Population Reports

Solutions for a Water-Short World

As populations grow and water use per person rises, demand for freshwater is soaring. Yet the supply of freshwater is finite and threatened by pollution. To avoid a crisis, many countries must conserve water, pollute less, manage supply and demand, and slow population growth.

Caught between growing demand for freshwater on one hand and limited and increasingly polluted water supplies on the other, many developing countries face difficult choices. Populations continue to grow rapidly. Yet there is no more water on earth now than there was 2,000 years ago, when the population was less than 3% of its current size. Rising demands for water for irrigated agriculture, domestic (municipal) consumption, and industry are forcing stiff competition over the allocation of scarce water resources among both areas and types of use.

Today 31 countries, accounting for under 8% of the world population, face chronic freshwater shortages. By the year 2025, however, 48 countries are expected to face shortages, affecting more than 2.8 billion people — 35% of the world's projected population. Among countries likely to run short of water in the next 25 years are Ethiopia, India, Kenya, Nigeria, and Peru. Parts of other large countries, such as China, already face chronic water problems.

In much of the world polluted water, improper waste disposal, and poor water management cause serious public health problems. Such water-related diseases as malaria, cholera, typhoid, and schistosomiasis harm or kill millions of people every year. Overuse and pollution of water supplies also are taking a heavy toll on the supply and quality of freshwater.
toxins on the natural environment and pose increasing risks for many species of life.

What Can Be Done?

It may already be too late for some water-short countries with rapid population growth to avoid a crisis. Many other countries can avoid the coming crisis if appropriate policies and strategies are formulated and acted on soon. Whether water is used for agriculture, industry, or municipalities, there is much room for conservation and better management. Effective strategies must consider not only managing the water supply better but also managing demand better.

To avoid catastrophe over the long term, it also is important to act now to slow the growth in demand for freshwater by slowing population growth. Currently, in many developing countries millions of people want to plan their families and to use contraception. Family planning programs have played an important role in assuring the supply and management of freshwater resources and on providing sanitation and health and even bring risks of outright conflict over access to scarce freshwater supplies. Finding solutions should become a high priority now.

Toward a Blue Revolution

The world needs a Blue Revolution to conserve and manage freshwater supplies in the face of growing demand from population growth, irrigated agriculture, industries, and cities—just as the Green Revolution transformed agriculture in the 1960s. A Blue Revolution will require coordinated responses to problems at local, national, and international levels.

Locally led initiatives show that water can be used much more efficiently. When communities manage freshwater resources efficiently, they also manage other natural resources better, improve sanitation, and reduce disease. At the national level, especially in water-short regions with dense populations, adopting a watershed or river-basin management perspective is a needed alternative to uncoordinated water-management policies by separate jurisdictions. At the international level countries that share river basins can fashion workable policies to manage freshwater resources more equitably. Development agencies need to focus more on assuring the supply and management of freshwater resources and on providing sanitation as part of development and public health programs.

A water-short world is an inherently unstable world. As the next century dawns, water crises in more and more countries will present obstacles to better living standards and better health and even bring risks of outright conflict over access to scarce freshwater supplies. Finding solutions should become a high priority now.
Freshwater is emerging as one of the most critical natural resource issues facing humanity (62, 66, 84). As the year 2000 approaches, the world’s population is expanding rapidly. Yet there is no more freshwater on earth now than there was 2,000 years ago, when the population was less than 3% of its current size (132).

Water is, literally, the source of life on earth. The human body is 70% water. People begin to feel thirst after a loss of only 1% of bodily fluids and risk death if fluid loss nears 10% (73). Human beings can survive for only a few days without freshwater. Yet, in a growing number of places people are withdrawing water from rivers, lakes, and underground sources faster than they can be recharged—“unsustainably mining what was once a renewable resource,” as one researcher puts it (11). Currently, 31 countries—mostly in Africa and the Near East—face water stress or water scarcity (65, 69). (For definitions, see glossary, p. 4.)

Population growth alone will push an estimated 17 more countries, with a projected population of 2.1 billion, into these water-short categories within the next 30 years. By the year 2025, 48 countries, with more than 2.8 billion people—35% of the projected global population in 2025—will be affected by water stress or scarcity (see p. 9). Another nine countries, including China and Pakistan, will be approaching water stress. Population growth itself, the demand for freshwater has been rising in response to industrial development, increased reliance on irrigated agriculture, massive urbanization, and rising living standards. In this century, while world population has tripled, water withdrawals have increased by over six times (98). Since 1940 annual global water withdrawals have increased by an average of 2.5% to 3% a year compared with annual population growth of 1.5% to 2% (38, 176). In developing countries over the past decade water withdrawals have been increasing by 4% to 8% a year (111). Moreover, the supply of freshwater available to humanity is shrinking, in effect, because many freshwater resources have become increasingly polluted. In some countries lakes and rivers have become receptacles for a vile assortment of wastes, including untreated or partially treated municipal sewage, toxic industrial effluents, and harmful chemicals leached into surface and ground waters from agricultural activities (114).

Caught between finite and increasingly polluted water supplies on one hand and rapidly rising demand from population growth and development on the other, many developing countries face uneasy choices (33, 85, 114, 215). The lack of freshwater is likely to be one of the major factors limiting economic development in the decades to come, warns the World Bank (165, 164).

### Slowing Demand, Conserving Supplies

To avoid a water crisis, particularly in water-short countries with rapid population growth, it is vital to slow the growth in demand for water by managing the resource better, while at the same time slowing population growth as soon as possible. Family planning programs play an important role not only for individual reproductive health but also for...
Glossary of Key Hydrological Terms

Aquifer: A layer or section of earth or rock that contains freshwater, known as groundwater (any water that is stored naturally underground or that flows through rock or soil, supplying springs and wells).

Hydrological (water) cycle: The natural cycle by which water evaporates from oceans and other water bodies, condenses as water vapor in clouds, and returns to oceans and other water bodies as precipitation. Precipitation over land has two components: runoff and moisture from evapotranspiration.

Nonrenewable water: Water in aquifers and other natural reservoirs that are not recharged by the hydrological cycle. If not consumed, the water may return to groundwater (any water that is stored naturally underground or that flows through rock or soil, supplying springs and wells).

Renewable water: Freshwater that is continuously replenished by the hydrological cycle for withdrawal within reasonable time limits, such as water in rivers, lakes, or reservoirs that fill from precipitation or from runoff. The renewability of a water source depends both on its natural rate of replenishment and the rate at which the water is withdrawn for human use.

Runoff: Water originating as precipitation on land that then runs off the land into rivers, streams, and lakes, eventually reaching the oceans, inland seas, or aquifers, unless it evaporates first. That portion of runoff that can be relied on year after year and easily used by human beings is known as stable runoff.

Water consumption: Use of water that results in its evaporation or transpiration (through plants) or that otherwise makes it unavailable for subsequent human use.

Water withdrawal: Removal of freshwater for human use from any natural source or reservoir, such as a lake, river, or aquifer. If not consumed, the water may return to the environment and can be used again.

Water scarcity: According to a growing consensus among hydrologists, a country faces water scarcity when its annual supply of renewable freshwater is less than 1,000 cubic meters per person. Such countries can expect to experience chronic and widespread shortages of water that hinder their development.

Water stress: A country faces water stress when its annual supply of renewable freshwater is between 1,000 and 1,700 cubic meters per person. Such countries can expect to experience temporary or limited water shortages.

Figure 1. Links Between Population and Freshwater
Water Availability and Use

Some 70% of the earth's surface is water, but most of that is ocean. By volume, only 1% of all water on earth is freshwater, and most of this is largely unavailable (39, 57). About three-quarters of all freshwater is locked away in the form of ice caps and glaciers located in polar areas far removed from most human habitation; only about 1% is easily accessible surface freshwater. This is primarily the water found in lakes, rivers, and the soil at underground levels shallow enough to be tapped at an affordable cost. Only this amount is regularly renewed by rain and snowfall and thus available on a sustainable basis (174) (see Figure 2). In all, only one one-hundredth of one percent of the world's total supply of water is considered easily accessible for human use (108).

Globally, between 12.5 and 14 billion cubic meters of water (12,500 to 14,000 cubic kilometers) are considered available for human use on an annual basis. This amounts to about 9,000 cubic meters per person per year, as estimated in 1989 (30, 107, 145, 157). (Note: 1 cubic meter equals 1,000 liters.) By the year 2025 global per capita availability of freshwater is projected to drop to 5,100 cubic meters per person as another 2 billion people join the world's population (184). Even then, this amount would be enough to meet human needs if it were distributed equally among the world's population (157).

Global per capita figures on water availability give a false picture, however. The world's available freshwater supply is not distributed evenly around the globe, throughout the seasons, or from year to year. In some cases water is not where we want it, nor in sufficient quantities. In other cases we have too much water, in the wrong place, at the wrong time. We "live under the tyranny of the water cycle," observes hydrologist Malin Falkenmark, referring to the earth's hydrological cycle (62).

The earth's hydrological cycle acts like a giant water pump that continually transfers freshwater from the oceans to the land and back again (see Figure 3). In this solar-driven cycle, water evaporates from the earth's surface into the atmosphere and is returned as rain or snow. Part of this precipitation evaporates back into the atmosphere. Another part flows into streams, rivers, and lakes, commencing a journey back to the sea. Still another part sinks into the soil and becomes soil moisture or groundwater. Plants incorporate soil moisture into their tissues and release it into the atmosphere in the process of evapotranspiration (174). Much of the groundwater eventually works its way back into the flow of surface waters (176).

Demand for freshwater is rising in irrigated agriculture, industry, and cities. The supply of freshwater is limited, however. Only 3% of all water on earth is freshwater, and most is locked away in ice caps and glaciers or in deep underground aquifers. Only 1% is considered easily accessible—contained in lakes, shallow aquifers, or other sources renewed by precipitation.

Freshwater Distribution
The hydrological cycle comes with no guarantees for mankind. About three-quarters of annual rainfall comes down in areas containing less than one-third of the world's population. Put the other way around, two-thirds of the world's population live in areas receiving only one-quarter of the world's annual rainfall (74). For instance, about 20% of the global average runoff each year is accounted for by the Amazon Basin, a vast region with fewer than 10 million people, a tiny fraction of the world's population. Similarly, the Congo River and its tributaries account for about 30% of the entire African continent's annual runoff, but the water-sheds contains only 10% of Africa's population (74, 174).

More than half the global runoff occurs in Asia and South America (31% and 25%, respectively) (74). On a per capita basis, however, North America has the most freshwater available, at over 19,000 cubic meters per year, estimated in 1990. In contrast, the per capita amount is just over 4,700 cubic meters in Iceland to only 75 cubic meters per person in Kuwait, as estimated in 1995 (69).

By country, the amount of renewable freshwater available per capita on an annual basis ranges from over 600,000 cubic meters in Iceland to only 75 cubic meters per person in Kuwait. There are also striking differences in water availability within countries. In Mexico, less than 10% of the land area provides more than half of the national rainwater runoff each year. Despite the fact that 90% of Mexico is arid and chronically water-short, its total per capita water availability in 1990 was over 4,000 cubic meters. Such a figure is grossly misleading as a measure of actual water availability for most Mexicans (30).

"The disparities between the rich and poor are never more stark than when it comes to access to water," according to the UN publication Earth Times (193). "Ask a person in New Delhi and you will be lucky if you escape with a 15-minute lecture on how the water flows once a day, it has to be stored, it smells and, if you drink it without boiling it, chances are you will get sick" (193).

Throughout much of the developing world the fresh-water supply comes in the form of seasonal rains. Such rains run off too quickly for efficient use, as during the monsoons in Asia (139). India, for instance, gets 90% of its rainfall during the summer monsoon season, which lasts from June to September. For the other eight months the country gets barely a drop of rain. As a result of the seasonal nature of the water supply, India and some other developing countries can make use of no more than 20% of their potentially available freshwater resources (132).

Altering natural supply systems. As water-short societies have done for centuries, many countries attempt to move water from where it occurs in nature to where people want it, and also to store water for future use. The Egyptians built thousands of canals and irrigation ditches to capture the Nile's waters in order to grow crops. In the first century AD Roman engineers brought water into Rome via huge aqueducts from as far away as 100 kilometers (21).

Worldwide there are some 40,000 dams higher than 15 meters, most of them built in the last 50 years (199). Although dams help insure a steady water supply, they often imperil aquatic ecosystems by disrupting flood cycles, blocking river channels, altering water flows in rivers, flood-plains, deltas, and other natural wetlands, and imperiling plant and animal life (141).

How Water is Used
It is difficult to estimate the amount of water needed to maintain acceptable or minimum living standards. Moreover, different sources use different figures for total water consumption and for water use by sector of the economy (53).

Gleick estimates annual freshwater needs to meet four basic needs for drinking, sanitation, bathing, and cooking. In 1990, Gleick estimates, 55 countries with a population of nearly 1 billion people did not meet this standard as a national average (73). Falkenmark uses the figure of 100 liters of freshwater per capita per day for personal use as an overall basic water requirement as a minimum standard needed for minimal living standards. More-
As the world becomes predominantly urban, while agriculture dominates. On a worldwide basis, agriculture accounts for about 69% of all annual water withdrawals; industry, about 23%; and domestic use, about 8% (49, 53, 168, 176).

There are wide differences by region. In Africa an estimated 88% of all freshwater use is for agriculture, 7% for domestic purposes, and 5% for industry. In Asia water also is used mostly for agriculture, estimated at 86% of total use, while industry accounts for 8%, and domestic use, 6%. In Europe, however, most water use is for industry, at 54%, while agriculture accounts for 31%, and domestic use, 13% (53).

**Freshwater and economic development.** A country’s level of freshwater use reflects—and, in fact, is one of the key measures of—its level of economic development. In developing regions of the world people use far less water per capita than in developed regions. In Africa annual per capita water withdrawals for personal use average only 17 cubic meters (equal to 47 liters of water per day), and in Asia, 31 cubic meters (equal to 85 liters per day) (30, 111). In contrast, comparable water use in the UK is estimated at 122 cubic meters per year (344 liters per day), and in the US, 211 cubic meters per year (578 liters per day) (53).

Developing countries devote most of their water supplies to agriculture. India, for instance, uses 90% of all water for agricultural purposes, with just 7% for industry, and 3% for domestic use (53). The higher the level of development, the more water is used for domestic and industrial purposes and the less for agriculture. There are some important exceptions to this rule, however. For example, Japan still uses the largest share of its freshwater for irrigating rice. Also, in some and areas of Europe, such as Spain and Portugal, most of the available water is used for irrigated agriculture (75).

Around the world freshwater demand per capita is rising substantially as countries develop economically. Withdrawals of water have grown in all three major categories of use—leisure and recreation, industrial demand, and domestic demand, including for municipal use, and increasing reliance on irrigation to produce food (174) (see Figure 4).

**Urbanization.** The level of water use also reflects the level of urbanization in a country. Low household water use in many developing countries today often reflects difficulty in obtaining freshwater. Piped water systems are rare in rural areas. Two-thirds of the world’s population, the majority in developing countries, get their water from public standpipes, community wells, rivers and lakes, or rainfall collected off roofs. Often rural people—usually women and girls (214)—must walk many kilometers and spend many hours fetching water for their household. In Africa, for instance, women and girls spend 40 billion person-hours a year hauling water (188).

Urbanization increases water use dramatically. For example, in 1900 the average American household used as little as 10 cubic meters of water per year compared with more than 200 cubic meters today (53). Why? A century ago, most Americans obtained their freshwater from wells or public standpipes. Running water was largely unavailable to households except in big cities, and most people lived in the rural areas. In contrast, virtually every American household today has running water available, and this water costs its users very little.

As the world becomes predominantly urban, while agriculture depends more and more on irrigation, it will be difficult for cities to meet the rising demand for freshwater. In developing countries rapid urban growth often puts tremendous pressure on antiquated, inadequate water supply systems. For instance, between 1950 and 1980, the populations of many cities in Latin America, such as Bogota, Mexico City, Sao Paulo, and Managua, tripled or even quadrupled. Such African cities as Naiobi, Dar es Salaam, Lagos, and Kinshasa grew sevenfold, primarily because of a rural exodus. In the 1990s cities of developing countries have had to cope with about 60 million new arrivals every year (63, 68). Yet many agencies are not equipped to manage the urban water supply, while some countries have ineffective water allocation systems that allow cities to run short of water at the same time that water resources are being used for subsidized agriculture (130).

### Facing Water Shortages

**Population Growth, Water Shortages**

The world’s population, at nearly 6 billion, is growing by about 80 million people each year. This number implies an increased demand for freshwater of about 64 billion cubic meters a year—an amount equivalent to the entire annual flow rate of the Rhine River (30). While population growth rates have slowed somewhat, the absolute number of people added to the population each year—the relevant figure...
considering the availability of and need for freshwater—remains near historic highs. For example, because nearly 2 billion people have been added to the planet since 1970, per capita availability of water is one-third lower now than it was then (139).

China and India, the world's first and second most populous countries, provide examples of how even modest population growth rates translate into large absolute numbers when the population base is large. In China the population growth rate is about 1% per year, estimated in 1998 (135). Nevertheless, because China's population is over 1.2 billion people, even a low population growth rate means 12 million additional people each year. India's population growth rate, which is substantially higher than China's, at about 1.9% per year, means about 18 million people added each year to India's current population of about 970 million (180).

In the two regions of the world that already face the most serious absolute or seasonal shortages of water—Africa and the Near East—population growth rates remain among the highest in the world. In sub-Saharan Africa population is growing by an average 2.6% a year; in the Near East and North Africa, by 2.2% (135). These population growth rates have ominous implications for per capita water supply in the countries of these regions (see Table 1).

**Water stress and scarcity.** As their populations grow, more and more countries are facing water shortages (62). A country is said to experience water stress when annual water supplies drop below 1,700 cubic meters per person. At levels between 1,700 and 1,000 cubic meters per person, periodic or limited water shortages can be expected. When annual water supplies drop below 1,000 cubic meters per person, the country faces water scarcity (57, 69, 139). Once a country experiences water scarcity, it can expect chronic shortages of freshwater that threaten food production, hinder economic development, and damage ecosystems.

Malin Falkenmark developed the concepts of water stress and water scarcity based on an index of per capita freshwater needs. She estimated a minimum need of 100 liters per day per person for household use and from 5 to 20 times as much for agricultural and industrial uses (65, 69). These concepts have been widely accepted and used by hydrologists, the World Bank, and other organizations. For example, Population Action International (PAI) has relied on them to make projections of per capita water availability and to forecast water shortages in 2025 and 2050 (49, 69) (see Table 1).

Figure 5. Water Scarcity and Stress

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Source: Gardner-Outlaw & Engelman 1997 (69) and Table 1

Water-Scarce and Water-Stressed Countries, Projected 2025

- **Water Scarcity**
  - Less than 1,000 cubic meters per person per year
  - Source: Gardner-Outlaw & Engelman 1997 (69) and Table 1

- **Water Stress**
  - 1,000 to 1,700 cubic meters per person per year

8

POPULATION REPORTS
Growing Water Shortages

Population Size and Growth and Renewable Freshwater Availability in Water-Short Countries, 1995 and 2025

Water-stressed countries are those with annual water resources between 1,000 and 1,990 cubic meters per person, shown in light type. Countries suffering from water scarcity are those with annual supplies of less than 1,000 cubic meters per person, shown in dark type.

Table 1

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Calculations of water stress and water scarcity are based on estimates of a country's renewable freshwater supplies and do not include water withdrawn from fossil groundwater (see glossary, p. 4). Fossil groundwater is essentially a non-renewable resource: it takes tens of thousands of years for these deep aquifers to replenish themselves. A country may temporarily avoid the effects of water stress by mining its renewable supplies, but this practice is not sustainable, particularly if the population continues to grow rapidly and per capita demand for freshwater increases.

As of 1995, 31 countries, with a combined population of over 458 million, faced either water stress or water scarcity (48) (see Figure 5). This represents an addition of only 3 countries since 1990, when 28 countries, with a combined population of 335 million faced chronic water stress or water scarcity (49). The number of people estimated to live in water-scarce and water-stressed countries rose by nearly 429 million during these five years, however, largely reflecting population growth in water-short countries.

The Coming Era of Water Stress and Scarcity

Already evident is a serious problem, these numbers are about to explode. By 2025, more than 8 billion people will live in 48 countries facing water stress or water scarcity, PARI
The Near East and North Africa. The 20 countries of the Near East and North Africa face the worst prospects. The Near East is the most water-short region in the world. In fact, the region’s total population was 122 million, according to Tony Allan, a University of London expert on water resources (117). Since then, the region has withdrawn more water from its rivers and aquifers every year than is being replenished. Currently, for example, Jordan and Yemen withdraw 30% more water from groundwater aquifers every year than is replenished (49, 138). Also, Israel’s annual water use already exceeds its renewable supply by 15% (73).

Saudi Arabia presents one of the worst cases of unsustainable water use in the world. This extremely arid country now must mine fossil groundwater for three-quarters of its water needs. Fossil groundwater depletion in Saudi Arabia has been averaging around 5.2 billion cubic meters a year (139). Of 14 countries in the Near East, 11 are already facing water scarcity (139). In five of these countries the populations are projected to double within the next two decades. Water’s one of the major political issues confronting the region’s leaders (117). Since virtually all rivers in the Near East are shared by several nations, current tensions over water rights could escalate into outright conflicts, driven by population growth and rising demand for an increasingly scarce resource (135).

Four Gulf states—Bahrain, Kuwait, Saudi Arabia, and the United Arab Emirates—have so little freshwater available that they resort to desalinization, the costly conversion of seawater from the Gulf. It has virtually no freshwater at all (157). Desalinization, however, is far too expensive and impractical for most water-short countries, not to mention land-locked countries, either today or in the foreseeable future.

Sub-Saharan Africa. Much of sub-Saharan Africa is facing serious water constraints (59, 61). Nearly 200 million people live in Africa’s water-stressed countries. While only 6 million live in countries facing water scarcity, rapid population growth will make this problem worse. By 2025 as many as 230 million people will be living in African countries facing water scarcity (39, 61). Another 460 million will be in water-stressed countries of Africa.

Water problems within countries. Parts of many large countries, such as India, China, and the United States, would be considered to face water stress or water scarcity if calculations were made regionally rather than nationally. Already, 19 major Indian cities face chronic water shortages (109). India as a whole is expected to enter the water-stress category by 2025. China, which has 22% of the world’s population but only 7% of all freshwater runoff, will narrowly miss the water stress category’s cutoff point of 1,700 cubic meters per capita in 2025 (138). China’s freshwater supplies have been estimated to be capable of sustainably supporting 650 million people—only half of the country’s current population of 1.2 billion (149). Despite periodic flooding in the south, along the Yangtze River, China faces chronic freshwater shortages in the northern part of the country—affecting 92 million people in the Hai River basin alone (15, 69). Many of China’s cities, including Beijing, face critical water shortages. The water table under Beijing has been dropping by roughly two meters per year, and one-third of the wells have dried up. (150).
Even in the US, which has plenty of water on a national basis, groundwater reserves are being depleted in many areas. Overall, groundwater is being used at a rate 25% greater than its replenishment rate (133). In the western part of the country, groundwater aquifers are being depleted at even faster rates in some areas. In particular, the huge Ogallala aquifer, which underlies parts of six states and irrigates 6 million hectares, has been overexploited. In some regions half of its available water has been withdrawn (138).

**Competition for Scarce Water Supplies**

In developed and developing countries alike, competition among water uses is increasing (12, 138). As might be expected, tensions are particularly high in water-short areas where population pressures, urbanization, and development needs combine to create intense demand for limited freshwater resources.

A number of developed water-short countries currently face tension over water, including Belgium, the United Kingdom, Poland, Singapore, and the US (60). In southern Britain, for instance, urban demand for water is growing so fast that it is outpacing the capacity of rivers and aquifers to supply it during the drier summer months. In the western US, farmers who want more irrigation water for their crops face off against fast-growing urban areas that demand more water for households and other municipal uses (138).

India's states have become embroiled in disputes over water rights and over dams that might provide more water for one state but at the expense of another. "Water disputes, if not attended to, will become a major headache for the stability of Indian society," says Mohan Katarki, a lawyer representing Karnataka state in a water dispute with Andhra Pradesh (129). These two states are arguing in court over the height of a dam on the Krishna River, which could affect the amount of water available for use by both states.

China already is practicing what some water experts call the "zero sum game of water management" (138). The zero sum game—when authorities increase water supply to one user by taking it away from another—is played both between competing areas of the country and between competing types of use, as when cities compete with farmers. China's Yellow River is a classic case of the zero sum game. The river is so oversubscribed that, for an average of 70 days a year for the past decade, its waters have dried up before reaching the Bohai Sea. In 1995 the dry period lasted for 122 days. In 1996, one of the few years when there was enough water for farming, villages near the river's mouth to feed their crops, the government authorities ordered them not to touch a drop. All of the water flowing by their parched fields was destined for use by a state-run oil field farther downstream (172).

Also, to meet urban needs, the government of China is diverting water from agricultural uses to feed a state-run oil field farther downstream (172). If China diverts too much water from agricultural uses, grain production is likely to suffer, possibly forcing China to import more grain. Other grain-producing countries, however, have little potential to boost exports, warns the Worldwatch Institute. In the US and Europe, for example, increases in agricultural productivity are just keeping up with population increases. Australia and Canada depend on dryland farming and are constrained by limited rainfall. Thus "China's water scarcity could soon become the world's grain scarcity," the Worldwatch Institute predicts (135). Increasing demand for grain in China could raise prices on the world market beyond the reach of some poor countries.

**Regional conflicts.** In nearly all water-short areas the threat of regional conflicts over limited water supplies is emerging as a serious issue (58, 120). For example, about 50 rivers are each shared by two or more countries. In particular, access to water from the Nile, Zambezi, Niger, and Volta river basins has the potential to ignite conflicts (197).

In Central Asia the Aral Sea Basin is beset by international conflicts over water. Turkmenistan, Uzbekistan, Kazakhstan, Kyrgyzstan, and Tajikistan all depend for their survival on the waters of the Amu Darya and Syr Darya rivers. The flows of both rivers are almost wholly diverted to feed water-intensive crops such as cotton and rice. In most years only a trickle reaches the Aral Sea (89, 164). As demand for this water grows, the countries are increasingly at odds over its division, with all five Central Asian republics demanding a greater share (40, 89). Disputes are growing between Kyrgyz and Uzbek over water and land in the fertile Fergana Valley; between Kyrgyz and Tajik over the allocation of irrigation water from the Syr Darya; and between Turkmen and Uzbeks over the distribution of irrigation water from the Amu Darya (138).

In the US, the Colorado River, which flows through the southwestern part of the country, has fed irrigated agriculture and enabled the explosive growth of desert cities. Now, however, demands on the river's water supply for irrigation and urban use have become so great that the river no longer reaches its mouth in Mexico's Gulf of California. Instead, its waters trickle off somewhere in the desert south of the US-Mexican border (140). The river's premature disappearance has been a cause of bickering between the US and Mexico.

**Consequences of Overuse and Pollution**

Overuse and pollution of the world's freshwater resources are a recent development. Their long-term consequences are unknown. Already, however, they have taken a heavy toll on the environment, and they pose increasing risks for many species (73, 174, 183). Pollutants and disease vectors that are spreading are fostering a human health tragedy (126, 221) (see p. 15). Moreover, the sad state of freshwater resources contributes to the deterioration of coastal waters and seas (see box, p. 12).

In 1996 the world's human population was using an estimated 54% of all the accessible freshwater contained in rivers, lakes, and underground aquifers. This percentage is conservatively projected to climb to at least 70% by 2025, reflecting population growth alone, and by much more if per capita consumption continues to rise at its current pace (93, 145). As humankind withdraws a growing share of all water, less remains to maintain the vital ecosystems on which we also depend (11, 140, 145).

A substantial portion of the total freshwater available in the hydrological cycle is needed to sustain natural aquatic ecosystems—marshes, rivers, coastal wetlands—and the millions
The Coastal Connection

Worldwide, population is concentrated along or near coasts and river valleys occupying just 10% of the earth's land area. Human activities in coastal areas are in the process of assaulting coastal and ocean ecosystems and the wealth of biodiversity that they harbor.

Population patterns. Around the world, people cluster near coasts. Over half of the world's population—about 3.2 billion—occupy a coastal zone 200 kilometers wide. With the exception of India, most of Asia's population is coastal. In China, for example, close to 60% of the population of 1.2 billion live in 12 coastal provinces, along the Yangtze River valley, and in two coastal municipalities—Shanghai and Tianjin. Along China's 18,000 kilometers of continental coastline, population densities average between 110 and 1,600 people per square kilometer.

The population of Latin America and the Caribbean is even more coastal. Among the region's coastal countries, with a total population of around 610 million, a full three-quarters of the population lives within 200 kilometers of the seacoast.

Only in Africa do more people live in the interior of the continent than along or near coasts. Over the past two decades, however, Africa's coastal cities—centers of trade and commerce—have been growing by 4% a year or more, as millions of people migrate from the interior. Accra, Abidjan, Dakar, Dar es Salaam, Lagos, and other coastal cities have seen their populations soar from in-migration.

In recognition of rapid population growth and increasing water pollution, representatives of Africa's 38 maritime countries met in July 1998 in Maputo, Mozambique, to consider ways to protect, manage, and save the continent's coastal environment in the face of limited resources, poor sanitation, and development needs.

Environmental consequences. Population growth, urbanization, and industrialization with little regard for the environment are polluting and degrading coastal and ocean resources. Consider the following examples:

- The world has lost half its coastal wetlands, including mangrove swamps and salt marshes. Over the past century mangrove forests have been decimated. An estimated 35 million hectares have been destroyed or grossly degraded.
- In virtually all inhabited coastal areas, seagrass beds, vital as fish nurseries and feeding areas, are diminishing. Coral reefs, the rainforests of the sea, are being pillaged in the name of development. Of the world's 600,000 square kilometers of reefs found in tropical and subtropical seas, 70% could be lost within 40 years.
- Coastal and ocean fisheries are in serious decline. According to the UN Food and Agriculture Organization (FAO), in 1995 nearly 70% of the world's marine fish stocks were either fully to heavily exploited, over exploited, depleted, or slowly recovering.
- As coastal waters become clogged with raw sewage and agricultural and industrial pollutants, ecosystems begin to unravel.

Link to freshwater. When human activities damage freshwater ecosystems, they ultimately damage the salt water environment as well. Oceans are connected to the land through the complex network of rivers, streams, and lakes that comprise watersheds. Managing freshwater resources better will help protect the world's coastal waters. Protecting the coastal environment, rather than treating oceans and seas as garbage dumps, would help avoid a possible ecological disaster in the future.


of species that they shelter (32, 132). Healthy natural ecosystems are indispensable regulators of water quality and quantity. For example, flood plain wetlands soak up and store water when rivers flood their banks, reducing downstream damage. The value of these environmental services to humankind is immense. One estimate, made by Robert Costanza, director of the Institute of Ecological Economics at the University of Maryland, puts the global value of wetlands at close to US$5 trillion dollars a year, based on their value as flood regulation, fisheries production and recreation, among other uses (92).

For example, flood plain wetlands soak up and store water for fisheries production and recreation, among other uses (92).

New York City is spending US$l billion to conserve and protect water catchment areas in upstate New York—the source of the city's drinking water. The alternative would be to spend $3 billion on a state-of-the-art water filtration plant that would cost an additional $300 million a year to operate (11, 28, 155).

In virtually all regions of the world, careless use of water resources is harming the natural environment. Globally, over 20% of all freshwater fish species are either endangered or vulnerable or recently have been made extinct (98). As the following examples demonstrate, overusing and misusing freshwater resources carries serious consequences for natural species as well as for human populations:

- Diverting water from the Nile River, along with build-up of sediments trapped behind dams and barrages, has caused the fertile Nile delta to shrink. Of 47 commercial species of fish, about 30 have become extinct or virtually extinct. Delta fisheries that once supported over a million people have been wiped out (1, 90).
- Lake Chad, in Africa's Sahel region, has shrunk from 25,000 square kilometers to just 2,000 square kilometers in the last three decades from periodic droughts and massive diversions of water for irrigation. The lake's once rich fisheries have entirely collapsed (1, 97).
- Despite cleanup efforts, the Rhine River, which runs through the industrial heartland of Western Europe, is so polluted that it has lost 8 of its 44 species of fish. Another 25 species have become rare or are endangered (1).
- In Colombia fish production in the Magdalena River plunged from 72,000 metric tons in 1977 to 23,000 metric tons by 1992—a two-thirds drop in 15 years—as a result of agricultural, urban, and industrial development and deforestation in the river's watershed (1).
Transport this dirty water before it can be used again, another discharged into rivers, streams, and lakes. To dilute and accommodate the solution is pollution. The world's tremendous output of pollutants challenges the capacity of waterways to assimilate or flush away pollution. The saying among water engineers is "the solution is pollution." This truism is taking on frightening dimensions.

6,000 cubic kilometers of clean water are needed—an amount equal to about two-thirds of the world's total annual useable fresh water runoff (221). If current trends were to continue, the world's entire stable river flow would be needed just for pollutant transport and dilution by the middle of the next century, according to an estimate by the UN Food and Agriculture Organization (187).

The Pollution Problem

Pollution is pervasive. Few countries, whether developing or industrialized, have adequately safeguarded water quality and controlled water pollution. Many countries do not have standards to control water pollution adequately, while others cannot enforce water quality standards.

Increasingly, international development agencies are urging that developing countries devote more attention to protecting and improving water quality (165, 198). The developed world also must spend more and do more to clean up degraded waterways, or economic development will stall and the quality of life will fall (61, 85).

Agriculture is the biggest polluter, even more so than industries and municipalities. In virtually every country where agricultural fertilizers and pesticides are used, they have contaminated groundwater aquifers and surface waters. Animal wastes are another source of persistent pollution in some areas. The water that goes back into rivers and streams after being used for irrigation is often severely degraded by excess nutrients, salinity, pathogens, and sediments that often render it unfit for any further use, unless cleaned—typically at great expense—by water purification plants (102).

In the US, agricultural chemicals, eroded sediment, and animal wastes have fouled over 173,000 miles of waterways. Farming is said to be responsible for 70% of current water pollution in the US (223). In India, which depends on irrigated agriculture for food supplies, more than 4 million hectares of high-quality land have been abandoned because of salinization and waterlogging caused by too much irrigation (164). The world's tremendous output of pollutants challenges the capacity of waterways to assimilate or flush away pollution. A saying among water engineers is "the solution to pollution is dilution." This truism is taking on frightening dimensions. Each year roughly 450 cubic kilometers of waste water are discharged into rivers, streams, and lakes. To dilute and transport this dirty water before it can be used again, another 6,000 cubic kilometers of clean water are needed—an amount equal to about two-thirds of the world's total annual useable fresh water runoff (223). If current trends were to continue, the world's entire stable river flow would be needed just for pollutant transport and dilution by the middle of the next century, according to an estimate by the UN Food and Agriculture Organization (187).

In Manila, the Philippines, as in many other cities worldwide, water pollution is pervasive. In developing countries an average of 90% of all domestic sewage is discharged into surface waters without any kind of treatment. In Europe many rivers and lakes are highly contaminated with industrial and agricultural pollutants.
### Table 2. Major Water-Related Diseases

<table>
<thead>
<tr>
<th>Disease</th>
<th>Cause and Route of Transmission</th>
<th>Geographic Extent</th>
<th>Number of Cases*</th>
<th>Deaths Per Year</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Major Water-Borne Diseases</strong></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Amoebic dysentery</td>
<td>Protozoa travel the fecal-oral route via contaminated water, food, person-to-person contact.</td>
<td>Worldwide</td>
<td>500 million per year</td>
<td>*</td>
</tr>
<tr>
<td>Bacillary dysentery</td>
<td>Bacteria travel the fecal-oral route via contaminated water, food, person-to-person contact.</td>
<td>Worldwide</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Cholera</td>
<td>Bacteria travel the fecal-oral route via contaminated water, food, person-to-person contact.</td>
<td>South America, Africa, Asia</td>
<td>384,000 per year</td>
<td>20,000</td>
</tr>
<tr>
<td>Hepatitis A</td>
<td>Virus travels the fecal-oral route via contaminated water, food, person-to-person contact.</td>
<td>Worldwide</td>
<td>600,000 to 3 million per year</td>
<td>2,400 to 12,000</td>
</tr>
<tr>
<td>Paratyphoid and typhoid</td>
<td>Bacteria travel the fecal-oral route via contaminated water, food, person-to-person contact.</td>
<td>80% in Asia; 25% in Latin America; Africa</td>
<td>16 million currently</td>
<td>600,000</td>
</tr>
<tr>
<td>Polio</td>
<td>Virus travels the fecal-oral route via contaminated water, food, person-to-person contact.</td>
<td>Worldwide</td>
<td>82,000 currently</td>
<td>9,000</td>
</tr>
<tr>
<td><strong>Major Water-Borne Diseases</strong></td>
<td></td>
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<tr>
<td><strong>Larval</strong></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td><strong>Dracunculiasis</strong> (guinea worm)</td>
<td>Bacteria travel the fecal-oral route via contaminated water, food, person-to-person contact.</td>
<td>Worldwide</td>
<td>80% in Asia; 54% in Latin America; Africa</td>
<td>300-500 million per year (clinical)</td>
</tr>
<tr>
<td><strong>Paragonimiasis</strong></td>
<td>Worms living in pulmonary cysts lay eggs in human lungs, which are coughed up and then swallowed. Worm eggs are passed out in feces and break when in fresh water. Larvae find snail host in which to replicate, then discharged larvae enter water.</td>
<td>Far East, Latin America</td>
<td>5 million currently</td>
<td>None reported</td>
</tr>
<tr>
<td><strong>Schistosomiasis</strong> (bilharzia)</td>
<td>Eggs of the schistosome worm are passed out in human feces. Eggs hatch on contact with water, releasing the parasite miracidium. parasite moves into freshwater snail, where it replicates, is then carried back into water, where it penetrates human skin through intestines wall and diaphragm to lungs, where it mates.</td>
<td>Africa, Near East, rain forest belt in Central Africa, Western Pacific, Kimberley, Latin America</td>
<td>200 million currently</td>
<td>30,000</td>
</tr>
<tr>
<td><strong>Dengue</strong></td>
<td>Virus is picked up by a mosquito from an infected human or animal. The virus incubates for 8 to 12 days and reproduces. The next time the mosquito takes a blood meal, the virus is injected into a human's blood.</td>
<td>All tropical environments concentrated in Asia, Central and South America</td>
<td>50-100 million per year</td>
<td>24,000</td>
</tr>
<tr>
<td><strong>Filariasis (includes elephantiasis)</strong></td>
<td>Worm larvae are ingested by a mosquito and develop.</td>
<td>Africa, Eastern Mediterranean, Asia, Sub-Saharan Africa, India, South America</td>
<td>120 million currently</td>
<td>None reported</td>
</tr>
<tr>
<td><strong>Malaria</strong></td>
<td>Protozoa develop in gut of a mosquito and are passed on in saliva each time it takes a blood meal. Parasites are then carried by the blood to the human's body, where they invade the cells and multiply.</td>
<td>Africa, Southeast Asia, India, South America</td>
<td>300-500 million per year (clinical)</td>
<td>2 million</td>
</tr>
<tr>
<td><strong>Onchocerciasis</strong> (river blindness)</td>
<td>Worm embryos are ingested by black flies. Embryos then develop into larvae within the black flies, and the flies inject the larvae into humans when they bite.</td>
<td>Sub-Saharan Africa</td>
<td>18 million currently</td>
<td>None reported **</td>
</tr>
<tr>
<td><strong>WNV (West Nile fever)</strong></td>
<td>Virus usually exists in animal hosts. Virus is picked up by mosquitoes and other blood sucking insects and injected into the blood of humans. Humans also are infected while working with body fluids of avian animals,</td>
<td>Sub-Saharan Africa</td>
<td>NA</td>
<td>1% of cases</td>
</tr>
</tbody>
</table>

*Number of cases are reported as incidence (per year)—the number of new cases occurring in a year—or as prevalence (Currently)—the number of cases existing at a point in time.

**Included in diarrheal disease**

No deaths but causes 270,000 reported cases of blindness annually.


Population Reports
Developing countries. Pollution is a vexing problem in countries where the population is growing rapidly, development demands are great, and governments have other investment priorities. In developing countries, on average, 90% to 95% of all domestic sewage and 75% of all industrial waste are discharged into surface waters without any treatment whatsoever (126). Consider these examples:

- All of India's 14 major rivers are badly polluted. Together they transport 50 million cubic meters of untreated sewage into India's coastal waters every year. The city of New Delhi dumps 200 million liters of raw sewage and 20 million liters of industrial wastes into the Yamuna River every day as the river passes through the city on its way to the Ganges (81).
- In Thailand and Malaysia water pollution is so heavy that rivers often contain 30 to 100 times more pathogens, heavy metals, and poisons from industry and agriculture than is permitted by government health standards (125). Over three-quarters of China's 50,000 kilometers of major rivers are so filled with pollution and sediment that they no longer support fish life (1). In 1992 China's industries discharged 36 billion metric tons of untreated or partially treated effluents into rivers, streams, and coastal waters (208). In 1986, along sections of the Liao River, which flows through a heavily industrialized part of northern China, almost every aquatic organism within 100 kilometers was killed when over 1 billion tons of industrial wastes were dumped into the river in a period of three months (90).
- In Buenos Aires city, Brazil, 300 metric tons of untreated effluents from 2,100 industries are dumped into the Tiete River every day as it flows through the city. As a result, the river contains high concentrations of lead, cadmium, and other heavy metals. The city also dumps some 1,000 metric tons of sewage into the river every day, of which only 15% gets any treatment whatever (201).
- Karachi, Pakistan's largest city, has completely overwhelmed the capacity of its outdated sewage treatment plants. Because of frequent breakdowns and clogged sewage pipes, these plies often operate at no more than 15% of capacity. The great majority of all sewage water leaks out into the surrounding soil, contaminating the wells used by city residents for drinking water (151).

Industrial and municipal pollutants. While agriculture remains the biggest source of water pollution, wastes from industries and municipalities have increased enormously in recent decades. Between 200 and 400 major chemicals are estimated to contaminate the world's rivers (160). Industrial pollutants, such as wastes from chemical plants, are often dumped directly into waterways. Oils and salts are washed off city streets. Heavy metals and organochlorines are leached from municipal and industrial dump sites (41). Furthermore, pollutants such as sulfur dioxide and oxides of nitrogen, which combine in the atmosphere to form acid rain, have had pervasive effects on both freshwater and land ecosystems. Acid rain lowers the pH of rivers and streams. Unless buffered by calcium (as contained in limestone), acidified waters kill many acid-sensitive fish, including salmon and trout. In the soil, acids can release heavy metals, such as lead, mercury, and cadmium, that then percolate into waterways (88).

Some of the worst pollutants are synthetic chemicals. Some 70,000 different chemical substances are in regular use throughout the world (147). Every year an estimated 1,000 new compounds are introduced (207). Many of them find their way into rivers, lakes, and groundwater aquifers. In the US alone, more than 700 chemicals have been detected in drinking water, 129 of them considered highly toxic (112).

A number of synthetic chemicals, particularly the group known as persistent organic pollutants (POPs), which include halogenated hydrocarbons, dioxins, and organochlorines such as DDT and PCBs, are long-lived and highly toxic in the environment (118). They do not break down under natural processes and thus tend to accumulate up the biological food chain, until they pose risks to human health. For example, Beluga whales swimming in the highly polluted St. Lawrence River, which connects the Atlantic Ocean to North America's Great Lakes, have such high levels of PCBs in their blubber that, under Canadian law, they now qualify as "toxic waste dumps" (147). Indigenous communities that once hunted these whales no longer are permitted to take any because of the health risks.

Water-related diseases are a human tragedy, killing millions of people each year, preventing millions more from leading healthy lives, and undermining development efforts (121, 126). About 2.3 billion people in the world suffer from diseases that are linked to water (106, 174). Some 60% of all infant mortality is linked to infectious and parasitic diseases, most of them water-related (116). In some countries water-related diseases make up a high proportion of all illnesses among both adults and children. In Bangladesh, for example, an estimated three-quarters of all diseases are related to unsafe water and inadequate sanitation facilities. In Pakistan one-quarter of all people attending hospitals are ill from water-related diseases (5).

Providing clean supplies of water and ensuring proper sanitation facilities would save millions of lives by reducing the prevalence of water-related diseases (174). Thus, finding solutions to these problems should become a high priority for developing countries and assistance agencies. While water-related diseases vary substantially in their nature, transmission, effects, and management, adverse health effects related to water can be classified into three categories: water-borne diseases, including those caused by both fecal-oral organisms and those caused by toxic substances; water-based diseases; and water-related vector diseases (14, 216) (see Table 2). Another category—water-scarce (also called water-washed) diseases—consists of diseases that develop where clean freshwater is scarce (216).

Water-borne Diseases

Water-borne diseases are "dirty-water" diseases—those caused by water that has been contaminated by human, animal, or chemical wastes. Worldwide, the lack of sanitary waste disposal and of clean water for drinking, cooking, and washing is to blame for over 12 million deaths a year (35, 190). Water-borne diseases include cholera, typhoid, shigellosis, polio, meningitis, and hepatitis A and E. Human beings and other animals can act as hosts to the bacterial, viral, or protozoal organisms that cause these diseases. Millions of people have little access to sanitary waste disposal or to clean water for

POPULATION REPORTS
A Successful Solution: The Global Guinea worm (Dracunculus) may soon become the first parasitic disease to be eliminated completely by human efforts, thanks to a worldwide eradication campaign (201). The campaign, initiated by the Carter Center to help national eradication programs, included making improvements in community water supplies, distributing cloth water strainers to families, providing health education, and monitoring disease surveillance (24).

To locate the areas in which guinea worm disease is endemic, the eradication campaign works closely with local health workers. In Pakistan and India, cash rewards up to US$500 were offered and publicized widely to help find any remaining guinea worm cases (201). A registry of reports of potential cases was created, and reports were promptly investigated by program staff. Cases found in Pakistan were paid up to US$130 to comply with containment measures, keeping the skin where the worm is emerging wrapped and abstaining from entering water, which prevents the worm from releasing more eggs (155, 191).

School teachers use visual aids and books provided by the eradication program to teach children how to avoid infection, while health educators instruct residents how to strain their drinking water through the cloth filters. In endemic areas water is treated with low concentrations of a nontoxic larvicide, temephos (Abate) (24). These efforts are concentrated in the growing season, when the larvae typically reappear (201) (see Table 2, p. 14).

In 1997, 19 countries where guinea worm was once endemic were officially certified as free of guinea worm transmission—that is, no cases had been reported for three consecutive years (201) (see Table 2, p. 14). A registry of reports of potential cases was created, and reports were promptly investigated by program staff. Cases found in Pakistan were paid up to US$130 to comply with containment measures, keeping the skin where the worm is emerging wrapped and abstaining from entering water, which prevents the worm from releasing more eggs (155, 191).

Personal hygiene. An estimated 3 billion people lack a sanitary toilet, for example. Over 1.2 billion people are at risk because they lack access to safe freshwater (99, 176, 195, 202). Where proper sanitation facilities are lacking, water-borne diseases can spread rapidly. Untreated excreta wash or leach into freshwater sources, contaminating drinking water and food. The extent to which disease organisms occur in specific freshwater sources depends on the amount of human and animal excreta that they contain (13).

Diarrheal disease, the major water-borne disease, is prevalent in many countries where sewage treatment is inadequate. Instead, human wastes are disposed of in open latrines, ditches, canals, and water courses, or they are spread on cropland. An estimated 4 billion tons of sewage disease occur every year, causing 3 million to 4 million deaths, mostly among children (126, 190, 195, 198).

Using contaminated sewage for fertilizer can result in epidemics of such diseases as cholera. These diseases can even become chronic where clean water supplies are lacking. In the early 1990s, for example, raw sewage water that was used to fertilize vegetable fields caused outbreaks of cholera in Chile and Peru (115, 174). In Buenos Aires, Argentina, a slum neighborhood faced continual outbreaks of cholera, hepatitis, and meningitis because only 4% of homes had either water mains or proper toilets, while poor diets and little access to medical services aggravated the health problems (3).

Toxic substances that find their way into freshwater are another cause of water-borne diseases. Increasingly, agricultural chemicals, fertilizers, pesticides, and industrial wastes are being found in freshwater supplies (see p. 13). Such chemicals, even in low concentrations, can build up over time and, eventually, can cause chronic diseases such as cancers among people who use the water (169).

Health problems from nitrates in water sources are becoming a serious problem almost everywhere. In over 130 countries nitrates from fertilizers have seeped into water wells, fouling the drinking water (112). Excessive concentrations of nitrates cause blood disorders (13). Also, high levels of nitrates and phosphates in water encourage growth of blue-green algae, leading to deoxygenation (eutrophication). Oxygen is required for metabolism by the organisms that serve as purifiers, breaking down organic matter, such as human wastes, that pollute the water. Therefore the amount of oxygen contained in water is a key indicator of water quality. Pesticides such as DDT and heptachlor, which are used in agriculture, often wash off in irrigation water. Their presence poses a significant threat to aquatic life and can lead to the loss of biodiversity. Other contaminants, such as heavy metals and pesticides, can accumulate in the food chain, posing a risk to human health.
Guinea Worm Eradication Effort

consecutive years. In the 16 countries of Africa, as well as in India and Yemen, where guinea worm still exists, prevalence is dwindling (201). Sudan, however, still has more than 100,000 cases of guinea worm—an estimated 78% of the world's total cases—largely because civil war makes surveillance difficult (189). Nevertheless, Kenya, although it is highly susceptible to the reintroduction of guinea worm from neighboring Sudan, has reported no cases for several years (201).

Ten years ago guinea worm afflicted millions of people in Africa and Asia. Today, only 10 countries report more than 1,000 cases. In 1989 Ghana reported 180,000 cases, but reported only 7,000 in 1994. Recent progress has been even more rapid. For example, in 1992 Niger reported 33,000 cases but reported only about 3,000 in 1996. In 1994 India reported almost 40,000 cases but reported only 9 cases in 1996 (201). If progress continues, guinea worms may soon be a thing of the past.

in water and food products has alarming implications for human health because they are known to cause cancer and also may cause low sperm counts and neurological disease (13). In Ohaka, Bangladesh, heptachlor residues in water sources have reached levels as high as 789 micrograms per liter—more than 25 times the WHO-recommended maximum of 0.3 micrograms per liter (210). Also, in Venezuela a study of irrigation water collected during the rainy season found that the water was contaminated with a number of pesticides. Examination of pregnant women in the area found that they all had breast milk containing DDT residues—toxins that can be passed to an infant (16).

The seepage of toxic pollutants into ground and surface water reservoirs used for drinking and household use causes health problems in industrialized countries as well. In Europe and Russia the health of some 500 million people is at risk from water pollution. For example, in northern Russia half a million people on the Kola Peninsula drink water contaminated with heavy metals, a practice that helps to explain high infant mortality rates and endemic diarrheal and intestinal diseases reported there (46).

Prevention and solutions. Improving public sanitation and providing a clean water supply are the two steps needed to prevent most water-borne diseases and deaths. In particular, constructing sanitary latrines and treating waste water to allow for biodegradation of human wastes will help curb diseases caused by pollution. At the least, solids should be settled out of waste water so that it is less contaminated. It is important that a clean water supply and the construction of proper sanitary facilities be provided together because they reinforce each other to limit the spread of infection (192).

Many studies link improvements in sanitation and provision of potable water with dramatic reductions in water-related morbidity and mortality (4, 7, 8, 9, 20, 31, 52, 78, 86, 100, 104, 116, 152, 171, 192, 212). A review in 1991 of over 100 studies of the effects of clean water and sanitation on human health found that the median reduction in deaths from water-related diseases was 69% among people with access to potable water and proper sanitation (52) (see Table 3).

Providing clean water and sanitation greatly reduces child mortality. According to a review of 144 studies from the 1980s, infant and child deaths fell by an average of 55% as a result of providing clean water and sanitation (190). In a study of countries where infant mortality rates dropped dramatically—as in Costa Rica, where the decline was from 68 deaths per 1,000 live births in the 1970s to just 20 per

POPULATION REPORTS
Water-based diseases are caused by aquatic organisms that spend part of their life cycle in the water and another part as parasites of animals. These organisms can thrive in either polluted or unpolluted water. As parasites, they usually take the form of worms, using intermediate animal vectors such as snails to thrive, and then directly infecting humans either by boring through the skin or by being swallowed (14).

Water-based diseases include guinea worm (dracunculiasis), paragonimiasis, clonorchiasis, and schistosomiasis (bilharzia). These diseases are caused by a variety of flukes, tapeworms, roundworms and tissue nematodes, often collectively referred to as helminths, that infect humans (119). Although these diseases usually are not fatal, they can be extremely painful, preventing people from working and some even making movement impossible.

The prevalence of water-based diseases often increases behind dams is ideal for snails, the intermediary host for many types of worms. For example, the Akosombo Dam, on the Volta Lake in Ghana, and the Aswan High Dam, on the Nile in Egypt, have resulted in huge increases of schistosomiasis. Millions of people suffer from infections that are transmitted by vectors—insects or other animals capable of transmitting an infection, such as mosquitoes and tsetse flies—that breed and live in or near both polluted and unpolluted water. Such vectors infect humans with malaria, yellow fever, dengue fever, sleeping sickness, and filariasis. Malaria, the most widespread, is endemic in about 100 developing countries, putting some 2 billion people at risk (26, 198). In sub-Saharan Africa malaria costs an estimated US$1.7 billion annually in treatment and lost productivity (126).

Prevention and solutions. Individuals can prevent infection from water-based diseases by washing vegetables in clean water and thoroughly cooking food. They can refrain from entering infected rivers, because many parasites bore through the feet and legs. In areas where guinea worm is endemic, people can use a piece of cloth or nylon gauze to filter out guinea worm larvae (see box, pp. 16-17) (14). As with water-washed diseases, providing hygienic disposal of human wastes helps control water-based diseases. Also, for irrigation channels and other constructed waterways, building fast-flowing streams makes it more difficult for snails to survive, thus eliminating the intermediary host (14).

Some water-development schemes have started disease control programs along with construction of facilities. In the Philippines, for example, where the development of water resources is a high priority, the National Irrigation System Improvement Project in Layug, begun in 1979, included specific provisions and funding to control schistosomiasis. As a result of these measures, the prevalence of water-based diseases fell from 24% in 1979 to 9% in 1985. Because fewer people fell ill, the average increase in productivity was an estimated 19 days of work per person per year, worth an additional US$1 million in wages (95).

### Table 3: Reducing Water-Related Disease

<table>
<thead>
<tr>
<th>Place</th>
<th>Place Type of Facilities or Improvement</th>
<th>Type of Study</th>
<th>Diseases Studied</th>
<th>Difference in Incidence After Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kerala, Bangladesh</td>
<td>Hand pumps and health education</td>
<td>Case-control</td>
<td>Diarrheal diseases</td>
<td>17% difference between groups</td>
</tr>
<tr>
<td>Northeast Brazil</td>
<td>Latrines, communal taps, laundry facilities, showers, and hand pumps</td>
<td>Case-control</td>
<td>Schistosomiasis</td>
<td>77% difference between groups</td>
</tr>
<tr>
<td>Khatunistan</td>
<td>Courtyard latrine and public standpipes</td>
<td>Case-control</td>
<td>Ascariasis</td>
<td>16% difference between groups</td>
</tr>
<tr>
<td>Uttar Pradesh, India</td>
<td>Piped water</td>
<td>Before and after</td>
<td>Dysentery</td>
<td>92% reduction in infant mortality between groups</td>
</tr>
<tr>
<td>Peninsular Malaysia</td>
<td>Toilets and running water</td>
<td>Case-control</td>
<td>Diarrheal diseases</td>
<td>92% reduction</td>
</tr>
<tr>
<td>Kwaara State, Nigeria</td>
<td>Boreholes, hand pumps, and health education</td>
<td>Before and after</td>
<td>Dracunculiasis</td>
<td>81% reduction</td>
</tr>
<tr>
<td>Ceko, Philippines</td>
<td>Private, sanitary latrines</td>
<td>Before and after</td>
<td>Diarrheal diseases</td>
<td>42% reduction</td>
</tr>
<tr>
<td>St. Lucia</td>
<td>Household water and latrines</td>
<td>Case-control</td>
<td>Ascariasis</td>
<td>31% difference between groups</td>
</tr>
<tr>
<td>Lesaka, Zambia</td>
<td>Extension of piped water supply</td>
<td>Before and after</td>
<td>Typhoid</td>
<td>37% reduction</td>
</tr>
</tbody>
</table>

**Impact of Improved Water Infrastructure, Selected Studies**

Source: Ery et al. 1991 (22); Van Demerle & Breman 1995 (116)

1,000 in the 1980s—researchers attribute these decreases to the mortality decline to water and sanitation projects provided as part of rural community health programs (211). While the cost of building freshwater supply systems and sanitation facilities is high, the costs of not doing so can become staggering. In Karachi, Pakistan, for example, a study found that poor people living in areas without any sanitation or hygiene education spent six times more on medical care than people who lived in areas with access to sanitation and who had a basic knowledge of household hygiene (99).

### Water-Related Vector Diseases

Millions of people suffer from infections that are transmitted by vectors—insects or other animals capable of transmitting an infection, such as mosquitoes and tsetse flies—that breed and live in or near both polluted and unpolluted water. Such vectors infect humans with malaria, yellow fever, dengue fever, sleeping sickness, and filariasis. Malaria, the most widespread, is endemic in about 100 developing countries, putting some 2 billion people at risk (26, 198). In sub-Saharan Africa malaria costs an estimated US$1.7 billion annually in treatment and lost productivity (126).

The incidence of water-related vector diseases appears to be increasing (202). There are many reasons: people are developing resistance to antimalarial drugs; mosquitoes are developing...
Lack of appropriate water management, along with failure to take biological methods and habitat management to reduce or eliminate the natural breeding grounds of the disease vectors (13). Such methods can include: filling and draining stagnant bodies of water; covering water storage containers; eliminating mosquito breeding sites by periodically clearing canals, reservoirs, and fish ponds of weeds; installing sprinkler and trickle irrigation systems; eliminating mosquito breeding sites by periodically clearing canals, reservoirs, and fish ponds of weeds; installing sprinkler and trickle irrigation systems; filling abandoned reservoirs; using biological methods and habitat management to reduce or eliminate the natural breeding grounds of the disease vectors (13). Such methods can include: filling and draining stagnant bodies of water; covering water storage containers; eliminating mosquito breeding sites by periodically clearing canals, reservoirs, and fish ponds of weeds; installing sprinkler and trickle irrigation systems; filling abandoned reservoirs; using biological methods and habitat management to reduce or eliminate the natural breeding grounds of the disease vectors (13). Such methods can include: filling and draining stagnant bodies of water; covering water storage containers; eliminating mosquito breeding sites by periodically clearing canals, reservoirs, and fish ponds of weeds; installing sprinkler and trickle irrigation systems; filling abandoned reservoirs; using biological methods and habitat management to reduce or eliminate the natural breeding grounds of the disease vectors (13). Such methods can include: filling and draining stagnant bodies of water; covering water storage containers; eliminating mosquito breeding sites by periodically clearing canals, reservoirs, and fish ponds of weeds; installing sprinkler and trickle irrigation systems; filling abandoned reservoirs; using biological methods and habitat management to reduce or eliminate the natural breeding grounds of the disease vectors (13). Such methods can include: filling and draining stagnant bodies of water; covering water storage containers; eliminating mosquito breeding sites by periodically clearing canals, reservoirs, and fish ponds of weeds; installing sprinkler and trickle irrigation systems; filling abandoned reservoirs; using biological methods and habitat management to reduce or eliminate the natural breeding grounds of the disease vectors (13).
No matter how freshwater is used—whether for agriculture, industry, or municipalities—there is great potential for better conservation and management. Water is wasted nearly everywhere. Until actual scarcity hits, most countries and most people take access to freshwater for granted.

“We have to stop living as if we had unlimited water supplies and start recognizing that we must deal with serious water constraints,” Falkenmark and colleagues have warned. The relevant question about freshwater is not “how much water do we need and where do we get it?” Rather, it is “how much water is there and how can we best benefit from it?” That is, we must do better at managing the demand for water rather than continuing to focus on “supply-oriented” water management (64).

On the demand side, a variety of economic, administrative, and community-based measures can help conserve water immediately. In the long run, slowing population growth will slow the increase in demand for water and help buy more time to develop better water conservation and management strategies (69).

In Asmara, Eritrea, one-third of the vegetables grown are irrigated with treated urban wastewater. Other countries also use this technique.

**Agriculture: Producing More from Less**

Since agriculture accounts for nearly 70% of all water withdrawn from rivers, lakes, and underground aquifers for human use, the greatest potential for conservation lies with increasing irrigation efficiencies. For example, increasing irrigation efficiency on the Indus Plains of Pakistan by just 10% would allow an estimated 2 million more hectares of farm land to be irrigated (30).

Most irrigation systems waste water. Typically, only between 35% and 50% of water withdrawn for irrigated agriculture ever reaches the crops. Most soaks into unlined canals, leaks out of pipes, or evaporates before reaching the fields (139). Although some of the water “lost” in inefficient irrigation systems returns to streams or aquifers, where it can be tapped again, water quality is invariably degraded by pesticides, fertilizers, and salts that run off the land. Poorly planned and poorly built irrigation systems have limited the yields on one-half of all irrigated land (185).

Paradoxically, even when sufficient irrigation water reaches agricultural fields, it can spoil much of the land unless drained properly. Particularly in many arid areas, salts that occur naturally in the soil must be drained away with irrigation runoff. If left to accumulate in the soil, they eventually work their way to the surface, poisoning the land (102). Also, poorly drained irrigation water can raise the groundwater table until it reaches the root zone, waterlogging and drowning crops. Globally, some 80 million hectares of farmland have been degraded by a combination of salinization and waterlogging (185).

**Improving irrigation efficiency.** A number of countries are working to improve irrigation efficiencies, thus saving water and protecting the land. Drip irrigation is one technique. Drip irrigation consists of a network of porous or perforated piping, usually installed on the surface or below ground, which delivers water directly to the root zones of the crops. This technique keeps evaporation losses low, at an efficiency rate of 95%. Drip irrigation systems cut water use by an estimated 40% to 60% compared with gravity systems (139, 142).

In the 1970s drip irrigation systems were used on only 56,000 hectares worldwide, mostly to supply water for vegetables and fruit orchards in Australia, Israel, Mexico, New Zealand, South Africa, and the US. By 1991 this figure had grown to 1.6 million hectares. Although this area constitutes less than 1% of all irrigated land worldwide, drip irrigation is widely used in some countries. Israel, for instance, uses drip irrigation on 50% of its total irrigated area (142).

Another promising conservation method—low-energy precision application (LEPA)—offers substantial improvements over conventional sprinkler systems that spray water into the air. Instead, the LEPA method delivers water to the crops from drop tubes that extend from the sprinkler’s arm. When applied together with appropriate water-saving farming techniques, this method also can achieve efficiencies as high as 95%. Since this method operates at low pressure, energy costs drop by 20% to 50% compared with conventional systems. Farmers in Texas who have retrofitted conventional sprinkler systems with LEPA have reported that their yields have increased by as much as 20% and that their investment costs have been recouped within one or two years (139, 142).

**Irrigation options for the rural poor.** Many developing countries cannot afford to invest in such techniques as drip irrigation and LEPA. Yet pressures to feed rapidly growing populations cannot be ignored.
rural populations require making better use of scarce freshwater resources. In many regions that face acute seasonal water shortages, censer-vation projects are working with rural farmers to build small reservoirs that collect and store water from the rainy season for use in the dry season (33). Also, in parts of East Africa subsistence farmers use “water harvesting”—ancient techniques that consist mainly of digging deep holes near each plant to collect and store water from the rainy season for use during the dry season (35, 186). Another traditional method involves placing long lines of stones along the contours of gently sloping ground to slow runoff and spread the water across a wider area. Developed in the Yatenga region of Burkina Faso, this method is now being used on over 8,000 hectares in 400 villages throughout the country. It is also used in Kenya and Niger. Combined with the practice of deep-hole water harvesting, this practice has increased crop production by about 50% (30, 35).

Reusing urban wastewater. A number of countries channel treated urban wastewater from towns and cities onto nearby farms growing vegetables and fruits. Today at least half a million hectares in 15 countries are being irrigated with treated urban wastewater, often referred to as “brown water.” Israel has the most ambitious brown-water program of any country. Most of Israel’s sewage is purified and reused to irrigate 20,000 hectares of farm land (139). Some developing countries also use this technique (177):

- In Mexico City treated urban wastewater irrigates and fertilizes alfalfa fields. The alfalfa in turn is sold as feed to small-scale farmers who raise guinea pigs and rabbits.
- One-third of the vegetables grown in Asmara, Eritrea, are irrigated with treated urban wastewater.
- In Lusaka, Zambia, one of the city’s biggest squatter settlements irrigates its vegetable crops with sewage water from nearby settling ponds.

Some places apply the same concept differently. For example, Calcutta, India, channels much of its raw sewage into a system of natural lagoons, where fish are raised. The city’s 3,000 hectares of lagoons produce about 6,000 metric tons of fish a year for urban consumption (177). The fish are safe to eat because the lagoons soak up and clean the sewage. Unless urban wastewater receives some pretreatment, either from natural wetlands or sewage treatment plants, however, it can transfer disease organisms to vegetables and fruits and endanger human health.

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Industry is water-intensive. For example, making one ton of steel can require almost 300 tons of water. In many countries water-intensive industries such as chemicals, iron and steel, and pulp and paper are making impressive progress in recycling water and reducing the amount of water needed for production.

Industry is water-intensive. For example, making one ton of steel can consume as much as 300 tons of water. In developed countries industries use from one-half to three-quarters of all water withdrawals compared with about one-quarter as the global average (139) (see p. 7). Driven by stiffer regulations and the need to cut costs, such water-intensive industries as chemicals, iron and steel, and pulp and paper have made impressive strides in reducing the amount of water needed for production. In some countries these industries are both reusing and recycling water in current production processes and also redesigning production processes to require less water per unit of production. Consider these examples (139):

- In the US, industrial water use fell by over one-third between 1950 and 1990, while industrial output nearly quadrupled.
- In the former West Germany the total amount of water used in industry today is the same as in 1975, while industrial output has risen by nearly 45%.
- In Sweden strict pollution control measures have cut water use in half in the pulp and paper industry, while production has doubled in little more than a decade.

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Recycling waste for agricultural purposes by using oxidation ponds and aerated lagoons does not require as much land as is often assumed. Moreover, it decreases pollution, reduces the need for fertilizers, and often can be accomplished with “small-scale, low-cost technology that is based in local traditions, decentralized, and ecologically sound,” according to water resource engineer Janus Niemczynowicz (124).
In a poor neighborhood of Santo Domingo, Dominican Republic, a resident taps water from a broken pipe under a sidewalk. Many cities face serious problems trying to supply water to their residents. In developing countries, however, there is tremendous scope for saving water in industry. Take China, for instance: The amount of water needed to produce a ton of steel ranges from convenient access to running water, consumers often use their water. For example, Geneva, Switzerland, loses only 13% of its water on the way from source to consumer (203). In Moscow, 30% of the water intended for consumers leaks out of the system instead (131).

Municipal Conservation
Conserving water for personal use in cities (including use by households and municipalities) requires managing both the supply of and demand for water. Much of the municipal water supply is lost before it can reach consumers, leaking out of water mains, pipes, and faucets, or disappearing through illegal taps (43, 192). Moreover, when they have convenient access to running water, consumers often use much more water than they actually need. For instance, in the US average personal water use is nearly 600 liters per day compared with about 50 liters per day in India (53).

Supply. Municipal water supply faces problems almost everywhere. A 1986 survey of 15 Latin American cities found that municipal systems lost between 40% and 70% of their water (203). In India over 40% of the total municipal water supply is lost in transit, before it can reach consumers (170). Even in Malta, one of the world’s most water-abstracted countries, 30% of the water intended for consumers leaks out of the system instead (131). Municipal supply systems do not have to lose so much of their water. For example, Geneva, Switzerland, loses only 13% of their water (203). In India over 40% of the total municipal water supply is lost in transit, before it can reach consumers (170). Even in Malta, one of the world’s most water-abstracted countries, 30% of the water intended for consumers leaks out of the system instead (131).

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scarce water supplies, sustainable development is impossible (17, 190, 218). Four principal policy weaknesses, in general, underscore the world's inability to manage freshwater supplies for sustainable development, according to Ismail Serageldin, Vice President for Environmentally Sustainable Development at the World Bank (164):

1. Water management is fragmented among sectors and institutions. There are too many agencies with their fingers on the water tap and virtually no coordination of policies between sectors of the economy. Issues of water quality and health often go entirely unaddressed because they do not fit within the mandate of any single government agency.

2. Governments depend too much on centralized administration to develop, operate, and maintain water systems. Agencies charged with managing water supplies often are already overextended and lack technical competence. At the same time, there is little stakeholder involvement and community participation in setting water policies and regulating use. So projects often do not meet people's needs.

3. Most countries undervalue freshwater as a resource and do not price it at its economic value. Many heavy users of water, such as farmers, receive government subsidies and in effect are encouraged to waste water that they otherwise probably would not waste. Most governments have found it politically more palatable to develop new water supplies than to charge heavy users the full costs of water.

4. Water management policies do not link the quality of water to human and environmental health. In most cases water is viewed as a resource to be pumped around and used as often and as much as needed for any purpose. Without adequate consideration of water's key role in human and environmental health, it is little wonder that water resources are degraded nearly everywhere.

Freshwater is the universal necessity—providing all forms of life with sustenance, nurturing natural ecosystems, and transporting and diluting wastes. Without assured supplies of freshwater, living standards decline, people suffer, and development becomes more difficult. Insuring sustainable development increasingly will require wise policies and effective strategies that not only conserve and protect freshwater sources but also manage them equitably to meet the needs of consumers, industry, and agriculture.

The Need to Slow Population Growth

While the links between population and freshwater resources are complex, there is no doubt that population growth increases the demand for freshwater (110). While new approaches in managing water supply and demand can help in the short term, reducing population growth is necessary to avoid catastrophe in the long term. There is an urgent need, therefore, to slow population growth and to stabilize population size as soon as possible (64).

When water scarcity affects countries in all regions of the world, it is particularly a problem in developing countries. Nearly three-quarters of the world's population of 6 billion live in developing countries. Moreover, close to 95% of population growth is taking place in the developing world. At current fertility rates, populations in sub-Saharan Africa, the Near East, and parts of South Asia would double in another 20 to 40 years (37, 182). At projected growth rates, by the year 2050 the global population's expected to be 9.4 billion, of whom 8 billion will live in developing countries (182).

How can population growth be slowed? Providing widespread access to family planning has already helped millions of couples who want to space and limit births. Family planning programs have helped lower fertility rates worldwide over the past 30 years, particularly in developing countries (159). Nevertheless, in the developing countries alone there are at least 100 million married women, and probably millions more unmarried people, who want to avoid pregnancy but are not using any contraception, according to surveys (158). Meeting this unmet need for family planning would avoid about one-third of the projected population increase in developing countries over the next half century (117).

Also, family planning and reproductive health services need to be extended and improved to serve the millions more people who are coming of reproductive age. As the world's population grows by 80 million each year, these young people's future decisions about family size and resource use will have a powerful impact on world conditions (113). About half of the projected population increase over the next 50 years will result from the fact that some 3 billion people will enter their reproductive years over the next 25 years. This number equals the entire world population in 1960. Providing these young couples with family planning information and services on a voluntary basis is essential. Even if each decided to have only two children apiece—replacement-level fertility—the world's population would still grow by nearly 2 billion over the next 50 years (117). For some countries, this fact makes a water crisis inevitable. For many others, it signals the need to address water demand and water supply issues immediately.

Towards a Blue Revolution

The world needs a Blue Revolution in water management, just as we need another Green Revolution in agriculture (91). Time is of the essence. Dwindling freshwater supplies per capita are threatening the health and living standards of millions of people in a growing number of countries, as well as undermining agricultural development. Achieving a blue revolution will require coordinated policies and responses to problems at international, national, and local levels.

International Responses

Countries have agreed to numerous recommendations at international conferences on water over the past 20 years. For the most part, however, the international development community and national governments have yet to turn these words into action (174).

The first international conference to draw attention to the coming water crisis was in 1977—the United Nations Water Conference held in Mar del Plata, Argentina (218). Several others have followed, including the Global Consultation on Safe Water and Sanitation for the 1990s, held in New Delhi in 1990, and the International Conference on Water and the Environment, held in Dublin in 1992.

POPULATION REPORTS
Wars over Water?

Conflicts over water—both political and violent—could erupt in coming decades as more countries, with larger and larger populations, face water stress and outright water scarcity, according to Peter Gleick of the Pacific Institute for Studies in Development, Environment, and Security. To Gleick, the potential for conflict is "symptomatic of our inability in general to manage limited supplies of freshwater on a sustainable basis." (73)

In particular, problems could erupt in a number of areas where freshwater use has already reached or even exceeded natural limits (62, 140). In these areas, mostly in North Africa and the Near East, countries not only face mounting internal competition for limited supplies of freshwater as a result of rapid population growth and escalating demand, but also find themselves squabbling with their neighbors over water rights. For example:

- **Water** has been at the center of a continuing controversy between Israel and Jordan. In May 1997 a ceremony to create a joint "peace park" on the site where seven Israeli school girls were killed by a Jordanian border guard was canceled after Jordan charged Israel with delaying implementation of a water agreement to the Jordan-Israel Peace Treaty of 1994. Under the treaty Jordan was to receive an additional 50 million cubic meters of water a year from Israel, mostly from the Yarmouk River, one of the River Jordan's main tributaries. (43). The treaty did not state who would pay for the water and its transportation, however. Since the May 1997 "peace park" crisis, Israel has offered to foot half the bill, and the Israeli cabinet has approved a plan to supply Jordan with 50 million cubic meters of water, constituting the second transfer under the treaty.

- Israel already has used its military power to maintain access to the Jordan River. In the early 1960s Israeli soldiers halted a Syrian-Jordanian scheme to divert the river for irrigation. Later, Israel occupied vital sections of the Jordan River's headwaters, thus making sure that most of its flow would be available for Israeli towns and farms (67).

- **Egypt** has threatened to go to war if it carries out plans to divert more water from the Blue Nile for agricultural use. The Egyptian government sees this issue as one of life or death (67). Without the Nile's nourishing waters, Egypt could not exist as a nation, since it depends on the Nile for 98% of its freshwater needs.

- The **Southeast Anatolia Project in Turkey** is one of the largest irrigation and power generation schemes in the Near East (103). This vast complex of dams, canals, and irrigation systems began operating in July 1992. By early in the next century it is expected to divert at least half of the flow of the Euphrates River—some 4 trillion gallons of water a year—into Turkish dams and irrigation canals. This diversion will leave the downstream countries, Syria and Iraq, with less than half of the stable flow they now have access to. Syria also is planning to take some 3.5 trillion gallons out of the Euphrates before it enters Iraq, thus depriving Iraqi farmers of badly needed irrigation water—water that people in the area have had access to for the past 6,000 years (120). The entire region is set for a potentially vicious conflict over limited water resources.

The Dublin Water Principles, agreed to at the 1992 conference, summarize the principles of sustainable water management:

- **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 uses and should be recognized as an economic good.

More recently, in 1997 a comprehensive assessment of global freshwater resources, based on a series of expert background analyses, was prepared for the fifth session of the UN Commission on Sustainable Development (174, 214, 215, 216, 217, 218, 219, 220, 223, 222). As a 1998 report of the Secretary-General states, "The assessment concludes that water shortages and pollution are causing widespread public health problems, limiting economic and agricultural development, and harming a wide range of ecosystems. Those problems may threaten global food supplies and lead to economic stagnation in many areas of the world. The result could be a series of local and regional water crises, with serious global implications" (223).

Making needed investments. Turning principles into practice will be difficult. Most countries need massive investments in sanitation and water supply infrastructure. In the developed world, for example, the United Kingdom must spend close to US$60 billion building wastewater treatment plants over the next decade in order to meet new European water quality standards. This amounts to about $1,000 for every person in the country (166). Hungary faces similar problems. One-fifth of the country's population is not connected to a functioning sewer system. Hungary will need to invest about US$3.5 billion over the next two decades to connect all of its citizens to wastewater treatment plants (71). In developing countries one of the most pressing problems is the overwhelming need to invest heavily in sanitation facilities and the provision of clean water. The World Bank has estimated that over the next decade between US$400 billion and US$500 billion will be required to meet the total demand for freshwater, including for sanitation, irrigation, and power generation (164).

Of this huge amount, the World Bank will be able to lend only US$33 to $40 billion at most (164, 165). The remainder will have to come from a combination of public funding and private investment. It will be difficult, if not impossible, for most developing countries to finance the remainder, however. In Latin America alone, for instance, it is estimated that investments in water resources management and infrastructure will require $100 billion over the course of the next two decades (67). Avoiding international conflicts. An important part of any international water-management strategy is to help countries that share river basins fashion workable policies to manage water resources more equitably. A water-short world is an inherently unstable world. Nearly 100 countries share just 13 major rivers and lakes. More than 200 river systems cross international borders (137). Conflicts can arise, especially where countries with rapidly growing populations and limited arable land collide over access to shared freshwater resources (222) (see box, this page).
The case of India and Bangladesh demonstrates how international river basins can be managed to meet demand in the face of scarce water supplies (137). The Ganges, the subcontinent’s largest and most important river, rises in Nepal and flows 1,400 miles through three densely populated Indian states—Uttar Pradesh, Bihar, and West Bengal—before entering Bangladesh and flowing into the Bay of Bengal. The river is the lifeblood of half a billion people, many of whom depend on the river for subsistence agriculture and fishing. After half a century of bitter rivalry over access to the waters of the Ganges, India and Bangladesh signed a new 30-year water-sharing agreement in December 1996. Both countries have proclaimed a new era of water management (119).

The agreement, if implemented fully, will provide Bangladesh with a guaranteed minimum amount of water during the dry season, especially the three driest months of March, April, and May. The new treaty sets 10-day periods during these three months when India and Bangladesh will alternately have access to an agreed-upon amount of the water reaching the Farakka Barrage, a huge dam built by India in 1974 in an effort to claim as much of the water for its own use as possible before the Ganges enters Bangladesh. In order to ensure implementation of the agreement, a team of inspectors from the two countries will monitor the flow rate at the Farakka Barrage during the dry months (119).

Critics argue that, if the agreement is to work over the long term, India must begin to manage the Ganges watershed much better than it does now (37, 163). Deforestation in Nepal and northern India has greatly increased the amount of sediment washed from the hills into the river during the monsoon season, clogging waterways and increasing the incidence of damaging floods. Unless ways can be found to capture more stable monthly runoff during the wet season for use during the dry season, Indian farmers might be tempted to take all the water they can get from the river during the driest months, putting the agreement in jeopardy.

Despite such caveats, the fact that two neighboring countries have successfully negotiated and reached a comprehensive agreement over such a contentious issue is a positive sign. It promises to permit downstream Bangladesh a more equitable supply of water from the Ganges and to foster better water management practices in upstream India (137).

National Responses

In water-short countries national governments need to give water resources management their highest priority. Crafting and implementing a national water strategy is essential to sustainable development. Such a strategy should include four elements:

- Adopting a watershed or river-basin management perspective, especially in water-short regions (also appropriate as an international response, since watersheds frequently cross national boundaries);
- Instituting a workable water infrastructure so that national, regional, and local water needs can be met within the context of a national water policy;
- Enacting and enforcing water legislation and regulations that conserve water and value the resource properly according to type of use; and
- Connecting water management to the needs of agriculture, industry, and municipalities, and meeting public health requirements for proper sanitation and disease prevention.

1. A watershed management perspective. Watershed management refers to managing an entire land area served by all the rivers and aquifers that drain into a particular body of water (such as a semi-enclosed bay). River basin management is essentially the same concept applied to one river system, although the two terms are used interchangeably. The US defines a watershed as the entire area drained by a river system or one of its major tributaries. The UK defines a watershed as the divide between river basins, a potentially much larger area. No matter how it is defined, “we need to see a river or lake, along with its entire watershed and all its physical, chemical, and biological elements, as part of a complex, integrated system,” according to Janet Abramovitz of the Worldwatch Institute (1).

Everyone has a watershed address: We all live in basins that drain rainwater into streams and rivers that eventually send the water back to the sea or into inland lakes. The people living in most of these addresses have radically altered the natural drainage systems around them. Tampering with watersheds has proved ruinous for many developing countries, where hillsides denuded of vegetation empty tons of soil into water courses every year, causing floods during the wet seasons and suffocating aquatic life during the dry seasons. Deforestation has ruined land and altered climates, causing less rain to fall in some areas. In others, rainfall runs off so fast that little can be collected for use. In sub-Saharan Africa, for example, national governments have declared a new era of water management. Both countries have proclaimed a new era of water management (119).
Restoring the Chesapeake Bay

Watershed management is complicated and can be contentious because watershed boundaries do not coincide with those of political or administrative jurisdictions. Thus management involves many levels of government and many different communities, each with its own constituencies and concerns. Balancing the multitude of interests involved is so time consuming and troublesome that watershed management rarely succeeds.

It can be done, however, as shown by the example of the Chesapeake Bay. North America’s largest brackish water estuary, the Chesapeake watershed presents a unique and seemingly insurmountable obstacle. Although the Bay itself covers only 2,200 square miles (5,500 square kilometers) and averages just 21 feet deep (6.5 meters), its watershed is vast, sprawling over 64,000 square miles (160,000 square kilometers) through six US states. Moreover, 15 million people live in the watershed, which is one of the most heavily populated areas on the East Coast (22).

By the early 1980s planners were confronted with the consequences of decades of accumulated abuse of the water resources in the Chesapeake watershed. Signs of decay everywhere:

- By 1987 the Bay was receiving about 184,000 metric tons of nitrogen and 74,000 metric tons of phosphorus a year from humans and animal wastes and commercial fertilizers.
- The Bay had lost more than half of its natural tidal and non tidal wetlands and 40% of its freshwater forests.
- Seagrass beds, which once covered half the Bay’s bottom, amounting to several hundred thousand acres, had been reduced to no more than 34,000 acres (14,000 hectares) by 1984—10% to 20% of their original area.
- Chronic overfishing, along with mounting pollution and habitat degradation, contributed to the dramatic decline in the Bay’s fish and shellfish populations. Commercial catches of rockfishes (seabass) dropped from 2,608 metric tons in 1970 to just 272 metric tons in 1983. The Bay’s oyster fishery had plunged catastrophically. From an all-time peak of 20 billion oysters in 1884, the oyster harvest declined to just 168,000 bushels in 1992.

A handful of local environmentalists launched the initiative to save the Bay in the late 1960s. At the time few people anticipated their efforts would blossom into a six-state, watershed-wide program to restore the Chesapeake. Eventually, the effort would become a multimillion dollar restoration that would involve local, state, and federal agencies and tens of thousands of people from all walks of life.

A nonprofit membership organization, the Chesapeake Bay Foundation, was one of the key groups urging state governments to take a comprehensive watershed approach to the Bay’s environmental problems. After a slow start in the early 1980s, the three key state governments—Maryland, Virginia, and Pennsylvania—with help from the US Environmental Protection Agency (EPA), agreed to launch an ambitious, integrated cleanup program.

In 1987, when the EPA and the governors of the three main watershed states met at a major strategy conference, nothing on this scale had ever been attempted before in the US. The result was the Chesapeake Bay Agreement between the

example, the albedo effect—the drying of the landscape as a result of the wholesale clearance of tropical forests and poor farming practices—has resulted in below-average rainfall over the past 40 years compared with the century as a whole (2). Watershed or river basin management pays multiple benefits. The Murray-Darling River Basin Commission in Australia, for instance, is an intergovernmental organization whose main aim is to coordinate the management of water resources across state borders within the Murray-Darling River Basin, the country’s largest river system (79). The commission’s technical abilities are comprehensive, covering river management and ecology, environmental impacts, finance and administration, and communication. All development activities within the river basin fall under the jurisdiction of the commission, and all government agencies connected to water management and its uses must collaborate (79).

In India, as a result of the 1987 National Water Policy Act, the states of Rajasthan and Gujarat are setting up a committee to regulate and control water use in the Sabarmati River Basin, which encompasses parts of both states (128). The average amount of water available in the Sabarmati River Basin amounts to no more than 360 cubic meters per person per year, making it one of the most water-stressed regions in the country (128). Water is not only a very limited resource, but it is also increasingly polluted by irrigated agriculture.

To deal with these problems, the committee will regulate and manage water resources in the entire river basin, with a structure that gives a voice to representatives from each major water user group. The committee hopes to establish broad

26 POPULATION REPORTS
To build capacity, the following measures are needed:

1. Assessing national capacity-building requirements. It is vital for governments to know the capacities of their water-sector agencies as a first step toward improvements.

2. Building institutional capacity. Managing watersheds and river basins sustainably means building institutional capacity. The technical and administrative competence of national, regional, and local agencies responsible for water management must be strengthened before progress can be made in water management.

3. Valuing freshwater resources. Freshwater must be valued as a scarce resource, instead of being considered supply needs and how to satisfy them, a demand-oriented approach is increasingly needed.

4. Creating competent administrative and legal structures. Since water issues embrace societal concerns and cultural values, water agencies should reach beyond the water-sector agencies as a first step toward improvements.

5. Making institutions more responsive and effective. Water-management agencies, both public and private, must also be able to respond to changing situations (political and social as well as environmental). Static organizations and outmoded procedures need to be overhauled, especially as countries enter the water-stressed category.

6. Establishing closer ties to universities and research institutes. Since water issues embrace societal concerns and cultural values, water agencies should reach beyond the usual government channels and draw on a wide spectrum of opinion and expertise in order to assess freshwater issues and find solutions.

7. Training senior water managers. Few hydrologists have been trained to consider water resources broadly. As well as an engineering approach to water management that considers supply needs and how to satisfy them, a demand-oriented approach is increasingly needed.

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part of any long-term solution is worldwide recognition of the links between rapid population growth and shrinking freshwater supplies. A commitment to solve the world’s water problems will require local, national, and international responses. Furthermore, a vital part of any long-term solution is worldwide recognition of the links between rapid population growth and shrinking freshwater supplies.

As the Organization for Economic Cooperation and Development (OECD) points out, proper pricing policies can encourage environmentally responsible water-use behavior as well as help to assure an adequate supply of water. To accomplish this, water should be valued appropriately in each of its various uses. The introduction of water markets and pricing mechanisms can have immediate and lasting impacts on water use (127).

There are several good examples of how water can be valued more appropriately than is the usual case. Chile established a water market in the mid-1980s that not only has saved water but also has enabled farmers to meet their needs by trading water rights among neighboring farms. A World Bank study of the water market system concluded that it contributed greatly to better management and fairer pricing (164).

Similarly, in southern California, US, chronically one of the most water-short regions in a water-short state, the San Diego County Water Authority reached an agreement with farmers in the Imperial Valley area east of the city of San Diego. The agreement encourages farmers to conserve up to 200,000 acre-feet of water a year and sell it to the county, which would finance the conservation measures and pay farmers cash incentives to participate. San Diego County would benefit from the guaranteed price of cheaper water, and the farmers would, in effect, be paid to conserve the resource. This approach to water management could change the dynamics of water use throughout California (42, 148).

Managing the Mossi Plateau.

In Burkina Faso’s main agricultural area, the Mossi Plateau, a group called the “Six S’s” (Se Servir de la Saison Seche en Savanne et au Sahel) has been promoting an integrated approach to water management since the late 1970s. The group encourages small-scale irrigation systems along with reforestation and erosion control. It teaches village leaders new techniques for saving water and growing crops, provides basic hygiene education, and helps with financing for water conservation (30, 35).

Balinese rice farmers. Balinese rice growers have used small-scale irrigation techniques for the past 500 years. Their system is not technically advanced but instead relies on loose stone dams and weirs to collect water, which is then distributed to terraced fields, using the hollowed-out trunks of coconut trees for piping. Accompanying this traditional system of water distribution is a social structure that regulates water among different communities, apportioning it according to the size of each rice paddy (30). The system works partly because women, the main source of paddy labor, have a hand in its management.

Urban sanitation in Karachi. In Pakistan the Orangi Pilot Project, carried out in one of the worst slums in Karachi, was able to provide 600,000 people with a sewer system.
and with covered latrines. The project, which was carried out with a small amount of external funding, worked because of progressive local leadership and strong community support. But the benefit did not end with piped water. The project also increased access to better reproductive health and family planning services, which would help reduce future demand for water (153).

• Potable piped water in Tegucigalpa. In Honduras six poor communities in the country's capital pooled limited resources to make a deal with the water utility to provide them with piped water. This scheme is notable because (1) the price that households paid for water actually dropped as a result of the piped water connections, since residents no longer had to buy water from street vendors, and (2) the average household connection rate in each of the six communities was 85%, and the consumers themselves paid for the connections (153). This example demonstrates, even in poor urban areas clean piped water can be provided at a price that community members can afford to pay and that water utilities can accept. Recent studies in a number of countries make clear that poor people are prepared to pay for piped water and prepay sanitation, if given the chance. In Onitsha, Nigeria, for instance, poor households were spending up to 18% of their meager monthly income on water purchased from street vendors, a percentage that dropped to under 5% when piped water was provided (153).

Taking action. Local communities should take an active part in planning and implementing water management schemes, if they are to be sustainable. Poor communities, in particular, have had notable success in introducing autonomous local systems of water supply, either through improvements in arrangements with the water authority or with private vendors. Communities also have set up community-managed vending kiosks or operated small, autonomous water supply systems (153).

Accessibility of clean water, as has been noted, promotes better household hygiene and improves health and well-being. Access to the water supply should be as close to homes as possible and should be reliable. Plans for piping water to poor households should consider the amount of water needed, choose the appropriate level of technology, and price the water according to the ability to pay (153).

Water supply and public health programs both should emphasize preventive health care education and encourage the use of clean water for personal and domestic hygiene (26, 54).

Time to Change Direction

The world needs sustainable water management, but we are not headed in the right direction fast enough. A Chinese proverb holds that, "If we don't change course we may end up where we are heading." Without moving in a new direction, many more areas will face water shortages, and more people will suffer, more conflicts over water will occur, and more precious wetland ecosystems will be destroyed.

While a freshwater crisis appears inevitable in many water-short regions, in other parts the problem could be managed, if appropriate policies and strategies were formulated, agreed to, and acted on soon. The international community is paying increasing attention to the world's water problems, and a number of organizations are providing funding and assistance to help manage water supply and demand (136, 164, 165). Increasingly, mechanisms are being put in place that permit more equitable water management. Countries in water-stressed regions are introducing better pricing mechanisms, fostering community-based water management schemes, and moving toward watershed and river basin management regimes. Both the number and scale of these activities need to increase substantially.

Also, population growth has slowed, reflecting international and national attention to family planning programs, together with rising popular demand for contraception. To meet people's needs, national governments and international donors need to increase their commitment to family planning, to improving sanitary conditions, to curbing pollution, and to reducing the scourge of water-related diseases.

A vital part of a long-term solution is worldwide recognition of the links between rapidly growing populations and shrinking freshwater supplies. Recognition, knowledge, and concern can help hold the political will to avert a crisis and develop the commitment needed to assure that humanity's apparently unquenchable thirst for freshwater does not exhaust the world's finite water supply.

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