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**Safeguarding our water**

## **MAKING EVERY DROP COUNT**

By Peter H. Gleick

**We drink it, we generate electricity with it, we soak our crops with it. And we're stretching our supplies to the breaking point. Will we have enough clean water to satisfy all the world's needs?**

The history of human civilization is entwined with the history of the ways we have learned to manipulate water resources. The earliest agricultural communities emerged where crops could be cultivated with dependable rainfall and perennial rivers. Simple irrigation canals permitted greater crop production and longer growing seasons in dry areas. Five thousand years ago settlements in the Indus Valley were built with pipes for water supply and ditches for wastewater. Athens and Pompeii, like most Greco-Roman towns of their time, maintained elaborate systems for water supply and drainage.

As towns gradually expanded, water was brought from increasingly remote sources, leading to sophisticated engineering efforts, such as dams and aqueducts. At the height of the Roman Empire, nine major systems, with an innovative layout of pipes and well-built sewers, supplied the occupants of Rome with as much water per person as is provided in many parts of the industrial world today.

During the industrial revolution and population explosion of the 19th and 20th centuries, the demand for water rose dramatically. Unprecedented construction of tens of thousands of monumental engineering projects designed to control floods, protect clean water supplies, and provide water for irrigation and hydropower brought great benefits to hundreds of millions of people. Thanks to improved sewer systems, water-related diseases such as cholera and typhoid, once endemic throughout the world, have largely been conquered in the more industrial nations. Vast cities, incapable of surviving on their local resources, have bloomed in the desert with water brought from hundreds and even thousands of miles away. Food production has kept pace with soaring populations mainly because of the expansion of artificial irrigation systems that make possible the growth of 40 percent of the world's food. Nearly one fifth of all the electricity generated worldwide is produced by turbines spun by the power of falling water.

Yet there is a dark side to this picture: despite our progress, half of the world's population still suffers with water services inferior to those available to the ancient Greeks and Romans. As the latest United Nations report on access to water reiterated in November of last year, more than one billion people lack access to clean drinking water; some two and a half billion do not have adequate sanitation services. Preventable water-related diseases kill an estimated 10,000 to 20,000 children every day, and the latest evidence suggests that we are falling behind in efforts to solve these problems. Massive cholera outbreaks appeared in the mid-1990s in Latin America, Africa and Asia. Millions of people in Bangladesh and India drink water contaminated with arsenic. And the surging populations throughout the developing world are intensifying the pressures on limited water supplies.

The effects of our water policies extend beyond jeopardizing human health. Tens of millions of people have been forced to move from their homes--often with little warning or compensation--

to make way for the reservoirs behind dams. More than 20 percent of all freshwater fish species are now threatened or endangered because dams and water withdrawals have destroyed the free-flowing river ecosystems where they thrive. Certain irrigation practices degrade soil quality and reduce agricultural productivity, heralding a premature end to the green revolution. Groundwater aquifers are being pumped down faster than they are naturally replenished in parts of India, China, the U.S. and elsewhere. And disputes over shared water resources have led to violence and continue to raise local, national and even international tensions [see box on page 44]. At the outset of the new millennium, however, the way resource planners think about water is beginning to change. The focus is slowly shifting back to the provision of basic human and environmental needs as the top priority--ensuring "some for all, instead of more for some," as put by Kader Asmal, former minister for water affairs and forestry in South Africa. To accomplish these goals and meet the demands of booming populations, some water experts now call for using existing infrastructure in smarter ways rather than building new facilities, which is increasingly considered the option of last, not first, resort. The challenges we face are to use the water we have more efficiently, to rethink our priorities for water use and to identify alternative supplies of this precious resource.

This shift in philosophy has not been universally accepted, and it comes with strong opposition from some established water organizations. Nevertheless, it may be the only way to address successfully the pressing problems of providing everyone with clean water to drink, adequate water to grow food and a life free from preventable water-related illness. History shows that although access to clean drinking water and sanitation services cannot guarantee the survival of a civilization, civilizations most certainly cannot prosper without them.

## **Damage from Dams**

Over the past 100 years, humankind has designed networks of canals, dams and reservoirs so extensive that the resulting redistribution of freshwater from one place to another and from one season to the next accounts for a small but measurable change in the wobble of the earth as it spins. The statistics are staggering. Before 1900 only 40 reservoirs had been built with storage volumes greater than 25 billion gallons; today almost 3,000 reservoirs larger than this inundate 120 million acres of land and hold more than 1,500 cubic miles of water--as much as Lake Michigan and Lake Ontario combined. The more than 70,000 dams in the U.S. are capable of capturing and storing half of the annual river flow of the entire country.

In many nations, big dams and reservoirs were originally considered vital for national security, economic prosperity and agricultural survival. Until the late 1970s and early 1980s, few people took into account the environmental consequences of these massive projects.

Today, however, the results are clear: dams have destroyed the ecosystems in and around countless rivers, lakes and streams. On the Columbia and Snake rivers in the northwestern U.S., 95 percent of the juvenile salmon trying to reach the ocean do not survive passage through the numerous dams and reservoirs that block their way. More than 900 dams on New England and European rivers block Atlantic salmon from their spawning grounds, and their populations have fallen to less than 1 percent of historical levels. Perhaps most infamously, the Aral Sea in central Asia is disappearing because water from the Amu Darya and Syr Darya rivers that once sustained it has been diverted to irrigate cotton. Twenty-four species of fish formerly found only in that sea are currently thought to be extinct.

As environmental awareness has heightened globally, the desire to protect--and even restore--some of these natural resources has grown. The earliest environmental advocacy groups in the U.S. mobilized against dams proposed in places such as Yosemite National Park in California and the Grand Canyon in Arizona. In the 1970s plans in the former Soviet Union to divert the flow of Siberian rivers away from the Arctic stimulated an unprecedented public outcry, helping to halt the projects. In many developing countries, grassroots opposition to the environmental and social costs of big water projects is becoming more and more effective. Villagers and community activists in India have encouraged a public debate over major dams. In China, where open disagreement with government policies is strongly discouraged, protest against the monumental Three Gorges Project has been unusually vocal and persistent.

Until very recently, international financial organizations such as the World Bank, export-import banks and multilateral aid agencies subsidized or paid in full for dams or other water-related civil engineering projects--which often have price tags in the tens of billions of dollars.

These organizations are slowly beginning to reduce or eliminate such subsidies, putting more of the financial burden on already strained national economies. Having seen so much ineffective development in the past--and having borne the associated costs (both monetary and otherwise) of that development--many governments are unwilling to pay for new structures to solve water shortages and other problems.

A handful of countries are even taking steps to remove some of the most egregious and damaging dams. For example, in 1998 and 1999 the Maisons-Rouges and Saint-Etienne-du-Vigan dams in the Loire River basin in France were demolished to help restore fisheries in the region. In 1999 the Edwards Dam, which was built in 1837 on the Kennebec River in Maine, was dismantled to open up an 18-mile stretch of the river for fish spawning; within months Atlantic salmon, American shad, river herring, striped bass, shortnose sturgeon, Atlantic sturgeon, rainbow smelt and American eel had returned to the upper parts of the river. Altogether around 500 old, dangerous or environmentally harmful dams have been removed from U.S. rivers in the past few years.

Fortunately--and unexpectedly--the demand for water is not rising as rapidly as some predicted. As a result, the pressure to build new water infrastructures has diminished over the past two decades. Although population, industrial output and economic productivity have continued to soar in developed nations, the rate at which people withdraw water from aquifers, rivers and lakes has slowed. And in a few parts of the world, demand has actually fallen.

## **Demand Is Down--But for How Long?**

What explains this remarkable turn of events? Two factors: people have figured out how to use water more efficiently, and communities are rethinking their priorities for water use. Throughout the first three quarters of the 20th century, the quantity of freshwater consumed per person doubled on average; in the U.S., water withdrawals increased 10-fold while the population quadrupled. But since 1980 the amount of water consumed per person has actually decreased, thanks to a range of new technologies that help to conserve water in homes and industry. In 1965, for instance, Japan used approximately 13 million gallons of water to produce \$1 million of commercial output; by 1989 this had dropped to 3.5 million gallons (even accounting for inflation)--almost a quadrupling of water productivity. In the U.S., water withdrawals have fallen by more than 20 percent from their peak in 1980.

As the world's population continues to grow, dams, aqueducts and other kinds of infrastructure will still have to be built, particularly in developing countries where basic human needs have not been met. But such projects must be built to higher standards and with more accountability to local people and their environment than in the past. And even in regions where new projects seem warranted, we must find ways to meet demands with fewer resources, minimum ecological disruption and less money.

The fastest and cheapest solution is to expand the productive and efficient use of water. In many countries, 30 percent or more of the domestic water supply never reaches its intended destinations, disappearing from leaky pipes, faulty equipment or poorly maintained distribution systems. The quantity of water that Mexico City's supply system loses is enough to meet the needs of a city the size of Rome, according to recent estimates. Even in more modern systems, losses of 10 to 20 percent are common.

When water does reach consumers, it is often used wastefully. In homes, most water is literally flushed away. Before 1990 most toilets in the U.S. drew about six gallons of water for each flush. In 1992 the U.S. Congress passed a national standard mandating that all new residential toilets be low-flow models that require only 1.6 gallons per flush--a 70 percent improvement with a single change in technology. It will take time to replace all older toilets with the newer, better

ones. A number of cities, however, have found the water conservation made possible by the new technology to be so significant--and the cost of saving that water to be so low--that they have established programs to speed up the transition to low-flow toilets [see "Leaking Away," by Diane Martindale, on page 54].

Even in the developing world, technologies such as more efficient toilets have a role to play. Because of the difficulty of finding new water sources for Mexico City, city officials launched a water conservation program that involved replacing 350,000 old toilets. The replacements have already saved enough water to supply an additional 250,000 residents. And numerous other options for both industrial and nonindustrial nations are available as well, including better leak detection, less wasteful washing machines, drip irrigation and water-conserving plants in outdoor landscaping.

The amount of water needed for industrial applications depends on two factors: the mix of goods and services demanded by society and the processes chosen to generate them. For instance, producing a ton of steel before World War II required 60 to 100 tons of water. Current technology can make a ton of steel with less than six tons of water. Replacing old technology with new techniques reduces water needs by a factor of 10. Producing a ton of aluminum, however, requires only one and a half tons of water. Replacing the use of steel with aluminum, as has been happening for years in the automobile industry, can further lower water use. And telecommuting from home can save the hundreds of gallons of water required to produce, deliver and sell a gallon of gasoline, even accounting for the water required to manufacture our computers. The largest single consumer of water is agriculture--and this use is largely inefficient. Water is lost as it is distributed to farmers and applied to crops. Consequently, as much as half of all water diverted for agriculture never yields any food. Thus, even modest improvements in agricultural efficiency could free up huge quantities of water [see "Growing More Food with Less Water," by Sandra Postel, on page 46]. Growing tomatoes with traditional irrigation systems may require 40 percent more water than growing tomatoes with drip systems. Even our diets have an effect on our overall water needs. Growing a pound of corn can take between 100 and 250 gallons of water, depending on soil and climate conditions and irrigation methods. But growing the grain to produce a pound of beef can require between 2,000 and 8,500 gallons. We can conserve water not only by altering how we choose to grow our food but also by changing what we choose to eat.

Shifting where people use water can also lead to tremendous gains in efficiency. Supporting 100,000 high-tech California jobs requires some 250 million gallons of water a year; the same amount of water used in the agricultural sector sustains fewer than 10 jobs--a stunning difference. Similar figures apply in many other countries. Ultimately these disparities will lead to more and more pressure to transfer water from agricultural uses to other economic sectors. Unless the agricultural community embraces water conservation efforts, conflicts between farmers and urban water users will worsen.

The idea that a planet with a surface covered mostly by water could be facing a water shortage seems incredible. Yet 97 percent of the world's water is too salty for human consumption or crops, and much of the rest is out of reach in deep groundwater or in glaciers and ice caps. Not surprisingly, researchers have investigated techniques for dipping into the immense supply of water in the oceans. The technology to desalinate brackish water or saltwater is well developed, but it remains expensive and is currently an option only in wealthy but dry areas near the coast. Some regions, such as the Arabian Gulf, are highly dependent on desalination, but the process remains a minor contributor to overall water supplies, providing less than 0.2 percent of global withdrawals [see "Sweating the Small Stuff," by Diane Martindale, on page 52]. With the process of converting saltwater to freshwater so expensive, some companies have turned to another possibility: moving clean water in ships or even giant plastic bags from regions with an abundance of the resource to those places around the globe suffering from a lack of water [see "Bagged and Dragged," by Peter H. Gleick, on page 53]. But this approach, too, may have serious economic and political constraints.

Rather than seeking new distant sources of water, smart planners are beginning to explore using alternative kinds of water to meet certain needs. Why should communities raise all water

to drinkable standards and then use that expensive resource for flushing toilets or watering lawns? Most water ends up flowing down the drain after a single use, and developed countries spend billions of dollars to collect and treat this wastewater before dumping it into a river or the ocean. Meanwhile, in poorer countries, this water is often simply returned untreated to a river or lake where it may pose a threat to human health or the environment. Recently attention has begun to focus on reclaiming and reusing this water.

Wastewater can be treated to different levels suitable for use in a variety of applications, such as recharging groundwater aquifers, supplying industrial processes, irrigating certain crops or even augmenting potable supplies. In Windhoek, Namibia, for instance, residents have used treated wastewater since 1968 to supplement the city's potable water supply; in drought years, such water has constituted up to 30 percent of Windhoek's drinking water supply [see "Waste Not, Want Not," by Diane Martindale, on page 55]. Seventy percent of Israeli municipal wastewater is treated and reused, mainly for agricultural irrigation of nonfood crops. Efforts to capture, treat and reuse more wastewater are also under way in neighboring Jordan. By the mid-1990s residents of California relied on more than 160 billion gallons of reclaimed water annually for irrigating landscapes, golf courses and crops, recharging groundwater aquifers, supplying industrial processes and even flushing toilets.

New approaches to meeting water needs will not be easy to implement: economic and institutional structures still encourage the wasting of water and the destruction of ecosystems. Among the barriers to better water planning and use are inappropriately low water prices, inadequate information on new efficiency technologies, inequitable water allocations, and government subsidies for growing water-intensive crops in arid regions or building dams.

Part of the difficulty, however, also lies in the prevalence of old ideas among water planners. Addressing the world's basic water problems requires fundamental changes in how we think about water, and such changes are coming about slowly. Rather than trying endlessly to find enough water to meet hazy projections of future desires, it is time to find a way to meet our present and future needs with the water that is already available, while preserving the ecological cycles that are so integral to human well-being.

## WHERE THE WATER WILL BE IN 2025

The total amount of water withdrawn globally from rivers, underground aquifers and other sources has increased nine-fold since 1900 (chart). Water use per person has only doubled in that time, however, and it has even declined slightly in recent years. Despite this positive trend, some experts worry that improvements in water-use efficiency will fail to keep pace with projected population growth. Estimated annual water availability per person in 2025 (map) reveals that at least 40 percent of the world's 7.2 billion people may face serious problems with agriculture, industry or human health if they must rely solely on natural, endowments of freshwater. Severe water shortages could also strike particular regions of water-rich countries, such as the U.S. and China. People's access to water also depends on factors not reflected here, such as political and economic conditions, changing climate patterns and available technology.

## CONTINUING CONFLICT OVER FRESHWATER

Myths, legends and written histories reveal repeated controversy over freshwater resources since ancient times. Scrolls from Mesopotamia, for instance, indicate that the states of Umma and Lagash in the Middle East clashed over the control of irrigation canals some 4,500 years ago.

Throughout history, water has been used as a military and political goal, as a weapon of war and even as a military target. But disagreements most often arise from the fact that water resources are not neatly partitioned by the arbitrary political borders set by governments. Today nearly half of the land area of the world lies within international river basins, and the watersheds of 261 major rivers are shared by two or more countries. Overlapping claims to water resources have often provoked disputes, and in recent years local and regional conflicts have escalated over inequitable allocation and use of water resources.

A small sampling of water conflicts that occurred in the 20th century demonstrates that treaties and other international diplomacy can sometimes encourage opposing countries to cooperate--but not always before blood is shed. The risk of future strife cannot be ignored: disputes over water will become more common over the next several decades as competition for this scarce resource intensifies.

### U.S. 1924

Local farmers dynamite the Los Angeles aqueduct several times in an attempt to prevent diversions of water from the Owens Valley to Los Angeles.

### India and Pakistan 1947 to 1960

Partitioning of British India awkwardly divides the waters of the Indus River valley between India and Pakistan. Competition over irrigation supplies incites numerous conflicts between the two nations; in one case, India stems the flow of water into Pakistani irrigation canals. After 12 years of World Bank-led negotiations, a 1960 treaty helps to resolve the discord.

## **Egypt and Sudan 1958**

Egypt sends troops into contested territory between the two nations during sensitive negotiations concerning regional politics and water from the Nile. Signing of a Nile waters treaty in 1959 eases tensions.

## **Israel, Jordan and Syria 1960s and 1970s**

Clashes over allocation, control and diversion of the Yarmouk and Jordan rivers continue to the present day.

## **South Africa 1990**

A pro-apartheid council cuts off water to 50,000 black residents of Wesselton Township after protests against wretched sanitation and living conditions.

## **Iraq 1991**

During the Persian Gulf War, Iraq destroys desalination plants in Kuwait. A United Nations coalition considers using the Ataturk Dam in Turkey to shut off the water flow of the Euphrates River to Iraq.

## **India 1991 to present**

An estimated 50 people die in violence that continues to erupt between the Indian states of Karnataka and Tamil Nadu over the allocation of irrigation water from the Cauvery River, which flows from one state into the other.

## **Yugoslavia 1999**

NATO shuts down water supplies in Belgrade and bombs bridges on the Danube River, disrupting navigation.

A comprehensive chronology of waterrelated conflicts can be found at [www.worldwater.org/conflictIntro.htm](http://www.worldwater.org/conflictIntro.htm)

## The Author

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## Further Information

THE WORLD'S WATER 1998-1999. Peter H. Gleick. Island Press, 1998. INTERNATIONAL RIVER BASINS OF THE WORLD. Aaron T. Wolf et al. in Water Resources Development, Vol. 15, No. 4, pages 387-427; December 1999. THE WORLD'S WATER 2.000-2.00 I. Peter H. Gleick. Island Press, 2000. Information on the world's water resources can be found at [www.worldwater.org](http://www.worldwater.org) United Nations Environment Program Global Environment Monitoring System's Fresh- water Quality Program can be found at [www.cciw.ca/gems/](http://www.cciw.ca/gems/) VISION 21: A SHARED VISION FOR HYGIENE, SANITATION AND WATER SUPPLY. Water Supply and Sanitation Collaborative Council. Available at [www.wsscc.org/vision21/docs/index.html](http://www.wsscc.org/vision21/docs/index.html)

MAP

GRAPH:Annual global water withdrawals

PHOTO (COLOR):Water supply line in Novi Sad, Yugoslavia, was destroyed along with this Danube River bridge during a NATO airstrike in April 1999.

PHOTO (COLOR)

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