Water and Conflict

Fresh Water Resources and International Security

Peter H. Gleick

Fresh water is a fundamental resource, integral to all ecological and societal activities, including food and energy production, transportation, waste disposal, industrial development, and human health. Yet fresh water resources are unevenly and irregularly distributed, and some regions of the world are extremely water-short. As we approach the twenty-first century, water and water-supply systems are increasingly likely to be both objectives of military action and instruments of war as human populations grow, as improving standards of living increase the demand for fresh water, and as global climatic changes make water supply and demand more problematic and uncertain. This article outlines the links between water and conflict, and presents some of the issues and information that make it possible to assess when and where water-related conflicts are most likely to occur. Tools for reducing the risks of such conflicts are also presented, together with recommendations for policymakers.

Where water is scarce, competition for limited supplies can lead nations to see access to water as a matter of national security. History is replete with examples of competition and disputes over shared fresh water resources. Below, I describe ways in which water resources have historically been the objectives of interstate conflict and how they have been used as instruments of war. Next, I explain why the maldistribution of fresh water together with current trends in population and development suggest that water is going to be an increasingly salient element of interstate politics, including violent conflict. Complicating the analysis are the incompleteness of the data, and growing uncertainties about the role of global climatic change in altering

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water supply and demand. Nevertheless, policymakers should be more aware of potential conflicts arising over, or exacerbated by, water issues, and the ways in which international bodies could either mitigate or avoid some possible conflicts.

How might we predict when and where such conflicts could arise? Many rivers, lakes, and ground water aquifers are shared by two or more nations. This geographical fact has led to the geopolitical reality of disputes over shared waters, including the Nile, Jordan, and Euphrates rivers in the Middle East; the Indus, Ganges, and Brahmaputra in southern Asia; and the Colorado, Rio Grande, and Paraná in the Americas. I suggest several quantitative indices for measuring the vulnerability of states to water-related conflict. Bearing in mind the uncertainties of such indices, tensions appear especially likely in parts of southern and central Asia, central Europe, and the Middle East, where the history of water-related conflicts already extends back 5000 years.

Identifying potential trouble areas does little good if we have no tools for mitigating the problem. International law for resolving water-related disputes must play an important role, and I outline here recent advances in developing principles for managing internationally shared water resources. Their strengths and shortcomings are also assessed, together with their ability to deal with the kinds of uncertainties that will increasingly dominate interstate disputes over water. Not all water resources disputes will lead to violent conflict; indeed most lead to negotiations, discussions, and non-violent resolutions. But in certain regions of the world, such as the Middle East and southern and central Asia, water is a scarce resource that has become increasingly important for economic and agricultural development. In these regions, water is evolving into an issue of "high politics," and the probability of water-related violence is increasing. Policymakers and the military should be alert to the likelihood of violent conflict over water, and to the possible changes in both international water law and regional water treaties that could be implemented to minimize the probability and consequences of such conflicts over this essential and irreplaceable resource.

Environment, Resources, and International Security

"Ecological" or "environmental" security has become one of the most controversial and stimulating issues in the field of international security studies today. The relationships between the environment and international conflict

and cooperation are drawing attention at many levels, from the military to the political, from the local to the global. While the concept of non-military aspects to "security" is not new, it has gained substantial attention in the last five years, largely as a result of the burgeoning interest in international environmental issues and the waning of the Cold War. Several new and dramatic environmental threats with international political implications have now been recognized, among them abuse and degradation of essential goods and services, such as those provided by the ozone layer and our global climate, and the growing inequities among nations in resource use. This situation has led, in turn, to a lively debate about the need for new definitions of security that explicitly incorporate environmental concerns.[1]

Implicit in this argument is the notion that local or regional instability, arising from a combination of environmental, resource, and political factors, may escalate to the international level and may become violent. Thus, it is imperative to clarify the terms of debate, and to identify and analyze those cases in which environmental variables threaten security.

There is some controversy over the role that resources and environmental problems play in affecting international security, but much of the argument stems from different definitions of "security" and from disagreement over the applicability of specific methods of analysis and conflict resolution to problems with environmental roots.[2] For the purposes of this article, threats

1. The earliest references to national "security" included concerns about economic issues, the strength of domestic industry, and the "proper correlation of all measures of foreign and domestic policy." For a brief history of definitions of national security, see Joseph J. Romm, "Defining National Security," Council on Foreign Relations Occasional Paper (New York: Council on Foreign Relations, forthcoming 1993). In their book, *The Ecological Perspective on Human Affairs with Special Reference to International Politics* (Princeton: Princeton University Press, 1965), Harold and Margaret Sprout identified the environment as one factor that influences a nation's foreign policy. For discussion of the principal points in the on-going debate, see Peter H. Gleick, "Environment, Resources, and International Security and Politics," in Eric Arnett, ed., *Science and International Security: Responding to a Changing World* (Washington, D.C.: American Association for the Advancement of Science, 1990), pp. 501–523; Peter H. Gleick, "Environment and Security: Clear Connections," *The Bulletin of the Atomic Scientists*, Vol. 47, No. 3 (April 1991), pp. 17–21; Jessica Tuchman Mathews, "Redefining Security," *Foreign Affairs*, Vol. 68, No. 2 (Spring 1989), pp. 162–177; Richard H. Ullman, "Redefining Security," *International Security*, Vol. 8, No. 1 (Summer 1983), pp. 129–153; Arthur H. Westing, ed., *Global Resources and International Conflict: Environmental Factors in Strategic Policy and Action* (Oxford: Oxford University Press, 1986). Definitional issues are discussed by Thomas F. Homer-Dixon, "On the Threshold: Environmental Changes as Causes of Acute Conflict," *International Security*, Vol. 16, No. 2 (Fall 1991), pp. 76–116.

2. These issues are reviewed in far more depth by Gleick, "Environment, Resources and International Security and Politics"; Gleick, "Environment and Security: Clear Connections"; Homer-Dixon, "On the Threshold"; and Daniel Deudney, "Environment and Security: Muddled Thinking," *The Bulletin of the Atomic Scientists*, Vol. 47, No. 3 (April 1991), pp. 22–28.

to security include resource and environmental problems that reduce the quality of life and result in increased competition and tensions among subnational or national groups. In the more extreme cases, this can lead to violent conflicts, though not all security threats have violent components to them. While this approach encompasses a broader range of problems than conventional international security analysis, there is little doubt that resources and environmental concerns are playing an increasingly important role in international politics, and even in war. Examples abound: preparations for the 1992 UN Conference on Environment and Development (UNCED) included especially controversial and high-level international negotiations about the role of environment and development in trade, foreign aid, and other international arrangements; the international treaty to protect the ozone layer involved both developed and developing countries, and produced unprecedented agreement for strong actions on product development, trade in goods and information, and compensation for poorer countries;[3] environmental issues have played a large role in the negotiations and debate over the free trade agreement between the United States and Mexico; and the recent Persian Gulf War had deep and pervasive environmental and resource roots.

This broader conception of security has gained considerable acceptance by the policy and military communities in the last few years,[4] and the 1992 presidential election in the United States elevated policymakers to the highest levels of government who understand the clear connections among the environment, interstate politics, and international security. The focus of security analysts must now be *when* and *where* resource-related conflicts are most

3. "The Vienna Convention for the Protection of the Ozone Layer, March 22, 1985," Final Act (Nairobi, Kenya: United Nations Environment Programme [UNEP]); "The Montreal Protocol on Substances That Deplete the Ozone Layer, September 16, 1987"; Final Act (Nairobi, Kenya: UNEP); and the London Revisions to the Montreal Protocol, June 1990, whose text can be found in "Report of the Second Meeting of the Parties to the Montreal Protocol on Substances that Deplete the Ozone Layer," UNEP/OzL. Pro. 2/3, June 29, 1990 (London: UNEP). The complete texts of all of these can be found together in Richard E. Benedick, *Ozone Diplomacy*, World Wildlife Fund and the Conservation Foundation (Cambridge: Harvard University Press, 1991).
4. For example, see President Gorbachev's speech, "Reality and Guarantees for a Secure World," published in English in *Moscow News*, supplement to issue No. 39 (3287), 1987; the statement by Secretary of State James A. Baker 3d on January 30, 1989, *New York Times*, January 31, 1989, p. 1; and comments by Senators Sam Nunn, Albert Gore, and Timothy Wirth, *Congressional Record*, June 28, 1990, S8929–8943. Environmental security was also a central topic of discussion among military analysts at the National War College, National Defense University symposium, "From Globalism to Regionalism—New Perspectives on American Foreign and Defense Policies," November 14–15, 1991.

likely to arise, not *whether* environmental concerns can contribute to instability and conflict. There are many possible levels and scales of conflict: regional disputes at the village level, disputes within national political subdivisions, border disputes between two nations, or frictions involving many nations that may not share borders. These conflicts may be political or economic; and they may be diplomatic or violent. Recent experience suggests that conflicts are more likely to occur on the local and regional level and in developing countries where common property resources may be both more critical to survival and less easily replaced or supplemented.[5] Still, however, environmental threats to security will be affected by the economic, cultural, and sociopolitical factors at work in a given country or region.

The Geopolitics of Shared Water Resources

There is a long history of water-related disputes, from conflicts over access to adequate water supplies to intentional attacks on water systems during wars. Water and water-supply systems have been the roots and instruments of war. Access to shared water supplies has been cut off for political and military reasons. Sources of water supply have been among the goals of military expansionism. And inequities in water use have been the source of regional and international frictions and tensions. These conflicts will continue—and in some places grow more intense—as growing populations demand more water for agricultural, industrial, and economic development. While various regional and international legal mechanisms exist for reducing water-related tensions, these mechanisms have never received the international support or attention necessary to resolve many conflicts over water. Indeed, there is growing evidence that existing international water law may be unable to handle the strains of ongoing and future problems.[6] In addition to improving international law in this area, efforts by UN and international aid agencies to ensure access to clean drinking water and adequate sanitation

5. Thomas F. Homer-Dixon, "Environmental Change and Violent Conflict," Occasional Paper No. 4, American Academy of Arts and Sciences, Cambridge, Mass., and the University of Toronto (1990); Ronnie Lipschutz and John P. Holdren, "Crossing Borders: Resource Flows, the Global Environment, and International Security," *Bulletin of Peace Proposals*, Vol. 21, No. 2 (1990), pp. 121–133; Gleick, "Environment and Security: Clear Connections."

6. Recent events such as the destruction of the Peruca dam in the former Yugoslavia, the controversy between Hungary and Slovakia over the Gabcikovo dam on the Danube, and the continuing water disputes throughout the Middle East suggest the limited influence of international water law when other political interests are paramount.

can reduce the competition for limited water supplies and the economic and social impacts of widespread waterborne diseases. In regions with shared water supplies, third-party participation in resolving water disputes, either through UN agencies or regional commissions, can also effectively end conflicts.

Interstate conflicts are caused by many factors, including religious animosities, ideological disputes, arguments over borders, and economic competition. Although I argue here that resource and environmental factors are playing an increasing role in such disputes, it is difficult to disentangle the many intertwined causes of conflict.[7] This section identifies several classes of water-related disputes and presents brief historical examples of each. These classes are not completely unrelated; in some regions water may play multiple roles in contributing to regional conflicts. These categories do, however, provide a useful way to think about not only how conflicts over water may arise, but also how they may be prevented.

WATER RESOURCES AS MILITARY AND POLITICAL GOALS

The focus of recent academic international security analysis has been "geopolitics" or "realpolitik," which stresses the concept of power politics as the root of conflict. Even at this level of analysis, the role of resources as a goal of military action is acknowledged, if the resources are a defining factor in the power of a nation.[8] The drive to possess or control another country's oil has often been a goal of military action in the twentieth century, including Japanese actions in World War II, the conflict over the Falkland Islands, and the recent Persian Gulf War. Although non-renewable resources such as oil and other minerals are more typically the focus of traditional international security analyses, even water can fit into this framework if water provides a source of economic or political strength. Under these conditions, ensuring access to water provides a justification for going to war, and water-supply systems can become a goal of military conquest.[9]

The characteristics that make water likely to be a source of strategic rivalry are: (1) the degree of scarcity, (2) the extent to which the water supply is shared by more than one region or state, (3) the relative power of the basin

7. Gleick, "Environment, Resources, and International Security and Politics."
8. Ronnie D. Lipschutz, *When Nations Clash: Raw Materials, Ideology and Foreign Policy* (New York: Ballinger Publishing Co., 1989).
9. Malin Falkenmark, "Fresh waters as a factor in strategic policy and action," in Westing, *Global Resources and International Conflict*, pp. 85–113.

states, and (4) the ease of access to alternative fresh water sources. Perhaps the clearest example of a region where fresh water supplies have had strategic implications is the Middle East.[10]

The Middle East region, with its many ideological, religious, and geographical disputes, is also extremely arid. Even those parts of the Middle East with relatively extensive water resources, such as the Nile, Tigris, and Euphrates river valleys, are coming under increasing population, irrigation, and energy pressures. And every major river in the region crosses international borders.

As far back as the seventh century BC, Ashurbanipal of Assyria seized control of water wells as part of his strategy of desert warfare against Arabia.[11] In modern times, the most pressing water conflicts in this region have centered on control of the Jordan River basin. This region has seen intense interstate conflict since the establishment of Israel in 1948, and the riparian dispute over the Jordan River is an integral part of the ongoing conflict. Although by international standards the Jordan is a small river, its basin is shared by several antagonistic nations (Jordan, Syria, Israel, and Lebanon) with extremely volatile political and military dynamics, and there are few alternative sources of water. One of the factors directly contributing to the 1967 War was the attempt by members of the Arab League in the early 1960s to divert the headwaters of the Jordan River away from Israel.[12] Israeli Premier Levi Eshkol declared that, "water is a question of life for Israel," and that therefore "Israel would act to ensure that the waters continue to flow";[13] in the 1967 Arab-Israeli War, Israel occupied much of the headwaters of the Jordan River, ensuring a more reliable water supply and denying Jordan a significant fraction of its available water. Today, approximately forty percent of the ground water upon which Israel is now dependent—and more than thirty-three percent of its total sustainable annual water yield—originates in

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10. See, for example, Thomas Naff and Ruth Matson, *Water in the Middle East, Conflict or Cooperation?* (Boulder: Westview Press, 1984); and Miriam R. Lowi, "The Politics of Water Under Conditions of Scarcity and Conflict: The Jordan River and Riparian States" (Ph.D. dissertation, Department of Politics, Princeton University, Princeton, New Jersey, 1990).

11. M.S. Drower, "Water-Supply, Irrigation, and Agriculture," in C. Singer, E.J. Holmyard, and A.R. Hall, ed., *A History of Technology* (New York: Oxford University Press, 1954).

12. Lowi, "The Politics of Water," see especially Chapter 5. Also see Miriam Lowi, "Transboundary Resource Disputes: The Case of West Bank Water," *International Security*, Vol. 18, No. 1 (Summer 1993), pp. 113–138.

13. British Broadcasting Corporation, "Summary of World Broadcasts," Part 4, the Middle East: "Eshkol's statements to foreign correspondents," January 18, 1965, No. 1761, p. A/1; "Levi Eshkol's speech at Tiberias," January 21, 1965, No. 1764, p. A/1. See Lowi, "The Politics of Water," Chapter 5.

the territories occupied in the 1967 War.[14] Indeed, almost the entire increase in Israeli water use since 1967 derives from the waters of the West Bank and the upper Jordan River.

The Nile River is also an international river of tremendous regional importance and the control of the Nile is increasingly contentious, as water demands in the region soar. The Nile flows through some of the most arid regions of northern Africa and is vital for agricultural production in Egypt and the Sudan. Ninety-seven percent of Egypt's water comes from the Nile River, and more than ninety-five percent of the Nile's runoff originates outside of Egypt, in the other eight nations of the basin: the Sudan, Ethiopia, Kenya, Rwanda, Burundi, Uganda, Tanzania, and Zaire. A treaty signed in 1959 resolved a number of important issues, but was negotiated and signed by only two nations, Egypt and the Sudan,[15] raising the possibility that additional water development in other upstream nations could reduce the supply available to Egypt and greatly increase tensions in this arid region. Egypt is extremely vulnerable to intentional reductions in the flow of the Nile, although Egypt has by far the stronger position militarily and has indicated its willingness to intervene with force to prevent any disruption of flow. In 1979, President Anwar Sadat said, "the only matter that could take Egypt to war again is water."[16] More recently, Egypt's foreign minister, Boutros Boutros-Ghali (now secretary general of the United Nations), said "the next war in our region will be over the waters of the Nile, not politics."[17] While these statements partly reflect political rhetoric, they also give an indication of the importance of the Nile to Egypt.

WATER-RESOURCE SYSTEMS AS INSTRUMENTS OF WAR

Although the usual instruments of war are military weapons of destruction, the use of water and water-resources systems as both offensive and defensive weapons also has a long history. In political conflicts that escalate to military aggression, water-resource systems have regularly been both the targets and the tools of war. While fresh water resources are renewable, in practice they

14. Lowi, "The Politics of Water," p. 342.
15. "Agreement Between the United Arab Republic and the Republic of Sudan for the Full Utilization of the Nile Waters," Cairo, November 8, 1959. The treaty allocated the presumed flow of the river and established an international commission between the two countries to negotiate additional issues and disputes.
16. Cited by Joyce Starr in "Water Wars," *Foreign Policy*, No. 82 (Spring 1991), pp. 17–30.
17. This statement has been widely cited. See, e.g., Tim Walker, "The Nile Struggles to Keep Up the Flow," *Sunday Nation* (Nairobi), January 10, 1988, p. 11.

are finite, poorly distributed, and often subject to substantial control by one nation or group. In such circumstances, the temptation to use water for political or military purposes may prove irresistible. Even the perception that access to fresh water could be used as a political tool by another nation may lead to violence.

When Sennacherib of Assyria destroyed Babylon in 689 BC as retribution for the death of his son, he purposefully destroyed the water-supply canals to the city.[18] Nebuchadnezzar of Babylon later used a system of canals in the defense of the city:

> To strengthen the defenses of Babylon, I had a mighty dike of earth thrown up, above the other, from the banks of the Tigris to that of the Euphrates 5 bern long and I surrounded the city with a great expanse of water, with waves on it like the sea.[19]

In this century, hydroelectric dams were bombed during World War II, and the centralized dams on the Yalu River serving North Korea and China were attacked during the Korean War.[20] Similarly, Iran claimed to have blacked out large portions of Iraq in July 1981 by bombing a hydroelectric station in Kurdistan.[21] Irrigation water-supply systems in North Vietnam were bombed by the United States in the late 1960s. When Syria tried to stop Israel in the 1950s from building its National Water Carrier, an aqueduct to provide water to southern Israel, fighting broke out across the demilitarized zone, and when Syria tried to divert the headwaters of the Jordan in the mid-1960s, Israel used force, including air strikes against the diversion facilities to prevent their construction and operation.[22] These military actions contributed to the tensions that led to the 1967 War.

Most recently, dams, desalination plants, and water-conveyance systems were targeted by both sides during the 1991 Persian Gulf War. Most of Kuwait's extensive desalination capacity was destroyed by the retreating Iraqis, and in mid-1992, the Iraqis were still suffering severe problems rebuilding Baghdad's modern water supply and sanitation system, which had intentionally been destroyed during the war.[23] In early 1993, it was reported

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18. Drower, "Water-Supply, Irrigation, and Agriculture."
19. Quoted in Drower, "Water-Supply, Irrigation, and Agriculture."
20. Amory B. Lovins and L. Hunter Lovins, *Brittle Power: Energy Strategy for National Security* (Andover, Mass.: Brick House Publishing, 1982), p. 69.
21. "Iran Says It Bombed Iraqi Hydroelectric Plant," *New York Times*, July 20, 1981, p. A2.
22. See, for example, Naff and Matson, *Water in the Middle East*.
23. "Iraq's Water Systems Still in Shambles," *U.S. Water News*, Vol. 8, No. 10 (1992), p. 2.

that Saddam Hussein was poisoning and draining the water supplies of southern Shiite Muslims in his efforts to quell the opposition to his government.[24] And in late January 1993, the Peruca dam, the second largest dam in the former Yugoslavia, was intentionally destroyed in the civil war there.[25] As water supplies and delivery systems become increasingly valuable in water-scarce regions, their value as military targets also increases.

A strange twist on this problem surfaced in 1986, when North Korea announced plans to build the Kumgansan hydroelectric dam on a tributary of the Han River upstream of South Korea's capital, Seoul. This raised fears in South Korea that the dam could be used as a tool to disrupt its water supply or to upset the ecological balance of the area, or that it could even be used as an intentional offensive weapon in the event of hostilities. South Korean military analysts predicted that the deliberate destruction of the dam by the North could be used as a military weapon to flood Seoul and that the sudden release of the entire contents of the dam would raise the level of the Han River as it passes through Seoul by over 50 meters, enough to destroy most of the city. A formal request to halt construction was made to the North Korean government, and South Korea built a series of levees and check dams above Seoul to try to mitigate possible impacts.[26]

In the Middle East, hydroelectric and agricultural developments on the Euphrates River have been the source of considerable international concern. This river flows from the mountains of southern Turkey through Syria to Iraq before emptying into the Persian Gulf. Both Syria and Iraq depend heavily on the Euphrates River for drinking water, irrigation, industrial uses, and hydroelectricity, and view any upstream development with concern. In 1974, Iraq threatened to bomb the al-Thawra dam in Syria; it massed troops along the border, alleging that the flow of water to Iraq had been reduced by the dam. More recently, Turkey has implemented an ambitious water-supply scheme to increase its hydroelectricity production and to irrigate an additional two million hectares of land. In 1990, Turkey finished construction of the Atatürk Dam, the largest of the twenty-one dams proposed for the

24. "New Repression of Iraqi Shiites Reported," *Boston Globe*, February 28, 1993, p. 4, reporting on a story in the British paper *Observer*.
25. Laura Silber, "Battle to avert Croat dam disaster," *Financial Times*, January 30/31, 1993, p. 2.
26. Susan Chira, "North Korea Dam Worries the South," *New York Times*, November 30, 1986, p. 3. Noel Koch, "North Korean Dam Seen as Potential 'Water Bomb'," *Washington Post/San Francisco Chronicle*, September 30, 1987, "Briefing," p. 3. North Korea denied any military intentions, but construction on the dam was halted in the late 1980s and the project remains on hold.

Grand Anatolia Project, and interrupted the flow of the Euphrates for a month to partly fill the reservoir. Despite advance warning from Turkey of the temporary cutoff, Syria and Iraq both protested that Turkey now had a water weapon that could be used against them. Indeed, in mid-1990, Turkish President Turgut Ozal threatened to restrict water flow to Syria to force it to withdraw support for Kurdish rebels operating in southern Turkey. While Turkish politicians later disavowed this threat, Syrian officials argue that Turkey has already used its power over the headwaters of the Euphrates for political goals and could do so again.[27] When the Turkish projects are complete, the flow of the Euphrates River to Syria could be reduced by up to 40 percent, and to Iraq by up to 80 percent.[28]

It is sometimes only a short step from capability to implementation. The ability of Turkey to shut off the flow of the Euphrates, even temporarily, was noted by political and military strategists at the beginning of the Persian Gulf conflict.[29] In the early days of the war, there were behind-the-scenes discussions at the United Nations about using Turkish dams on the Euphrates River to deprive Iraq of a significant fraction of its fresh water supply in response to its invasion of Kuwait.[30] While no such action was ever taken, the threat of the "water weapon" was again made clear.

Resource Inequities and the Impacts of Water Developments

There are growing tensions between rich and poor nations due to inequitable distribution and use of resources. While most of the attention of political scientists interested in the links between resources and interstate conflict has focused on non-renewable mineral resources such as rare metals and oil, some renewable resources such as water also suffer great maldistribution and may pose comparable risks to international peace in the future. Unlike

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27. Alan Cowell, "Water Rights: Plenty of Mud to Sling," *New York Times*, February 7, 1990, p. A4.
28. This estimate comes from Professor Thomas Naff of the University of Pennsylvania and is cited in "Water Wars in the Middle East," *The Economist*, May 12, 1990, pp. 54–59.
29. See Peter Schweizer, "The Spigot Strategy," *New York Times* op-ed, November 11, 1990.
30. These closed-door discussions were described to the author by the ambassador of a member nation of the U.N. Security Council under the condition that he remain anonymous. See also the statement of the Minister of State of Turkey, Kamran Inan, at the Conference on Transboundary Waters in the Middle East: Prospects for Regional Cooperation, Ankara, Turkey, September 3, 1991. At that meeting, Minister Inan stated that Turkey would never use water as a means of political pressure and noted that it had declined to do so during the Gulf War.

rare metals, water is quite difficult to redistribute economically. Unlike oil, water has no substitutes.

In some regions, water availability is coming up against the limits of minimum water requirements—the so-called "water barrier" defined by Malin Falkenmark.[31] Falkenmark identifies levels of water availability below which serious constraints to development will arise. Falkenmark sets this level at between 1000 and 2000 people for every million cubic meters of water per year. In fast-growing semi-arid nations and regions, limits to supply will eventually be reached, despite efforts to reduce waste and to redirect priorities. While there is no doubt that great improvements in the efficiency of water use can be made throughout the world, as can trade-offs between water-consumptive and water-efficient sectors, these actions only push back the barrier, they do not eliminate it.

As a result, some countries could eventually reach an absolute limit on the type and extent of industrial development due solely to constraints on the availability of fresh water. How fast these limits are reached depends on three factors: (1) the absolute availability of water; (2) the population needing to be supplied; and (3) the level of development desired, as measured by both the need for water and the efficiency with which water is used. Such limits will contribute to tensions between water-poor and water-rich nations and could be the source of future conflict.

Other hydrologic conditions may contribute to regional tensions. Enormous human suffering occurs because of the lack of satisfactory water for health and sanitation. Despite great efforts during the International Drinking Water Supply and Sanitation Decade of the 1980s, 1.3 billion people are still without access to safe, clean water, and over 1.7 billion are without access to appropriate sanitation facilities.[32] By 2000, 900 million more people will have been born in regions without these essential services.

These conditions are directly responsible for the severe impact of waterborne diseases around the world, including dysentery, malaria, cholera, and the parasitic diseases rampant in parts of Africa and Asia. These diseases can explode in intensity in regions that lack sanitation services and clean water for drinking. In 1990, 71,000 cases of cholera were reported to the

31. Malin Falkenmark, "Fresh Water—Time for A Modified Approach," *Ambio*, Vol. 15, No. 4 (1986), pp. 194–200.
32. Joseph Christmas and Carel de Rooy, "The Decade and Beyond: At a Glance," *Water International*, Vol. 16, No. 3 (Urbana, Illinois: International Water Resources Association, 1991), pp. 127–134.

World Health Organization; none came from Latin America, which had been free of cholera since the mid-1800s. One year later, in 1991, cholera exploded in the region, with over 390,000 cases reported in fourteen Latin American countries alone, and over 590,000 cases worldwide.[33] This epidemic is clear evidence of the shortfall in provision of water, sanitation, and health services in the poorest areas of the Americas.

Lack of progress in providing safe drinking water and sanitation services during the 1980s was due in large part to population growth, the substantial and growing debt burden carried by developing countries, and the lack of industrial and intellectual infrastructure for building and maintaining sanitation and water-supply projects. Unless there is a renewed effort on the part of the richer nations to fill these gaps, the world's water-related health burden will rise.

Similar inequities exist in the use of water for energy production and for irrigation. Two percent of global hydroelectricity comes from Africa, which has 12 percent of the world's population; in contrast, nearly 30 percent comes from North America, with only 6 percent of the world's population.[34] Only nine countries in Africa irrigate more than 10 percent of their cropland; over sixty countries worldwide fall into this category. In Africa as a whole, only six percent of cropland is irrigated; worldwide the total is close to 16 percent. In fact, nearly twenty nations in Africa have effectively *no* irrigation supply systems at all.[35] Differences in the level and quality of water development are not always the result of shortages in water availability, but of access to capital, technology, and know-how,[36] and the inefficiency of governmental

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33. The updated 1991 cholera data come from a personal communication with Dr. S.J. Siméant of the World Health Organization in Geneva. See also Pan American Health Organization, "Mortality Due to Intestinal Infectious Diseases in Latin America and the Caribbean, 1965–1990," and "Cholera Situation in the Americas: An Update," *Epidemiological Bulletin*, Vol. 12, No. 3 (1991), pp. 1–13.

34. U.S. Department of Energy, *International Energy Annual,* DOE/EIA-0219(90) (Washington, D.C.: Energy Information Administration, 1990).

35. Food and Agriculture Organization, *FAO Production Yearbook 1990,* FAO Statistical Series, Vol. 44, No. 99 (Paris: Food and Agriculture Organization of the United Nations, 1990). These data are for 1989. For a summary of cropland use by region and country see Table E.1 in Peter H. Gleick, ed., *Water in Crisis: A Guide to the World's Fresh Water Resources* (New York: Oxford University Press, 1993).

36. For example Professor Charles Okidi, from Moi University in Kenya, pointed out that there are only four Ph.D-level hydrologists in all of Kenya to work on problems of water supply, sanitation, hydroelectricity, and hydroclimatology. Charles Okidi, "Environmental Stress and Conflicts in Africa: Case Studies of African International Drainage Basins," paper prepared for the Project on Environmental Change and Acute Conflict, American Academy of Arts and Sciences and the University of Toronto (May 1992).

organizations in many developing nations in implementing effective agricultural or energy policies.

What is the link between these water-resource problems and conflict? In most cases, resource inequities will lead to more poverty, shortened lives, and misery, but not directly to violent conflict. But in some cases, these resource gaps will increase the likelihood of international disputes, create refugees who cross borders, and decrease the ability of a nation to resist economic and military activities by neighboring countries.

Conflicts over sources of irrigation water may become particularly severe, given the urgent demands to increase food production to meet both current needs and expected increases in population. Even where arable land suitable for irrigation exists, political or physical constraints may hinder any expansion of irrigation. In northern Africa, for example, the Sudan is considered one of the few nations with great potential for increased irrigation: there is sufficient arable land and there is, in theory, sufficient water in the Nile. In reality, however, withdrawing additional water from the Nile would require that the Sudan renegotiate or abrogate the treaty it signed in 1959 with Egypt.[37]

Similarly, many major hydroelectric projects are multi-national. Occasionally a dam is built by a smaller nation that then sells excess electricity to a larger neighbor. The Itaipú Dam on the Paraná River, for example, was built jointly by Brazil and Paraguay, although almost all of the hydroelectric benefits go to Brazil. Changes in electricity needs of the region may require difficult renegotiation of the present agreement. In addition, some subsidiary effects of the dam, such as changes in the timing and magnitude of downstream flows, caused disputes between Brazil and Argentina, which wanted to build its own dam on the Paraná that would have affected the operation of the Itaipú dam. A compromise agreement was ultimately reached after some tense negotiations, permitting the construction of the Yacyreta dam by Argentina. The Kariba Dam, one of the largest in Africa, is built on the Zambezi River on the border of Zambia and Zimbabwe, and dam operation has sometimes been difficult to coordinate. Situations like these can promote cooperation and peace. But they may also be the source of conflict where

37. Peter H. Gleick, "Climate Changes, International Rivers, and International Security: The Nile and the Colorado," in Robert Redford and Terrill J. Minger, editors, *Greenhouse Glasnost* (New York: The Ecco Press, 1990), pp. 147–165; Peter H. Gleick, "The Vulnerability of Runoff in the Nile Basin to Climatic Changes," *The Environmental Professional*, Vol. 13, No. 1 (1991), pp. 66–73.

there are gross inequities in energy use. When disputes arise over the distribution of electricity, or for other reasons, conflicts for these hydroelectric resources are a distinct possibility.

OTHER LINKS BETWEEN CONFLICT AND WATER DEVELOPMENTS

Water-related conflicts may also arise over the secondary impacts of water development schemes such as irrigation facilities, hydroelectric developments, and flood-control reservoirs. Major water developments often lead to displacement of large local populations, adverse impacts on downstream water users and ecosystems, changes in control of local resources, and economic dislocations. These impacts may, in turn, lead to disputes among ethnic or economic groups, between urban and rural populations, and across borders. Table 1 lists some of the most severe population displacements caused by the construction of dams and reservoirs worldwide.

There are many examples of local and regional water disputes. In South Africa in 1990, for example, a pro-apartheid council cut off water to the Wesselton township of 50,000 blacks following their protest over miserable sanitation and living conditions.[38] Zimbabwe recently reported that its output of ethanol, which is mixed with gasoline to reduce the country's fuel imports, has dropped because the severe African drought has crippled sugar cane production.[39] This has a direct impact on Zimbabwe's economic strength, and may affect its ability to maintain both domestic and regional stability. Violent conflicts have arisen over water allocations in India, most recently in early 1992 following a court decision to allocate the waters of the Cauvery River between the states of Karnataka and Tamil Nadu. The Cauvery River originates in Karnataka, but the greatest use of the water is in Tamil Nadu, before it flows to the Bay of Bengal. Over fifty people were reported killed in riots in Karnataka following the allocation of additional water to Tamil Nadu.[40]

These examples mostly involve regional political borders, but they are little different from the kinds of disputes that can be international. Indeed, some of the regional resource disputes within what was the Soviet Union must now be considered international due to the changing political status of the

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38. Rodney Pinder, "50,000 Blacks Deprived of Water" Reuters Press/*San Francisco Chronicle,* October 24, 1990, p. A-11.
39. "Drought reduces output of ethanol," *The Herald* (Harare), February 24, 1992. p. 1.
40. Marcus Moench, 1992, personal communication with author.

Table 1. Populations Displaced as a Consequence of Dam Construction.

Dam	Countries	Installed Capacity (MW)	Area of Reservoir (km^2)	Number of People Displaced	Date Completed[a]
Sanmenxia	China			870,000	1960
Maduru Oya	Sri Lanka		64	200,000	1983
Aswan	Egypt, Sudan	1,815	6,500	120,000	1970
Mangla	Pakistan	600		110,000	1967
Kaptai	Bangladesh		777	100,000	1962
Damodar (4 projects)	India			93,000	1959
Nanela	Pakistan			90,000	1967
Tarbela	Pakistan	1,750	243	86,000	1976
Akasombo	Ghana	882	9,000	80,000	1965
Kossou	Ivory Coast		1,700	75,000	1972
TVA (about 20 projects)	United States			60,000	1930s on
Kariba	Zambia, Zimbabwe	1,266	5,100	50,000–57,000	1959
Gandhi Sagar	India			52,000	
Itaparica	Brazil	1,500		50,000	1988
Kainji	Nigeria			42,000–50,000	1968
Ataturk (Southeast Anatolia Project)	Turkey			40,000	1991
Bhakra	India	450		36,000	1963
Lam Pao	Thailand		400	30,000	1970
Keban	Turkey	1,360	675	30,000	1974
Mython (Jharkh)	India	200		28,030	1955
Kedong Ombo	Java, Indonesia			27,000	1992
Nam Pong	Thailand		20	25,000–30,000	1965
Tucurui	Brazil	4,000	2,430	23,871	1984
Upper Pampanga	Phillippines			14,000	1973
Ruzizi II	Rwanda, Zaire	40		12,600	
Manantali	Mali	200		10,000	
Salvajina	Colombia		22	10,000	1985
Brokopondo	Suriname			5,000	1971
Caracol	Mexico			5,000	1986
Batang Ai	Sarawak, Borneo	92	85	3,000	
Nam Ngum	Laos			3,000	1971
Netzahualcoyotl	Mexico			3,000	1964

NOTE:
a. Approximate date of completion. Blanks in the table mean this information is not available.

SOURCE: Compiled by Cynthia Chiang. See Peter H. Gleick, ed., *Water in Crisis: A Guide to the World's Water Resources* (New York: Oxford University Press, 1993).

former republics. The destruction of the Aral Sea from overuse of the Amu Dar'ya and Syr Dar'ya rivers was once was an internal Soviet matter; now the problem affects five independent nations.

The impacts of some water developments involve more than one nation from the beginning. The construction of the Aswan High Dam by Egypt led

to flooding and dislocation of populations in the Sudan. The construction of the Farakka Barrage on the Ganges in India affected water conditions and availability in Bangladesh. The construction of several major irrigation projects in the southwestern United States led to the serious degradation of Colorado River water quality delivered to Mexico and an intense political dispute that was ultimately resolved through diplomatic negotiations.[41] In 1992, a serious political dispute arose between Hungary and Czechoslovakia over the construction and operation of the Gabcikovo/Nagymaros project on the Danube River. In May 1992, Hungary abrogated a 1977 treaty with Czechoslovakia governing construction of the project, complaining of possible severe environmental damage, but Czechoslovakia continued construction unilaterally, completing the Gabcikovo dam and diverting the Danube out of its bed into a canal inside of the Slovakian republic. This prompted massive public protests in both Hungary and Slovakia, rumors of military actions, Hungarian appeals to the International Court of Justice, consultation with the Conference on Security and Cooperation in Europe (CSCE), and the intervention of the European Community Commission. As of early 1993, the risk of violent conflict appears to have decreased as other political mechanisms have come into play, particularly the participation of European Community negotiators, but the relationship between the parties remains very tense.[42]

Conflicts in regions with other simmering tensions, such as the Middle East, have been contained less successfully than in regions with few other political disputes. The major dam developments in Turkey, as part of the Grand Anatolia Project, have caused growing, and so far unresolved, tensions among Turkey, Syria, and Iraq. In addition, the construction of a large dam on the Han River, discussed earlier, adds another layer to the long-standing dispute between North and South Korea.

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41. Peter H. Gleick, "The Effects of Future Climatic Changes on International Water Resources: The Colorado River, the United States, and Mexico," *Policy Sciences*, Vol. 21, No. 1 (February 1988), pp. 23–39.

42. During the height of the dispute, as Slovakia began to divert the Danube, there were rumors of military maneuvers. Nicholas Denton, "Hungarians furious over work on dam," *Financial Times*, October 26, 1992, p. 3. The controversy was complicated by the presence of a large ethnic Hungarian minority in Slovakia near the construction site, by Slovakia's claim that the project is essential to its "energy security and economic well-being," by disputes over navigation rights on the Danube, and by the participation of Austrian banks and construction companies on the project. Nicholas Denton, "Hungary backed by Germany over dam," *Financial Times*, October 27, 1992, p. 3.

Future Conflicts over Water

Nations fight for access to water, use water as a tool and weapon in battle, and target the water facilities of enemies. While water resources have rarely been the sole cause of conflict, fresh-water resources are becoming more valuable in many regions, and the likelihood of water-induced conflicts is thus increasing. In arid and semi-arid areas of the world, where water is already a vital resource, conflicts over access and possession are likely to worsen.

In addition to the threats of scarcity caused by growing populations and changing levels of development, there is a new danger posed by the so-called "greenhouse effect."[43] The preceding discussion has assumed that total water availability in the future will not change, and will be subject only to natural variations in flow. But in fact, future climatic changes effectively make obsolete all our old assumptions about the behavior of water supply. Perhaps the greatest certainty about future climatic changes is that the future will not look like the past. We may not know precisely what it will look like, but changes are coming, and by the turn of the century, many of these changes will already be apparent.

Global climatic change will affect water availability in many ways, although the precise nature of such changes is still obscure.[44] Our challenge is to identify those cases in which conflicts are likely to be exacerbated and to work to reduce the probability and consequences of those conflicts.

Despite many remaining scientific uncertainties, the outlines of important water resource changes can now be seen. The clearest threat posed by climatic change is the increase in both evaporative losses and water demands caused by higher average temperatures. Even without changes in precipitation, water availability can decrease by 10 percent or more simply owing to average temperature increases of 2 to 3°C, well within the range of expected changes over the next few decades.[45] These effects are independent of the increased

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43. Peter H. Gleick, "The implications of global climatic changes for international security," *Climatic Change*, Vol. 15, No. 1–2, (October 1989), pp. 309–325.

44. For more detail on the science of climate change, see the report of the Intergovernmental Panel on Climate Change, *Climate Change: The IPCC Scientific Assessment* (Cambridge, U.K.: Cambridge University Press, 1990).

45. See the summary of climate and water issues in Peter H. Gleick, "Climate Change, Hydrology, and Water Resources," *Review of Geophysics*, Vol. 27, No. 3 (1989), pp. 329–344. For details on future climate conditions, including a discussion of the uncertainties, see Table 4.1 from Stephen H. Schneider, Linda Mearns, and Peter H. Gleick, "Climate-Change Scenarios for

demands from both human users and natural ecosystems that will occur at the same time.[46]

In addition to temperature changes, annual precipitation changes of 10 to 25 percent may occur, and even larger fluctuations may occur on a monthly basis. These shifts are more than enough to cause serious problems in some places, and some benefits in others, with concomitant impacts on local populations. Regions subject to droughts and water competition may benefit from increases in rainfall or suffer from decreases in rainfall. Areas vulnerable to periodic floods may suffer from climate-induced increases in runoff or benefit from reductions in peak flows. Regions dependent on hydroelectricity for a substantial fraction of their energy production may suffer from reductions in reservoir levels that result from prolonged shortages, and the associated economic stresses such energy losses will bring.

Climate impact information combined with data on per-capita water availability and supply reveals that certain regions are highly vulnerable. A recent review of climate changes estimated by large-scale climate models (so-called "general circulation models" or "GCMs") for the Middle East shows both the uncertain nature of the changes and the possibility that the climate changes will be severe. For the region of the Jordan and Litani Rivers, three different climate models estimate that precipitation could change by an amount between −14 and +48 percent.[47] For the region of the Nile, comparable changes are possible. Using estimates of plausible changes in temperature and precipitation derived from large-scale global climate models, some studies suggest that runoff in the Nile basin as a whole could decrease by 25 percent.[48] While short-term changes in flow of this magnitude are manageable, a long-term decrease of this magnitude could be catastrophic.

In some regions flooding may be a more severe problem than droughts. Floodplains, river deltas, and mountainous areas are particularly vulnerable to increases in flow. The risk of flooding depends on the intensity of storms,

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Impact Assessment," in Robert L. Peters and Thomas E. Lovejoy, eds., *Global Warming and Biological Diversity* (New Haven: Yale University Press, 1992), pp. 38–55.

46. Estimates of evaporative losses as a function of temperature come from Richard Wetherald and Sykuro Manabe, "Influence of Seasonal Variation upon the Sensitivity of a Model Climate," *Journal of Geophysical Research*, Vol. 86 (C2), (1981), pp. 1194–1204; and Mikhail I. Budyko, *The Earth's Climate: Past and Future*, International Geophysics Series, Vol. 29 (New York: Academic Press, 1982).

47. Stephen Lonergan, "Climate Warming, Water Resources, and Geopolitical Conflict: A Study of Nations Dependent on the Nile, Litani and Jordan River Systems," Operational Research and Analysis Establishment, ORAE Paper No. 55 (Ottawa: National Defence, 1991).

48. Gleick, "The Vulnerability of Runoff in the Nile Basin."

the level of floodplain development, geomorphology, and the extent of physical protection such as levees and dams. If estimates of increased intensity of monsoons are correct, southern Asia, including Bangladesh, Bhutan, Cambodia, and Laos, will be particularly vulnerable to flooding.[49] Other regions that already suffer from severe periodic floods include central Sudan, eastern India, Turkey, Congo, and Guyana.

Perhaps the most important effect of climatic change on water resources will be a great increase in the overall uncertainty associated with water management and supply. Rainfall, runoff, and storms are all natural events with a substantial random component to them; in the language of hydrologists, they are "stochastic." In many ways, therefore, the science of hydrology is the science of estimating the probabilities of certain types of events. But these estimates are almost always done assuming that climate is stationary—i.e., variable but unchanging over the long term. Indeed, hydrologists and water managers have few analytical tools with which they can incorporate future changes of uncertain magnitude.

Recent studies of the effects of future climatic changes suggest that present methods of water allocation, dam and turbine operation, and the inflexible setting of delivery priorities may leave international rivers open to significant water supply and quality problems.[50] Yet no organizations or agencies responsible for shared international river management have yet indicated a willingness to consider changing operating rules to improve their ability to handle possible climatic changes. For example, increased flexibility on the timing of hydroelectricity generation and deliveries of water to users of the Colorado River (shared by seven states of the United States and by Mexico) could reduce the risks of shortages there.[51] Adding to this problem is the fact that many water data are still classified as secret by national governments. Changes in flow could therefore be perceived and misinterpreted by

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49. Schneider, Mearns, and Gleick, "Climate Change Scenarios."
50. Gretta Goldenman, "International River Agreements in the Context of Climatic Change," Pacific Institute for Studies in Development, Environment, and Security (Berkeley, Calif.: Pacific Institute, 1989); Linda Nash and Peter H. Gleick, "The Sensitivity of Streamflow in the Colorado Basin to Climatic Changes," *Journal of Hydrology*, Vol. 125 (July 1991), pp. 221–241; Linda Nash and Peter H. Gleick, "The Sensitivity of Streamflow and Water Supply in the Colorado Basin to Climatic Changes" (Washington, D.C.: U.S. Environmental Protection Agency, 1993); Peter H. Gleick, "Effects of Climate Change on Shared Fresh Water Resources," in Irving M. Mintzer, ed., *Confronting Climate Change: Risks, Implications and Responses* (Cambridge, U.K.: Cambridge University Press, 1992), pp. 127–140.
51. Nash and Gleick, "The Sensitivity of Streamflow and Water Supply."

downstream nations as intentional manipulations rather than geophysical events, thereby provoking conflict.

We thus see growing pressures on both the supply of and demand for water resources because of global climate changes. Unless we can anticipate where these pressures will be the most severe, and where conflicts may arise, we will be condemned to react to outbreaks of actual conflict, rather than able to act to prevent them or reduce their probability. It is crucial, therefore, to try to anticipate where and when water-related conflicts will occur. Despite the unpredictable and uncertain nature of resource disputes, the next section explores how one might evaluate a country's vulnerability to water-resource problems or reliance on disputed supplies.

Indices of Water-Resources Vulnerability

Water-resources vulnerability is a function of many things, including economic and political conditions, water availability, and the extent to which a source of water supply is shared. Although they should be considered rough, some quantitative indices that look at several of these factors suggest "regions at risk."[52] Countries where such indicators suggest that the risk of conflict may be high might also be regions where creative regional cooperation or the intervention of international organizations would be particularly valuable.

Table 2 measures the ratio of annual water demand (withdrawals) to annual renewable water availability (supply). Countries whose present water withdrawals exceed one-third of their total renewable supply are listed. In these countries, shortages could result from limited overall water supply or high water demands: either situation can lead to a conflict over water with neighboring or relatively water-rich countries. As the data in Table 2 indicate, twenty-one countries use more than one-third of their renewable supply, with nine of them already forced to import additional fresh water, pump ground water at a non-renewable rate, or desalinate non-potable sources at

52. A similar series of regional indices of water resource vulnerability for the United States was developed using measures of supply, demand, dependence on hydroelectricity, overpumping of ground water, and hydrologic variability. See Peter H. Gleick, "Vulnerability of Water Systems," in Paul E. Waggoner, ed., *Climate Change and U.S. Water Resources* (New York: John Wiley and Sons, 1990), pp. 223–240. Such indices are not meant to be definitive. In many regions of the world, water resource data are limited or unreliable, making the quantification of these indices difficult. For some of the measures, more detailed regional data, or data on a seasonal basis rather than on an annual average basis, would be valuable.

Table 2. Ratio of Water Demand to Supply by Country.

Country	Water Withdrawals as a Percentage of Renewable Supply[a]	Country	Water Withdrawals as a Percentage of Renewable Supply[a]
Libya	374	Belgium	72
Qatar	174	Cyprus	60
United Arab Emirates	140	Tunisia	53
Yemen	135	Afghanistan	52
Jordan	110	Pakistan	51
Israel	110	Barbados	51
Saudi Arabia	106	Iraq	43
Kuwait	>100	Madagascar	41
Bahrain	>100	Iran	39
Egypt	97	Morocco	37
Malta	92		

NOTE:

a. These data are for the late 1980s and show the percentage of water used annually compared to the annually renewable supply of water including river flows from other countries. Nine countries use more than 100 percent of available supply, which means that these countries partly depend on water imports, non-renewable ground water, or desalination of brackish or salt water.

SOURCES: United Nations Environment Programme, "The State of the World Environment in 1991," *Climate Change: Need for Global Partnership* (Nairobi, Kenya: United Nations, 1991); World Resources Institute, *World Resources 1990–91: A Guide to the Environment* (New York: Oxford University Press, 1990); and Professor Thomas Naff, personal communication (1992).

great expense. All nine of these are in the Middle East, a region where political and resource tensions are already high.

A second quantitative indicator, which takes into account growing populations, is shown in Table 3. This Table lists those countries where annual per capita water availability in 1990 falls below 1,000 cubic meters per person, or will do so by 2025.[53] As described earlier, this level of water availability is typically considered the minimum per-capita water requirement for an efficient, industrialized nation. For many of the countries in Table 3, annual availability falls below 250 cubic meters per person, suggesting significant water scarcity and stress. No developed country uses this little water. Even Israel, which has done a great deal to increase its water-use efficiency and

53. Falkenmark, "Fresh water."

Table 3. Per Capita Water Availability Today and in 2025 (cubic meters/person/year).[a]

Country	Per Capita Water Availability 1990	Projected Per Capita Water Availability 2025
Africa		
Algeria	750	380
Burundi	660	280
Cape Verde	500	220
Comoros	2,040	790
Djibouti	750	270
Egypt	1,070	620
Ethiopia	2,360	980
Kenya	590	190
Lesotho	2,220	930
Libya	160	60
Morocco	1,200	680
Nigeria	2,660	1,000
Rwanda	880	350
Somalia	1,510	610
South Africa	1,420	790
Tanzania	2,780	900
Tunisia	530	330
North and Central America		
Barbados	170	170
Haiti	1,690	960
South America		
Peru	1,790	980
Asia/Middle East		
Cyprus	1,290	1,000
Iran	2,080	960
Israel	470	310
Jordan	260	80
Kuwait	<10	<10
Lebanon	1,600	960
Oman	1,330	470
Qatar	50	20
Saudi Arabia	160	50
Singapore	220	190
United Arab Emirates	190	110
Yemen	240	80
Europe		
Malta	80	80

NOTE:

a. Some hydrologists have identified 1000 cubic meters per person per year as a minimum water requirement for an efficient, moderately industrialized nation. The countries listed here are those that either in 1990 or in 2025 will fail to meet this level of fresh water availability. The change between 1990 and 2025 is due solely to increases in population.

SOURCES: Computed from United Nations population data and estimates. Population and water availability data come from World Resources Institute, *World Resources 1991–92* (New York: Oxford University Press, 1991).

minimize water-intensive development, uses over 400 m^3/person/year.[54] Note that most of the water-limited nations are located in Africa and Asia; few nations in Europe, the Pacific, or the Americas face these constraints. Over the next few decades, some of these countries will begin to see limits to their economic development because of the limited availability of water. Ethiopia, Kenya, Rwanda, Tanzania, and Burundi, all listed in Table 3, are all part of the Nile Basin and are likely to want to increase their utilization of Nile waters, at the ultimate expense of Egypt. Libya, Yemen, and many countries in the Persian Gulf (Saudi Arabia, Qatar, United Arab Emirates, and Kuwait) are pumping ground water resources at rates faster than they are being replenished by rainfall. These countries are vitally dependent on ground water and on desalination fueled by inexpensive oil and gas, and they may exhaust ground water supplies early in the next century, at the risk of severe economic dislocations.

An index that measures the extent to which water supplies are shared, and hence potentially vulnerable to competing interests, is shown in Table 4. This table lists those nations with a large fraction of their total water supply originating outside of their borders and under the control of other nations. The best example of this is Egypt, which is entirely dependent on the Nile River for its water, ninety-seven percent of which originates outside of Egypt's border. Thirty other nations receive more than one-third of their surface water across national borders.[55] This suggests that frictions and tensions over water may arise in parts of Europe (Hungary, Germany, Austria, Belgium, the Czech Republic, and Slovakia) and in Asia (Cambodia, Bangladesh, and Pakistan), where water is controlled by neighboring countries.

A fourth measure of vulnerability to hydrologic conditions is a high dependence on hydroelectricity as a fraction of total electrical supply. Table 5 lists those nations that use hydroelectricity to provide more than 50 percent of their total electrical demand. For nations that rely on hydroelectricity for 50 percent of their total energy supply, military actions against hydroelectric

54. All countries, including Israel, can do more to reduce waste of water and thus extend the amount of water available for other use. In addition, most data on water use do not differentiate between water withdrawn and water *consumed.* Better data on water consumption are needed.
55. These data precede the breakup of the Soviet Union and Yugoslavia. Many major rivers in these regions cross the borders of the newly formed political states. When the political status of these regions becomes clearer, it will be possible to recalculate the number of nations receiving significant fractions of water from sources originating outside of their political boundaries.

Table 4. Dependence on Imported Surface Water.

Country	Percent of Total River Flow Originating Outside of Border[a]	Country	Percent of Total River Flow Originating Outside of Border[a]
Egypt	97	Iraq	66
Hungary	95	Albania	53
Mauritania	95	Uruguay	52
Botswana	94	Germany	51
Bulgaria	91	Portugal	48
Netherlands	89	Yugoslavia	43
Gambia	86	Bangladesh	42
Cambodia	82	Thailand	39
Romania	82	Austria	38
Luxembourg	80	Pakistan	36
Syria	79	Jordan	36
Congo	77	Venezuela	35
Sudan	77	Senegal	34
Paraguay	70	Belgium	33
Czechoslovakia	69	Israel[b]	21
Niger	68		

NOTES:

a. Using average annual river flows originating outside national borders.

b. Although only 21 percent of Israel's water comes from outside current borders, a significant fraction of Israel's fresh water supply comes from disputed lands, complicating the calculation of the origin of surface water supplies. This percentage would be affected by a political settlement of the Middle East conflict.

SOURCES: These data come from many sources compiled by the World Resources Institute, *World Resources, 1991–92* (New York: Oxford University Press, 1991).

dams, the intentional alteration of flows that cross borders, and any changes in climate that affect water availability would all be strongly felt. Once again, the countries of the Nile basin appear highly vulnerable, as are portions of west Africa and South America.

Combining the index of hydroelectric dependence with the index of dependence on water originating outside of national borders provides some measure of the vulnerability of a nation's energy supply to outside intervention. Nations that show up on both lists—Congo, Paraguay, Uruguay, Albania, and Austria—are especially at risk and may be worthy of more attention.

Table 5. Hydroelectric Production, by Continent and Country.[a]

Region	Hydroelectric Production as a Percent of Total Electricity Generation 1987	Region	Hydroelectric Production as a Percent of Total Electricity Generation 1987
Africa	**17.4**	**North and Central America**	**17.9**
Angola	74.2		
Burundi	96.3	Canada	63.7
Cameroon	97.2	Costa Rica	98.3
Central African Republic	80.4	El Salvador	54.2
		Haiti	71.1
Congo	99.1	Honduras	81.1
Cote D'Ivoire	58.6	Panama	70.0
Ethiopia	80.2		
Gabon	77.1		
Ghana	98.3	**Asia**	**17.5**
Kenya	72.7		
Madagascar	53.6	Afghanistan	60.8
Malawi	97.6	Laos	95.5
Mali	79.4	Nepal	95.2
Rwanda	97.7	N. Korea (DPRK)	58.0
Tanzania	69.8	Sri Lanka	80.4
Uganda	98.3		
Zaire	97.4		
Zambia	99.6	**Europe**	**18.7**
South America	**75.2**	Albania	87.2
		Austria	70.9
Bolivia	74.3	Iceland	94.0
Brazil	91.7	Norway	99.5
Chile	77.7	Switzerland	60.2
Colombia	72.3		
Ecuador	80.7		
Paraguay	99.8	**Oceania**	**20.9**
Peru	77.8		
Suriname	70.3	Fiji	81.4
Uruguay	77.6	New Zealand	72.9

NOTE:
a. For all countries with 50 percent or more of total electricity supplied by hydroelectricity.

SOURCE: United Nations Statistical Office, *Energy Statistics Yearbook 1987* (New York: United Nations Publications, 1989).

Reducing the Risks of Water-Related Conflicts

How can we reduce the risks of water-related conflict? International law and international institutions must play a leading role. There have already been some attempts to develop international law protecting the environment, but almost all of these focus on attempting to limit the environmental impacts of conflicts and war; few efforts have been made to address the equally important problem of limiting the use of the environment as an instrument of conflict, preventing conflicts over access to resources, or averting military responses to the consequences of environmental damages, such as population displacements.

An example of such an effort is the Environmental Modification Convention of 1977, negotiated under the auspices of the United Nations, which states, in part, that "each State Party to this Convention undertakes not to engage in military or any other hostile use of environmental modification techniques having widespread, long-lasting or severe effects as the means of destruction, damage or injury to any other State Party" (Article I.1).

In 1982 the United Nations General Assembly promulgated the World Charter for Nature, supported by over 110 nations, which states that "nature shall be secured against degradation caused by warfare or other hostile activities" (Article V) and that "military actions damaging to nature shall be avoided" (Article XX).

The 1977 Bern Geneva Convention on the Protection of Victims of International Armed Conflicts (additional to the Geneva Conventions of 1949), declares that "it is prohibited to employ methods or means of warfare which are intended, or may be expected, to cause widespread, long-term and severe damage to the natural environment" (Article XXXV.3) and that "care shall be taken in warfare to protect the natural environment against widespread, long-term and severe damage. This protection includes a prohibition of the use of methods or means of warfare which are intended or may be expected to cause such damage to the natural environment and thereby to prejudice the health or survival of the population" (Article LV.1).

Such agreements and statements, however, carry little weight in the international arena when politics, economics, and other factors are considered more important. One of their greatest limitations is the lack of enforcement teeth. Until the ideals expressed by these agreements are considered true facets of international law and behavior, and until enforcement mechanisms are included, they will remain ineffective.

International water law and institutions have important roles to play despite the fact that no satisfactory water law has been developed that is acceptable to all nations. Developing such agreements is difficult because of the many intricacies of interstate politics, national practices, and other complicating political and social factors. For nations sharing river basins, factors affecting the successful negotiation and implementation of international agreements include whether a nation is upstream, downstream, or sharing a river as a border, the relative military and economic strength of the nation, and the availability of other sources of water supply.

PRINCIPLES OF INTERNATIONAL LAW

In the last few decades, however, international organizations have attempted to derive more general principles and new concepts governing shared fresh water resources. The International Law Association's Helsinki Rules of 1966 (since modified) and the work of the International Law Commission of the United Nations are among the most important examples. In 1991, the International Law Commission completed the drafting and provisional adoption of thirty-two articles on the Law of the Non-Navigational Uses of International Watercourses.[56] Among the general principles set forth are those of equitable utilization, the obligation not to cause harm to other riparian states, and the obligation to exchange hydrologic and other relevant data and information on a regular basis. Some of these principles are described below. Questions still remain, however, about their relative importance and means of enforcement.[57] In particular, defining and quantifying "equitable utilization" of a shared water supply remains one of the most important and difficult problems facing many nations. Similar problems remain in determining the implications of severe variability; for example, how to share shortages and who should bear the costs of protecting against floods.

EQUITABLE UTILIZATION. The principle of equitable utilization means that each basin state is entitled to a reasonable and equitable share in the beneficial use of shared water. It contrasts with the so-called "Harmon Doctrine," which holds that a nation can use the water within its borders without restriction, even if that use substantially injures a neighbor. While some upstream na-

56. UN International Law Commission, *Report of the International Law Commission on the Work of Its Forty-Third Session* (New York: United Nations, 1991).
57. Goldenman, "International River Agreements"; Stephen McCaffrey, "Water, Politics, and International Law," in Gleick, ed., *Water in Crisis* (New York: Oxford University Press, 1993).

tions still cite the Harmon Doctrine, almost all river treaties signed in the last 100 years reject this practice and restrict the freedom of action of upstream nations. "Equitable" does not mean equal use. Rather it means that a large variety of factors, including population, geography, availability of alternative resources, and so on, can be considered during negotiations over the allocation of water rights. One region where the concept of equitable utilization needs to be applied is the disputed territories of the West Bank of the Jordan River. Disagreements between the Israeli and Palestinian populations over the sources, control, and allocation of scarce surface and ground water are contributing to the conflict there. Quantifying the equitable distribution of these resources, while fraught with technical and political difficulties, would go a long way toward reducing tensions there.

PREVENTION OF SIGNIFICANT HARM TO OTHER STATES. Another principle of the Law on Non-Navigational Uses of International Watercourses, though perhaps subordinate to the principle of equitable utilization, is the obligation not to cause significant harm to other states through actions to international watercourses. Often the maxim, "sic utere tuo ut alienum non laedas"—use your property in a way not to injure others—is cited. This principle says that a state is responsible for preventing actions within its borders that would harm the activities or property of another state. As sometimes applied, however, this principle permits harmful actions but requires compensation or mitigation as acceptable alternatives to avoidance. A major complication in applying this principle is the difficulty in quantifying downstream environmental and economic impacts and in determining the extent of responsibility for those impacts resulting from upstream activities. The dispute between Hungary and Slovakia over the Gabcikovo/Nagymaros project on the Danube arose in part because of Hungary's perception that the project would lead to significant environmental damage in Hungary. Particularly worrisome was the possibility of contamination of one of the largest untapped ground water supplies in the region. The unwillingness of Slovakia to redesign the project or to do a complete environmental assessment led Hungary to abrogate the 1977 agreement with Czechoslovakia to construct the project.

OBLIGATION TO NOTIFY AND INFORM. Both the Helsinki Rules and the International Law Commission recommendations state that nations have an obligation to notify and inform other nations of any activities on shared watercourses that will affect them. Such notification permits the affected state to negotiate mitigation or to protest and, perhaps, modify or prevent the action. One recent application of this principle was Turkey's closure of

the Atatürk Dam on the Euphrates River in 1991 in order to fill the reservoir behind the dam. Prior to taking action, Turkey notified the downstream nations of this closure, which effectively reduced the flow in the river to zero for approximately one month. Although both Syria and Iraq complained, Turkey's obligation to notify under the principles of international water law was met.

OBLIGATION TO SHARE DATA. The obligation to share data is reaching widespread acceptance, but there are still several regions of the world where some basic water-resources data are considered classified and are withheld from neighboring nations. For example, many data on river flows in India are considered state secrets. Similarly, Israel classifies as secret some water supply and use data, particularly data from the disputed territories. Releasing all water-resources data, and setting up a mechanism to ensure wide access to those data, would help reduce tensions in the Middle East over water.[58] Unless all basin states share hydrologic data, no satisfactory agreements on allocations, responses during shortages, and flood management and planning can be reached. International organizations, such as those under the umbrella of the United Nations or scientific associations, should actively encourage the collection and open sharing of water-resource data.

COOPERATIVE MANAGEMENT OF INTERNATIONAL RIVERS. The International Law Commission is considering adoption of a "principle of participation" that affirms the duty of all basin states to participate in the development, use, and protection of shared water resources. Such participation would generally take the form of a joint basin commission empowered to negotiate disputes and resolve questions of resource allocation. Establishing such a commission does not ensure successful or effective management, in part because nations only reluctantly grant decisionmaking power to multinational bodies. Other problems arise if the commission does not include *all* affected participants. One example is the Nile commission—the Permanent Joint Technical Committee—set up by the 1959 treaty between the Sudan and Egypt, which does not include the other seven riparian nations along the Nile. While these other nations have played only a small part in the hydropolitics of the region in the past, several are now beginning to view the

58. Peter H. Gleick, "Reducing the risks of conflict over fresh water resources in the Middle East," in Hillel Shuval and Jad Isaac, eds., *Proceedings of the First Israeli-Palestinian International Academic Conference on Water Resources*, December 10–13, 1992, Zurich, Switzerland (Netherlands: Elsevier Publishers, forthcoming 1993).

waters of the Nile as an important resource for their future development. Their exclusion from the 1959 Treaty complicates the debate now underway.

OBLIGATION TO RESOLVE DISPUTES PEACEFULLY. The Charter of the United Nations requires that nations resolve all disputes, not just those over water resources, without resorting to force. Because international shared water resources have been the source of violent conflicts in the past, international negotiations over water law devote considerable time and effort to identifying non-violent approaches to resolving disputes. When combined with the principle of cooperative management, this often leads to the suggested creation of joint basin management commissions with the authority to receive and investigate complaints, and to offer findings to the governments of the affected parties. Recourse is sometimes made to the International Court of Appeals in The Hague, as in the Hungarian-Slovakian dispute over the Gabcikovo project described above, but unless both parties agree to accept The Hague's jurisdiction, this mechanism has limited success. In the case of Gabcikovo, Czechoslovakia rejected the jurisdiction of the International Court of Appeals and other means of dispute resolution were sought.

TREATIES

Until now, individual water treaties covering river basins have been more effective, albeit on a far more limited regional basis, than the broader principles described above. International treaties concerning shared fresh water resources extend back centuries and there are hundreds of international river treaties covering everything from navigation to water quality to water rights allocations. For example, freedom of navigation was granted to a monastery in Europe in the year 805, and a bilateral treaty on the Weser River, which today flows through Germany into the North Sea, was signed in 1221.[59] Such treaties have helped reduce the risks of water conflicts in many areas, but some of them are beginning to fail as changing levels of development alter the water needs of regions and nations. The 1959 Nile River Treaty, the 1977 Agreement on Sharing of the Ganges Waters (now expired, but still observed), and some limited bilateral agreements on the Euphrates between Iraq and Syria, and between Iraq and Turkey, are good examples of treaties now under pressure because of changes in the political and resource condi-

59. Food and Agriculture Organization, *Systematic Index of International Water Resources Treaties, Declarations, Acts and Cases by Basin*, Legislative Study No. 15 (Rome: Food and Agriculture Organization of the United Nations, 1978). This index is irregularly updated.

tions of the region. India and Nepal agreed by a December 1991 treaty to go forward on hydroelectric, irrigation, and flood control projects that have been pending for many decades. Yet this agreement does not include Bangladesh, which will certainly be affected by any changes in the flows of the Ganges, and which may claim to have been deprived of its equitable share of the benefits of the Ganges, or to have been appreciably harmed by the projects.[60]

To make both regional treaties and broader international agreements over water more flexible, detailed mechanisms for conflict resolution and negotiations must be developed, basic hydrologic data must be acquired and completely shared with all parties, flexible rather than fixed water allocations are needed, and strategies for sharing shortages and apportioning responsibilities for floods need to be developed before shortages become an important factor. For example, both the 1944 Colorado River treaty between the United States and Mexico and the 1959 Nile River treaty between Egypt and the Sudan allocate fixed quantities of water, based on assumptions about the total average flows of each river. However, mistaken estimates of average flows, or future climatic changes that could alter flows, would make this type of rigid allocation ripe for disputes. Proportional sharing agreements, if they include agreements for openly sharing all hydrologic data, can help to reduce the risk of conflicts over water, and modifications to these treaties should be undertaken by their signatories now, before such changes become evident.

In sum, existing institutions appear sufficient to design and implement the kinds of conflict resolution mechanisms described above, but some major improvements in them are needed. The UN has played an important role, through the International Law Commission, in developing guidelines and principles for internationally shared watercourses, but it should continue to press for the adoption and application of the principles in water-tense regions such as the Middle East, central and southern Asia, and parts of Europe. Similarly, bilateral or multilateral river treaties have been effective in the past, but they should consistently include all affected parties, they should include a joint management committee empowered to negotiate disputes, and they should be flexible enough to adapt to long-term changes in hydrologic conditions, such as those that may result from global climatic change. Finally, as disputes over shared ground water resources become far more important

60. McCaffrey, "Water, Politics, and International Law."

and common in the future, international ground water law and principles must be better developed.

Conclusions

Water already contributes to conflicts among nations, and future conflicts over water are increasingly likely. Nations fight over access to water resources in some regions of the world and use water and water-supply systems as instruments of war, while growing populations and development are increasing the competition for limited water supplies, and many countries depend on sources of supply that are under the control of other nations.

Human needs for water are growing. Many countries in the Middle East and elsewhere already use water at a rate faster than natural processes can replenish it, leading to falling ground water levels, reliance on expensive desalination projects, and imports of water across borders. Oddball schemes that would have been laughed at a few decades ago are now being implemented or seriously considered, including the importation of water in tankers, pipelines thousands of kilometers long, or the diversion of icebergs from the polar regions.

Global climatic changes will increase the demand for water for human and industrial uses, change irrigation requirements, and alter in unpredictable ways the availability and quality of fresh water resources. Countries or regions that use a significant fraction of their total available supply are vulnerable to slight changes in flow or water quality. Countries or regions with considerable dependence on irrigation water or hydroelectricity are vulnerable to changes in flow and the vagaries of a changing climate.

The Middle East and the Persian Gulf exhibit many vulnerabilities to water-related conflict, as do certain countries of Africa, Europe, and southern and central Asia. Given the high level of political conflict already evident in some of these areas, and the inability of nations in these regions to reach agreements on water sharing, future water-related disputes appear inevitable. Conflicts over the Nile, the Jordan, the Euphrates, the rivers of Central Asia, and the Ganges/Brahmaputra river systems appear increasingly likely because of growing competition for limited water resources, or because of disputes over the ownership and the right to use the resource. Disputes may also arise because of the contamination of shared water by upstream parties on the Colorado, the Rhine, and the Mekong; because of the complications of managing multiple interests in a river, such as with the Danube, the

Mekong, the Niger, and the Zambezi; or because of the difficulty of rationally sharing hydroelectric generation on international rivers, such as the Zambezi and the Paraná.

Water-related disputes are more likely to lead to political confrontations and negotiations than to violent conflict. But recent disturbing examples of water-related conflicts, the apparent willingness to use water-supply systems as targets and tools of war, and growing disparities among nations between water availability and demand make it urgent that we work to reduce the probability and consequences of water-related conflict. Hydrologists and water-resources specialists must begin to collect and more widely disseminate data on the supply and use of shared water resources, and on ways of reducing inefficient uses of water. International legal experts must better understand the links among natural resource needs, national sovereignty, and water rights. And academic and military scholars need to better understand the threats of conflict arising from a wide range of resource and environmental problems, and to hone the tools for preventing those conflicts.