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WATER IN CRISIS: PATHS TO SUSTAINABLE WATER USE

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Abstract. A wide range of ecological and human crises result from inadequate access to, and the inappropriate management of, freshwater resources. These include destruction of aquatic ecosystems and extinction of species, millions of deaths from water-related illnesses, and a growing risk of regional and international conflicts over scarce, shared water supplies. As human populations continue to grow, these problems are likely to become more frequent and serious. New approaches to long-term water planning and management that incorporate principles of sustainability and equity are required and are now being explored by national and international water experts and organizations. Seven "sustainability criteria" are discussed here, as part of an effort to reshape long-term water planning and management. Among these principles are guaranteed access to a basic amount of water necessary to maintain human health and to sustain ecosystems, basic protections for the renewability of water resources, and institutional recommendations for planning, management, and conflict resolution. "Backcasting" a positive future vision of the world's water resources as a tool for developing rational policies and approaches for reducing water-related problems is also discussed in the context of the Comprehensive Freshwater Assessment prepared for the United Nations General Assembly in 1997.

Key words: aquatic ecosystems; basic water requirement; BWR; water; water policy; water, sustainable use of.

INTRODUCTION

The world faces a wide range of ecological and human health crises related to inadequate access to, or inappropriate management of, clean fresh water. As human populations continue to grow, regional conflicts over water, ecological degradation, and human illness and death are becoming more frequent and serious. As we approach the turn of the century, new approaches to long-term water planning and management that incorporate principles of sustainability and equity are required. Among these principles are guaranteed access to a minimum amount of water necessary to maintain human health and to sustain ecosystems. This paper discusses the concept of a "basic water requirement (BWR)" as part of seven sustainability criteria designed to reshape long-term water planning. Backcasting a positive future vision of the world's water resources is described as a tool for developing rational approaches for reducing water-related problems and for developing more effective water policies and management.

TWENTIETH CENTURY WATER PLANNING: FORECASTING A FUTURE WE DO NOT WANT

The 20th-century water development paradigm, which was driven by an ethic of growth powered by continued expansion of water supply infrastructure, has been slowed in most industrialized nations as social values and political and economic conditions have changed. And while there have been efforts to extend this traditional development paradigm to many other parts of the world, a growing understanding of the adverse ecological implications of such projects, scarce economic and social capital, and the increasingly effective voices of local and international nongovernmental organizations have begun to slow massive water projects in developing countries as well.

In the past, the primary goals of water development policy were to support increasing levels of economic development and to figure out ways of increasing the availability of fresh water to meet anticipated demands. Incidental to or excluded from these policies has been consideration of basic human needs, ecological water requirements, the roles of communities and culture, and the desires and needs of future generations.

The goal of relying on new supply projects to meet unlimited growth in demand has produced decidedly mixed results. Much of the massive water infrastructure developed over the past 100 years has been enormously effective at permitting great expansions of irrigated land and crop production necessary to feed rapidly growing populations. Massive urban population growth in most regions has been enabled by moving huge amounts of water from distant sources to cities. Dev-

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astating floods in many countries have been captured, curtailed, and tamed by flood control projects. The severe impacts of deep droughts are often mitigated by large storage systems that permit multiyear carry-over of water.

Against these benefits must be weighed the full economic, social, and environmental costs of such projects and the apparent failure to provide for the basic water needs for billions of people. The best sites for large dams have, for the most part, been developed in the industrialized world and are increasingly controversial everywhere. Millions of people die every year from water-related diseases. Water-scarce regions are increasingly looking at water resources as a strategic resource worth fighting over. A focus on water supply led to the neglect of attention to water use, leading in turn to many inefficient technologies and applications and to inequitable allocations of limited water supplies.

Perhaps most importantly, traditional approaches to water planning neglected the ecological and environmental impacts of projects, both singular and cumulative. As a result, a wide range of unanticipated or ignored ecological impacts have occurred, with sometimes devastating consequences. Among the kinds of ecological problems encountered are acidification of waters, unsustainable fisheries management, the wide spread of non-native species, and a cascade of biological effects from interbasin transfers and dam, reservoir, and aqueduct construction. A plethora of land-use actions also adversely affect aquatic systems, such as deforestation, urbanization, and agricultural chemical contamination. Covich (1993) summarizes many of these issues and observes that more intelligent water resources management will be necessary to sustain our aquatic biological resources. In particular, he suggests that among the needed solutions are to provide adequate quantity and quality of water for natural habitats, minimize alterations of natural ecosystem processes and losses of biodiversity and integrity, and preserve remaining natural freshwater habitats with high biodiversity and many endemic species.

The need for a new vision

To broaden water policy to include issues of sustainability, a new debate has now begun, as reflected by the nature of the statements coming from the 1972 Stockholm Conference on the Environment, the 1977 Mar del Plata Water Conference, the 1992 Dublin statement, Chapter 18 of Agenda 21 from Rio, and more recent missives from the World Bank, the Global Water Partnership, and others (see Lundqvist and Gleick 1996).

These statements suggest the need for new definitions and concepts, particularly the concepts of sustainability and equity. Simply stated, incorporating characteristics of sustainability and equity in water planning and policy goals has become a major policy priority, and requires placing a high value on maintaining the integrity of water resources and the flora, fauna, and human societies that have developed around them. And it means that the costs and benefits of water resource management and development are to be decided and distributed in a fair and prudent manner. Together, these goals represent a commitment to nature and the diverse social groups of the present and future generations.

Twenty-First Century Water Planning: Backcasting a Future We Want

An ethic of sustainability requires a fundamental change in how we think about water regionally and internationally. Traditional long-term water planning has relied on the use of scenario development and forecasting tools, which take current and expected trends in technology, population growth, economic development, and water use, and extends those trends into the future. These projections generate anticipated water demands, which are then compared with expected supply. One typical regional example of this approach is the California Water Plan, produced every five or six years since 1957, and which always predicts a supply shortfall (DWR 1994, Gleick et al. 1995). These projections are then used to help identify and justify which new supply options might be needed to bridge the gap.

In many developed nations, it is now increasingly difficult to build major new water supply systems because of both environmental and economic constraints. As a result, there is growing interest in exploring options on the other side of the equation—the demand side. Rather than projecting current demand trends forward and then trying to find the water to meet these future desires, some analysts are beginning to deconstruct demand in order to better identify actual needs and the most efficient way of meeting those needs. One particular approach is to determine what kind of water future we desire and to backcast a way of reaching that positive vision.

Backcasting permits society to plan to meet present and future human and ecological needs with the water that is available, and to determine what desires can be satisfied within the limits of our resources. Water-resource planning in a democratic society requires more than simply deciding what project to build next or evaluating which scheme is the most cost-effective. Planning must provide information that helps the public make judgments about which "needs" and "wants" can and should be satisfied. Water is now recognized as a common good and community resource, but it is also used as a private good or economic commodity; it is not only a necessity for life but also a recreational resource; it is imbued with cultural values and plays a part in the social life of our communities. The principles of sustainability and equity can help bridge the gap between such diverse and competing interests.

Regional and global water planning must now address such questions as: How much water is needed for satisfying the domestic use of a family in a dense urban center or in a rural agricultural community? Should people be able to use as much water as they can pay for? Under what situations should water be delivered to farmers at rates below full operating and capital costs? How much water is needed to maintain ecological systems and environmental quality and services, and at what level? How much water should be available and at what quality for the use of future generations?

I present below a set of criteria for guiding water-resource management. These sustainability criteria constitute an ethic that helps prioritize competing claims over water. The real challenge of this ethic is to define the specifics. What do sustainability and equity mean when applied in the real world? What kind of planning practices are consistent with these objectives?

While not all will agree with this specific approach, the direction that is set out can be used to guide rational and meaningful debate over water-resource policy. Rather than allowing the overall goals to be determined by the outcomes of fights among the most powerful and wealthy interest groups, goals to further a genuine common interest can be forged, and real conflicts can be resolved in a fair and equitable manner based on democratic ideals. In the absence of democratic dialogue, water-resource development can only continue down a course plotted decades ago, one that may have been appropriate then, but that fails to meet the challenges of the next century.

Water and sustainability

With respect to water resources, as with many other resources, sustainability has not been clearly defined, though several recent efforts have made progress in defining the issues (Golubev et al. 1988, Koudstaal et al. 1992, Plate 1993, Raskin et al. 1995). Water is not only essential to sustain life, but it also plays an integral role in ecosystem support, economic development, community well-being, and cultural values. Several basic questions must be addressed in any discussion over the sustainability of water use. How are all these values, which sometimes conflict, to be prioritized? What is to be sustained? For how long? What are the benefits? Who are the beneficiaries? In the context of freshwater resources, any discussion of sustainable development requires that we understand the stocks and flows of global, regional, and local freshwater resources, and the benefits or services that those resources must provide (Gleick et al. 1995).

The simplest definition of the sustainable use of water would require the maintenance of a desired flow of benefits to a particular group or place, undiminished over time. Benefits involve cultural values and issues, and are a function of the stock of, and the demand for, water, both of which vary with technology and population. Demands for water include not just what people need, but what they want. This latter demand is potentially much larger than minimum basic needs (Gleick 1996). This simple definition of sustainability, however, would permit maintaining benefits to one user group at the expense of another user group. A better definition would incorporate the requirement that benefits to all current users be maintained, without reducing benefits to other users, including natural ecosystems. This definition is flawed too, by excluding explicit rights for future generations or growing populations.

Further refinement requires that the sustainability of current benefits be maintained without affecting the ability to provide comparable benefits into the future—similar to the definition developed during the work of the World Commission on Environment and Development (WCED 1987) and widely quoted:

> *Humanity has the ability to make development sustainable—to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs.*

The desired set of benefits provided by a resource does not have to be, and is unlikely to be, the same across different users or periods of time. Indeed, desired benefits of water use vary widely given political, religious, cultural, and technological differences. But in any realistic discussion of sustainability, the benefits to be provided must be explicitly evaluated. Benefits of water use can be subdivided in several ways: by form or sector of use, such as domestic, agricultural, industrial, and ecosystem use; or by the well-being provided by use, such as economic wealth, human and ecological health, level of satisfaction, and so on. Sophisticated measures of well-being are often difficult to quantify but provide a more complete view of the consequences of resource use than the traditional measures of simple quantities of per capita use.

Unsustainability of water resources

Gaining an understanding of the sustainable use of water can also be approached by understanding what constitutes the "unsustainable" use of water. Using the definitions above, water use is unsustainable if the services provided by water resources and ecosystems, and desired by society, diminish over time. Equity also requires that a reduction of services over time to one user group be declared unsustainable even if other users are able to maintain their desired services. It should be noted, however, that inequities by themselves are not unsustainable; indeed, many inequities in resource allocation and use can be maintained for indefinite periods of time.

Unsustainable water use can develop in two ways: (1) through alterations in the stocks and flows of water that change its availability in space or time and (2) through alterations in the demand for the benefits provided by a resource, because of changing standards of living, technology, population levels, or societal mores.

Water availability is affected by both natural and anthropogenic factors, including climatic variability and change, population growth that reduces per capita water availability, contamination that reduces usable water supplies, physical overuse of a stock, such as groundwater overdraft, and technological factors. Similarly, demands for water are not constant; they increase with growing populations, change as social values and preferences change, and increase or decrease with technological innovation and change.

Two problems deserve special attention: increasing populations and changing technology; the first leads to both decreasing per capita water availability and increasing overall demand; the second affects both water supply and demand. Assuming constant levels of total water availability, increasing populations lead directly to decreasing per capita water availability and to pressures on the levels of benefits or the mix of benefits that water provides. Ultimately, unlimited population growth must lead to decreasing water availability, the reallocations of water from one user or sector to another, the unsustainable "mining" of nonrenewable stocks of water, and, in the end, decreasing overall benefits and well-being.

Technological developments can alter water availability, and can affect the amount of water required to satisfy demands. In theory, practically unlimited quantities of fresh water are available by mining water currently trapped in glaciers and ice caps, or on an even larger scale, through the mass desalination of seawater. In practice, however, increases in overall water supply should occur only where the value of water exceeds the economic and environmental costs of supplying that water through new technology.

Similarly, changes in technology can increase or decrease the amount of water required to supply a particular societal benefit. If technological development proceeds independently of water constraints, a new technology to supply energy, for example, may require more water than previous alternatives. If water resources are constrained, technology can be manipulated to reduce overall water requirements in the same way that energy efficiency technologies reduce energy needs without sacrificing the desired benefit.

Finally, truly sustainable water use must involve the management of the distribution of water in space and time. Social systems, i.e., institutions, to control water resources must be capable of coping with changes in supply and demand and in responding to varying priorities of water use under different conditions.

A new framework for sustainable water management and use

Given all of these issues, Gleick et al. (1995) offer a working definition of sustainable water use as:

the use of water that supports the ability of human society to endure and flourish into the indefinite future without undermining the integrity of the hydrological cycle or the ecological systems that depend on it.

TABLE 1. Sustainability criteria for water planning.

A basic water requirement will be guaranteed to all humans to maintain human health.
A basic water requirement will be guaranteed to restore and maintain the health of ecosystems.
Water quality will be maintained to meet certain minimum standards. These standards will vary depending on location and how the water is to be used.
Human actions will not impair the long-term renewability of freshwater stocks and flows.
Data on water resources availability, use, and quality will be collected and made accessible to all parties.
Institutional mechanisms will be set up to prevent and resolve conflicts over water.
Water planning and decision making will be democratic, ensuring representation of all affected parties and fostering direct participation of affected interests.

This definition of sustainable water use provides an overarching framework by which decisions about human water use can be judged. By itself, however, it is too general to offer guidance for water managers, planners, and scientists. To make decisions about how to allocate and use water resources, other goals and criteria need to be identified. Explicit criteria and goals for the sustainability of freshwater resources are presented in Table 1. These criteria lay out human and environmental priorities for water use, taking into account not only the needs of the current populations, but also those of future generations.

The criteria and goals of Table 1 are the result of considerable dialogue and analysis with academic, governmental, and nongovernmental interests working on regional, national, and international water problems. They are not, by themselves, recommendations for actions; rather they are endpoints for policy. They lay out specific societal goals that could, or should, be attained. In particular, these criteria can provide the basis for alternative "visions" for future water management and can offer some guidance for legislative and nongovernmental actions in the future (Gleick et al. 1995). In contrast, without specific criteria to guide planning, unsustainable water policies are inevitable.

Policy discussions must inevitably turn to identifying how much water is required to satisfy these priorities and which of the many economic, technical, educational, and regulatory means that are available should be pursued. While debate on how to attain these goals is unavoidable and desirable, having a set of clear targets will help focus the ultimate policy decisions.

Criterion 1. Basic human water requirements.—The first criterion listed above sets as a primary goal the provision of a basic amount of water for meeting the essential needs of humans. This elementary goal, com-

TABLE 2. Basic water requirements for human needs, excluding water required to grow food.

Purpose	Recommended commitment ($L \cdot individual^{-1} \cdot d^{-1}$)
Drinking water†	5
Sanitation services	20
Bathing	15
Food preparation	10

Source: Gleick (1996).
† This is a true minimum to sustain life in moderate climatic conditions and average activity levels.

mon to many different interpretations of sustainability over the past few years, was raised in basic needs requirements of the 1977 Mar del Plata statement, restated in the United Nations Agenda 21, which explicitly recognized the standing of both humans and ecosystems, and is part of the compact for human development described in the 1994 United Nations Development Programme (UNDP) Human Development Report. For humans, insufficient access to potable water is the direct cause of millions of unnecessary deaths every year. The provision of a certain amount of fresh water to support human metabolism and to maintain human health should be a guaranteed commitment on the part of governments and water providers.

A true minimum can only be defined for maintaining human or ecological survival. For humans, this amount is ~5 $L \cdot individual^{-1} \cdot d^{-1}$ under average climatic conditions and levels of activity. Additional basic needs have been quantified, however, for providing sanitation services, preparing food, and bathing. Gleick (1996) recommends that 50 $L \cdot individual^{-1} \cdot d^{-1}$ be committed to satisfy these needs (Table 2).

No legal or institutional mechanisms exist, however, to guarantee even this basic requirement to present and future generations. The first sustainability criterion, therefore, guarantees access to this basic water requirement to meet the fundamental domestic needs of people.

Criterion 2. Basic environmental water requirements.—The second of the criterion listed above requires a minimum amount of water be guaranteed to meet the essential needs of natural ecosystems. This goal was also supported as part of the basic needs requirements of Agenda 21 of the United Nations (UN 1992). Some limited efforts have been made to set minimum requirements for certain threatened or high priority ecosystems, but few criteria have been set, particularly in the developing world.

In part because of the lack of clearly defined legal water rights, many aquatic ecosystems and individual species have become severely threatened or endangered. The recent disasters to the natural fisheries of Lake Victoria and the Aral Sea are but two examples. Overall, >700 species of fish have been recognized by international organizations as threatened or endangered. In just the last couple of years, many more have been added to the list, including several anadromous species, because of increasing pressures on water resources. Anadromous fisheries, in particular, are extremely vulnerable to changes in water supply and quality and to modifications in habitat (Covich 1993, Nash 1993*b*).

While efforts are being made to identify basic ecosystem water requirements, there is little agreement about minimum water needs for the environment and few legal guarantees for environmental water have been set. The ecosystems for which water is necessary include both natural ecosystems where there is a minimum of human interference and ecosystems that are already highly managed by humans. Societal decisions will have to be made regarding the degree to which these ecosystems should be maintained or restored and the indicators by which to measure their health. Examples of such decisions include identifying stretches of undisturbed rivers to preserve, establishing minimum flow requirements in some river stretches, reallocating water from major water projects to the environment, and developing standards to protect wetlands and riparian habitats. Protecting natural aquatic ecosystems is not only vital for maintaining environmental health, but there are important feedbacks between these systems and both water quality and availability as well. The recent decision to place a cap on further development and diversions in the Murray-Darling river system in Australia (MDBMC 1996) and the complete revision of South African water law to include water for ecosystems as a fundamental priority (MWAF 1996) are two important examples of this new focus.

Ultimately, allocations of water for the basic needs of ecosystems will have to be made on a flexible basis, accounting for climatic variability, seasonal fluctuations, human needs, and other factors. Management will have to follow an adaptive model where decisions are reviewed frequently based on the latest information, and special efforts are made to avoid irreversible environmental consequences.

Criterion 3. Water quality standards.—Different uses require water of differing qualities. As a result, water quality standards for different purposes must be developed and water quality must be monitored and maintained to meet these standards. Water in most developed countries is protected from contamination by national regulations (WHO 1984, MNHW 1992, USEPA 1992). These water quality standards are supposed to ensure that potable water is reasonably free from contaminants known to affect human health. In many parts of the developing world, however, even minimal water quality standards are not in place, leading to widespread cases of waterborne diseases. Lack of sufficient, clean drinking water and sanitation services lead to many hundreds of millions of cases of water-

TABLE 3. Estimates of global morbidity and mortality of water-related diseases.

Disease	Morbidity (episodes/yr)	Mortality (deaths/yr)
Diarrheal diseases	1 000 000 000	3 300 000
Intestinal helminths	1 500 000 000 (people infected)	100 000
Schistosomiasis	200 000 000 (people infected)	200 000
Dracunculiasis	100 000 (people infected, excluding the Sudan)	···
Trachoma	150 000 000 (active cases)	···
Malaria	400 000 000	1 500 000
Dengue fever	1 750 000	20 000
Poliomyelitis	114 000	···
Trypanosomiasis	275 000	130 000
Bancroftian filariasis	72 800 000 (people infected)	···
Onchocerciasis	17 700 000 (people infected; 270 000 blind)	40 000 (mortality caused by blindness)

Source: WHO (World Health Organization) (1995).

related diseases and between five to ten million deaths annually, primarily of small children (Table 3) (Nash 1993*a*, Warner 1995, WHO 1995).

Water used for nonhuman consumption need not be protected to the drinking water standards. For example, water used for many industrial, commercial, or landscaping purposes could be protected to a lower standard, with substantial economic savings. Similar water quality criteria need to be developed for ecological water requirements. Substantial effort should go into identifying these differences and developing ways of meeting various demands with water at appropriate levels of quality.

Criterion 4. Renewability of water resources.— Freshwater resources typically are considered renewable: they can be used in a manner that does not affect the long-term availability of the same resource. However, renewable freshwater resources can be made nonrenewable by mismanagement of watersheds, overpumping, land subsidence, and aquifer contamination. Water policy should explicitly protect against these irreversible activities.

Groundwater stocks are renewable on timelines that depend upon the rate of inflow of water, the rate of withdrawals of water, and the geophysical characteristics of the aquifer. In some instances, overpumping of groundwater—the extraction of groundwater at a rate that exceeds the rate of natural recharge—can continue for some time with no adverse consequences if the aquifer is permitted to be recharged during wet periods. Thus, a short-term nonrenewable use may still be compatible with long-term renewability.

TABLE 4. Heavily exploited aquifers of the world.

Region	Aquifer	Average annual recharge (km^3/yr)	Average annual use (km^3/yr)
Algeria/Tunisia	Saharan basin	0.58	0.74
Saudi Arabia	Saq	0.3	1.43
Canary Islands	Tenerife	0.22	0.22
Gaza Strip	Coastal	0.31	0.50
United States	Ogallala	6 to 8	22.2
United States	selected Arizona	0.37	3.78

Source: Margat (1996).

In regions where groundwater recharge rates are extremely low, such as in many arid and semiarid regions, overpumping of groundwater is unsustainable and represents a one-time use of a resource stock; the same as pumping oil out of the ground. Eventually, the costs of taking out additional cubic meters of water will exceed their economic value to the user. This kind of water use is going on in several regions of the world (Table 4), including Saudi Arabia, Yemen, India, parts of the western U.S., and northeastern China, to mention only a few of the major problem areas.

Some forms of groundwater pumping may lead to the irreversible decline in the ability of a region to store water in the ground. Even where overpumping during dry periods may, in theory, be replenished by rainfall during wet periods, geophysical characteristics may prevent this in practice. Excessive groundwater pumping in parts of the Central Valley of California, for example, has led to land subsidence, which reduces the ability of wet years to fully recharge groundwater aquifers. Estimates are that California's Central Valley has lost $>24 \times 10^9$ m^3 of storage capacity owing to compaction of overexploited groundwater aquifers (Bertoldi 1992). To put this loss in perspective, the entire storage capacity of all constructed reservoirs in the state is $<60 \times 10^9$ m^3 (DWR 1994). Overpumping of groundwater in coastal aquifers can also lead to irreversible and unsustainable effects, including salt water intrusion and the ultimate contamination of the entire groundwater stock (Gleick et al. 1995).

Surface waters can also be contaminated or lost through watershed mismanagement. For example, animal grazing or excessive human use at high elevations can lead to fecal contamination of surface runoff in mountain streams. Urbanization can lead to storm runoff that is lost to sewers rather than feeding streams or recharging groundwater. Water managers and land-use planners must coordinate whenever these kinds of land-use decisions can lead to irreversible changes in the hydrological cycle.

Criterion 5. Data collection and availability.—If water planning and management are to be democratic and effective, data on all aspects of the water cycle must be collected and made available in an unrestricted manner. At present, data on many aspects of regional and national water supply and use are not collected, and when they are, are not widely available. At the extreme, some national governments continue to classify basic water data for so-called security reasons. This is unjustified and greatly inhibits effective water planning and management.

Substantial data gaps exist on the condition of different groundwater basins, extraction amounts, current pumping practices, and recharge rates. Similarly, water-use information is sketchy or site specific, making actions for increasing efficiency or improving conservation programs hard to plan and implement. Information should be produced in reasonable time with reasonable resources, and it should be freely and widely shared.

Recent advances in electronic communications makes sharing resource information easy and inexpensive. In particular, Internet resources related to water are growing at a phenomenal rate, and many sources of information are already freely available. This trend should be encouraged and expanded.

Criteria 6 and 7. Institutions, management, and conflict resolution.—Criteria for sustainability are not only about measuring appropriate biological or physical indicators. They must also provide guidance for the institutions that are to resolve conflicts over water and deal with the unavoidable uncertainties and risks in decision making. The greatest debates over water in the past several decades have focused on how to reach particular goals. The water debate must now be broadened to address the means by which these goals are set. Accordingly, sustainability criteria must also apply to water-resources management, particularly to ensure democratic representation of all affected parties in decision making, open and equitable access to information on the resources, and the options for allocating those resources.

Water planning and decision making in many regions is limited to a narrow range of professionals trained in engineering, agriculture, and the hydrological sciences. The power of these groups remains significantly greater than that of rural interests, religious or ethnic minority groups, environmental groups, academics, and other users. Mechanisms to broaden their participation are needed. Ways must be found to incorporate and protect the interests of future generations; a fundamental criterion of sustainability as defined by the United Nations in Agenda 21 (UN 1992).

In addition to mechanisms to broaden participation, institutional mechanisms need to be set up to prevent and resolve conflicts over water. There is a long history of conflict over shared water resources, described in detail in Gleick (1993, 1998). Nearly half of the land area of the earth is part of an international river basin and >220 nations share water with a neighboring country. Although a wide range of tools for resolving water disputes already exist, their effectiveness varies greatly depending on the issue and the extent of political manipulation and interference. The most effective approach is specific treaties among river basin nations allocating water, setting up management oversight, and developing acceptable standards for operations and water quality. Unfortunately, few of the world's international rivers have such treaties, and many of the existing ones inadequately address either current or future problems. Another approach, the development of general international principles, has also been tried, with limited success. The International Law Commission has worked for many years to define such principles, and while much progress has been made, the application of these principles to solving specific regional conflicts has had very limited success (McCaffrey 1993). Future institutions and efforts to settle the problems posed by international rivers must be open and democratic, and must resolve conflicts over water in an equitable, prudent, and fair manner.

Perhaps the greatest flaw with many water institutions is their failure to adequately address issues of equity. Equity is a measure of the fairness of both the distribution of positive and negative outcomes as well as the process used to arrive at particular social decisions. The sustainability goals in Table 1 explicitly incorporate institutional criteria for participation and conflict resolution so as to ensure at least a degree of procedural equity necessary for sustainability.

Some would argue that sustainability should be defined narrowly so that questions of equity are excluded. But from this perspective, sustainability could be achieved under otherwise morally reprehensible conditions. For example, the terrible health conditions in many parts of the world tied to inadequate water supplies (Table 3), are certainly "sustainable", but no ethical argument can be made for sustaining them. Similarly, higher rates of species extinction may be tolerated for some time, but the moral implications of failing to slow them must be addressed. Questions of equity overlap with sustainability when trying to determine what is to be sustained, for whom it is to be sustained, and who decides. In general, great disparities in wealth, inequities in power between women and men, and discrimination based on race, ethnicity, or age can lead to conflicts that undermine attempts to achieve sustainability. Thus, a fair political process is itself a necessary component of sustainability.

Summary and Conclusions

The sustainability criteria presented provide a framework for prioritizing competing interests and for making decisions about future water use and management. The first two criteria require that we identify and meet basic allocations for humans and ecosystems, which are to be satisfied before other demands. In this respect, the approach defined above defines criteria for basic needs as recommended by Agenda 21 of the United Nations. The sustainability criteria not only set out quantity and quality requirements, but they also set an upper limit to water use and provide some institutional guidance. As long as basic needs are met, then all remaining demands on water are acceptable as long as they do not impair the renewability of the resource and as long as allocations between both present and future generations are equitable. The criteria do not provide guidance for how to allocate these remaining demands; rather, they lay out guidelines for a process of how to decide among conflicting demands. Because these remaining demands often conflict, a higher degree of social value judgments will be required to set standards or even decide which demands should come before another. This, in turn, will require more democratic and open water-planning institutions. It is easier to agree and quantify minimum standards for human health, which has some biophysical basis, than it is to determine how much water should be allocated for irrigation or for industrial use, but these decisions need to be made as well. In allocating water to these other demands, planners must move beyond simple economics and incorporate concepts such as efficiency, equity, and participatory democracy as well.

The sustainability criteria are not meant to be all encompassing. They help answer only certain questions for public policy and planning. Nevertheless they can provide a strong set of guidelines for positive action. Ultimately, until discussions about the sustainable use of water become an integral part of long-term water planning, the world will be faced with continued unsustainable water use and threats to both human and ecological survival.

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