decisions which result in frequent changes in product quality.

Action by national agencies

- Define their technology needs in terms of their foreseeable information requirements, with due consideration given to staff capabilities and long-term sustainability (foreign exchange requirements, maintenance facilities, etc);
- develop comprehensive medium and long term (approximately 3 year and 10 year) technology strategies which meet those defined needs, emphasis should be placed on long-term consistency of practice and product quality;
- work with international organizations and donor countries to ensure that assistance meets the real needs of the country.

Action by international and regional organizations

There are many areas in which further technology development and/or transfer is required; some of these have been referred to in preceding sections. Technology is particularly required for areal assessment of water resources, for acquisition of groundwater, sediment, and water quality data, and for data collection in remote areas or difficult conditions. To be of the widest possible utility, instruments should be robust, easily and cheaply maintained, and simple to use. Software should be user-friendly, well-documented, and robust in terms of its input data requirements. Data banks should be established according to common standards to allow easy data exchange. Procedures too should be well-documented, and fully supported by manuals which are explicitly addressed to the likely users, and easily read and understood. New technology should be selected according to user needs and capabilities rather than for technological capability itself, which may provide sophisticated, expensive, and—for many agencies—impractical technology. River and lake basin authorities should play an important role in the WRA technology transfer. The role

of international organizations and donor countries should be geared to:

- ❑ assist countries to define their information and technology needs, and to develop appropriate plans; development of appropriate new methodologies may be required;
- ❑ continue intercomparison of WRA technology (instruments, procedures, computer software, models, etc), and widely disseminate the results;
- ❑ continue to facilitate technology transfer, particularly through WMO's Hydrological Operational Multipurpose Subprogramme (HOMS) and UNESCO's IHP, and develop further approaches to effective technology transfer;
- ❑ promote the development of WRA technology, especially that which takes advantage of the capabilities of micro-electronics (e.g. telemetry, dataloggers), remote sensing, computers (e.g. geographical information systems, hydrological models), and which is particularly appropriate to the requirements of and conditions in developing countries;
- ❑ help countries select technology which is appropriate to their socio-economic and physiographic conditions, and which will most effectively meet their needs for information;
- ❑ provide funds to enable countries to establish a basic WRA capability, where it is presently lacking, with particular reference to basic requirements like textbooks and manuals, laboratories, maintenance facilities, and database management systems (electronic and other media, as appropriate);
- ❑ promote and assist the development and assembly of regional streamflow data bases on new high-volume computer storage devices (e.g. optical disks) and related user-friendly software for basic hydrological analysis and WRA;
- ❑ assess the performance of technology transfer projects, comparing them against well defined standards, identify successes, shortcomings, and contributory factors, and revise future project plans accordingly;
- ❑ promote and facilitate the establishment of regional research institutes and technology transfer, where countries are unable to justify or sustain national capabilities.

Action by donor countries

- ❑ Match their offers of assistance to the defined needs of the recipient countries, ensuring that technology that is offered is suitable, and consistent with their technical capabilities; they should ensure that recipient countries receive the most suitable technology, irrespective of its source;
- ❑ make full provision for long-term sustainability, after a project is completed, paying particular attention to availability of spare parts, and thorough training of national staff in maintenance and repair;
- ❑ assess the performance of technology transfer projects and revise future project plans accordingly.

Strategy component 4—human resources development, education and training

Salaries and wages commonly account for half or more of the expenditure of an effective WRA programme. Because people are the most important resource available to the WRA manager, personnel matters should—but rarely do—receive great attention in any WRA programme. Achievement of any objective related to personnel is dependent upon availability of funds, both to pay them and to train them.

Action by national agencies

- ❑ Provide attractive terms of employment and career paths for WRA professionals and technical staff;
- ❑ assess their personnel requirements for WRA, and develop appropriate targets and plans for human resource development and training for all levels of staff (managerial, supervisory, professional, senior and junior technician, observer);
- ❑ make full and integrated use of all education and training resources available, including universities, technical and research institutes, in-service training, and international courses.

Action by international and regional organizations

International and regional organizations play an important role in education and training, because many countries are too small to justify their own facilities. It is often easier for the staff of an international organization to keep in touch with WRA developments that should be included in revised training programmes, than it is for staff of many individual countries, and to disseminate their findings. These organizations should therefore:

- ❑ continually monitor human resource needs for WRA, and develop and provide education and training programmes which meet those needs; particularly important are programmes for the training personnel themselves;
- ❑ prepare appropriate materials, syllabi, and courses for use by national and regional organizations;
- ❑ use water resources projects and consultancies as

means to further the education and training of national staff, make use of national experts and include training of counterpart staff in the terms of reference of foreign consultants;

- promote and facilitate specific education and training at a regional or continental level, where individual countries do not have large enough numbers of WRA staff to justify providing a national capability;
- promote the organization of workshop, seminars and conferences in collaboration with international professional non-governmental organizations.

6

Implementation of the Action Proposals

The strategy and action proposals given in the previous chapter are expected to form an integral component of the UN strategy on the water resources for this decade and beyond. They are geared to assist countries in improving their WRA capabilities, in support of their objectives for sustainable development. The success in implementing the action programme will primarily depend on:

- Commitment of the national governments, and their continued support to the objectives and goals of WRA;
- Co-ordination of WRA activities at the national level; and
- Support from the multilateral and bilateral organizations, particularly in terms of technical co-operation, funding and improved co-ordination of external assistance for WRA.

Commitment of resources

The importance of implementing the activities of the action proposals must be recognized by national policy makers and planners, as well as by resource managers. This means that the acceptance of the action programme, at the country level, should involve as appropriate government ministries responsible for natural resources, water, planning, environment, economic development and other relevant areas. Any other organizations with interest in water resources should also be incorporated, to win their commitment. To achieve a high level of commitment and co-ordination, a dialogue with concerned national authorities is highly desirable.

It is recognized that many countries are faced with extremely difficult economic situations. Nevertheless, it is important that when governments make their commitment to the action proposals, they should commit appropriate financial support and local, trained manpower for the implementation required. National governments must take into consideration the possibility of allocating extra-budgetary sources of funds to support their WRA programme, if and when required. Since the action proposals deal with a most important sector of the national economy, namely water development on a sustainable basis, then the need to give priority to these actions should be well recognized by national governments.

The role of UN organizations is to provide technical assistance and mobilize international support for investment and development of the water sector.

Bilateral and multilateral donor communities have played, and will continue to play, a very significant and important role in water resource development and management, particularly in financial terms. Donor communities have various criteria for selecting programmes and projects to support, but all have the same goal: to promote accelerated development of the host country's resources. Donors increasingly have accepted the concept of "sustainable development" as a basic criterion for providing assistance to developing nations.

Therefore, the commitment of bilateral and multilateral donors is also necessary if the action proposals are to make a tangible contribution to sustainable management of water resources in developing nations.

International programmes in support of WRA

Resolution 1 of the Mar del Plata Action Plan stated that

> "International co-operation aimed at the strengthening of water resources assessment, particularly within the International Hydrological Programme (IHP) of UNESCO and the Operational Hydrology Programme (OHP) of WMO, be keyed to the targets set by the UN Water Conference and appropriately supported by national and international governmental and non-governmental institutions."

The programmes of both WMO and UNESCO in support of water resource assessment are described in Appendix B to this report.

In addition, a number of other UN organizations such as the Food and Agriculture Organization (FAO) and the International Atomic Energy Agency (IAEA) have concern for the WRA area, while other bodies have an interest in the applied aspects of WRA, such as the United Nations Department of Technical Co-operation for Development (UN/DTCD), the World Health Organization (WHO), the United Nations Development Programme (UNDP), World Bank (WB), the United Nations Environment Programme (UNEP) and the Regional Economic Commissions. Their activities in the field of WRA are summarized also in Appendix B.

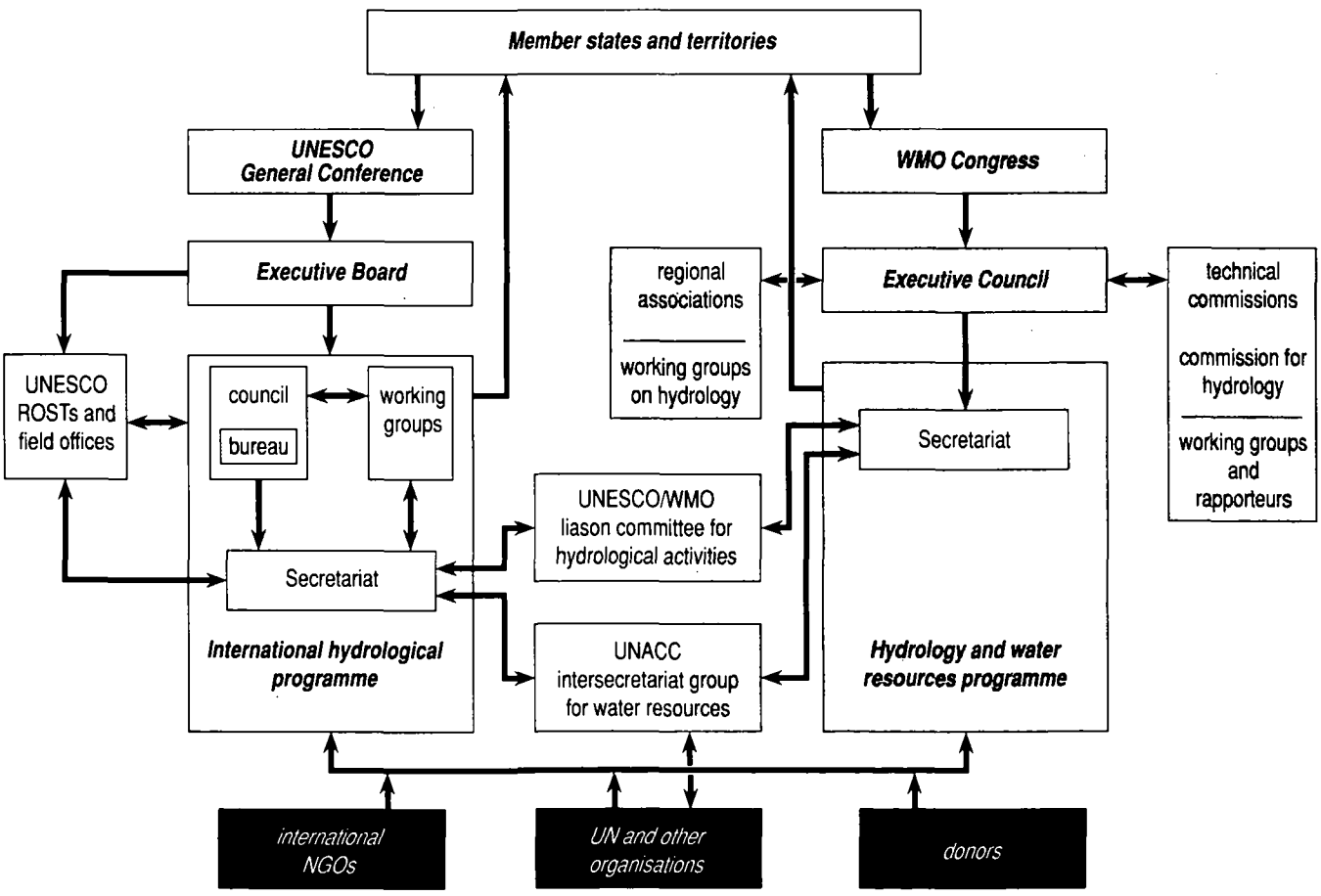
The UN agencies concerned are expected to provide an appropriate level of support to the action proposals through commitments in their regular programme, participation in joint project formulation missions, technical assistance projects, and through exchange of information and technology by means of technical publications, guidance material, seminars, workshops and training events.

System-wide co-operation in the field of water will continue to be facilitated through the UN Administrative Co-ordination Committee Intersecretariat Group for Water Resources (the tasks of which are also described in Appendix B). While the ISGWR, in its present form, has a number of achievements to its credit, the growing importance of water, particularly in environmental matters, demands that its role, form and operation receive attention. There is a need to strengthen the Group, to make it more effective in its co-ordinating role, and to make it the essential focus for collaboration in UN water orientated activities. There are a number of other needs including the establishment of efficient links with other international bodies, both governmental and non-governmental, and providing a higher profile for water in the UN.

On the other hand, the joint WMO/UNESCO Liaison Committee for Hydrological Activities will continue to be instrumental in the co-ordination of relevant WRA activities of both organizations.

The link between WMO and UNESCO and between their programmes in hydrology and water resources is of special significance. The emphasis given by UNESCO to research and education, with WMO concentrating on operational hydrology and services, provides a unique

Organizational linkages between WMO and UNESCO



example of the amplification of effort—a hydrological symbiosis—which is particularly valuable in these times of financial stringency.

Non-governmental organizations provide extensive support and stimulus to the programmes of both UNESCO and WMO.

Implementation

Once the integral UN strategy in the field of water resources for the 1990's has been adopted by the ACC-ISGWR, the action proposals will be distributed to all Members mainly through UNDP Resident Representatives, WMO Permanent Representatives, National IHP Committees and other UN system focal points. Thus the action proposals will be available to relevant government institutions, to enable them to initiate the implementation of actions as required. It should also allow them to prepare requests for any technical or funding assistance needed.

It is, however, also foreseen that UN organizations concerned, as well as multilateral and bilateral donors, can initiate action by identifying opportunities for assisting countries, based on their past and ongoing activities in the field of water development. Such initiatives would need to be fully discussed with the relevant national government agencies, before project proposals are prepared or actions are initiated to develop projects for implementation.

Since the action proposals form part of the overall UN water-resources strategy, the UN system has also a critical role to play. Basically the following three major functions should be fulfilled:

- response to requests by national governments for technical and investment assistance, within the framework of the overall strategy;
- co-ordination of the responses within the UN system, in order to provide the most appropriate and effective assistance and service; and
- consultation with multilateral and bilateral donor communities on provision of the necessary support to meet the governments' requests.

Appendices

Appendix A

Recommendation A of the Mar Del Plata Action Plan[1]

Assessment of water resources[2]

1. In most countries there are serious inadequacies in the availability of data on water resources, particularly in relation to ground water and water quality. Hitherto, relatively little importance has been attached to its systematic measurement. The processing and compilation of data have also been seriously neglected.

2. To improve the management of water resources, greater knowledge about their quantity and quality is needed. Regular and systematic collection of hydrometeorological, hydrological and hydrogeological data needs to be promoted and be accompanied by a system for processing quantitative and qualitative information for various types of water bodies. The data should be used to estimate available precipitation, surface-water and ground-water resources and the potentials for augmenting these resources. Countries should review, strengthen and coordinate arrangements for the collection of basic data. Network densities should be improved; mechanisms for data collection, processing and publication and arrangement for monitoring water quality should be reinforced.

3. To this end, it is recommended that countries should:

(a) Establish a national body with comprehensive responsibilities for water-resources data, or allocate existing functions in a more coordinated way and establish data banks for the systematic collection, processing, storage and dissemination of data in agreed formats and at specified intervals of time;

(b) Expand and extend the network of hydrological and meteorological stations, taking a long-term view of future needs, following as far as possible the recommendations of the United Nations specialised agencies on standardization of instruments and techniques and comparability of data, and use existing meteorological and hydrological data series for the study of seasonal and annual fluctuations in climate and water resources. Such analysis could also be used in the planning and design of networks;

(c) Establish observation networks and strengthen existing systems and facilities for measurements and recording fluctuations in groundwater quality and level; organize the collection of all existing data on groundwater (borehole logs, geological structure, and hydrogeological characteristics, etc.) systematically index such data, and attempt a quantitative assessment so as to determine the present status of the gaps in knowledge; increase the search for, and determination of, the variables of aquifers, with an evaluation of their potential and the possibilities of recharge;

(d) Standardize and organize as far as possible the processing and publication of data so as to keep the statistics up to date and take advantage of the observations made in stations operated by different institutions;

(e) Include consideration of diseases associated with water as an integral part of water assessments and the consideration of the interrelationships of water quality, quantity and related land use;

(f) Make periodic assessments of surface- and ground-water resources, including rainfall, evaporation and run-off, lakes, lagoons, glaciers and snowfields, both for individual basins and at the national level, in order to determine a programme of investigation for the future in relation to development needs; intensify programmes already underway and formulate new programmes wherever needed;

(g) Provide the means for national mechanisms so established to use, as appropriate, modern technologies (remote sensing, nuclear methods, geophysical techniques, analogue and mathematical models) in collecting, retrieving and processing data on the quantity or quality of water resources; manual data-processing methods may still satisfy the simple requirements of small collections, although it may be necessary to introduce various degrees of automation, ranging from small punch-card machines to large electronic computing systems;

(h) Standardize measurement techniques and instruments, and automate stations as appropriate; reference should be made to international standards and recommendations adopted by Governments through various international organizations;

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[1] Mar del Plata Action Plan, United Nations Water Conference, Argentina, March 1977.

[2] General note: many recommendations for action contain references to national or country action, organization, policies and legislation. A number of countries with federal systems of government interpret such recommendations in the light of their constitutional division of responsibilities. Actions, organizations, policies and legislation in these countries accordingly will be taken at the appropriate level of government.

(i) Support and promote national contributions to regional and international programmes on hydrological studies (eg. the International Hydrological Programme and Operational Hydrological Programme);
(j) Cooperate in the coordination, collection and exchange of relevant data in the case of shared resources;
(k) Appropriate substantially increased financial resources for activities related to water resources assessment and to establish or strengthen related institutions and services as necessary;
(l) Establish or strengthen training programmes and facilities for meteorologists, hydrologists and hydrogeologists at professional and subprofessional levels;
(m) Prepare an inventory of mineral and thermal waters in countries possessing such resources with a view to studying and developing their industrial potential as well as their use as spas;
(n) Develop methods for the estimation of available water resources using aerological observations for the computation of the atmospheric water budget in large river basins, rivers and continents;
(o) Provide for the studying and analysing of hydrological data on surface and groundwater by multidisciplinary teams so as to make adequate information available for planning purposes;
(p) Include the development of forecasting methods in quantitative and qualitative assessment, especially in the developing countries;
(q) Include effective decision-making methods in the management of water quality, based on techniques of natural quality regulation that have been proved in practice;
(r) Take specific national characteristics and conditions into account in different countries in assessing water quality and establishing water-quality criteria.

4. International organizations and other supporting bodies should, as appropriate, and on request, take the following action:

(a) *Surface water*
i) Offer technical assistance, at the request of interested Governments, to review the adequacy of existing networks and make available the use of advanced techniques such as remote sensing;
ii) technical assistance, including personnel, funds, equipment and training, to strengthen the networks and to establish laboratories for comprehensive water analysis;
iii) Offer assistance and facilities for the establishment of data banks, processing and periodic publication of data by modern methods of electronic data processing, archiving and retrieval;
iv) Help in making qualitative and quantitative assessments of surface-water resources, both gross and economically usable quantities, for different sectoral uses;
v) Strengthen, in general, technical assistance programmes for the development of integrated national data systems.

(b) *Groundwater*
i) Offer assistance for the establishment or strengthening of observational networks for recording quantitative and qualitative characteristics of groundwater resources;
ii) assistance for the establishment of groundwater data banks and for reviewing the studies, locating gaps and formulating programmes of future investigations and prospection;
iii) Offer help, including personnel and equipment, to make available the use of advanced techniques, such as geophysical methods, nuclear techniques, mathematical models, etc.

(c) *Snow and ice*
Advise on international standards and the establishment of observation networks regarding snow and ice in order to permit international exchange of this information, especially concerning international rivers.

Appendix B

1. World Meteorological Organization (WMO)

1.1 Purpose and scope of water related activities

One of the major purposes of WMO as set out in Article 2(e) of the WMO Convention is "to promote activities in operational hydrology and to further close co-operation between Meteorological and Hydrological Services". This commitment is exercised through the Hydrology and Water Resources Programme (HWRP), which assists the Hydrological Services of Members in operational hydrology and in mitigating water-related hazards such as floods and droughts. It also promotes co-operation between countries at regional and sub-regional levels, particularly where shared river basins are concerned, and it includes education and training activities in hydrology.

The term "operational hydrology" is defined as including the "measurement of basic hydrological elements from networks of meteorological and hydrological stations: collection, transmission, processing, storage, retrieval and publication of basic hydrological data" ... and the "supply of meteorological and hydrological data for design purposes". Thus operational hydrology is strongly inter-related with water resource assessment.

The overall objective of the HWRP proposed for the Decade 1992-2001 within the WMO Third Long-term Plan is:

> To ensure the assessment and forecasting of the quantity and quality of water resources, in order to meet the needs of all sectors of society, to enable mitigation of water-related hazards, and to maintain or enhance the condition of the global environment (reference 20).

This objective accords with the recommendations of the UN Water Conference.

The HWRP is closely linked to other WMO programmes which have important hydrological components, such as the Tropical Cyclone Programme (TCP) and the World Climate Programme (WCP). In addition, a substantial proportion of WMO's technical co-operation is in the field of operational hydrology, funded largely through UNDP. Regional aspects of

projects covered by the HWRP are implemented principally by the six regional working groups on hydrology of WMO's regional associations. The HWRP contributes to or has links with a large number of other international programmes, in particular those of UNESCO, UNEP, WHO, FAO, and the UN Regional Economic Commissions.

Because of the leading role the Organization plays with regard to natural hazards such as tropical cyclones, floods and droughts, the UN International Decade for Natural Disaster Reduction (IDNDR) (1990-1999) has called for a significant response from WMO.

1.2. Programme components

The HWRP is one of the major programmes of WMO, with three main components:

Operational Hydrology Programme (OHP)—Basic Systems

This component concentrates on the basic organization and phased development of Hydrological Services. It includes development, comparison, standardization and improvement of instruments and methods for the collection and archiving of water resources information (quantity and quality of both surface water and groundwater), and human resource development. Specific support to the transfer of technology is provided through the Hydrological Operational Multipurpose Subprogramme (HOMS).

Operational Hydrology Programme (OHP)—Applications and Environment

The component brings together hydrological activities in support of water-resource development and management, including hydrological modelling and forecasting, and the provision of data for a range of projects, including those for environmental protection. It contributes to various meteorological and climatological programmes of WMO, such as the Tropical Cyclone Programme (TCP) and the World Climate Programme (WCP).

Programme on Water-related Issues

The component contributes to the international programmes of other bodies within the UN family and to those of intergovernmental organizations and NGO's through inter-agency co-ordination and collaboration in water-related activities, including regional projects associated with large international river basins.

The future development of the HWRP is set out in WMO's successive Long-Term Plans as agreed by the Congress of WMO.

1.3. Programme implementation

The OHP is planned and executed under the aegis of the WMO Commission for Hydrology (CHy). Implementation is principally through a system of working groups and individual rapporteurs, who address specific aspects of operational hydrology appropriate to their expertise, through the convening of technical meetings and symposia, and through organizing training courses.

Specific projects are designed to investigate and compare technology such as instruments, forecasting models and network design techniques. Project results are published, principally in the series of WMO Operational Hydrological Reports. The essence of these and other activities are summarized in the Guide to Hydrological Practices, currently being updated for its fifth edition, which provides guidance to key subjects over a wide range of conditions including minimum network densities. Agreed standard practice is published in Volume III (Hydrology) of the WMO Technical Regulations.

Working groups on hydrology are also established by the six regional associations of WMO to address some topics covered by the HWRP and others relevant to the hydrological problems of their respective Regions, including particularly:

- surveys of the adequacy of networks of hydrological stations, hydrological data transmission and processing facilities, data banks, hydrological forecasting;
- the application of WMO standards and recommended practices in hydrology;
- the development and promotion of the Hydrological Operational Multipurpose Subprogramme (HOMS); and
- contributions to projects under the World Climate Programme-Water.

The Hydrological Operational Multipurpose Subprogramme (HOMS) is a technology transfer system for operational hydrology, established in 1981 under the OHP. Its aim is to assist hydrologists, primarily in developing countries, by making available to them technology largely from developed countries, in order to solve their problems.

HOMS is a cooperative effort of the Member countries of WMO, co-ordinated through CHy. Secretariat support is provided by the HOMS Office. Countries that wish to participate in HOMS designate a HOMS National Reference Centre (HNRC), and 108 countries have done so to date. HNRCs in developing countries tend to co-ordinate requests for the transfer of technology while those in developed countries more usually make national technology available to users in countries making requests for transfers. The technology available through HOMS is presented in over 400 "components"—computer software, technical and general guidance manuals, and instrument descriptions covering much of operational hydrology. Between 1981 and August 1990, over 2000 requests for the transfer of components were notified to WMO. These requests came from some 94 different countries and 14 international organizations. The success of HOMS is a credit to the effective co-operation amongst the Hydrological WMO Members aided by the Meteorological Services.

Two computer data bases have been established as part of the HWRP, namely:

- The Hydrological Information Referral Service (INFOHYDRO) which contains information on national and regional hydrological agencies, networks and data banks of WMO Members;
- The Global Run-off Data Centre (GRDC) at the Federal Institute of Hydrology, Koblenz, Federal Republic of Germany (as part of WCP-Water), which holds daily and monthly flow records of selected stations from over one hundred countries.

Both these data bases are regularly updated, and the key information is published.

1.4. Human resource development

Training in hydrology uses a number of different approaches, including: in-service training, training in educational institutions, workshops, seminars, and short-term residency of experts. WMO grants fellowships for study in operational hydrology, and organizes training courses, particularly for hydrological technicians. It also prepares and publishes related guidance and training material. Much of the Organization's support for certain training activities, including international training courses in hydrology, workshops and symposia, is undertaken in collaboration with UNESCO and other agencies of the United Nations system, and with non-governmental organizations.

1.5. Technical co-operation

The objective of WMO's Technical Co-operation Programme is to assist Members in developing their capabilities and self-reliance to the point where efficient hydrological and meteorological services can contribute effectively to economic and social development. Presently there are three major sources of support, while a smaller effort is channeled through HOMS activities:

- the United Nations Development Programme (UNDP);
- WMO's Voluntary Co-operation Programme (VCP); individual countries request assistance of various types and individual donors agree to support the requests that they are willing to fund (the VCP includes support to hydrology and water resources activities);
- Trust Fund arrangements, by means of which assistance is provided by donor countries to specific projects.

Other sources, such as the World Bank, the regional development banks, or economic groupings like the Southern African Development Coordination Conference (SADCC), augment the assistance provided. Technical co-operation funds allocated under the regular budget of WMO are very limited, and are used almost exclusively for training and fellowships.

1.6. Resources

The regular programme of WMO provides four-yearly budgets for the implementation of the activities under the HWRP. The HWRP is supported by WMO's Hydrology and Water Resources Department.

WMO's technical assistance projects are administered by the Technical Co-operation Department, with scientific support and technical backing from the Hydrology and Water Resources Department. The two departments jointly offer, on request, sectoral advisory services in hydrology to UNDP field offices.

1.7. Future activities

Over a period of some 20 years the HWRP has responded to the changing needs of Members in a world which has seen rapid changes social and economic conditions, advances in technology, and a growing awareness of the importance of the environment. Accordingly, the proposals contained in WMO's Third Long-term Plan (1992-2001) show an increase in activities at the interfaces between operational hydrology and meteorology, in climate studies and, in particular, in environmental management. The Plan takes account of recent shifts in emphasis towards the study of surface and groundwater quality, and the operational hydrology of urban areas, lakes and reservoirs. It includes the development of geographical information systems (GIS) and studies in response to the accidental release of hazardous pollutants. The programme also comprises areas of activity where greater effort has been called for, such as contributions to the hydrological aspects of the UN International Decade for Natural Disaster Reduction (IDNDR) (1990-1999), and the follow-up to the International Drinking Water Supply and Sanitation Decade (IDWSSD) (1981-1990).

In many parts of the world the availability of water is presently the limiting factor for the provision of water supplies and the development of sanitation. More and more areas will suffer from this restriction in future. This will demand a greater precision and extension of the water-resource assessment activities that are central to the role of the Hydrological Services of Members and to the Hydrology and Water Resources Programme of WMO.

2. United Nations Educational, Scientific and Cultural Organization (UNESCO)

2.1 Purpose and scope of water related activities

Following the success of the International Hydrological Decade (1965-1974), and according to the new needs expressed by the Member States, the General Conference of UNESCO decided, in 1974, to launch the International Hydrological Programme (IHP). Its main purpose is to develop the scientific and technological basis for the rational management of water resources, in countries having different geographical, technological, and economic characteristics.

The IHP, which is the major component of UNESCO's water resources programme, is planned in successive phases, normally of six years, to coincide with the medium term plan of UNESCO. The fourth phase, IHP-IV, started in 1990.

The main specific objectives of IHP include the improvement of water resources assessment, together with water management and planning, and promotion of education and training. The major thrusts of IHP-III and IHP-IV are:

IHP III: Hydrology and the scientific bases for the rational management of water resources for economic and social development.

IHP IV: Hydrology and water resources for sustainable development in a changing environment.

2.2 Programme components

The fourth phase of the IHP (1990-1995) is divided into three sub-programmes:

Hydrological research in a changing environment (Sub-programme H):

(i) to improve knowledge of the processes involved in the hydrological cycle and to determine the manner in which these processes might be most appropriately described to meet the demands for planning, design, construction,

maintenance and operation of water management schemes within changing environmental situations, including the possibility of climate change;

(ii) to provide, in co-operation with the international scientific community, a general framework for the national, regional and international development of hydrology and the related water sciences.

Management of water resources for sustainable development (Sub-programme M):

(i) to provide methodologies for the assessment and integrated management of water resources to meet the needs of society;

(ii) to promote and provide methodologies, and assist in the establishment and development of scientific and technical water related information and documentation systems;

(iii) to provide methodologies for the evaluation of the environmental status of freshwater systems, their protection and conservation, and for the evaluation and prediction of the impacts of management activities.

Education, training, transfer of knowledge and public information (Sub-programme E)

(i) to promote, implement and provide methodological guidelines (with special emphasis on the changing climatic and environmental conditions) for education and training programmes, in the fields of hydrology and other relevant water sciences, for technicians and professionals;

(ii) to elaborate guidelines for, and actively work towards, the transfer of scientific and technological knowledge between researchers and practitioners and between countries;

(iii) to develop procedures and guidelines for providing relevant water-related information to the general public, planners decision-makers, and specialists in related fields.

2.3 Programme implementation

The programme is guided and supervised by the Intergovernmental Council for the IHP consisting of the representatives of thirty elected Member States; the Secretariat of the Council is provided by the Division of Water Sciences of UNESCO. The Programme is executed by the Member States through their National Committees for IHP (IHP/NC) and the international scientific community. By December 1989, 102 countries had established IHP national committees and 33 had nominated focal points for IHP. Country contributions include participation in working groups, hosting symposia and workshops, and taking charge of certain IHP projects either partially or entirely.

Five Regional Offices for Science and Technology (ROST's) help the Member States to contribute to the implementation of UNESCO's activities, and foster regional co-operation: ROSTA (Africa), ROSTAS (Arab States), ROSTCA (South and Central Asia), ROSTLAC (Latin America and the Caribbean), ROSTSEA (South and East Asia).

Proper account is taken of the contribution of the UN system organizations dealing with water resources, such as UNEP, FAO, WHO, IAEA; of particular significance is the co-operation with WMO's Hydrology and Water Resources Programme (HWRP). There is co-operation also with international non-governmental organizations (NGO) whose objectives are closely related to IHP: International Association of Hydrological Sciences (IAHS), International Association of Hydrogeologists (IAH), International Commission of Irrigation and Drainage (ICID), International Water Resources Association (IWRA), and International Geosphere-Biosphere Programme (IGBP).

2.4 Achievements

In addition to the scientific studies of hydrological processes, the IHP has emphasized the application to WRA of technology such as remote sensing, nuclear techniques, geophysical methods, data processing, and mathematical modelling. Methodologies of groundwater resources assessment are also the subject of several projects, reflecting the difficulties which arise from, in particular, the inter-action between surface and groundwater. The assessment of groundwater resources needs a multidisciplinary approach in which hydrological data must be integrated with other hydrologeological information (geology, geophysics, drilling, pumping test) to model withdrawal scenarios.

The practical implications of water resources assessment have been examined in the context of water management needs in different regions of the world; mountain regions, flatlands, arid and semi-arid regions, humid tropics, small islands, karstic regions, etc. Water quality has increasing importance. Shared water resources of river basins have been the subject of several IHP projects, and emphasis is given, in the current phase of IHP, to areal assessment of water resources.

In conclusion, more than 280 studies, reports and technical papers and documents were published in the past 25 years.

2.5 Human resources development

Technicians and specialists are essential to water resources assessment and management. UNESCO has therefore given great emphasis to education and training in the IHP.

It sponsors an international network of regular training courses; In 1990, 32 courses will be sponsored around the world. About 2500 water resources professional from developing countries have participated in these courses, and a large number of technicians had been trained at ad-hoc courses.

Through IHP, UNESCO also supports education and training activities, by providing guidance material, improvement of teaching methods, training programmes, curricula and textbooks. The programme also emphasizes public information, to foster involvement in water resources planning and management.

Transfer of knowledge and technology to technicians and specialists of developing countries will be enhanced by a strategy to increase the effectiveness of the transfer; a regular evaluation will be part of this strategy.

3. The role of other organizations of the UN system in WRA

In addition to WMO and UNESCO, a number of other UN organizations have either a main concern in the WRA area, such as FAO and IAEA, while others have an interest in applied aspects of WRA, namely UN/DTCD, WHO, UNDP, WB, UNEP and the

Regional Economic Commissions. Their activities in the field of WRA are summarized below:

UN/DTCD: Activities of the UN Department of Technical Co-operation for Development encompass economic and institutional aspects of water-resource development and management (water administration and law), exploration of groundwater resources and general water-resource surveys.

UNEP: Monitoring of inland waters to assess environmental impacts is an activity of the United Nations Environment Programme (within the Global Environmental Monitoring System (GEMS)).

UN Regional Economic Commissions: In general, activities include co-ordination of international water-resource activities in the region as they pertain to economic and social development.

FAO: In its central area of activities the Food and Agricultural Organization is developing effective water-resource inventories within its sectoral responsibility for water as a basic resource for agriculture, forestry and fisheries.

WHO: Activities of the World Health Organization include collection and assessment of data on environmental and sanitary conditions in rivers and other natural water resources used as sources of community water supply.

IAEA: The International Atomic Energy Agency is actively involved in the development and application of nuclear techniques in the water resources sector. A substantial part of the regular programme and technical co-operation activities is devoted to the use of natural isotope methodologies in field investigations related to water resources assessment, development and management, including geothermal waters in member countries. Furthermore, the establishment and/or strengthening of national capabilities, the dissemination of information and basic environmental isotope data for this purpose, are also part of the programme of activities of the IAEA.

It should be noted that the above-mentioned activities in WRA cover all facets of the assessment of requirements and needs for water supply: the UN Headquarters on a multi-purpose basis, and FAO and WHO on a sectoral basis.

Many projects supported by the United Nations Development Programme (UNDP) have had as primary or subsidiary purpose the assessment of the water resources of one or several countries. Most projects in which UNESCO, WMO, WHO, FAO and other UN agencies act as technical executing agencies are financed by UNDP. Similarly, many projects financed by the World Bank (WB) or the International Bank for Reconstruction and Development (IBRD) have had WRA components.

4. Interagency links

4.1 Systemwide co-operation

Amongst the many important and long-standing outcomes of the UN Water Conference was a strengthening of inter-agency coordination in the water field. Following the Conference, the Economic and Social Council requested the Administrative Committee on Co-ordination (ACC), the organizations undertaking water-related activities and, where appropriate, the regional commissions, to make the necessary arrangements for intensifying inter-organizational co-operation and to detail appropriate procedures, so as to provide support for the periodic intergovernmental review of the MPAP.

Pursuant to this request the ACC, at its third session in 1979, established an Intersecretariat Group for Water Resources (ISGWR), involving all the organizations of the United Nations system active in the water field. Its tasks include:

a) *Co-operation in the monitoring of the progress being made in the implementation by Governments of the Action Plan adopted by the United Nations Water Conference*
The ISGWR serves as a focal point at the global level for the gathering, analysis and synthesis of information from Governments in order to furnish the relevant governing bodies of the organizations concerned with the necessary information to undertake their reviews of the progress in the implementation by Governments and by the organizations of the United Nations system of the MPAP.

b) *Promotion of co-operation and joint planning of the water-related programmes of the United Nations system and review of their implementation*
The ISGWR is entrusted with the responsibility of drawing up system-wide plans encompassing joint action by the organizations concerned in the implementation of the MDPAP.

c) *Assistance in co-ordinating the water-related activities of the United Nations system at country and regional levels*
The review of organizations' field programme activities (in particular technical assistance projects) and the periodic discussion on the requirements for co-operation in the execution of projects constitutes another main task of the ISGW.

The ACC-ISGW meets annually and the Secretariat for the Group is provided by UN-DIESA on a part-time basis.

4.2 UNESCO/WMO co-operation

A mechanism for co-ordination was established in 1972 with the signing of a working agreement between the WMO and UNESCO Secretariats in the fields of hydrology and water resources. It is implemented through meetings of the joint WMO/UNESCO Liaison Committee for Hydrological Activities, which are held annually.

This agreement also foresees the convening of joint international hydrology conferences every five to six years to evaluate the progress made within the respective UNESCO and WMO programmes in the field of hydrology and water resources and to draw up recommendations on the orientation of the future programmes of the two organizations. The most recent of such events was hosted by WMO in Geneva in March 1987 under the title: Third WMO/UNESCO International Conference on Hydrology and Scientific Bases of Water Resources Management. It was held precisely on the occasion of the tenth anniversary of the UN Water Conference.

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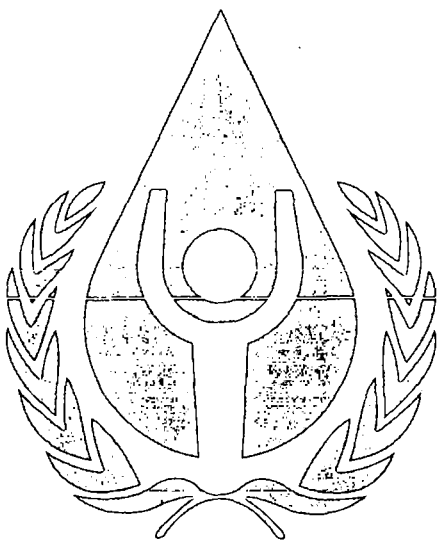
Abbreviations used in the Report

ACC ISGWR	Administrative Co-ordination Committee—Intersecretariat Group for Water Resources (UN)
ASEAN	Association of South East Asian Nations
CHy	Commission for Hydrology (WMO)
CNR	Committee on Natural Resources (UN)
DTCD	Department of Technical Co-operation for Development (UN)
DIESA	Department of International Economic and Social Affairs (UN)
ECA	Economic Commission for Africa (UN)
ECLAC	Economic Commission for Latin America and the Caribbean (UN)
ECE	Economic Commission for Europe (UN)
ECOSOC	Economic and Social Council (UN)
ENSO	El Niño Southern Oscillation
ESCAP	Economic and Social Commission for Asia and the Pacific (UN)
ESCWA	Economic and Social Commission for Western Asia (UN)
FAO	Food and Agriculture Organization (UN)
FREND	Flow Regimes from Experimental and Network Data (UNESCO)
GEMS	Global Environmental Monitoring System (UNEP)
GIS	Geographic Information System
GRDC	Global Run-off Data Centre (WMO/Federal Republic of Germany)
HNRC	HOMS National Reference Centre (WMO)
HOMS	Hydrological Operational Multipurpose Sub-programme (WMO)
HWRP	Hydrology and Water Resources Programme (WMO)
IAEA	International Atomic Energy Agency (UN)
IAH	International Association of Hydrogeologists
IAHS	International Association of Hydrological Sciences (IUGG)
IBRD	International Bank for Reconstruction and Development
ICID	International Commission on Irrigation and Drainage
ICSU	International Council of Scientific Unions
IDNDR	International Decade for Natural Disaster Reduction (UN)
IDWSSD	International Drinking Water Supply and Sanitation Decade (WHO)
IGADD	Intergovernmental Authority on Drought and Development
IGBP	International Geosphere-Biosphere Programme (ICSU)
IHP	International Hydrological Programme (UNESCO)
IHP/NC	International Hydrological Programme—National Committees (UNESCO)
INFOHYDRO	Hydrological Information Referral Service (WMO)
IWRA	International Water Resources Association
MPAP	Mar del Plata Action Plan (UN)
NGO	Non-governmental Organization
OHP	Operational Hydrology Programme (WMO)
R & D	Research and Development
ROSTA	Regional Office for Science and Technology—Africa (UNESCO)
ROSTAS	Regional Office for Science and Technology—Arab States (UNESCO)
ROSTCA	Regional Office for Science and Technology—South and Central Asia (UNESCO)
ROSTLAC	Regional Office for Science and Technology—Latin America and the Caribbean (UNESCO)
ROSTSEA	Regional Office for Science and Technology—South and East Asia (UNESCO)
SADCC	Southern African Development Co-ordination Conference
TCP	Tropical Cyclone Programme (WMO)
UN	United Nations
UNCED	United Nations Conference on Environment and Development (UN)
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
VCP	Voluntary Co-operation Programme (WMO)
WB	World Bank
WCP	World Climate Programme (WMO)
WHO	World Health Organization (UN)
WMO	World Meteorological Organization (UN)
WRA	Water resources assessment
WWW	World Weather Watch Programme (WMO)

Note: The second column gives the full title in English (though the abbreviation may derive from the French title), followed by the initials of the parent or lead sponsoring body or programme (in brackets).



Progress in the Implementation of the Mar del Plata Action Plan and a Strategy for for the 1990s