An ICSU Position Statement

WATER SYSTEMS INCLUDING QUALITY

(one page summary)

Because there is so much water on our planet, perhaps it should be called *water* rather than *earth.* However*,* most of this water is in the seas and oceans and is salty. Fortunately the hydrological cycle distils and transports freshwater from the oceans to the surface of the land. Since the start of time human beings have made use of this water for a host of purposes including drinking, agriculture, and more recently for industry, producing power. Now there is increasing demand for water especially for irrigation to produce more food to feed a rapidly rising population. The result is that water resources are dwindling in areas like the Middle East and parts of Africa and Asia, where water is in short supply. Experts foresee a world water crisis in as little as 50 years as these shortages spread across the globe. There are also the needs of the environment to consider: as humans use more water there is less available to support the natural environment.

There are a number of ways that science and technology can help to collect and analyse information to understand the environmental and social implications of water policy decisions. Scientists have been studying water, its distribution and the life it supports, for several centuries, and their knowledge has provided the basis for harnessing water to the needs of civilisation. However the range of problems where water is involved has been increasing as the use of water has grown, water resources have declined, and fewer funds are available. For example, there is less water data available now than 20 years ago, particularly in those parts of the world where the problems are the most severe, such as in the Aral Sea basin and in many African countries. Lack of data handicaps the methods that can be used for modelling, predicting and controlling water systems in order to alleviate floods and to maintain water supply systems. Lack of data is also means that systems for safeguarding human health against waterborne diseases and protecting ecosystems are less effective. Where sufficient data are being captured and effective methods are being employed water management systems function well and lives are protected against floods and droughts.

A river basin approach to water is advocated with land and water being managed together so as to improve the sustainability of water resources and the life it supports, both human and natural. Scientists, policy makers and decision makers must come closer together to ensure that each understands the relevant issues and the consequences of proposed solutions**.** Progress in meeting challenges related to information management, cultural diversity, technology, institutional organization, public responsibility, and education are essential steps on the path to sustainable water use.

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The Water Cycle

Water, in its solid, liquid and gaseous forms, is the most abundant substance on Earth. Distributed globally by the hydrological cycle and intimately linked to the energy cycle, as expressed by climate, this exchange of water also plays an important part in most of the other global cycles. In fact water has shaped the earth's evolution, and presently maintains the life on it, humankind included. While most of the water in the global water system is salty, it is the freshwater which is important to the long-term vitality of the terrestrial environmental and human systems. This is the water precipitated from the atmosphere, the water moving and stored on the land surface and that evaporated from it, including its physical, chemical and biological attributes. And it can be argued that progress in understanding water systems, and the application of that understanding has provided the basis for modern human civilisation, and maintains them today. Indeed it is difficult to discover some facet of life that does not depend on water abstracted from the natural hydrological cycle. But human societies have exploited the natural benefits provided by fresh waters for centuries without understanding how these systems maintain their vitality. Today, with ever increasing demands being made on fresh waters, the resolution of major research challenges including a basic understanding of trends in resource use, and the ecological consequences of multiple alterations, are essential for formulating sound policy and management.

World Water Crisis

There is, however, growing concern that the world will be facing a water crisis as the middle of the Century approaches, should current consumption trends continue. Countries in the Middle East, parts of Africa and Asia already face considerable stress, because demand for water is outstripping the available resource. The situation in the basin of the Aral Sea is a pointer towards what the future. By 2050, with a world population increase of some 4 billion, water requirements will probably be double today's figure, particularly water for food, about 70 and 80% of all demands. At the same time mounting pollution and the impact of climate-change on hydrological regimes will further stress the available resource. The result will be greater strains on water resources and aquatic environments over widening areas of the globe. The population increase also means that many more people will suffer from floods, droughts, soil erosion and other hazards—hazards which are likely to be intensified by continuing land use changes, especially urban growth in the Third World. The vitality of freshwater ecosystems, as we know them, will be changed, possibly for ever. The hydrological impacts of climate change will cause water problems in agriculture, forestry, fisheries, power generation, environmental integrity, and in the many other areas. And of course, the bigger the demand for water to support society and the economy, in general, the less there is to meet environmental needs.

Water Problems and Science

While these are major threats, it is becoming increasingly apparent that there are many other water problems, internationally, nationally and locally and that few water institutions possess the capabilities to deal with them. Issues of governance, investment, risk, poverty, riverine cooperation, decision-making, capacity building, and awareness suffer significant barriers to progress. Old attitudes towards water, including aquatic ecosystems, remain entrenched in many regions. For example, a demand driven approach still prevails in a number of countries, at a time when a shift toward integrated water resources management would bring major benefits. The question is "how can progress in science and technology help to overcome or alleviate these problems?"

Since the UN World Water Conference in 1977, a series of international conferences has addressed global water issues, while several global and many national assessments of water resources have been made, including their use and management. The conclusions and calls for action have ranged widely, but common to most has been the recognition that advances in science and technology can continue to assist progress towards sustainable development.

Understanding demands data

The scientific understanding of water systems is, of course, only as good as the available data, but the assessments of water resources which have been conducted together with other surveys, invariably indicate that water data are lacking over much of the globe. It is a twin paradox that those parts of the world with most water resources, namely mountainous regions, have the least data and that nations in Africa, where the demand for water is the fastest growing, have the worst capabilities to acquire and manage water data. This lack of data applies to surface and groundwater, and to quantity and quality. Indeed the reliability and availability of data have declined since the mid 1980s, largely because national hydrological and allied networks have been retrenched. Data on water chemistry, for example, are lacking, as are data on productivity, biodiversity, temporal changes in abundance, and similar biological expressions of the state of the environment. Data on water use are in an even worse condition. There are effective national systems for collecting and managing water use data and allied information in, at most, 30 countries. For the remaining 180 or so, estimates of water use rely on population figures and assessments of the irrigated area. Several international initiatives have been launched to counter these problems. For example, the World Hydrological Observing System (WHYCOS) is stimulating hydrological data collection and management in several data-poor regions. A different approach may be possible when water becomes an economic good: then water data will have commercial value. There are also the advances stemming from the use of remote sensing, which offer increasing potential for monitoring a growing number of hydrological variables and overcoming the difficulties of determining meaningful spatial patterns from ground based observations. Data provided by geographical information systems along with digital terrain models are becoming very important. Data produced by tracer techniques are also proving to be very useful in quantifying sources of streamflow, residence times and in exploring flow paths. The advent of global data centres, such as the Global Runoff Data Centre in Koblenz, has eased the problem of access to data world and national sets and the International Association of Hydrological Sciences (IAHS) Global Databases Metadata System facilitates finding existing data sets. The Internet is a prime tool in accessing these data.

Modelling water systems

Progress in understanding water systems has developed considerably over the last 20-30 years, particularly through advances in modelling; modelling being a prerequisite of successful water resources management. Now a very wide range of models exists and more are being developed including: rainfall-runoff models, aquifer models, ecosystem models and catchment models, many including quality, process models, hydroecological models and management models backed up by decision support systems and expert systems. There are stochastic and deterministic models and the complexity of these models range from simple lumped and black box models to very sophisticated physically based models with high resolution of the land surface, including the subsurface-soil-vegetation-atmosphere interface and the processes operating there. However there are several studies, which demonstrate that the sophistication and likeness to reality of a model is no guide to its predictive success.

Scale is a problem when the results of a limited experiment carried out over distances of tens of metres have to be extrapolated by modelling to kilometres. This problem has to be addressed when different types of model are to be coupled. For example, the coupling of surface and ground water models presents difficulties because of the differences in time scales. The large scale of operation of global circulation models (GCMs) makes it difficult to couple them to hydrological models, which are designed for much smaller scales. This disparity has led to the development of meso and macro scale hydrological models. The growth in computing power has given GCMs with smaller grid cells, while techniques for aggregation, nested scale modelling and the use of fractals mark further progress. Experiments within GEWEX (Global Energy and Water Cycle Experiment) and IGBP (International Geosphere Biosphere Programme), such as the Biospheric Aspects of the Hydrological Cycle (BAHC) aim to bridge these differences in scale.

Utilising Improved Modelling

In recent years the application of more realistic models has improved capabilities for forecasting, prediction and control of water systems for various purposes. The increased reliability and range of weather forecasts, particularly forecasts of precipitation, including quantitative forecasts, has allowed more timely and precise river flow forecasts to be made. Longer-term seasonal forecasts of rainfall and the resulting forecasts of hydrological conditions has been the basis for mitigation measures. For example, using forecasts of El Niño/Southern Oscillation (ENSO) and Atlantic conditions for northeast Brazil, the seed distributed to subsistence farmers in 1992 and 1993 had a shorter growing season, so averting crop failure. Water consumption was restricted and a new dam constructed to save the city of Fortaleza from running out of drinking water. Seasonal rainfall forecasts have been made for the same area from GCMs and another method to derive forecasts of flow volumes and then to simulate the operation of a reservoir. It is recognised that further improvements to these capabilities could lead to enhanced predictions of the magnitude and distribution of regional climate variables, especially with advances in the understanding of the incidence of ENSO events. Some progress has been made in forecasting the occurrence of low precipitation 3 to 12 months ahead for Australia and runoff variability and the potential for abstracting from rivers for water supply. Increased success in flood forecasting in Japan, from the 1960s onwards, has resulted in a reduction of deaths to low levels, but damage to property remains high.

Dynamics of freshwater systems

The increasing demand for water and the alteration of hydrological regimes can result in substantial biological impoverishment and increasing risks to human health. Dam construction, drainage of wetlands, over-pumping of groundwater, large-scale water transfers, discharges of untreated wastes, salinization and similar measures lead to habitat destruction, invasion by exotic species, reduction of fisheries, increasing incidence of infectious diseases and like effects. Wetlands, for example have a critical environmental role to play in river regulation, habitat provision, preservation of fisheries and in attenuating the effect of pollutants. However many of the issues involved are poorly understood and yet are amenable to the scrutiny of science. For example, despite the activities of the World Commission on Dams, the debate about dams requires a better scientific base. While the role of dams in flood control and water management is well documented, the part they play in degrading downstream aquatic ecosystems is not. But as the use of water resources becomes more intensive, the risk to human health and the aquatic environment increases unless there is an equal effort to counter this risk by scientifically based monitoring and assessment programmes. Surface and ground water abstracted for drinking may be contaminated by faecal pathogens and by chemicals used in agriculture and industry. Declining standards in many countries means that health problems are being aggravated. Measures to save water also need to be stepped up as use intensifies. Extensive use of improved methods of applying irrigation water, such as through subsurface systems coupled with modelling of the soil water balance to schedule irrigation, would ensure that wastage is reduced and demand brought down. Demand can also be diminished by attention to leakage from distribution systems, price increases, pressure reduction and similar means.

More intensive use of water resources is usually the accompaniment to more intensive land use and changes in land cover. Indeed there are strong and intimate links between terrestrial and aquatic systems that shape the character and productivity of the environment over broad spatial and temporal scales. This leads to arguments for combining land and water resources planning and management, with the result that river basin authorities with these powers have been established in certain parts of the world. This basic strategy for sustainable freshwater resources management has created many responsibilities for science and as many opportunities. Equitable sharing of resources between upstream users and those downstream, including the environment as a legitimate user of fresh water, poses a number of questions which become even more pertinent when the basin is shared between several nations.

The Challenges Ahead

Too little and too much water in the wrong place at the wrong time, pollution of surface and ground water and the degradation of aquatic habitats are facets of the world we live in —a world that is highly dependent on a reliable supply for virtually every activity. A basic need is the incorporation of ecological principles into aquatic resource use and management decisions. Specifying ecological principles, such as those related to time, place, species, disturbance, and scale, and understanding their environmental and social implications, are essential steps on the path to sustainability.

The sciences that deal with the water cycle have played an important part in husbanding and protecting water resources and ecosystems and will continue to do so in the future. The challenges are many, but of paramount importance is the improvement of the connection between the scientist on the one hand and the policy maker and decision maker on the other. This reciprocal relationship deserves strengthening so that each party benefits from increasing awareness of the others needs and requirements. This benefit will also translates into the betterment of the lives of every woman, man and child on this planet and of the environment that ultimately supports them.