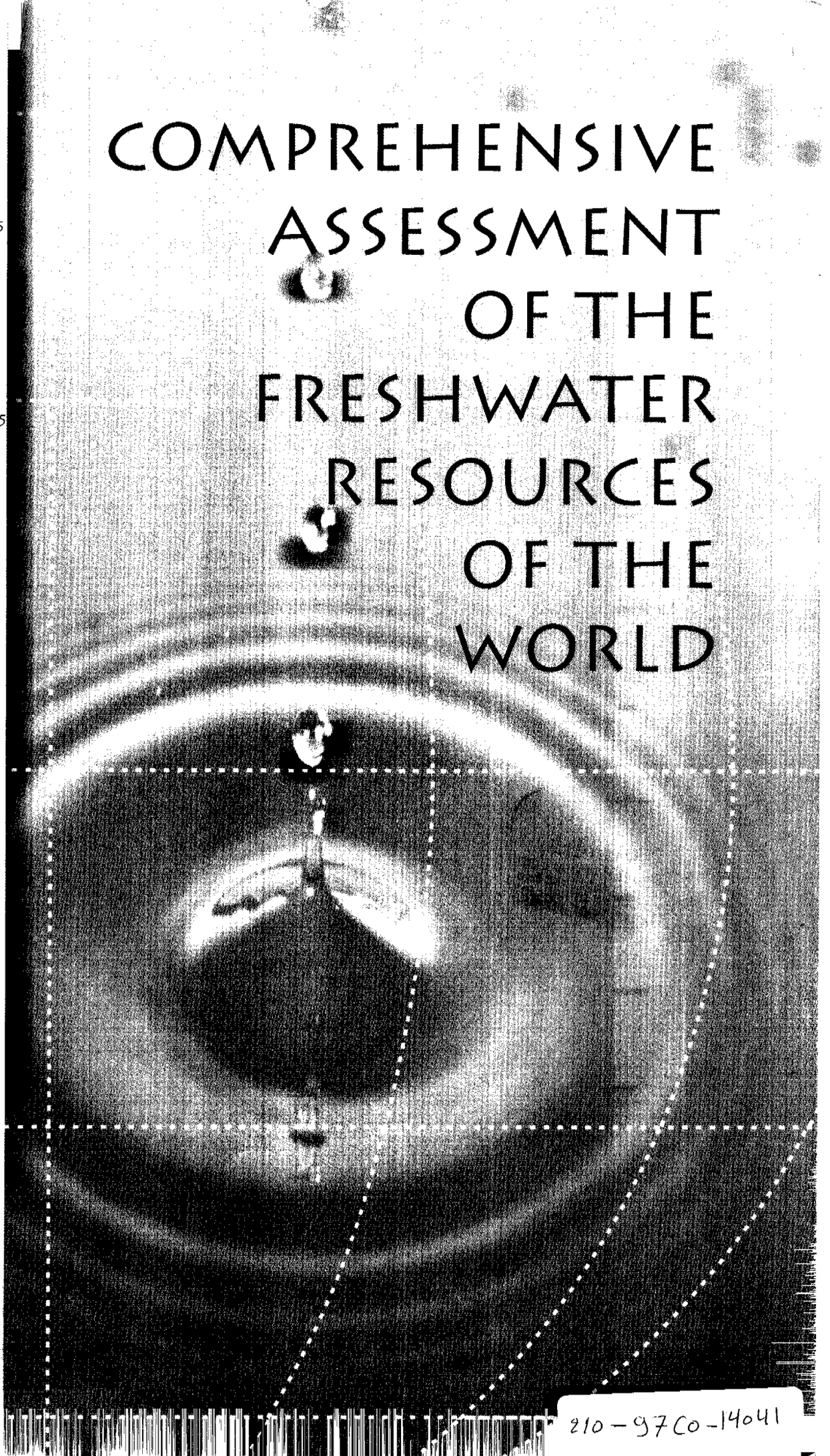
COMPREHENSIVE ASSESSMENT OF THE FRESHWATER RESOURCES OF THE WORLD



"The holistic management of freshwater as a finite and vulnerable resource, and the integration of sectoral water plans and programmes within the framework of national economic and social policy, are of paramount importance for action in the 1990s and beyond."

"Integrated water resources management is based on the perception of water as an integral part of the ecosystem, a natural resource and a social and economic good, whose quantity and quality determine the nature of its utilization. To this end, water resources have to be protected, taking into account the functioning of aquatic ecosystems and the perenniality of the resource, in order to satisfy and reconcile needs for water in human activities."

From Agenda 21, chapter 18, paragraphs 18.6 and 18.8, as adopted by the United Nations Conference on Environment and Development, Rio de Janeiro, June 1992.

UN

UNDP

UNEP

FAO

UNESCO

WMO

World Bank

WHO

UNIDO

COMPREHENSIVE ASSESSMENT OF THE FRESHWATER RESOURCES OF THE WORLD

SEI

This document has been published by the World Meteorological Organization on behalf of the participating agencies and with the sponsorship of the Stockholm Environment Institute.

CONTENTS

	Page
FOREWORD	v
SUMMARY	1
INTRODUCTION	5
I. SUPPLY, AVAILABILITY AND USE OF THE WORLD'S FRESHWATER RESOURCES	7
A. Water availability	7
B. Water uses	8
C. Water scarcity	9
D. Human-induced stresses	9
1. Quantity	9
2. Impacts of demand for water	10
3. Water pollution issues	10
E. Human health at risk due to water problems	12
1. Water supply, sanitation and health	12
2. Health effects of other contaminants	13
F. Stress on land resources	14
G. Extent and geographical distribution of water stresses due to scarcity	14
H. Coping capability based on income levels	14
I. Freshwater vulnerability	15
1. High-income countries with low water stress	15
2. High-income countries with high water stress	15
3. Low-income countries with low water stress	15
4. Low-income countries with high water stress	17
II. WATER CHALLENGES: A 30-YEAR OUTLOOK	19
A. Driving forces of change	19
B. Outlook and challenges that lie ahead	19
1. Water needs for food production	20
2. Water supply and sanitation and health	21
3. What will happen?	21
III. CONCLUSIONS AND POLICY OPTIONS	23
A. Elements of a water strategy: general considerations	23
1. Making water available to increase food production	23
2. Access to drinking water supply and sanitation needs to be dramatically increased	24
3. Water pollution must be reduced to protect human health and the rest of the environment	24
4. Need for cooperation is clearly demonstrated for transboundary waters	24
5. Water needs to be considered a resource having an economic value	25
6. Building human and institutional capacity to solve our water problems	25
7. Access to reliable data is presently inadequate	26
B. Strategy development	26
C. Policy options for country categories	27
1. High-income countries with low water stress	27
2. High-income countries with high water stress	27
3. Low-income countries with low water stress	28
4. Low-income countries with high water stress	28
D. Action: recommendations	28
BACKGROUND DOCUMENTS	31

FOREWORD

Water is a fundamental resource to all socio-economic development and for maintaining healthy ecosystems. The increasing stress on freshwater resources brought about by an ever rising demand and profligate use as well as by growing pollution world wide, is a matter of serious concern.

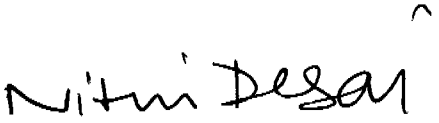
This concern is not new. It was raised at the United Nations Water Conference in Mar del Plata, Argentina, in 1977 and continues to be addressed in numerous international fora, notably the International Conference on Water and the Environment held in Dublin, Ireland, and the United Nations Conference on Environment and Development in Rio de Janeiro in 1992 and the Ministerial Conference on Drinking Water and Environmental Sanitation in Noordwijk, the Netherlands, in 1994. The Commission on Sustainable Development at its second session, in 1994, expressed great concern that many countries are facing a water crisis.

The assessment presented in this report has been prepared in response to a request by the Commission on Sustainable Development for its consideration at its fifth session and by the Special Session of the General Assembly in 1997. In order to address the many issues pertaining to the assessment, the organizations of the United Nations dealing with freshwater, together with the Stockholm Environment Institute, established a Steering Committee. A number of scientists from different countries were consulted and invited to prepare background documents which are to be published in conjunction with the assessment. Financial support was provided by the Governments of Sweden, Norway, Denmark, the Netherlands and Canada.

The results of the assessment confirm the view that in many parts of the world, the current patterns in the development and use of freshwater resources are not sustainable, either from an economic, social or environmental point of view. Reduction in river flows have had serious consequences for downstream users and aquatic ecosystems. Falling groundwater tables have resulted in land subsidence in both urban and rural areas and have brought about salt water intrusion in coastal areas. Increasing levels of pollution have rendered many water bodies unfit for most human uses without costly water treatment. Land-based sources of pollution transported by rivers are, in addition, accountable for a majority of the pollution of coastal waters and oceans.

Under the current patterns of water use, an estimated two-thirds of the total world population may well face moderate to severe water stress by 2025, as compared to one third at the present time. The number of people without access to safe water supply and sanitation will remain unacceptably high unless efforts towards solving the problems by all concerned are dramatically increased. The total effect in terms of health, economic development, food production and food security, trade and social well-being is likely to have global implications. Millions of people are suffering from water related diseases and millions of children die each year due to inadequate water supplies and sanitation services, not least in the fast growing urban areas of many developing countries. In view of increasing competition among various uses, increased cooperation among watercourse states is becoming increasingly essential so as to maximize social and economic benefits from the development of the resource.

The prognosis is bleak, but a crisis is not inevitable. Action toward reversing the current trend is a matter of the highest priority. Many good practices exist already and need to be replicated and adapted to specific conditions. The Mar del Plata Action Plan and the Dublin, Rio de Janeiro and Noordwijk conferences have all formulated recommendations for action which need to be implemented. A continuing international dialogue with the aim of refining and expanding pathways for action is needed. Nothing short of a firm commitment to action by Governments, the International Community, Non-governmental Organizations and Major Groups will suffice in order to redress the increasingly alarming situation.



Nitin Desai, Under-Secretary-General
New York, May 1997

SUMMARY

The assessment presented in the present report shows that in many countries, both developing and developed, current pathways for water use are often not sustainable. There is clear and convincing evidence that the world faces a worsening series of local and regional water quantity and quality problems, largely as a result of poor water allocation, wasteful use of the resource, and lack of adequate management action. Water resources constraints and water degradation are weakening one of the resource bases on which human society is built.

Water use has been growing at more than twice the rate of the population increase during this century, and already a number of regions are chronically water-short. About one third of the world's population lives in countries that are experiencing moderate-to-high water stress partly resulting from increasing demands from a growing population and human activities. By the year 2025, as much as two thirds of the world population could be under stress conditions.

Water shortages and pollution are causing widespread public health problems, limiting economic and agricultural development, and harming a wide range of ecosystems. They may put global food supplies in jeopardy, and lead to economic stagnation in many areas of the world. The result could be a series of local and regional water crises with global implications.

This report finds that in some cases people have taken action to reduce demand and pollution, thus relieving water stress. However, far more widespread and sustained action is essential to reverse many of the unsustainable trends. This report presents policy options designed to improve understanding of how to reach sustainable levels of water use, while satisfying a wide range of needs including agricultural irrigation, industrial development, domestic use and water to maintain natural ecosystems.

There is a steady increase in the number of regions of the world where human demands are outstripping local water supplies, and the resulting water stress is limiting development, especially of poor societies. Owing largely to poverty, at least one fifth of all people do not have access to safe drinking water, and more than one half of humanity lacks adequate sanitation. At any given time, an estimated one half of the people in developing countries suffer from water- and food-related diseases caused either directly by infection, or indirectly by disease-carrying organisms that breed in water and food.

In much of the world, women play a key role in acquiring water and deciding how it is used (L. de Toledo)

Water demands are so high that a number of large rivers decrease in volume as they flow downstream, with the result that downstream users face shortages, and ecosystems suffer, both in the rivers and in adjacent coastal areas. Many underground water resources, known collectively as groundwater, are being drained faster than nature can replenish them.

A growing number of the world's rivers, lakes and groundwater aquifers are being severely contaminated by human, industrial and agricultural wastes. Not only does the pollution affect freshwater quality, but much of it flows into the world's oceans, threatening marine life. The future health of the oceans depends heavily on how the freshwater systems are managed.

High withdrawals of water and heavy pollution loads have already caused widespread harm to a number of ecosystems. This has resulted in a wide range of health effects, in which humans have been harmed by eating food from contaminated ecosystems. Reproductive failures and death in various wildlife species, particularly at higher levels in the food chain, are being reported in various regions of the world. In addition, rising human demands will put increasing pressure on ecosystems. As more water is withdrawn for human uses, there is an increasing need to make certain that an adequate water supply to wetlands, lakes, rivers and coastal areas is maintained to ensure the healthy functioning of ecosystems.

However, there are bright spots to be noted. There have been some significant improvements in water quality, particularly when citizen pressure for clean-ups grew, and Governments and industry responded. Most developed countries have begun treating an increasing part of their municipal sewage, and a number of their industries are reducing discharges of many toxic substances. As a result, there have been improvements in the health of some wildlife species, and reduced risks to human health.

Some countries have also made impressive reductions in the amount of water needed for irrigation, industrial and municipal purposes by using more effective water management systems and better technologies. These improvements were usually driven by shortages, and by increases in the price of water. Improved irrigation water management leads to less seepage and pooling of water which have a favourable impact on the transmission of vector-borne diseases such as malaria and schistosomiasis.

On balance, these gains have not reversed either the general trend towards water shortages, or the widespread

decline in water quality. A number of studies by United Nations agencies show that many countries lack the capacity to carry out comprehensive water resources assessments that include not only water quantity and quality but also other factors such as changes in population and industrial development. There is a need for countries to strengthen their capabilities in this regard in order to be able to meet more effectively current and future stresses on their water resources.

There are driving forces of change that could make water problems worse, unless actions are taken. Those forces include a world population that is now at 5.7 billion, and is heading towards a figure of 8.3 billion by the year 2025. Much of this increase will be in the rapidly growing urban areas of developing countries, many of which are already experiencing serious water stress.

Another driving force will be increasing consumption of food and industrial goods produced using water. Irrigation already accounts for 70 per cent of the water taken from lakes, rivers and underground sources, and there will be pressure to use more water to produce food for the increasing population. An increasing number of water-short countries will have to make choices about the amount of water they allocate for food production as compared with other uses. They may find that limited water resources are more profitably invested in producing goods that can be exported to buy food, rather than in trying to grow all their food at home. Countries will also face increasing demands for water supplies for industrial development, hydroelectric generation, navigation, recreation and domestic use. Unless development stays within the limits of water supplies, there could be shortages that hamper economic development.

Water pollution will continue to increase unless more effort is put into pollution prevention, increasing sewage treatment, and employing cleaner and more water-efficient forms of industrial production. This means using substances that are less toxic, and reducing the release into the environment of potentially harmful materials that are used in agriculture, industry and homes.

Because of increasing competition among demands for a finite resource, there is already a growing perception of water as an economic good and as a tradable commodity. As human demands grow, so will the price of water and possibly food prices, placing a heavier burden on the poorer strata of the world's population. Economic planners often neglect to account for the amount of water that will be needed for certain forms of development, especially food production, for the world of 2025.

Countries, often working in regional groups and with international institutions such as the United Nations, need to develop a broad range of water strategies based on the best information available. There is a need to use water more efficiently, reduce pollution, provide people with access to safe drinking water and sanitation, and work for a global trading system in which countries that lack enough water to grow all their own food will have access to food grown in water-rich regions. Concerted actions are needed at the local, national and international levels. These include incorporating water into economic analyses, which should change consumption patterns and reduce demand for water. Poverty alleviation will be closely linked to the success of water policies.

About 300 major river basins and many groundwater aquifers cross national boundaries. It is essential for riparian countries to find ways of cooperating over the development and management of these transboundary water sources, if they are to maximize mutual benefits from the use of the resource.

There are many technologies for reducing water use. In some countries, waste water is already being treated and used for irrigation. A number of industries have developed or adopted water management techniques and technologies that greatly reduce water use. Irrigation can become much more efficient in delivering water directly to plants, and still be designed and maintained in a way that avoids or minimizes such harmful side effects as waterlogging and salinization of the soil. Changing to crops using less water together with sequencing and shifting growing seasons can reduce water use substantially as well.

The amounts of water available and its quality are directly related to such activities as forestry, farming, urban developments and industrial strategies. To make water use more sustainable, planners at all levels need to understand water issues, and make them a central part of their development plans. The wise management of both water quantity and quality has to be a central part of health, economic and social policies.

Water management must adopt an integrated approach, taking into account a wide range of ecological, economic and social factors and needs. Decision-making should include full public participation, with all sectors of society. The fact that, in developing countries, women are the main providers of water for household uses, makes it critical to involve them at all levels in the decision-making process.

In making decisions about water resources management it is important to have overall planning and coordination, but it is also helpful to delegate as much responsibility as possible to the lowest appropriate levels. This helps to ensure participation of more people with a stake in the success of water projects.

Water used for development should be considered natural capital, an economic good, and the market place can help to decide where its services are best used to generate wealth. It is important to ensure that the way in which water resources are developed does not result in worsening poverty.

Because of the lengthy period of planning, design and construction of large water resources projects, it is crucial for decision makers to start making plans based on the best evidence available. It is no exaggeration to say that water resources projects to meet the needs of societies and economies in the year 2025 must be started or be in an advanced planning stage within the next few years. It is essential to plan and design new projects in ways that avoid the past mistakes that resulted in excessive water use and degraded water quality.

The world faces many challenges over use of the environment as a source of natural resources and as a sink for

wastes. Water has to be considered one of the main issues facing the world. It is as important as atmospheric change, deforestation, protection of biodiversity and desertification, all of which are linked to water management. Many of the negative trends will take years to reverse, so it is imperative that actions to reverse them begin immediately.

All people require access to adequate amounts of clean water for such basic needs as drinking, sanitation and hygiene. In return, those who use water have a responsibility to see that water is used wisely and not degraded.

It will be vital to monitor and report on progress in dealing with water issues. Among the indices that measure the effectiveness of water management are:

(*a*) Human health, which has a direct correlation with vector- and water-borne diseases and water supply and sanitation;

(*b*) Environmental health, which correlates with water use and pollution discharges;

(*c*) Food production, with its correlation with nutrition, and the availability of affordable water.

INTRODUCTION

A growing number of regions face increasing water stresses because more people are both polluting water and demanding more of it for all uses, and water is, after all, a renewable but finite resource. They are thus suffering from scarcities caused by failure to adapt to the amount of water that is regularly made available by rain and snowfall.

Concern over the global implications of water problems was voiced as far back as the United Nations Conference on the Human Environment in Stockholm in 1972. It has been the focus of a number of meetings, including the United Nations Water Conference in Mar del Plata, Argentina, in 1977, the Global Consultation on Safe Water and Sanitation for the 1990s in New Delhi, India, 1990, and the International Conference on Water and the Environment: Development Issues for the 21st Century, in Dublin, Ireland, and the United Nations Conference on Environment and Development in Rio de Janeiro, Brazil, both in 1992. Since then, the Ministerial Conference on Drinking Water and Environmental Sanitation, in Noordwijk, the Netherlands, in 1994, has reinforced these concerns. Most recently, the Committee on Natural Resources noted with alarm that some 80 countries, constituting 40 per cent of the world's population, were already suffering from serious water shortages and that, in many cases, the scarcity of water resources has become the limiting factor to economic and social development. It further noted that ever-increasing water pollution had become a major problem throughout the world, including coastal zones. The Commission on Sustainable Development, at its second session in 1994, noted that in many countries a rapid deterioration of water quality, serious water shortages and reduced availability of freshwater were severely affecting human health, ecosystems and economic development.

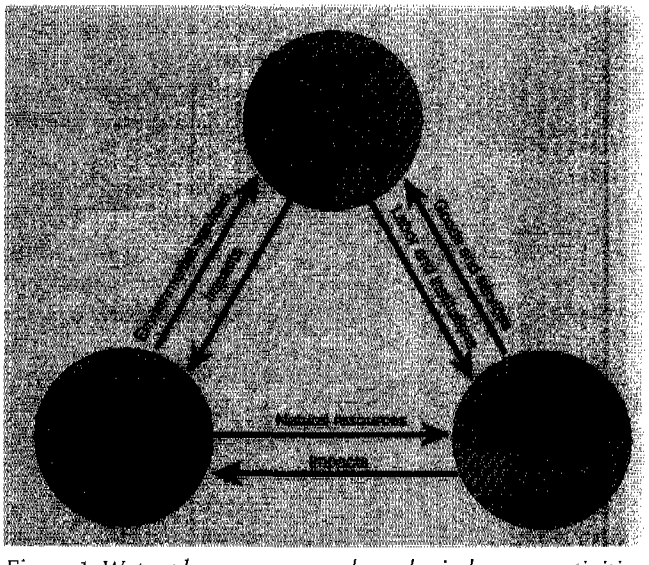


Figure 1. Water plays many complex roles in human activities and natural systems. A comprehensive approach must thus relate to water use from many different aspects. The assessment describes the human interaction within the economic, social and environmental framework. It seeks to point out how the systems are interacting through different global linkages such as cultural influences, environmental impacts, global governance and trade, showing that the socio-ecological system is complex with connections within and between the different subsystems.

The Commission on Sustainable Development requested this comprehensive assessment of the freshwater resources of the world, to be submitted to it at its fifth session, and to the General Assembly at its special session in 1997. This assessment was prepared by a number of United Nations organizations, the Department for Policy Coordination and Sustainable Development of the United Nations Secretariat, the Department for Development Support and Management Services of the United Nations Secretariat, the Food and Agriculture Organization of the United Nations (FAO), the United Nations Development Programme (UNDP), the United Nations Environment Programme (UNEP), the United Nations Educational, Scientific and Cultural Organization (UNESCO), the United Nations Industrial Development Organization (UNIDO), the World Bank, the World Health Organization (WHO) and the World Meteorological Organization (WMO), working in collaboration with the Stockholm Environment Institute, and with the advice of experts on a wide range of subjects. The support given to this project by the Governments of Sweden, Norway, Denmark, the Netherlands and Canada is acknowledged with sincere appreciation.

The recommendations in this report were guided by the content of reports from previous conferences, particularly the report of the Dublin Water Conference (A/CONF.151/PC/112, annex II) and chapter 18 of Agenda 21.[1] More recent information has also been evaluated, particularly on water availability and use.

This assessment provides an overview of major water quantity and quality problems with the aim of helping people understand the urgent need to deal with these issues before they become even more serious. In spite of its limitations, the available information provides the basis for a broad understanding of the problems facing various regions of the world, and of the nature and magnitude of the global implications of not dealing with these problems.

[1] *Report of the United Nations Conference on Environment and Development, Rio de Janeiro, 3-14 June 1992*, vol. I, *Resolutions Adopted by the Conference* (United Nations publication, Sales No. E.93.I.8 and corrigendum), resolution 1, annex II.

I. SUPPLY, AVAILABILITY AND USE OF THE WORLD'S FRESHWATER RESOURCES

Freshwater is one of the most essential of the elements that support human life and economic growth and development. It is irreplaceable for the purposes of drinking, hygiene, food production, fisheries, industry, hydropower generation, navigation, recreation and many other activities. Water is equally critical for the healthy functioning of nature, upon which human society is built.

A. WATER AVAILABILITY

Many people have an image of the world as a blue planet, for 70 per cent of it is covered with water. The reality is that 97.5 per cent of all water on Earth is salt water, leaving only 2.5 per cent as freshwater. Nearly 70 per cent of that freshwater is frozen in the ice caps of Antarctica and Greenland, and most of the remainder is present as soil moisture, or lies in deep underground aquifers as groundwater not accessible to human use. As a result, less than 1 per cent of the world's freshwater, or about 0.007 per cent of all water on Earth, is readily accessible for direct human uses. This is the water found in lakes, rivers, reservoirs and those underground sources that are shallow enough to be tapped at an affordable cost. Only this amount is regularly renewed by rain and snowfall, and therefore available on a sustainable basis.

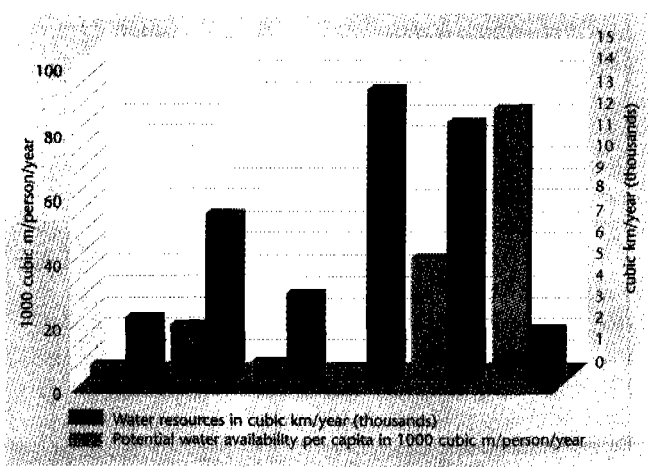
Much of the approximately 110,000 cubic kilometres of precipitation that fall on the continents each year evaporates back into the atmosphere, or is absorbed by plants. About 42,700 cubic kilometres of the water that falls on Earth flows through the world's rivers. (This is roughly the amount of water now stored in some of the world's largest lake systems — Lake Baikal in the Russian Federation and Lake Tanganyika and Lake Victoria in Africa — combined.) When the world's total river flow is divided by the world population (of 1995), the quotient amounts to an average of 7,300 cubic metres of water per person per year. Owing to the growing world population, this represents a drop of 37 per cent per person since 1970.

Freshwater resources are very unevenly distributed: at one extreme are the deserts, where almost no rain falls, and at the other are the most humid regions, which can receive several metres of rainfall a year. Most of the flow is in a limited number of rivers: the Amazon carries 16 per cent of global run-off, while the Congo-Zaire river basin carries one third of the river flow in all of Africa. The arid and semi-arid zones of the world, which constitute 40 per cent of the land mass, have only 2 per cent of global run-off.

Even in parts of the world with large river flows, there can be a great amount of variability in terms of when and where the water is available. Most of the annual water flow may come as floods following snow melt or heavy rains and, unless captured by reservoirs, the water flows to the seas, sometimes causing seasonal flooding. Later in the year, the same areas may suffer droughts. Another major factor in the availability of water is the rate of evapotranspiration, the loss of water from land to the atmosphere by evaporation from the soil and water surfaces, and transpiration from plants. For example, Sweden and Botswana receive about the same amount of precipitation each year, yet the climate in Sweden is humid, while that of Botswana is semi-arid because so much of its water is drawn up by the heat of the sun. One more important factor is that much of the world's accessible run-off occurs in areas far from human settlements, and water is very expensive to transport over long distances.

Experts have estimated the amount of freshwater that is readily accessible for human use at about 9,000 cubic kilometres per year. They add another 3,500 cubic kilometres of water that is captured and stored by dams and reservoirs. Harnessing the remaining water resource for human needs becomes increasingly costly, because of topography, distance and environmental impacts. Currently, humans are using about half the 12,500 cubic kilometres of water that is readily available. Given an expected population increase of about 50 per cent in the next 50 years, coupled with expected increases in demand as a result of economic growth and lifestyle changes, this does not leave much room for increased consumption. Water needs to be left in rivers to maintain healthy ecosystems, including fisheries. Recreation, navigation and hydropower generation all require the preservation of adequate amounts of water.

Figure 2. Average Annual Runoff. The amount of freshwater varies sharply among continents. The size of the population determines how much water is potentially available per person. While Asia has the world's greatest river flow, it has billions of people, so the per capita availability is the lowest of all the continents. The high per capita runoff in Australia/Oceania shows that despite the fact much of Australia is very dry, the population density is quite low, and there is very heavy rainfall in parts of the country, and on the Pacific islands.



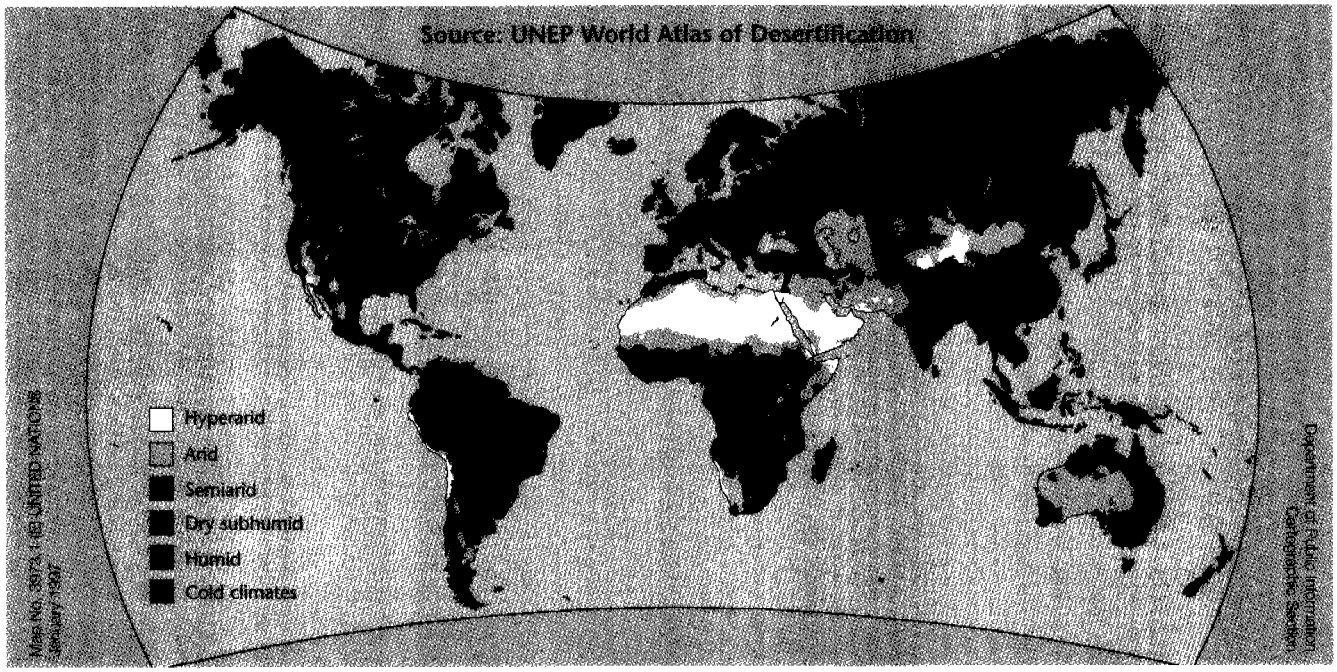


Figure 3. Naturally dry zones of the world mean that there are limitations to the pattern of development that may be available on the basis of water resources availability, particularly for agriculture.

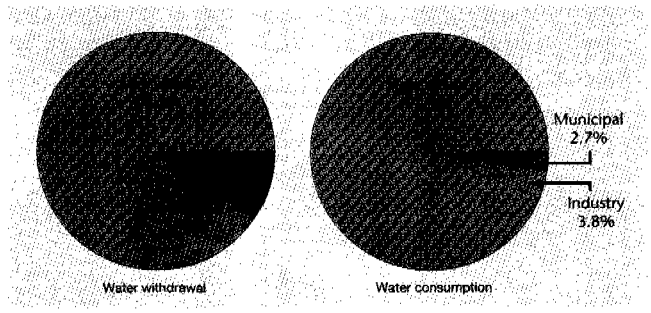


Figure 4. Present water withdrawal and consumption by sector.

When the global water picture is examined at country level, some countries still have large amounts of water per capita, but others are already facing serious difficulties. Future increases in demand due to population growth and increased economic activities will inevitably impinge further on the available water resources.

B. WATER USES

A number of human actions — including the building of dams and canals, the drainage of wetlands, and the removal of forests and other plant cover — are changing the flow of water in parts of the world. Trees and other plants modify the flow of water that falls on the land, consume water, and release some into the atmosphere, where it may result in more rain.

Humans interact with the hydrologic cycle at many levels. We use surface water and groundwater. Pollution not only contaminates water on and beneath the ground, but also changes the chemical composition of water in the atmosphere. Waste discharges from a wide range of sources, including motor vehicles, homes, offices and industries, as well as chemicals and animal wastes from agricultural production, create contaminated run-off, some of which seeps into groundwater. Changes in the landscape affect the run-off and quality of both surface water and groundwater.

Part of the water withdrawn from rivers, streams, lakes, reservoirs and groundwater is consumed and not returned later as available water. Such consumption includes water that plants use to build plant tissue or release into the air during evapotranspiration. It also includes water that evaporates from land or reservoirs, and water that is not returned to water sources from industrial production or community use. The major forms of water withdrawal and consumption are for agriculture, industry and domestic use. Most of the water withdrawn by industries and municipalities is used then returned, often degraded in quality, to lakes and rivers or other watercourses. Water withdrawn for irrigation use is partly consumed in the process of crop production, and partly required to flush salts out of the soil. However, most irrigation is inefficient and about 60 per cent of the withdrawn water returns to the river basin and to groundwater.

In addition to domestic and municipal water supply, irrigation of crops, production of energy and industrial uses, navigation and recreation also require that adequate flows be available in rivers, and that water levels be maintained in lakes and reservoirs. Reserving water for the healthy functioning of ecosystems is sometimes seen as far less important than providing all the water that humans demand. In recent years, however, an understanding has emerged on the need to maintain ecosystem health not just for ethical reasons, but also because of the very practical benefits, sometimes called ecosystem services, that are provided to humans. These include the production of food, reduction of flood risk and filtering of harmful pollutants. Great strides have been made in understanding the freshwater needs of aquatic ecosystems. Such needs are being accepted as legitimate calls on water, leading an increasing number of decision makers to give these "environmental" flows priority along with water use for economic activities.

C. WATER SCARCITY

Global withdrawals of water to satisfy demands have grown dramatically in this century. Between 1900 and 1995, water withdrawals increased by a factor of over six, more than double the rate of population growth. This rapid growth in water demand is due to the increasing reliance on irrigation to achieve food security, the growth of industrial uses, and the increasing use per capita for domestic purposes.

The increased demands are causing water stress in many areas of the world, even in some humid areas where rising demand or pollution have caused overutilization of the local resource. Already, about 460 million people, more than 8 per cent of the world's population, live in countries using so much of their water resources that they can be considered to be highly water-stressed. A further one quarter of the world's population lives in countries where the use of water is so high that they are likely to move into situations of serious water stress.

WATER SCARCITY

Water scarcity occurs when the amount of water withdrawn from lakes, rivers or groundwater is so great that water supplies are no longer adequate to satisfy all human or ecosystem requirements, bringing about increased competition among potential demands.

Scarcities are likely to occur sooner in regions where the per capita availability of water is low to start with, and with high population growth. They become more serious if demand per capita is growing owing to changes in consumption patterns.

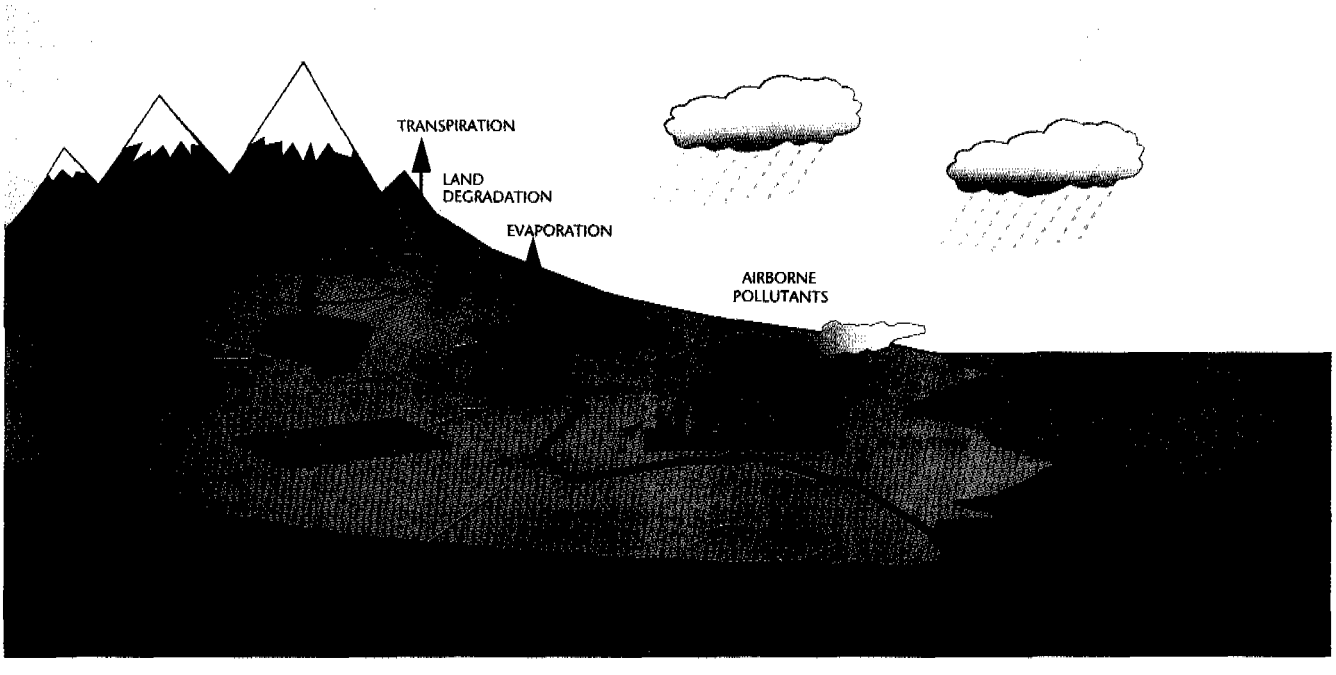
D. HUMAN-INDUCED STRESSES

1. Quantity

Irrigated agriculture takes about 70 per cent of water withdrawals, and the figure rises to 90 per cent in the dry tropics. Agriculture lays claim to by far the biggest consumptive use of water, representing 93.4 per cent of the total. Traditionally, most food has been grown on rain-fed lands, relying on soil moisture supplied by rainfall, but as food demand rises, this is increasingly supplemented by irrigation, using water drawn from lakes, rivers and underground aquifers. Irrigated agriculture contributes nearly 40 per cent of world food production from just 17 per cent of cultivated land. Much of the dramatic increase in food production of recent decades, including the green revolution, requires high-yield plant varieties, combined with fertilizers and pest control, and depends on irrigation to ensure adequate and timely water for high growth. Water withdrawals for irrigation have increased by over 60 per cent since 1960.

Until the late 1970s, the growth in the amount of land being irrigated exceeded the rate of population growth. Since then, the amount of irrigated land has increased more slowly than population, owing to a limited amount of additional land suitable for irrigation, increasing water scarcities and the loss of some irrigated areas to soil degradation

Figure 5. In the hydrological cycle, the sun constantly evaporates water into the atmosphere, part of which is returned on land as rain and snow. Part of that precipitation is rapidly evaporated back into the atmosphere. Some drains into lakes and rivers to commence a journey back to the sea. Part infiltrates into the soil to become soil moisture or groundwater. Under natural conditions, the groundwater gradually works its way back into surface waters and makes up the main source of dependable river flow. Plants incorporate some of the soil moisture and groundwater into their tissues, and release some into the atmosphere in the process of transpiration.



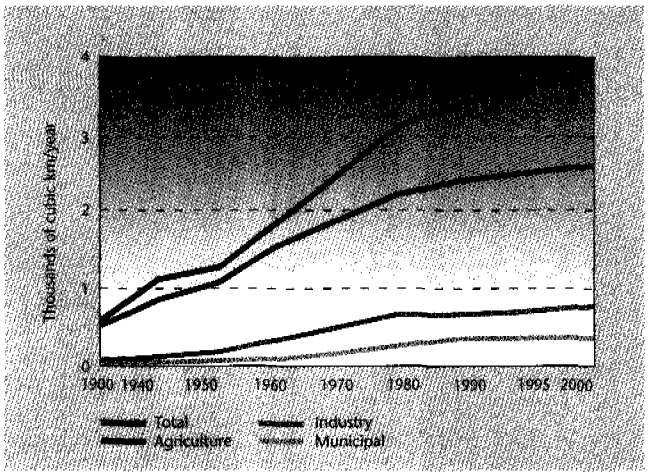


Figure 6. Global water withdrawals by sector, 1900-2000.

including soil salinization. However, total agricultural output has continued to outstrip population growth, owing to productivity increases. Currently, the world can produce enough food for everyone, but an estimated 840 million people lack access to sufficient food for their nourishment, and are hampered in carrying on productive working lives because they cannot afford to buy enough food. As the number of people to feed increases, it will be ever more of a challenge to produce enough food at prices people can afford. In many regions, in particular arid and semi-arid regions, the amount of water available for irrigation will become increasingly limited and costly.

2. Impacts of demand for water

In some areas, the withdrawals are so high that the flow of rivers decreases as they move downstream, and some lakes are shrinking.

Groundwater supplies one third of the world's population, and is the main or only source of water for rural dwellers in many parts of the world and also increasingly the main source for irrigation. Underground sources are being heavily overused in a number of regions, with water being pumped out faster than nature can replenish the supply. The excessive use of groundwater is likely to increase over the next 30 years. Overpumping groundwater has dropped water levels by tens of metres in places, making it increasingly difficult and expensive for people to have continued access to the water. In a number of regions, depletion has forced people to turn to lower-quality groundwater sources, some of which contain natural contaminants. The overuse of groundwater can have a serious effect on the base flow of rivers, especially during dry periods, which is so vital for aquatic ecosystems.

Many groundwater aquifers are recharged on a regular basis by rain and melting snows. However, some groundwater reservoirs that were filled under different climatic conditions, often thousands of years ago, are known as fossil aquifers and if used, they will not be recharged by nature for a very long time, if ever.

In some cases, groundwater depletion results in the sinking of the land above aquifers. Land subsidence caused by high water withdrawals has been recorded in many countries, including Mexico, the United States of America, Japan, China and Thailand, with the land sinking from 1 to 10 metres.

Overutilization of aquifers near sea coasts leads to intrusion from the ocean, which contaminates the freshwater with salt. Small islands fall into a special category because for many of them freshwater is a fragile resource. If the freshwater is overdrawn, this leads to salt-water intrusion. People on some small islands have been forced to turn to expensive alternatives, including desalination and importing of water by tanker.

3. Water pollution issues

For millennia, people have used water as a convenient sink into which to dump wastes. The pollution comes from many sources, including untreated sewage, chemical discharges, petroleum leaks and spills, dumping in old mines and pits, and agricultural chemicals that are washed off or seep downward from farm fields. In one area after another, the amounts and types of waste discharged have outstripped nature's ability to break them down into less harmful elements. Pollution spoils large quantities of water which then cannot be used or, at best, can be used for restricted purposes only.

THE ARAL SEA

In 1960, the Aral Sea was the fourth largest inland body of water in the world. Since then it has shrunk to less than half its original size because of the nearly total cut-off of inflow from the Amu Darya and Syr Darya rivers as a result of heavy withdrawals for irrigation. The desiccation of the Aral has resulted in the loss of its fishing industry, the destruction of its ecosystem and deltas, the blowing of salts from the exposed seabed which are toxic to humans and deleterious to crops, and the depressing of the economy. Indiscriminate use of water for non-agricultural purposes, inefficient irrigation practices, excessive use of chemicals for growing cotton and rice crops, and the lack of adequate drainage caused extensive waterlogging and salinity, and polluted the groundwater and drainage inflows to the rivers and the sea. Water pollution from urban and industrial wastes has further aggravated the problems. To stabilize the environment and rehabilitate the economy of the Aral Sea Basin, the Governments of the five independent riparian States have begun a large and complex programme intended to assist them in cooperating and adopting sustainable regional development policies, and to provide a framework for selected national macroeconomic and sectoral policies for achieving sustainable land, water and other natural resources development.

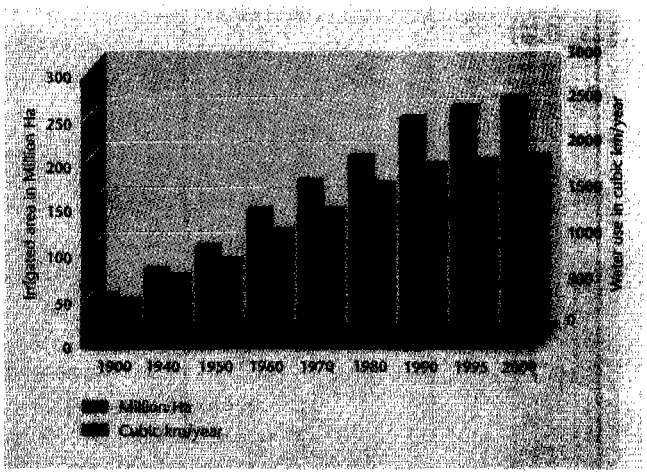


Figure 7. Amount of irrigated land in the world, and water consumption for irrigation. Dark-coloured bars depict the amount of water consumption while light-coloured bars show the amount of land that is irrigated.

The impairment of water quality near major urban centres is recognized as a major problem. In parts of the world, water qual-ity has been so degraded that it is unfit even for industrial purposes. Even when the levels of some pollutants seem to be low, they can pose a threat by accumulating in the aquatic food chain, affecting the health of these creatures, and threatening the health of humans who eat contaminated wildlife. Groundwaters, once contaminated, are very difficult to clean up because the rate of flow is usually slow.

Major water pollution problems include those described directly below:

(*a*) Contaminated water that people drink without adequate treatment is one of the major causes of human illness. Micro-organisms found in human and animal wastes include a wide range of bacteria, viruses, protozoa and other organisms that cause many diseases. These are present in virtually all wastes discharged, even those from most sewage treatment plants. As a result, it is necessary to treat drinking water to prevent outbreaks of disease;

(*b*) There is an accelerated growth of algae fertilized by the phosphorus and nitrogen present in many discharges, including human and animal wastes, detergents and run-off from fertilizers. These two elements, when discharged into water, act as nutrients, greatly speeding up the process called eutrophication. Excessive algal growth leads to a decline in the oxygen content of the water, which can result in suffocation of some forms of aquatic life. It can also impart a foul taste to drinking water. Eutrophication, first noticed in many Western European and North American lakes in the 1950s, is now leading to a decline in water quality on all continents. The draining of nutrients into oceans can lead to an increase in the number of toxic algal blooms, sometimes known as red tides, which can make seafood unsafe to eat;

(*c*) Nitrates from fertilizers, human and cattle wastes are polluting groundwater in many regions. High nitrate levels in drinking water decrease the oxygen-carrying capacity of haemoglobin in blood, which can threaten the health of infants. A United Nations study has stated that nitrate pollution will likely be one of the most pressing water quality problems in Europe and North America in the coming decade, and will become a serious problem in other countries, such as India and Brazil, if present trends continue;

(*d*) Some of the more than 100,000 commercial chemicals in the world, as well as a number of chemical waste by-products, are known or suspected to cause harmful effects in humans, plants and animals. The members of one class of compounds, known as persistent organic pollutants (which include such well-known substances as polychlorinated biphenyls (PCBs) and dichlorodiphenyltrichloroethane (DDT), have created many of these problems because they are toxic, and highly persistent in the environment, and build up in the food chain. These and other chlorinated organic chemicals have been so widely distributed by air and ocean currents that they are found in the tissues of people and wildlife everywhere;

(e) Heavy metals are found naturally in soil and water, but their worldwide production and use by industry, agriculture and mining have released large amounts into the environment. The metals of greatest concern for human health are lead, mercury, arsenic and cadmium. Many other metals, including copper, silver, selenium, zinc and chromium, are also highly toxic to aquatic life. Water pollution related to metal production and use, including the release of acids from mining wastes, is a problem in many of the world's mining and metal processing regions. Elevated levels of some metals, such as lead and mercury, are also found around many cities, and downwind from metal smelters and coal-burning power plants.

In theory, virtually all pollutants can be removed from water but in practice, decontaminating water, especially in the case of toxic substances, is very expensive and requires sophisticated techniques.

Water pollution problems vary in severity around the world, depending on population densities, the types and amounts of industrial and agricultural development, and the number and efficiency of waste treatment systems that are used. The global magnitude of pollution is difficult to quantify because of a scarcity of information in many countries. There are estimates that in developing countries, which often lack the resources to build and maintain sewage treatment systems, 90 per cent of waste water is discharged without treatment. A United Nations study found that in Latin America, virtually all domestic sewage and industrial waste are discharged untreated into the nearest streams. In most areas, domestic sewage volumes are far higher than those of industrial discharges. There were similar findings for West Africa, where there were also signs that shallow aquifers were being contaminated by the seepage of human wastes. In Western Asia, the major water quality problem identified was the salinity caused by widespread irrigation, although other water quality problems may not be evident owing to lack of monitoring programmes. In the Asia and Pacific region, in addition to domestic and industrial

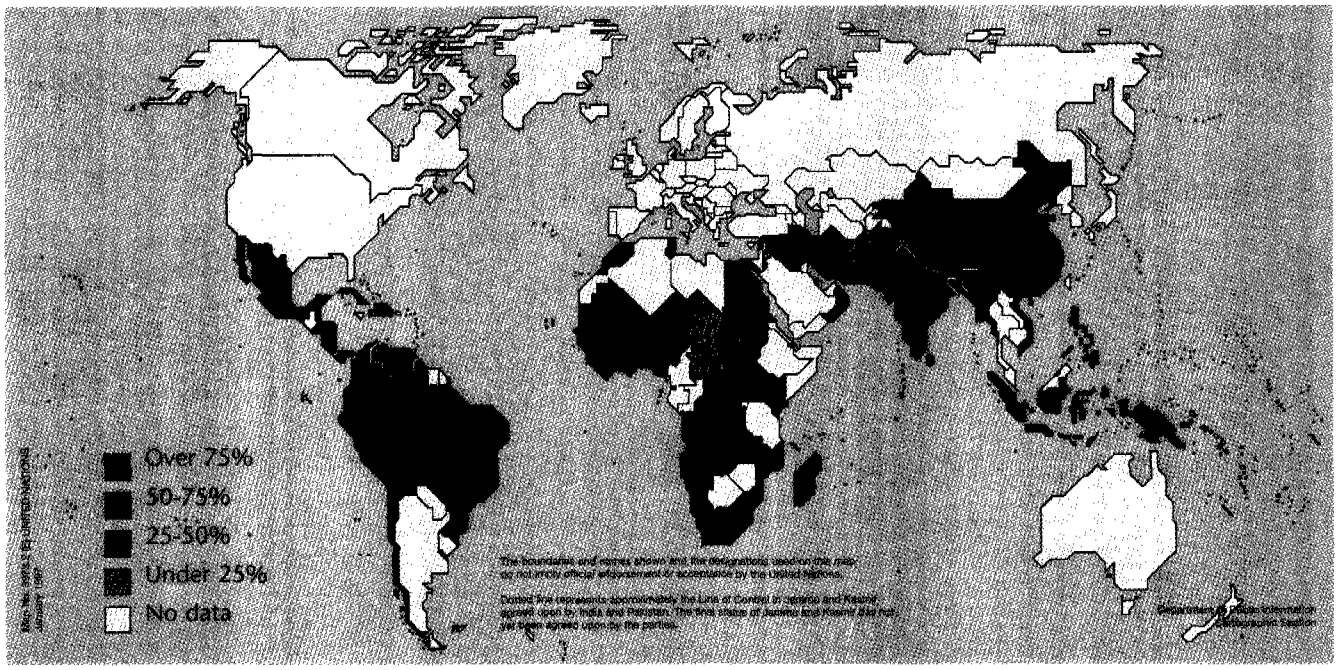


Figure 8. Water supply service coverage (per cent of population served) at the end of 1994.

wastes, there are also high sediment loads in rivers resulting from high erosion upstream where much land is left exposed owing to the removal of forest.

The water pollution problems in many developing countries mirror those already experienced by developed countries in Europe and North America. A few decades ago some rivers in rich nations were so polluted that fires broke out on their oil-slicked surfaces. This was documented both in Canada and in the United States. Owing largely to public pressure, controls have been imposed on much of the gross pollution, and clean-ups are taking place, often at very high cost to the present generation.

While much of the world's pollution is directly released from discharge pipes and sewers, or is carried off from polluted industrial, municipal and agricultural areas by rainfall and melting snows, a significant pollution load is transferred over long distances by the atmosphere. Several decades ago, researchers discovered that the release of tens of millions of tons per year of sulphur and nitrogen caused sulphuric and nitric acid fallout. This acid rain affects large areas of the world, including parts of Europe, North America, Latin America, India and Asia. It has killed parts of ecosystems, and can threaten human health by dissolving metals into the water. In addition to acids, there is long-range airborne transport of a wide range of chemicals and metals from such sources as industries, motor vehicles, power plants, smelters and incinerators. Pesticide use is another important source because some of the chemicals evaporate into the air, and others adhere to tiny dust particles, and in both cases these chemicals can then be carried great distances by wind currents. Sometimes, the pollutants build up in the food chain, and are passed on to humans who rely on unprocessed foods. Tests of breast milk from women in some northern latitudes, where there is little industry and no agriculture, found that levels of PCBs and certain pesticides were 4-10 times higher than in women from regions hundreds of kilometres to the south.

Since most lakes and rivers eventually drain to the seas, the freshwater waste discharges also have an impact on coastal and even on deep-sea ecosystems. About 80 per cent of marine pollution is caused by human activities on land. The water in the oceans will never be clean unless pollution from sources on land is controlled.

E. HUMAN HEALTH AT RISK DUE TO WATER PROBLEMS

1. Water supply, sanitation and health

The need to provide safe drinking water and sanitation and to reduce water contamination entails basic questions of equity and protection of human health. They were emphasized in the Mar del Plata conference of 1977. In 1980, the General Assembly in its resolution 35/18, proclaimed the period 1981-1990 as the International Drinking Water Supply and Sanitation Decade, during which Member States would assume a commitment to bring about a substantial improvement in the standards and levels of services in drinking water supply and sanitation by the year 1990. The issue continued to receive attention at such intergovernmental conferences as the Global Consultation on Safe Water and Sanitation in New Delhi in 1990 and the Noordwijk conference of 1994.

In the past two decades, these essential services were provided to millions of people worldwide, saving a great many lives and reducing illness. However, the rate of supply has not kept pace with that of population growth, and 20 per cent of the world's population lacks access to safe water supply, while 50 per cent lacks access to adequate sanitation. The vast majority of these people live in developing countries. This lack of access to safe drinking water and sanitation is directly related to poverty and, in some cases, to the inability of Governments to invest in these systems. In a number of regions, poor people lack access to piped water,

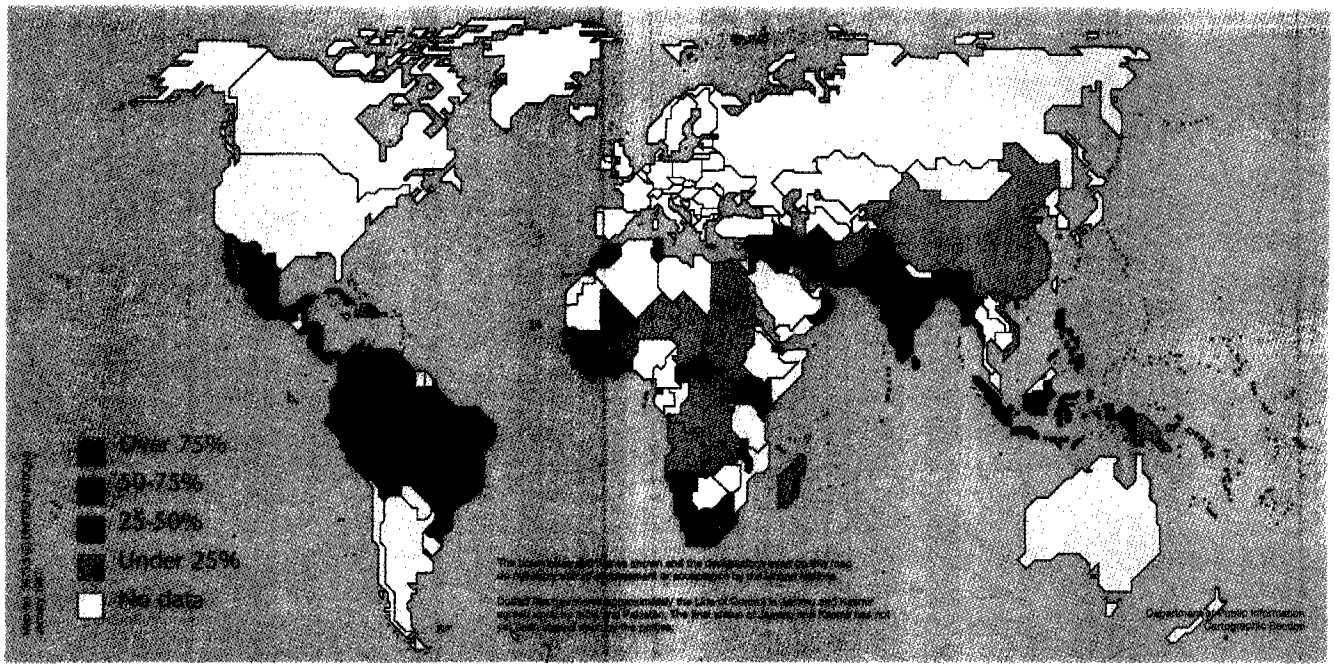


Figure 9. Sanitation service coverage (per cent of population served) at the end of 1994.

and must buy from vendors, so they pay more for their water than rich people.

A great deal of treated drinking water is lost unnecessarily. There are estimates that about half the water in drinking water supply systems in the developing world is lost owing to leakage, illegal hook-ups and vandalism. This deprives the operators of water supply systems of the money they could use to maintain and expand service. The World Bank estimates that about $600 billion needs to be invested worldwide to repair and improve waterdelivery systems.

Human health is closely linked to safe drinking water and sanitation, and to sound management of land and water resources, particularly in the context of water resources development projects. At any given time, an estimated one half of the people in developing countries are suffering from water- or food-associated diseases caused either directly by infection through the consumption of contaminated water or food, or indirectly by disease-carrying organisms (vectors), such as mosquitoes, that breed in water. Of these diseases, the most widespread and with the greatest impact on human health status are diarrhoea, malaria, schistosomiasis, dengue, infection by intestinal worms, and river blindness (onchocerciasis). According to WHO, some 2 billion people are at risk of malaria alone, with 100 million people affected at any one time and between 1 million and 2 million deaths per year.

WHO estimates that a total of more than 5 million people die each year just from diseases caused by unsafe drinking water, and a lack of sanitation and water for hygiene. Provision of safe drinking water and sanitation could reduce the amount of illness and death by as much as three quarters, depending on the disease. Not only is the toll a human tragedy, but it means these people are less able to carry on productive lives, and this undermines social and economic development. An outbreak of cholera, a waterborne disease, began in Peru a few years ago and spread through many parts of Latin America, killing hundreds of people, and costing hundreds of millions of dollars in lost income.

There are other economic impacts caused by poor water supply systems. Women are the main water providers, especially in developing countries, and the provision of basic drinking water supply systems could also reduce the annual expenditure of over 10 million person-years of effort by women and female children carrying water from distant sources. Reallocation of the time spent in this unproductive activity would assist in poverty alleviation.

2. Health effects of other contaminants

In humans, high levels of exposure to some chemicals and heavy metals have been linked to a number of illnesses, including cancer, damage to the nervous system and birth defects. Pollutants can build up in the food chain to the point where they harm people, as in Minamata disease which is caused by the eating of seafood contaminated with mercury from industrial discharges. The cumulative effects of long-term exposure to a variety of chemicals at what seem like low concentrations cannot be well quantified at present. Studies in North America suggest a link between foetal exposure to high levels of some organochlorines and reduced learning ability in children. There is also suggestive evidence from wildlife studies that humans may be at risk from a number of subtle effects, such as disruptions in the endocrine system caused when synthetic materials interfere with the body's normal chemical balance.

Toxic chemical effects have been more clearly recorded in wildlife. The effects include cancer, death, eggshell thinning, population declines, reduced hatching success, abnormal behaviour, changes in organ development, infertility, birth defects and a range of other illnesses. There are also less visible effects on body chemistry, including abnormalities in the thyroid, liver and endocrine system. Some

organochlorines appear to have the ability to mimic or block the normal functioning of hormones, interfering with natural body processes, including normal sexual development.

F. STRESS ON LAND RESOURCES

The stresses on water and land are closely linked. For thousands of years, humans have been drawing water from rivers and wells to irrigate dry lands, thus growing more food; and, for millennia, inadequate drainage systems have resulted in waterlogging and soil salinization. The salinization occurs when water in the ground evaporates, leaving behind natural salts that were present in the water. It is estimated that about 20 per cent of the world's 250 million hectares of irrigated land are salt-affected to such an extent as to significantly reduce crop production. A further 1 1/2 million hectares are affected each year. The countries most severely affected are located predominantly in arid and semi-arid regions.

The mismanagement of soil and water resources is also exacerbating erosion brought about by water. This depletes the land of soil and nutrients, and increases water pollution in the form of soil particles that often carry agricultural chemicals with them. When suspended soil particles arrive at a dam, they often sink to the bottom of the reservoir, gradually reducing the amount of water it can hold. This process has caused serious losses of reservoir capacity in a number of river basins.

G. EXTENT AND GEOGRAPHICAL DISTRIBUTION OF WATER STRESSES DUE TO SCARCITY

In keeping with the concept of water scarcity previously defined, the ratio of water withdrawal to water availability on an annual basis is used as a measure of stress.

It has been observed that water stress can begin once the use of freshwater rises above 10 per cent of renewable freshwater resources, and it becomes more pronounced as the use level crosses the 20 per cent level. On average, a country can only capture about one third of the annual flow of water in its rivers using dams, reservoirs and intake pipes. A further limitation arises from the growing lack of acceptance for the social and environmental impacts of large dams. The closest and most economical sources of water are used first, and it becomes increasingly expensive to tap sources that are farther away from the site of needs. Another limitation on water use stems from the fact that once withdrawals pass certain thresholds, which vary from site to site, lake and river levels fall to the point where other uses are harmed.

This report distinguishes four categories of water stress based on the amount of available freshwater that is used (category number is in parentheses following category title):

(*a*) *Low water stress (1).* Countries that use less than 10 per cent of their available freshwater generally do not experience major stresses in respect of the available resources;

THE MURRAY-DARLING BASIN

The Murray-Darling Basin covers one seventh of Australia, and accounts for half the country's gross agricultural production. As demands for water increased, reservoirs were constructed to increase the available supply to individual States. In recent years, use approached the sustainable yield of the basin as a whole, and pressure mounted for sharing the resource between jurisdictions. In 1985, a Basin Commission was formed and in 1989, agreement was reached on sharing. The next issue requiring resolution was soil salinity which had the potential to expand to 95 per cent of the total irrigated area within 50 years. The three upstream States were the primary beneficiaries of water diversion, while the damage caused by salinity was most severe in the downstream State. An agreement was reached on joint funding of remedial measures, and collaboration was initiated, driven primarily from the community level. Action has been under way for four years, and the spirit of collaboration continues as a demonstration of integrated water management success.

(*b*) *Moderate water stress (2).* Use in the range of 10-20 per cent of available water generally indicates that availability is becoming a limiting factor, and significant effort and investments are needed to increase supply and reduce demand;

(*c*) *Medium-high water stress (3).* When water withdrawals are in the range of 20-40 per cent of the water available, management of both supply and demand will be required to ensure that the uses remain sustainable. There will be a need to resolve competing human uses, and aquatic ecosystems will require special attention to ensure that they have adequate water flows. Developing countries in particular will need major investments to improve water-use efficiency, and the portion of gross national product (GNP) allocated to water resources management can become substantial;

(*d*) *High water stress (4).* Use of more than 40 per cent of available water indicates serious scarcity, and usually an increasing dependence on desalination and use of groundwater faster than it is replenished. This means that there is an urgent need for intensive management of supply and demand. Present use patterns and withdrawals may not be sustainable, and water scarcity can become the limiting factor to economic growth.

H. COPING CAPABILITY BASED ON INCOME LEVELS

The ability of countries to cope with water scarcities, including the effects of pollution, depends on a number of factors. This report uses income levels as a rough measure of the ability of different groups of countries to deal with water

issues. In general, countries with higher per capita incomes are in a better position than low-income countries to respond to water scarcity, as the financial resources and skilled people for management and development are more readily available. Because of low income levels, many developing countries face severe difficulties in creating the infrastructure to fully utilize their water resources.

The World Bank has grouped countries into four categories, based on their average annual per capita GNP, in United States dollars:

1. *Low income:* per capita income of less than $795
2. *Lower-middle income:* per capita income of $796-$2,895
3. *Upper-middle income:* per capita income of $2,896-$8,955
4. *High income:* per capita income of over $8,956.

I. FRESHWATER VULNERABILITY

When water stress and income levels are combined, the result is a series of categories showing the vulnerability of various countries and regions to problems caused by water scarcities. Each of these could be subdivided into a number of specialized categories, by water stress and financial coping capability. For illustrative purposes, this report shows the effects on four broad categories.

1. High-income countries with low water stress

The main problem of these countries is water pollution rather than supply, although some large countries contain water-poor regions. They have the financial resources to deal with regional water supply problems, often using water diversions.

2. High-income countries with high water stress

This category includes a number of countries that have fairly large amounts of water, but are facing stress conditions as a result of continuing overuse and pollution of their water resources which will be causing problems, such as groundwater depletion, in the near future. Other countries, however, have already used most of their accessible water resources. They have little if any scope for increasing the amount of water supplied to human uses through conventional means without inflicting damage on aquatic ecosystems, or seriously depleting groundwater aquifers.

3. Low-income countries with low water stress

There are several different types of countries within this grouping — low-income countries that have low water stress because of abundant water resources (primarily tropically humid countries) and large countries that have a tropical region. Most of these countries or their humid regions suffer from too much water in the form of floods that occur during a short rainy or monsoon season, causing damage to buildings, structures and agriculture. Since these countries are poor, they often suffer from inadequate drinking water supply and sanitation.

Another category, which includes much of sub-Saharan Africa and some countries in arid and semi-arid areas, is characterized by little water and little water stress because people are too poor to tap much of the resource. Overall, this grouping of countries suffers from inadequate access to its water resources owing to insufficient financial resources, technical expertise and institutional support. Because of these constraints, there is a lack of adequate water supply, sanitation and waste-water treatment. In cases where there

Table — Water Stress category. Withdrawal to availability ratio (population in millions of people)

INCOME	Withdrawal /Availability 1995				
	1 (<10%)	2 (10-20%)	3 (20-40%)	4 (>40%)	Total
1	806.18	1,265.89	957.70	238.07	3,267.84
2	542.40	285.95	165.33	137.91	1,131.59
3	258.95	13.10	137.30	63.44	472.79
4	108.44	514.41	181.25	19.74	823.84
Total	1,721.97	2,079.35	1,441.58	459.16	5,696.06

This grid shows how the 5.7 billion people in the world in 1995 were distributed in terms of their use of available freshwater, and by their income as measured in GNP. Over one half the world falls in the low income category, and more than one third of these people are in countries that already face medium-high to high water stress. An additional 39 per cent are in countries with moderate water stress. As well, one fifth of the world is in the lower-middle income category. Of these, 31 per cent are in countries with medium-high water stress, and 24 per cent are in countries with moderate water stress. Unless water resources are managed with a view to achieving efficiency and equity, water shortages could become a serious obstacle to economic and social development in many poorer countries.

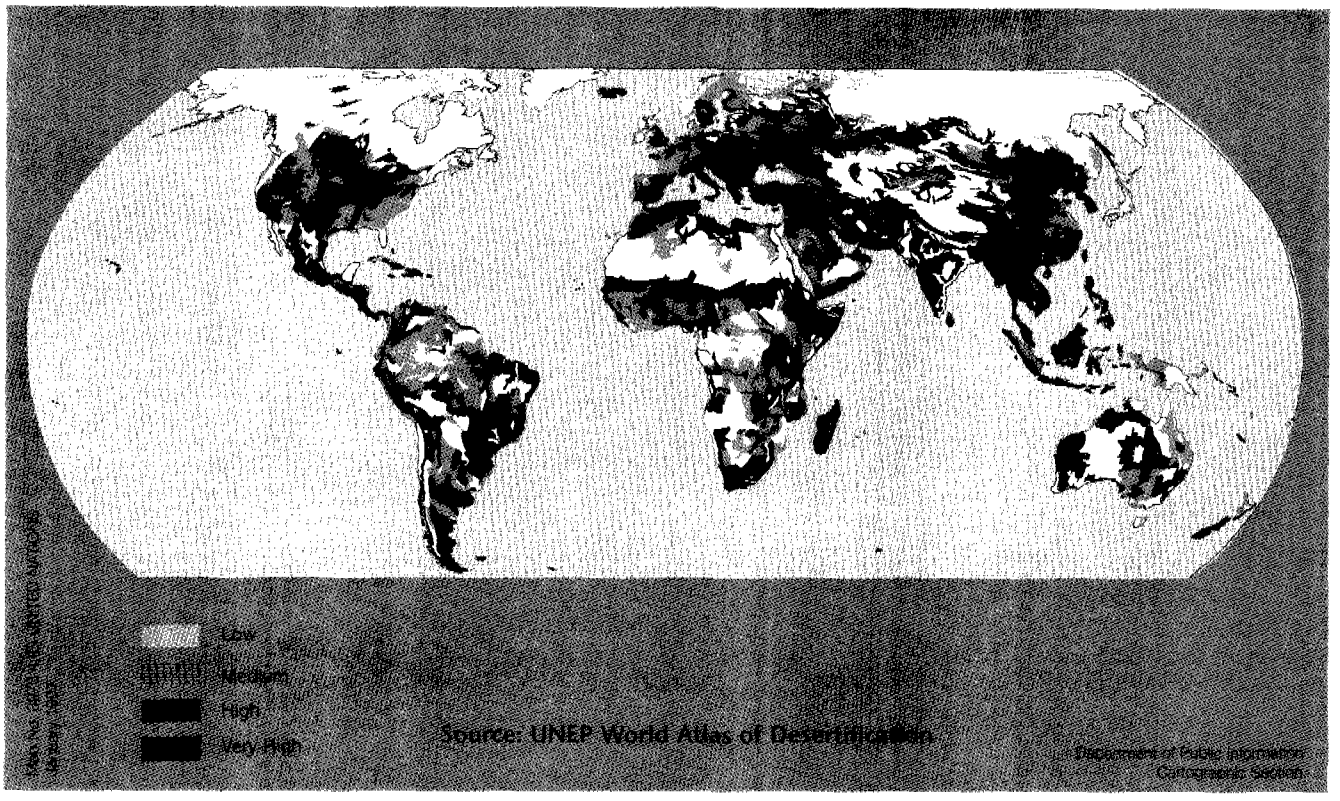
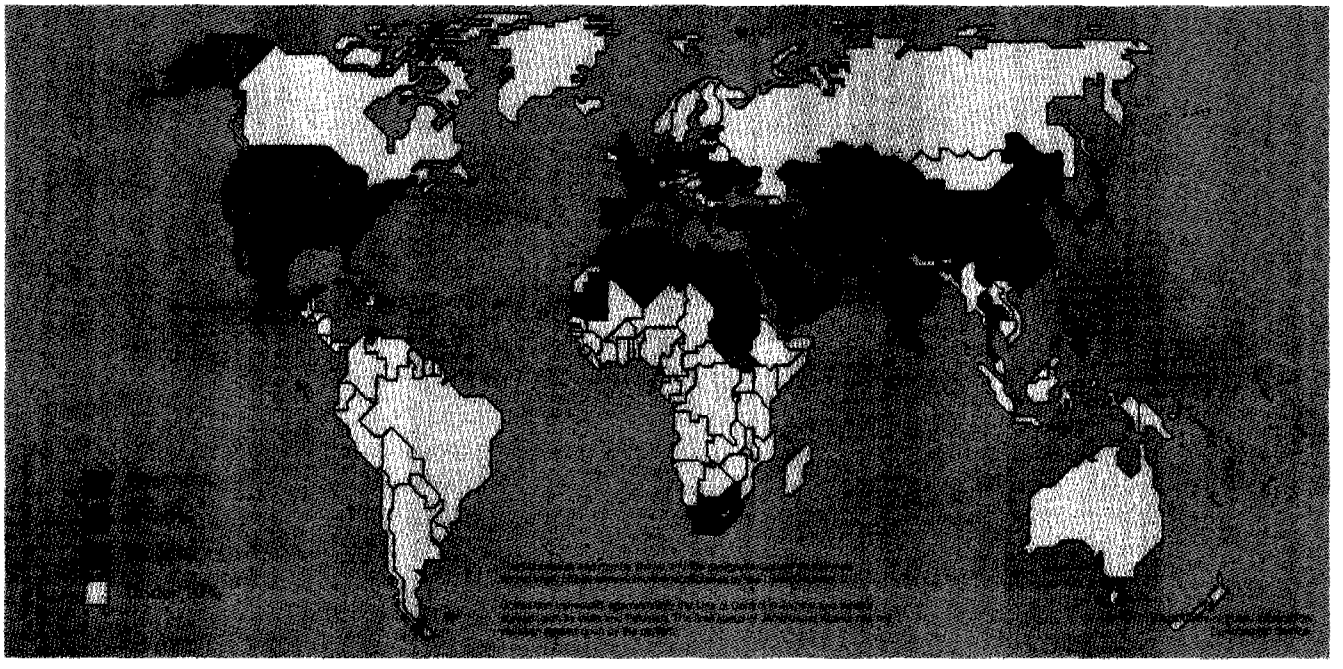


Figure 10. Map of soil degradation.

Figure 11. This map shows water withdrawal as a percentage of water availability — 1995. Calculations are based on both internal water resources and water available from upstream sources in international basins. Many countries with high water withdrawal rates are also very dependent on external water. Because the data used to prepare this map were gathered at a country level, there are some apparent contradictions. For example, the Sahel region does not show as having a high water stress, even though it is a dry region. This is because a number of countries in dry regions have relatively abundant water resources in part of the country, as in one large river, such as the Nile or Niger. They might also have abundant rainfall for part of the year. However, the poor countries in this category lack the financial and technical resources to capture rainfall or to move water to many of their people. Even water rich countries can have tremendous disparities internally.



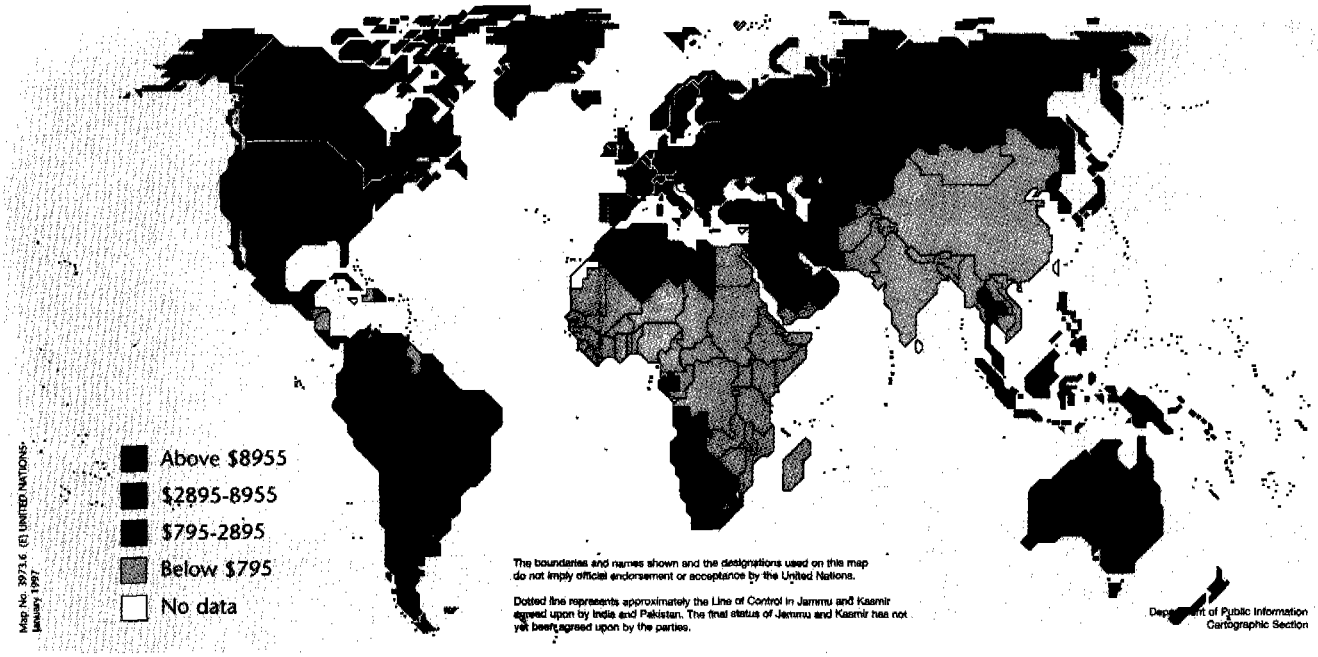


Figure 12. GNP per capita in 1994 based on figures from the World Bank.

is high population growth or economic development, there is likely to be an increase in water demand. If that demand is not well managed, it could drive the country into a high vulnerability situation.

4. Low-income countries with high water stress

This category is made up of low-income countries that are using their water resources heavily now, often for farm irrigation. They also suffer from a lack of pollution controls. A number of countries in the arid or semi-arid regions of Africa and Asia fall within this category. These countries are the most constrained with respect to future development because they have neither the extra water nor the financial resources to shift development away from intensive irrigation and into other sectors that would create employment and generate the income with which to buy food from water-rich countries.

II. WATER CHALLENGES: A 30-YEAR OUTLOOK

In the present section, this report draws a number of implications for future water-use patterns, based on current trends. From 1995, it looks forward for 30 years, which is the span of a generation, examining major forces that will affect and be affected by water use. It is difficult to provide a detailed picture of the world of 2025 because of many uncertainties in political and economic developments. However, it is possible to look ahead, and provide some general analyses.

A. DRIVING FORCES OF CHANGE

Water use in the year 2025 is going to be shaped by several major driving forces characterizable as follows:

(*a*) Population will influence how much water will be needed for a wide range of needs, including food production, industrial development and domestic use. The mid-range projection from the United Nations is that world population will grow from 5.7 billion in 1995 to about 8.3 billion in 2025, amounting to an increase of 2.6 billion people. Much of the population increase will be in the rapidly growing urban areas of developing countries, many of which are already experiencing serious water stress;

(*b*) The magnitude of the impact of a given population will vary depending on the amount and patterns of consumption of natural resources and of pollution. Depending on what technologies are used, the impact from a given type of consumption can be increased or decreased from today's levels. For example, if more food is produced by increasing the amount of irrigation, using the same mix of technologies as today, the water use will increase. The same is true of continuing industrial development. A United Nations Industrial Development Organization (UNIDO) study showed that current trends will lead to more than a doubling of 1995 industrial water use by 2025, with an over fourfold rise in industrial pollution loading, unless changes are made. If more water-efficient technologies are used, this will cut wastage, and thus reduce the amount of water that needs to be taken from various sources to produce a given amount of food or industrial output. In the agricultural and industrial sectors, there are already many examples of technology changes that have reduced both the amount of water used and the amount of pollution released without reducing the output of products. At the domestic level, there are many examples of water-efficient fixtures, and there are attempts to educate more people in the safe use of hazardous materials so as to reduce the amount dumped into waterways or drains leading to waterways;

(*c*) Trade policies. A large part of the increase in world food demand will come from the arid and semi-arid developing world, where there are high population growth rates. Many of these countries will find it difficult to keep increases in food production in line with demand increases, and water will be a limiting factor. Countries may have to choose between using their scarce water resources to maintain food self-sufficiency, and using the water to produce high-value products that can be exported to pay for food imports.

Most of the new population will be found in the developing world, and the countries therein will move from being 37 per cent urban in 1995 to 56 per cent urban in 2025. At the same time, there will be more industrial development. These trends will take both people and water supplies from agriculture, creating an urgent need for more urban sanitation. Peri-urban agriculture is also increasing. By 1995, the world had 321 cities with a population over 1 million, including 15 mega-cities with populations in the 10 million-20 million range. The number of mega-cities is forecast to double over the next 20 years. In spite of that, there will still be more rural poor in 2025. If regions with high rates of urbanization are to maintain current levels of water and sanitation supply, this could mean investments of over 1 per cent of gross domestic product (GDP) by 2025.

There is another potential factor that could affect water availability. According to the Intergovernmental Panel on Climate Change, the release of gases such as carbon dioxide (CO_2) is increasing the ability of the atmosphere to trap heat. The Panel warns that this may bring about temperature increases, precipitation changes and sea-level rise, with varying impacts on the availability of freshwater around the world. Computer models of possible future climate patterns are not yet precise enough to forecast changes at the local or small basin level. Current indications are that if climate change is gradual, the impacts may be only minor by 2025, with some countries having positive impacts, and most being negatively affected. Climate change impacts are predicted to become increasingly strong during the decades following 2025.

B. OUTLOOK AND CHALLENGES THAT LIE AHEAD

Although there is a very large uncertainty about future water needs, it is clear that all sectors will have growing requirements, and they already face stresses in many regions of the world. Given current trends, as much as two thirds of the world population in 2025 may be subject to moderate-to-high water stress, and almost half the world could have clear difficulties in coping owing to inadequate financial resources. Since many of the countries currently facing moderate-to-high water stress, as well as those that risk moving into higher stress categories by 2025 belong to the lower-income groups, it is clear that water resources could become a limiting factor in the development of a number of countries. For reasons spelt out earlier in this report, it will also be more difficult and expensive to easily augment reliable water supplies by building more dams and creating

reservoirs. There will be a need to modify consumption patterns, and to design and construct water supply projects in such a way as to bring into the planning both the people who may suffer and those who benefit, and to ensure that benefits are distributed fairly. Demand management will serve as an essential policy tool.

Many economic forecasts do not currently account for the amount of water that will be required to achieve their goals, and water may become a limiting factor. Certain current water-intensive patterns of development will become less and less feasible.

As the risk of water stress increases, there will be a need for increased demand management in order to maximize the socio-economic benefits derived from the competing users of water. Water management must also be more prudent than in the past so as to avert the further degrading of agricultural areas through such impacts as salinization, water erosion and waterlogging. Failure to protect the food growing capability of the world would have severe implications. To avert such problems, countries, particularly water-scarce countries, need to look at projections in such sectors as population, urbanization, and economic and agricultural development, and establish water strategies and policies.

One of the trends identified in this report is that where, as water becomes more scarce in relation to demand, and competition among various users increases, water ceases to be available as a free good and becomes in some cases a tradable commodity. There is a shift taking place in the role of Governments — a shift from their role of providing water at very low cost, to one of regulating water markets. As competition for available water grows among users, such as municipalities, industries, hydroelectric generators and irrigators, the price of water rises. While this allows the market place to choose the highest-valued use for water in economic terms, it will almost certainly entail water price increases, and this means that some users will be able to outbid others for the available water. This has the potential to impose hardships on some users, and there will be a need to ensure that everyone has a basic amount of water available at reasonable cost.

1. Water needs for food production

World population forecasts suggest that within 30 years nearly 50 per cent more people than in 1995 will need to be fed. A substantial portion of future population growth is forecast for arid and semi-arid regions. Here, rain-fed crop production is insecure because of a short rainy season, erratic rainfall, recurrent drought years, high evaporation of the rain that does fall and crust-forming, desertification-prone soils. In sub-Saharan Africa, where over 95 per cent of the farmers depend on rain-fed farming, the per capita production of cereals in the past two decades has not risen, and remains below what is needed to feed the population.

A number of estimates were made of how much water would be needed to produce enough food to give everyone in the world a healthy diet. The estimates ranged between a 50 per cent and a 100 per cent increase in water for food production over 30 years. The bulk of the increase in food production will need to come from irrigated land. Some of the estimates found that by 2025, it would require virtually all the economically accessible water in the world to meet the needs of agriculture, industry and households, and maintain adequate lake levels and flows in rivers. If more water is needed, more expensive projects such as high-cost dams and diversions to bring water from sources far away from the area will be required.

As water becomes more scarce, municipalities and industries will be able to outbid most farmers, and this will push up the cost of water. If cost of water is passed on to the consumer, then food prices will go up. If farmers have to absorb the increased cost, poorer farmers growing relatively low-value products could be forced out of business. While in

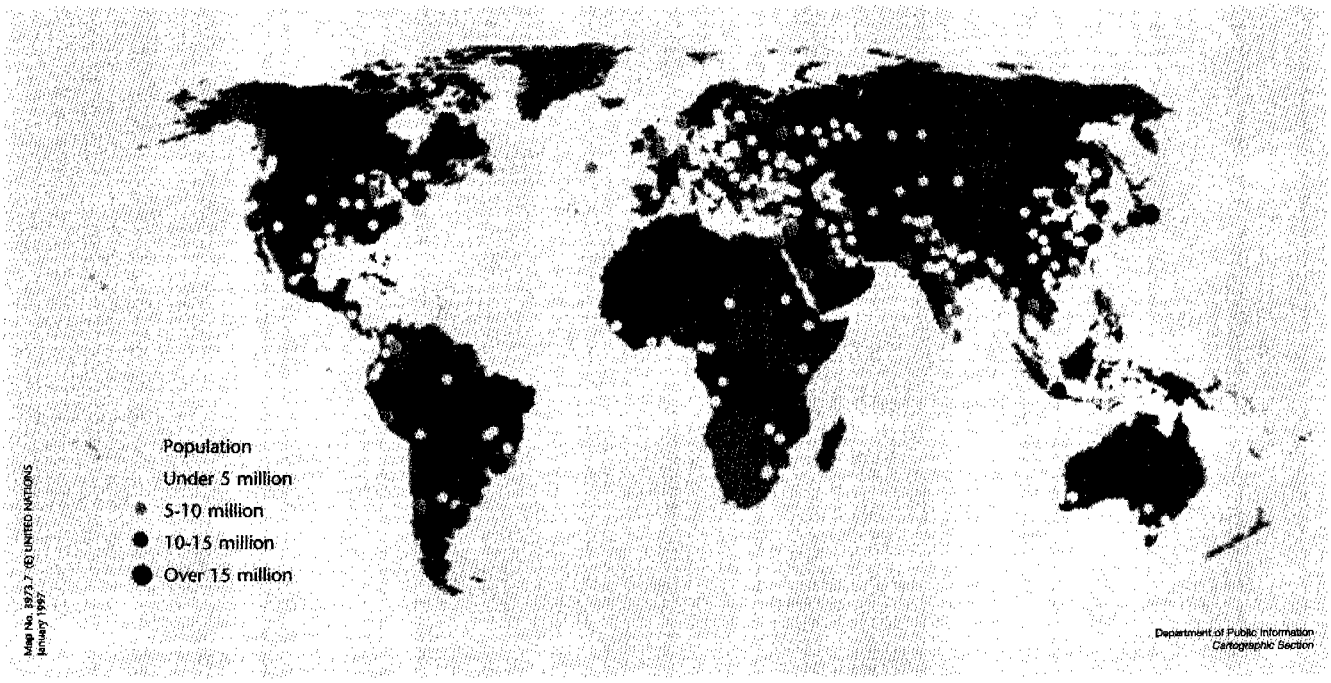


Figure 13. This map shows locations of large cities.

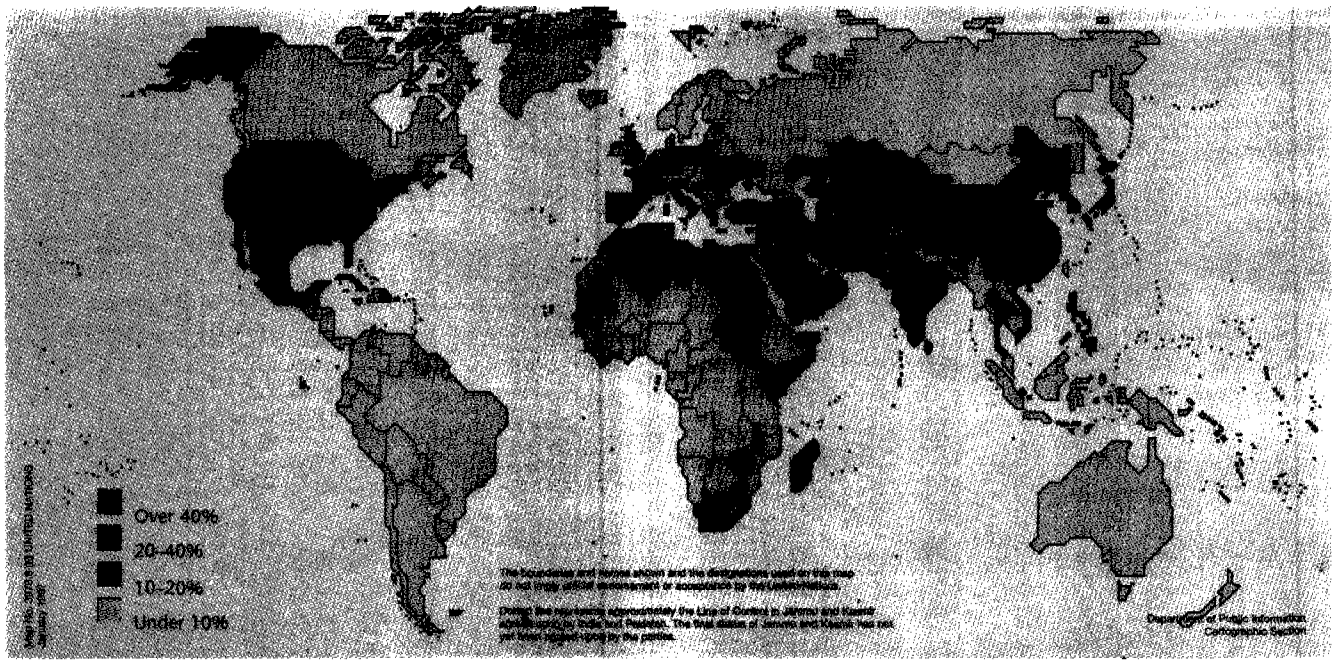


Figure 14. This map shows the impact of the expected population growth on water usage by 2025. It is based on the UN mid-range population projection and assumes that the current rate of use per person will not change. No account is taken of probable increases in water use patterns with economic growth or improvements in efficiency in water use.

the long run the use of pricing as a tool for allocating water resources is effective, the implementation of pricing policies needs to take into account the possible economic and social impacts on the peri-urban and rural poor.

As food production is closely linked to the quality of land, the proper management of irrigation is essential in order to prevent land degradation through, for example, salinization and waterlogging. The installation of adequate drainage, while protecting this natural capital, is likely to raise the cost of irrigation.

2. Water supply and sanitation and health

The regions most vulnerable to domestic water shortages include those that currently have poor access to water, are characterized by rapid population growth, uncontrolled urbanization and financial problems, and lack a skilled workforce. Even if the world maintained the pace of the 1990s in water supply development, it would not be enough to ensure that everyone had access to safe drinking water by 2025. The challenge is particularly critical in Africa. Sanitation development is even more difficult to achieve. If everyone is to have sanitation facilities by 2025, this means providing services for more than 5 billion people in 30 years.

The continued neglect of the need for waste-water treatment and the damage from water pollution will lead to increases in public health problems and further damage to ecosystems, including the oceans, and forgone opportunities to recover and treat waste water for other uses, such as irrigation.

3. What will happen?

The analyses show that if many of the current approaches to water management do not change, this will lead to increasing water stress. As scarcities increase, there will be the risk of greater conflict over the water in the more than 300 transboundary rivers as well as in many underground aquifers. This shows the importance of cooperation over river systems shared by countries. It will be crucial to work out water-sharing arrangements that seek to maximize benefits for all users.

Since typically it takes at least a decade to bring even a modest water resources project from planning to completion, and even more time for large projects, it is crucial for decision makers to establish and implement immediately water policies and programmes based on the best evidence available.

The concluding section (below) provides suggestions for development of global, regional and national water strategies.

III. CONCLUSIONS AND POLICY OPTIONS

Although many current water-use patterns and pollution habits are propelling the world towards a series of local and regional water crises, mankind has not yet reached the point of no return. There are many practical, cost-effective measures that can reduce the strain on water resources. They represent a series of critical investment opportunities that one cannot afford to ignore.

A. ELEMENTS OF A WATER STRATEGY: GENERAL CONSIDERATIONS

It is crucial for water resources to be given a high priority in planning. There are some promising national efforts in water policy development, but these efforts must be spread and reinforced. Governments must reduce the fragmentation of institutional responsibilities on water issues. They also need to include water resources in economic analysis.

A critical element in planning is information on the state of the water resources. Over recent decades, the ability of many countries to assess water resources has actually declined because measurement networks and staffing levels have been reduced.

Since it will take time to change many unsustainable development patterns, urgent and decisive action must begin now. Experience has shown that the consequences of inaction, in terms of human suffering, social disruptions, forgone economic opportunities and the cost of undoing the harm caused to the resource and the environment, will usually outweigh the human and financial resources needed in order to embark on a sustainable development path. Many of the problems are of a local and regional nature, and action is primarily a national (and regional) responsibility. Nevertheless, it would be illusory to believe that anything short of a global commitment would provide the means to sustainability. Because some of the water crises could be very severe, the whole world has a stake in averting them.

1. Making water available to increase food production

Both the need and the demand for food are rising steadily because of steady population increases. A large amount of the world production of grains is used for meat production in developed countries, and as the diet in developing countries gets fuller and more balanced, an increased demand for animal proteins is expected. This growing demand for meat means that more water will be needed since more water is required to produce meat than to produce a vegetarian diet.

In many regions, water scarcity is resulting in severe constraints on the expansion of agricultural production, thus raising pressure for water policy interventions and for more efficient water-use practices. Because globally little new land of adequate quality remains to be put into production, and since the environmental cost of converting land use is high, the largest part of future food requirements will have to be satisfied through higher productivity on existing agricultural land. Application of water through various forms of irrigation, and the use of genetically improved crops and the considered application of pest management and plant nutrition systems, are main factors for the agricultural productivity increases required to feed the world. Countries can improve the efficiency of water use for irrigation with such techniques as lining of canals and the use of more efficient ways of applying water to plants. However, attention must be drawn to the fact that water use in the entire river basin can be highly efficient even though the individual irrigation schemes within the basin are inefficient, in which case seeking a higher irrigation efficiency in one scheme is bound to result in further water scarcity in the downstream schemes. Under such situations, water savings have to be sought in the use of a less water demanding mix of crops and in shifts of the cropping period into a less evaporation-intensive season.

Besides new cropping patterns and conventional first-generation irrigation, many other "drought-proofing" techniques exist. They include high-efficiency irrigation, water harvesting, inland valley swamp development, low-lift pump schemes, peri-urban irrigation with treated urban waste water and conjunctive use of surface water and groundwater. Irrespective of what method is chosen, it would imply a consumption of water now passing through the landscape, meaning that water would not be available downstream for other uses.

If treated waste water was used for irrigation, this would mean that the amount of freshwater that could be used for other purposes would increase. In those water-scarce countries that, because of the domestic water shortage, will become heavy importers of basic foodstuffs, waste water may well represent in the future the predominant long-term water supply for irrigated agriculture. Water harvesting, which means small-scale projects to capture run-off, can also improve soil moisture and food production.

Desalination of sea water is an option for such relatively low-volume, high-value users as industries and homeowners with at least a moderate income. However, even with technological advances, wheat production with desalinated water is economically prohibitive.

As water prices rise, small-scale farmers will increasingly face difficulties in regard to competing for the scarce water resources. There may thus be a need to help small irrigation farmers, particularly with partnerships that will give them access to capital, technology, know-how and markets.

However, there are limitations on how much these techniques will improve the situation, especially in arid countries. Countries may have to turn towards increasing food imports, as is already the case for a number of arid countries, particularly in the Middle East and North Africa. Countries may have non-economic reasons for pursuing a

course of substantial food self-sufficiency. From an economic point of view, they may find it advantageous to shift their production pattern towards less water-intensive and higher-income-yielding products, either in agriculture or in the industrial sector. This transition is already taking place in a few countries. In Israel, the water use within various sectors is very efficient. Water availability, however, is so limited that allocation choices among sectors competing for the water resources are increasingly necessary. In this situation, the previous high priority given to irrigation is reduced and urban use is pronounced. In most countries, this shift will require training of the rural population to acquire skills needed in other sectors of the economy, and an infusion of capital so as to create new economic opportunities.

The world needs to move towards achieving the objective of global food security. In some countries, this could be done through a transition from food self-sufficiency (a capacity to produce all food within the country) to food self-reliance (a capacity to provide food from national sources and through purchase from the international market). However, such an integration of the world economy is unlikely to be painless without proper consideration of world market conditions, and the potential impact on the poorer strata of the population of developing countries. Countries can only make such a transition if they can rely on the world agricultural markets to provide a dependable and efficient source of supplies at stable international prices.

2. Access to drinking water supply and sanitation needs to be dramatically increased

Without adequate quality and sufficient quantities of water for human consumption and for personal and domestic hygiene, billions of people will continue to suffer from diarrhoea and enteric diseases, helminthic infections and other illnesses arising from unsanitary environments, improper disposal of excreta and polluted water. Even though most of the suffering takes place in developing countries, the whole world will suffer. Diseases can be communicated easily over long distances. Economic stagnation resulting from ill health affects the global economy.

There are a number of relatively simple and inexpensive techniques for supplying drinking water and sanitation. If they are to succeed, they must be chosen in consultation with the users, and they must use technologies that can be installed and maintained at the community level. They must thus be user-friendly, affordable and appropriate.

Top priority needs to be given to the African region, Latin America and South-East Asia. Recent estimates are that $54 billion would be needed between 1990 and 2000 to provide universal coverage in only the urban areas of the regions most in need. The resources required are more than three times the rate of present expenditure. There is no sign that this amount of funding will be made available in the near future in the form of reallocation of internal government spending in nations, or of development assistance from abroad. Experience shows that in many cases additional funding for water supply and sanitation systems could be raised by charging users even modest amounts of money for the water they draw. Countries need to apply a higher degree of demand management.

When it comes to making decisions on water supply and sanitation systems, it is vital to involve all users. For example, women already play a crucial role in providing water and in decisions on hygiene in families. They should be closely involved in decision-making as well as in implementation of the water and sanitation supply programmes.

3. Water pollution must be reduced to protect human health and the rest of the environment

If not controlled, untreated sewage from cities, industrial discharges and non-point pollution from agricultural activities and urban run-off will continue to damage rivers, aquifers and coastal zones, with devastating effects on our freshwater resources and oceans. Even though pollution prevention sometimes has a higher initial cost than discharging untreated wastes, experience shows that in the long run it is cheaper than clean-ups. Waste water, especially that which is not heavily polluted, can often be used for other purposes, such as industrial cooling and sometimes for irrigation. To encourage pollution prevention, it is important to apply the Polluter Pays Principle.

It is important to build on the water-quality management experiences of different regions. For example, Nigeria has interim national water quality guidelines and standards that are used to set water-quality standards. The United States and Canada have adopted controls on discharges that take into account the effect on downstream ecosystems, such as the Great Lakes. Canada looks at impacts on the marine environment when setting water-quality objectives for rivers flowing directly to the seas.

4. Need for cooperation is clearly demonstrated for transboundary waters

Some of the world's more than 300 major river basins and a number of major aquifers that cross national boundaries are

Irrigation accounts for 70 per cent of water taken from lakes, rivers and underground sources (Celia Kirby, Institute of Hydrology, UK)

in regions where serious water-quality or -quantity problems are or will soon be evident. A wide range of transboundary water agreements exist, dealing with rivers, lakes and other water bodies. While a number of these agreements refer to river basins, most of them deal with specific waterworks, water uses and measures to control and regulate water flows. A few deal with pollution. In 1995, a Protocol was signed by the eight heads of member Governments of the Southern African Development Community on regionally shared watercourses. The member States recognized that a failure to develop water resources in a sustainable manner could hamper economic productivity and social development in the region. The agreement promotes the equitable use of shared water resources, including the development of integrated water resource development plans. The Rhine Action Plan has led to pollution control objectives that are to improve water quality to the point where sensitive species can once again live in the Rhine River. It is also aimed at reducing pollution to the North Sea. The 1909 Boundary Waters Treaty between Canada and the United States has led to a series of agreements over the sharing of waters and controls on pollution, particularly in the Great Lakes.

The need for a comprehensive legal instrument for international water bodies has been voiced by several countries. The draft articles of the law of the non-navigational uses of international watercourses[2] were adopted by the International Law Commission in 1994. The Commission recommends the elaboration of a convention by the General Assembly on the basis of the draft articles.

This report, like many others before it, has identified the river basin as the logical unit for water management, as any activity in one part of the basin will influence that in other parts, especially downstream. Thus, there is a clear need for cooperation in the management of international and transboundary watercourses to maximize mutual benefits for all riparian countries.

5. Water needs to be considered a resource having an economic value

Water has economic value, and should be considered an economic as well as a social good. Like any valuable commodity, water use has a cost in terms either of its development or of its forgone opportunities. The cost of using or misusing water does not disappear, but is paid either by the user or by the community at large or through a depletion of the existing natural capital. As water demands increase, it becomes more important to see that water is put to high-valued economic uses. It is important to see that there is full cost accounting, and full cost recovery for the provision of water, and that users pay for the water used for economic purposes.

At the same time, it is essential that water planning secure basic human and environmental needs for water. Otherwise, there will be a risk of shortages, which impose costs on society in terms of both health impacts and losses in economic performance. An example is Brazil which is undergoing social reform programmes, including in the water sector. The country still needs to settle some controversial issues, but the direction is towards recognizing water as an economic good while also stressing that provision for human consumption must be given top priority.

There is a need in many countries to begin or to continue a shift from the Government's being the provider of water services to its being the creator and regulator of an environment that allows involvement of communities, the private sector and non-governmental organizations in the provision of water supply and sanitation services as well as in the development and utilization of water in other sectors of the economy. Uganda is undergoing water reforms and is moving away from a centralized system to a system where communities will actively take part in the decision-making and where choices of solution to water services will relate to local affordability and needs. Thus, the new Water Action Plan and Water Statute aim to facilitate flexible and coherent water resources management at all levels in the society.

The introduction of water markets and pricing mechanisms can encourage the private sector to play an increasingly important role in providing the necessary financial resources and management skill needed for the successful development and utilization of the resources. Governments need to establish laws and regulations for the fair and efficient operation of water markets. Wherever subsidies or income transfers are deemed necessary for social or other national considerations, the objectives of such subsidies or transfers should be well defined and the incidence of the subsidy should not fall on the public or private utilities providing the service.

It is essential that economic planning incorporate the idea of water as natural capital whose services can be depleted, as in the using up of groundwater or polluting of water sources. Those services can only be restored at high cost. In the long run, a failure to include the state of water resources in economic analysis, particularly in macroeconomic analysis, leads to unnecessary, wasteful and costly investments in water supply developments, to misallocation of water resources among competing uses and, in some cases, to the actual collapse of schemes.

6. Building human and institutional capacity to solve our water problems

Capacity-building is an essential step in preparing sustainable water strategies. It includes education, awareness-raising and the creation of a legal framework, institutions and an environment that enables people to take well-informed decisions for the long-term benefit of their society. Women, youth, non-governmental organizations and indigenous people need to be brought into capacity-building strategies, as they are essential in building a sustainable water future.

If people, particularly in poor and water-scarce countries, are going to come up with solutions to problems such as how to attain food security, they must be educated and given access to the information that will help them make

[2] See *Official Records of the General Assembly, Forty-ninth Session, Supplement No. 10* (A/49/10), chap. III, sect. D.

decisions. The world needs more well-trained people, especially women, to assess and develop freshwater supplies, and to manage water projects for sustainable use. Capacity-building should be aimed at giving professionals from different backgrounds and working in different sectors the skills to participate effectively in the intersectoral dialogue during the planning, design and construction of water resources projects. There is a further need to create new or strengthen existing institutions capable of integrated water management and to build networks linking institutions with expertise in land, water quality and water quantity.

Many Governments will need to assign a high priority to their capacity-building efforts towards institution-building, legislation and human resources development. National efforts in this regard need to be supported by international, regional and national external support agencies, and by the non-governmental community, including the private sector.

7. Access to reliable data is presently inadequate

Effective water resources assessment and management are not possible without adequate information, including hydrologic information, water-use and -quality data, demographic data (separated by gender where relevant), forestry and land management, and capacity to assess the data. There is a need for national and internationally agreed upon and harmonized information systems that provide data needed for decision making, as well as common ways of analysing the information.

Ideally, the river basin or watershed should constitute the geographical unit for data collection and analysis. Even though some countries have hydrologic data available, usually on the river basin level, almost no country has socio-economic data sorted at a comparable level.

The experience with the current assessment demonstrates that the capability to provide accurate water-quantity and -quality data is sorely lacking in the majority of countries. For years, the capacity of hydrologic offices in many developing countries, particularly in Africa, has been declining in terms of the operation, maintenance and extension of hydrologic networks. Few, if any, developing countries have a significant capability for water-quality monitoring, which would give important information from a health perspective. It is very difficult to obtain reliable, systematic information on water resources management and irrigation in most developing countries. There is also poor data on land degradation related to water use. Even developed countries have been reducing their environmental monitoring systems as part of general budget cuts in recent years. Despite problems in finding resources for data-gathering, there have been some encouraging signs. As part of the Southern African Development Community protocol on water resources, there was agreement to create a water sector dealing with integrated water planning and development of shared river basins. India's national water policy calls for the development of a standardized national information system with multidisciplinary units for water management.

Support from international, regional and national external support agencies is urgently needed. The World Hydrological Cycle Observing System (WHYCOS) programme, developed by the World Meteorological Organization (WMO) with support from the World Bank and other donors, is an important first step with regard to the strengthening of hydrologic networks. The United Nations Environment Programme (UNEP)/World Health Organization (WHO)/Global Environment Monitoring System (GEMS) water programme provides international support for the monitoring of water quality. The WHO/United Nations Children's Fund (UNICEF) Global Drinking Water Supply Monitoring Programme collects and analyses information involving water supply and sanitation coverage in developing countries. The Rural Water Statistical System (AQUASTAT) programme of the Food and Agriculture Organization of the United Nations (FAO) assembles information on rural water use in participating countries, and makes it available in a standard format. The International Hydrological Programme of the United Nations Educational, Scientific and Cultural Organization (UNESCO) includes the FRIENDS (Flow Regime from International Experimental and Network Data Sets) programme that places a strong emphasis on water resources management. Despite these important programmes, international support efforts concerning information management remain fragmented and incomplete.

B. STRATEGY DEVELOPMENT

Important action recommendations on global water issues have been formulated at various meetings, ranging from the United Nations Water Conference in Mar del Plata, 1977, and the Global Consultation on Safe Water and Sanitation for the 1990s in New Delhi, India, 1990, to the International Conference on Water and the Environment in Dublin, and the United Nations Conference on Environment and Development, both in 1992. Further recommendations were provided by the Ministerial Conference on Drinking Water and Environmental Sanitation in Noordwijk, and by the Commission on Sustainable Development at its second

THE DUBLIN WATER PRINCIPLES

Principle No. 1. Freshwater is a finite and vulnerable resource, essential to sustain life, development and the environment.

Principle No. 2. Water development and management should be based on a participatory approach, involving users, planners and policy makers at all levels.

Principle No. 3. Women play a central part in the provision, management and safeguarding of water.

Principle No. 4. Water has an economic value in all its competing uses and should be recognized as an economic good.

session, both in 1994. Considerable progress has been achieved in some places in terms of implementing these recommendations, with significant achievements oriented towards a more equitable and efficient utilization of water resources. On the whole, however, we are still far from achieving the sustainable development objective.

The findings of this report dramatize the importance of putting into practice the concept of a holistic management of freshwater as a finite and vulnerable resource, and the integration of sectoral water plans and programmes within the framework of national economic and social policy.

Through a series of meetings, particularly the Dublin water conference, a set of principles, later reflected in chapter 18 of Agenda 21, for water planning and management have emerged and are gaining wide acceptance.

The concept of water as an economic good needs to be implemented taking into account the provision of water for the satisfaction of basic needs.

Some important progress has been achieved in a number of countries in this regard. However, a much greater commitment to the implementation of these recommendations is needed worldwide to achieve sustainability.

Governments should incorporate these important principles in their social, economic and environmental planning.

C. POLICY OPTIONS FOR COUNTRY CATEGORIES

Given many current trends, there is a risk that an increasing number of low-income countries will find themselves facing water stress. Some countries may also experience economic growth that will shift them to higher-income categories, giving them the financial means to develop suitable water strategies. It should be noted that some economic growth projections used by planners do not take into account water as a possible limiting factor in future economic development.

As the pressure on water increases, so will the number of problems that countries must solve. In order for a country not to move to a position of higher water stress possibly with serious economic implications, certain actions must be taken, and most of them are urgent if the country is not to suffer a decline in its human, economic and environmental health.

The factor of relatively small amounts of water per capita does not prevent development, but it does shape it. There are examples of countries that are coming to terms with the question by using technology and economic strategies to live within their means.

All countries need to implement the recommendations contained in the Rio Declaration on Environment and Development[3] and in chapter 18 of Agenda 21 in the framework of their water management policies. They should also encourage demand management and pricing principles, as discussed above.

At a time when development assistance funds are limited, it will be important to focus on assisting people who suffer from lack of funds in making use of their water resources. This must be done in a way that helps economic and social development without overexploiting water and other natural resources. After the provision for basic human needs, development projects in most countries need to focus on efficient use of water for relatively high-value products.

1. High-income countries with low water stress

Pollution reduction and control are the major water-related challenge facing most countries in this category. Many of them also need to look at the issue of water-pricing, because the fact that water might be plentiful does not mean that it should be free. Development and distribution costs need to be covered by either public or private utilities. Some countries in this group, with favourable land and climate conditions, may have a significant potential for increased food production from irrigation and rain-fed agriculture, and could play a significant role in providing food to world markets.

Because of the averaged nature of water availability and use, some large countries classified in this category nevertheless contain arid and semi-arid areas which would have to be regarded as being highly stressed and vulnerable. In such regions, demand management measures and water rights markets are becoming critically important.

2. High-income countries with high water stress

For those countries with low per capita water availability, the allocation of water to the highest-value uses is a necessity. Demand management and water allocation policies designed to maximize the socio-economic value of water are of paramount importance, as is pollution control. Water markets with tradable water rights and permits are already beginning to play an important role in the allocation of water, and will need to continue to play an increasingly important role. With increased allocation efficiency, it is likely that irrigated agriculture will decrease in importance, and it appears that more countries in this category will become increasingly dependent on the world market for agricultural products.

The depletion of groundwater aquifers and sea-water intrusion need to be avoided. The protection of surface- and groundwater from pollution is vital. It is recommended that all countries in this category give urgent attention to pollution monitoring and control through economic and regulatory measures of both surface- and groundwater.

Waste-water treatment and reuse will constitute essential mechanisms for pollution control and the augmentation of water supplies. For example, Israel already recycles and reuses two thirds of the water discharged after urban and industrial use.

[3] *Report of the United Nations Conference on Environment and Development, Rio de Janeiro, 3-14 June 1992*, vol. I, *Resolutions Adopted by the Conference* (United Nations publication, Sales No. E.93.I.8 and corrigendum), resolution 1, annex I.

3. Low-income countries with low water stress

Countries in this group that are well endowed with land and water resources may have the opportunity to increase agricultural production and exports into the world market from either irrigated or rain-fed agriculture. For those countries with relative water scarcity, and high levels of evaporation, agricultural production is probably best directed into high-value, low-water-intensive products. Some poor countries lack adequate access to what little water they have, and development assistance could help them in using that water wisely.

Both water-rich and water-poor countries with low incomes generally suffer from a lack of sanitation and waste-water treatment. Water pollution from human or animal wastes is often already a problem, and steps are now needed to improve pollution control and treatment so as to protect human and ecosystem health.

The acceptance of highly polluting industries with little or no control on their discharges may be tempting on the basis of short-term economic growth considerations. However, the overall long-term costs to redress environmental damages resulting from such decisions have often been shown to be more expensive than the creating of low-polluting industries in the first place.

Countries are urged to give high priority to investments for waste-water treatment and reuse, and to formulate and implement pollution monitoring and control policies.

4. Low-income countries with high water stress

If appropriate action is not taken between now and the year 2025, the number of people in this category could grow substantially. Water resources will become a major limiting factor for socio-economic development unless early measures are taken towards restructuring production and consumption patterns away from wasteful and low-value, water-intensive uses. There is evidence that some countries are already reaching this kind of developmental bottleneck. Achieving sustainable use of water resources for most countries in this category will require that per capita water use decrease as population increases.

Given the high ratio of water use to availability, population growth and future economic development will require shifts in the utilization of water towards the production of high-value products. Under current trends, many of these countries will become less self-sufficient in food production, and will have to rely on the world market for food imports. The economic transformation of these countries will need to be accompanied by social support programmes involving education and training of the labour force to enable it to cope with the demands of an increasingly industrialized society.

Countries in this category are urged to give the highest priority to the formulation of economic and regulatory measures designed to increase irrigation efficiency and optimize water allocation among various uses. In particular, they need to pay attention to the generation of foreign exchange that might be needed for food imports.

Countries should increase waste-water treatment and reuse, and should control pollution from agricultural chemicals through land management and integrated pest management measures.

These countries may need to adopt the following strategies:

(*a*) To develop the educational and information infrastructure necessary to improve the skills of the labour force required for the industrial transformation that needs to take place;

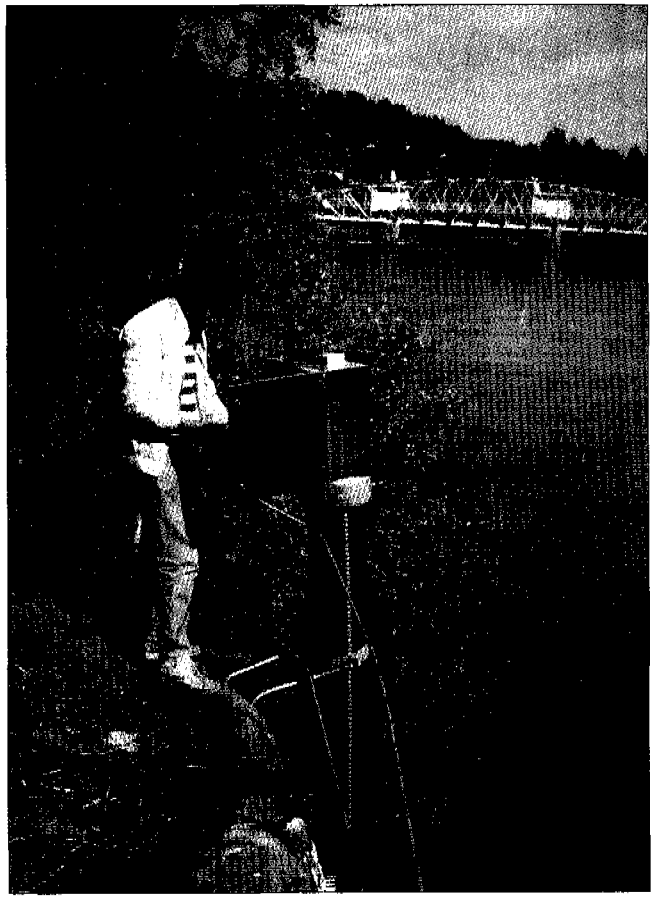
(*b*) To shift to more high-value, less water-intensive crops, and develop the associated agricultural industries to process more of the products, thus raising the value-added component in their countries.

To be able to move out of this category in the next 30 years, assistance of the international community will be needed in order to generate the financial resources for the economic transformation required.

D. ACTION: RECOMMENDATIONS

Bearing in mind existing principles and the recommendations in chapter 18 of Agenda 21, the following action is recommended partly based on the discussion in previous sections of this report.

- Manage water quantity and quality together in an integrated and comprehensive manner, taking into



Monitoring of river levels is essential to the assessment of water resources (RTM Offenbach)

account the upstream and downstream consequences of management actions, regional and sectoral relations and social equity.

- Base strategies for the sustainable development of water resources on a participatory process that integrates all aspects of freshwater management.
- Provide equitable access to clean water for all people and include human health and the state of the environment as water resource management indicators.
- Develop sustainable water strategies that address basic human needs, as well as the preservation of ecosystems, in ways that are consistent with socio-economic objectives of different societies.
- Develop adequate national and regional water policies and plans, and promote cost-efficient water technologies. Water management must be integrated into physical, social and economic planning, including land-use planning, forest resource utilization and protection of coastal zones from land-based activities. Land and water use are closely intertwined.
- Integrate water in economic planning analysis. Recognize water and the environment as vital capital. This means accounting for the value of water in each nation's system of national accounts. The accounts need to reflect the economic losses caused by a degradation of water resources.
- Integrate the private sector into the water development process. While people must be provided with access to water for basic needs at affordable cost, the private sector can play a helpful role in seeing that water for a number of industrial and agricultural uses is priced in a manner that reflects its value to society.
- Build up needed expertise on water issues among water users and decision makers at all levels, thus increasing their capacity to deal with complex water management questions. There is a need for people with expertise in hydrology, water quality, water law, and water conflict resolution, and people who can identify and help implement the best water technologies. It is essential also to build expertise in dealing with the socio-economic aspects of water management, such as water-pricing, and the role of the private sector in water supply and sanitation.
- Enhance national water resource assessment capabilities and measurement networks and establish water resource information systems that enable people to understand the options available for sustainable urban, industrial, domestic and agricultural development in combination with environmental conservation.
- Pay attention to the role of gender in water resources management. In much of the world, women play a key role in acquiring water and deciding how it is used. They need to be part of the decision-making process for water projects and for industrial and land-use projects that affect water quality and quantity.
- Accelerate or initiate actions that will result in global, international or regional agreements or programmes to address:
  (*a*) Provision of safe drinking water and environmental sanitation;
  (*b*) Elimination of unsustainable uses of toxic materials, especially persistent organic pollutants.
- Accelerate actions within the framework of existing programmes, conventions and agreements towards:
  (*a*) The combating of desertification and drought, by better integrating land and water management;
  (*b*) The protection and sustainable use of biodiversity related to freshwater;
  (*c*) The protection of coastal areas and oceans from land-based activities.
- Develop models of cooperation aiming at maximizing the benefits from the development of transboundary river basins or aquifers.
- Accelerate the implementation of the water-related activities contained in the action plans adopted at the:
  (*a*) Global Conference on the Sustainable Development of Small Island Developing States, Barbados, 1994;[4]
  (*b*) International Conference on Population and Development, Cairo, 1994;[5]
  (*c*) Fourth World Conference on Women, Beijing, 1995;[6]
  (*d*) United Nations Conference on Human Settlements (Habitat II), Istanbul, 1996.[7]
- Within the framework of the World Food Summit Plan of Action, approved by the World Food Summit in Rome in 1996, examine and report on water-related activities aiming at securing access to food.
- Develop an institutional and regulatory framework to ensure functional water markets and protection of water rights.
- Establish, within existing institutions, especially the United Nations system, a global water information network to compile information with particular emphasis on water quality, water quantity and water use. The institutions should also conduct regular global and regional water assessments. Water information programmes should be implemented at the national level, and international institutions should propose models to ensure compatibility between data of individual countries. There is a need for a periodic review and it is recommended that the Commission on Sustainable

[4] See *Report of the Global Conference on the Sustainable Development of Small Island Developing States, Bridgetown, Barbados, 25 April-6 May 1994* (United Nations publication, Sales No. E.94.I.18 and corrigenda), chap. I, resolution 1, annex II (Programme of Action for the Sustainable Development of Small Island Developing States).

[5] See *Report of the International Conference on Population and Development, Cairo, 5-13 September 1994* (United Nations publication, Sales No. E.95.XIII.18), chap. I, resolution 1, annex (Programme of Action of the International Conference on Population and Development).

[6] See *Report of the Fourth World Conference on Women, Beijing, 4-15 September 1995* (A/CONF.177/20 and Add. 1), chap. I, resolution 1, annex II (Platform for Action).

[7] *Report of the United Nations Conference on Human Settlements (Habitat II), Istanbul, 3-14 June 1996* (A/CONF.165/14), chap. I, resolution 1, annex II (The Habitat Agenda).

Development carry out periodic global freshwater assessments, using the existing network of experts.

- Build on international collaborative arrangements such as the Global Water Partnership, the Global Water Supply and Sanitation Collaborative Council, and the World Water Council, and strengthen collaboration with non-governmental organizations.
- Develop North-South academic partnerships to develop the research capacity on a broad range of water-related issues, including those of quantity and quality and those related to helping people understand the value of water as natural capital.
- Develop partnerships with the private sector and industries to take advantage of their expertise to achieve mutual benefits in the water sector.

Given the seriousness of the situation and future risk of crises, there is an urgent need to act now. The international community has to strive for a situation in which there is no undermining of the natural resource base. Land and water need to be protected from the long-term degradation that threatens food production, aquatic ecosystems, human health and biodiversity. There is a need to reduce water use per unit of production, using water-efficient technologies. Pollution has to be sharply reduced, and persistent toxic substances that accumulate in the food chain must no longer be released into the environment. Agricultural water use has to become highly efficient, so as to ensure an adequate food supply for everyone. Generally accepted political goals need to be developed based on the fair sharing of benefits from water use.

In order to achieve this future, it is necessary for Governments to take the steps needed to reach a global consensus over and above what is contained in the existing principles and agreements on freshwater resources of the world. Such a consensus should take into account factors brought forth in this report.

BACKGROUND DOCUMENTS*

World Freshwater Problems — Call for a new realism
***by* M. Falkenmark, Natural Science Research Council, and J. Lundqvist, Linköping University, Sweden**

Abstract
This report aims at spelling out the rationale for the Comprehensive Freshwater Assessment. Starting from an overview based on global data available in 1994 in UNESCO's International Hydrological Programme, an analysis and diagnosis is made of the present water resources predicament, demonstrating, inter alia, that water-related problems tend to appear in clusters.

A distinction is made between negotiable and non-negotiable dimensions in resource management. Non-negotiable refers to hydroclimatic and physical/geographical contexts, and negotiable to human adaptation and ingenuity. Management perspectives are discussed, such as the potential of demand management, development options under water scarcity conditions, and the past neglect of social capability problems. In addition to shortcomings in institutional arrangements and human skills and knowledge, more profound problems seem to contribute to mismanagement, such as poor understanding of water cycle integrity, and water-blind perceptions.

Potential responses are discussed, addressing in particular four key dilemmas: the fact that water-scarce regions will be unable to achieve food self-sufficiency; the decreasing usability of polluted water; the upstream/downstream competition for the water passing down a river; and the growing competition between urban and rural users. Potential conflicts in relation to water are also addressed. The report calls for a new water resources stewardship, acknowledging non-negotiable environmental preconditions.

Finally, examples are given of long-term tasks and imperative actions, what needs to be done on international, national and municipal levels, as well as by private and public NGOs and water user associations.

Assessment of Water Resources and Water Availability in the World
***by* Igor A. Shiklomanov, State Hydrological Institute, Russian Federation**

Abstract
This report serves as the primary technical document source for Section 1 of the Comprehensive Freshwater Assessment. It contains an estimate of the water storage on the Earth including fresh and salt water, the amount and distribution of the freshwater renewable resource, and estimates of past, present and future water withdrawals and consumption by sectors. The report also contains specific information on water quality and its implications for human health, and the use, and overuse, made of groundwater to meet the ever growing needs of the world's population.

An evaluation is made of water availability per capita and regions of the world are identified where the present and future disparity between uses and renewable water supply will be the greatest. Future demand will be greatest in the developing countries because of population growth, and increasing agricultural and industrial sector utilization.

The report details the extreme difficulty in preparing a global assessment because of the lack of sufficient and reliable information on water availability, its quality, and water use in many areas of the world. Efforts to balance supply and demand, and plans for a sustainable future are severely hampered by this lack of information. International action is required to overcome these limitations, and assist those countries most in need to reach self-sufficiency in terms of reliable information and the capability to carry out water resource assessments and manage their water and related resources in a sustainable fashion.

Water Futures: Assessment of Long-range Patterns and Problems
***by* Paul Raskin*, Peter Gleick†, Paul Kirshen*, Robert G. Pontius, Jr*, Kenneth Strzepek+**

*= Stockholm Environment Institute, Boston, USA,
†= Pacific Institute, USA, += Colorado University, USA

Abstract
Water requirements to the year 2025 at regional and national levels are examined in order to assess emerging problems of stress on freshwater resources. Long-range water patterns will be governed by future factors such as population, economic scale and structure, technology, consumption patterns, agricultural practices and policy approaches. This study focuses on Conventional Development Scenarios which are driven by: 1) commonly used demographic and economic projections, 2) a convergence hypothesis that developing region consumption and production practices will evolve in a globalizing economy toward those of industrialized regions, 3) an assumption of gradual technological advance without major surprises, and 4) the absence of major policy changes affecting water needs or use.

The scenarios show a rapid increase in water requirements, especially in developing regions. Several indices are introduced for assessing the level of future water vulnerability at the country level. These include the use-to-resource ratio, a gauge of average overall pressure on water resources and threats to aquatic ecosystems; coefficient of variation of precipitation, a measure of hydrological fluctuations; storage-to-flow ratio, an indicator of the capacity of infrastructure to mute such fluctuation; and import dependence, an index of reliance on inflows from external water sources. To supplement these physical indices of vulnerability, a socio-economic coping capacity index (average future income) represents a country's ability to endure emerging water problems and uncertainties. Together, the indices are

* Published separately

used to signal changing water vulnerability for each country as the scenarios unfold. The information is capsulated in a series of "water stress" maps.

It is agreed that the deteriorating water conditions found for the scenario are by no means inevitable, and a more sustainable water future is envisaged.

Sustaining Our Waters into the 21st Century
by Jan Lundqvist, Linköping University, Sweden and Peter H. Gleick, Pacific Institute, USA

Abstract
This report elaborates on the policy approaches and policy options that would facilitate a long-term sustainable water use, building on other background material for the Assessment and on the outcome of an international workshop.

Water planners, managers and users have to deal with many challenges as we approach the 21st century. Among the multiple functions that water fulfils, the basic human and ecosystems needs are of paramount importance. Water is also indispensable for food production, for industrial development and for a wide range of activities and processes in the landscape as well as in society. Involvement of users and sharing of responsibilities and management tasks is a prerequisite for proper choice of technological and organizational approaches. It is argued that allocation of finite water resources must be agreed upon through political and socio-economic negotiations and that due consideration must be given to the various functions that water fulfils in society and in the landscape. Intersectoral coordination and priorities in allocation are particularly demanding and current sectoral allocations may have to be reviewed. In particular, the issue of national food-sufficiency versus national food self-reliance needs to be addressed in national policies and in international agreements on global food security.

The report urges that more attention be given to the qualitative aspects of water. Threats of water quality degradation will increasingly affect human and ecosystem health, as well as industrial development.

Water is recognized as a vital resource for life, human and societal development and environmental sustainability. Related to this basic view is also a wide acceptance that water should be treated as an economic and social good and that management must aim for the most worthwhile use ensuring equity concerns, efficiency and environmental sustainability.

COMMISSIONED PAPERS

Freshwater and Gender — A Policy Assessment
by Anna Brismar, Stockholm, Sweden

Abstract
The pressure on limited freshwater resources increases to meet the escalating demands of households, municipalities and industry. Meanwhile, in the developing world, widespread inequalities exist between women and men regarding their respective opportunities to influence and participate in activities within their society and to benefit from its resources.

In order to suppress further deterioration of the present natural resource base and to relieve human poverty and suffering, the competence and expertise within each society need to be optimally utilized. This requires the right for both men and women to participate — on equal terms and to an equal extent — in societal activities. In addition, it demands the acknowledgement of the assets of both men and women, and consideration of their unique interests and needs. In this way, not only is the life quality of women and their families improved, but also the prospects of sustainable freshwater utilization and management. However, despite a growing gender awareness worldwide, the process of attaining gender equality within all areas of social life is only in its infancy. As part of this process, the author calls for an evaluation of the gender awareness of current freshwater policies, programmes and projects, whether local or regional. An extensive assessment of prevalent national and international policies, laws and practices, and societal attitudes is also proposed, with the aim of achieving a sustainable interaction between men, women and freshwater.

Urban Water — Towards Health and Sustainability
by Marianne Kjellén and Gordon McGranahan, Stockholm Environment Institute, Sweden

Abstract
Few would dispute that urban water systems should be both healthy and sustainable. Ideally, along with efficiency, these would be central pillars in every urban water strategy. Unfortunately, the narrow pursuit of health can undermine the sustainability of water systems and vice versa. Such trade-offs must not be rationalized away, but circumvented or adapted to. It is crude policies, such as promoting health by providing free water for all, or promoting sustainability by charging everyone high prices, that create the steepest trade-offs. Trade-offs are far less evident with more sophisticated policies, targeting particular users or uses, and built upon a better understanding of water-related disease, hydrology, markets and politics. Our ignorance is no excuse for inaction: there are many obvious things that need to be done. But nor is the need for action an excuse for remaining ignorant: there remains a great deal of relevance to learn regarding urban water, and how it relates to both health and sustainability.

Water: Commodity or Social Institution
by Paul Seabright, University of Cambridge, UK

Abstract
This paper begins with the idea that water is an economic resource, characterized by scarcity, and goes on to explore the many different economic characteristics that water has in different circumstances. It notes that while freshwater is not globally scarce, its scarcity arises from the fact that it is costly to make available in the right quantity and the right quality in the place where it is needed. Its uses are multifarious and the economic characteristics of systems of water use and management are correspondingly varied.

Furthermore, the kinds of property right vested in water vary greatly according to circumstances: the degree of scarcity and the nature of the external effects between different users influence to a considerable extent the character of legal and social systems where water management is important for the overall economy. Although such systems have historically shown remarkable flexibility and adaptability to the needs of water use, they are far from being adequate to the changing demands on global water resources that will arise in the coming century.

International Freshwater Resources: Sources of Conflicts or Cooperation
by **Peter Wallensteen and Ashok Swain, Uppsala University, Sweden**

Abstract
The scarcity of freshwater is now an important issue in many parts of the world. When multiple countries are jointly dependent on the same water body, one's withdrawal or pollution provides the ground for conflict as well as cooperation among the riparian countries to get the best use of the available resource. By making comparative analysis of the sharing of five international rivers, the study tries to determine under what conditions the conflict or cooperation takes place among nation-states over the freshwater issues. The river systems which are selected for close scrutiny are the Rhine in Europe, Colorado in North and Central America, Paraná in South America, Nile in Africa and Ganges in Asia.

The authors conclude: there is a larger conflict potential in water quantity issues than in water quality issues. Issues of river water pollution and regulation appear to have a record of finding solutions. Finally, the successful cases of handling river water disputes appeared to be those cases where an "international regime" covered an entire river basin, not just two major users of the river. The reason might be that this gives a chance of more relaxed discussions, more coalition building and, in essence, more third party activity.