from Lester R. Brown, *Eco-Economy: Building an Economy for the Earth*
(W. W. Norton & Co., NY: 2001)

2

Signs of Stress: Climate and Water

On August 19, 2000, the *New York Times* reported that an icebreaker cruise ship had reached the North Pole only to discover this famous frozen site was now open water. For a generation that grew up reading the harrowing accounts of explorers such as American Richard Byrd trying to reach the North Pole as they battled bitter cold, ice, and snow, this new view taxed the imagination.[1]

In its many earlier trips to the North Pole, the cruise ship had allowed passengers to disembark in order to be photographed standing on the ice. This time, the ship had to move several miles away to find ice thick enough for the photo session. If the explorers of a century or so ago had been trekking to the North Pole in the summer of 2000, they would have had to swim the last few miles.

Media reports of melting ice typically focus on individual glaciers or ice caps, but the ice is melting almost everywhere. Given that the 14 warmest years since recordkeeping began in 1866 have all occurred since 1980, this does not come as a surprise.[2]

Water shortages are also in the news. Some of the world's major rivers are being drained dry, failing to reach the sea. Among them is the Colorado, the major river in the southwestern United States. In China, the Yellow River, the northernmost of the country's two major rivers, no longer reaches the sea for part of each year. In Central Asia, the Amu Darya sometimes fails to reach the Aral Sea because it has been drained dry by upstream irrigation.[3]

Wells are going dry on every continent. As population expands and incomes rise, the demand for water is simply outrunning the supply in many countries. Those with money drill deeper wells, chasing the water table downward. Those unable to deepen their wells are left in a difficult position.

The situation promises to become far more precarious, since the 3.2 billion people being added to world population by 2050 will be born in countries already facing water scarcity. With 40 percent of the world food supply coming from irrigated land, water scarcity directly affects food security. If we are facing a future of water scarcity, we are also facing a future of food scarcity.[4]

Temperature Rising

Since agriculture began, the earth's climate has been remarkably stable. Now the earth's temperature is rising, apparently due to the greenhouse effect—the warming that results from the rising concentration of heat-trapping gases, principally carbon dioxide (CO_2), in the atmosphere.

This rise in CO_2 concentration comes from two sources: the burning of fossil fuels and deforestation. Each year, more than 6 billion tons of carbon are released into the atmosphere as fossil fuels are burned. Estimates of the net release of carbon from deforestation vary widely, but they center on 1.5 billion tons per year.[5]

The release of CO_2 from these two sources is simply overwhelming nature's capacity to fix carbon dioxide. When the Industrial Revolution began in 1760, carbon emissions from the burning of fossil fuels were negligible. But by 1950, they had reached 1.6 billion tons per year, a quantity that was already boosting the atmospheric CO_2 level. In 2000, they totaled 6.3 billion tons. (See Figure 2–1.) This fourfold increase since 1950 is at the heart of the greenhouse effect that is warming the earth.[6]

The carbon emissions of individual fossil fuels vary. Coal burning releases more carbon per unit of energy produced than oil does, and oil more than natural gas. The global fleet of 532 million gasoline-burning automobiles, combined with thousands of coal-fired power plants, are literally the engines driving climate change.[7]

In addition, in recent years the world has been losing 9 million

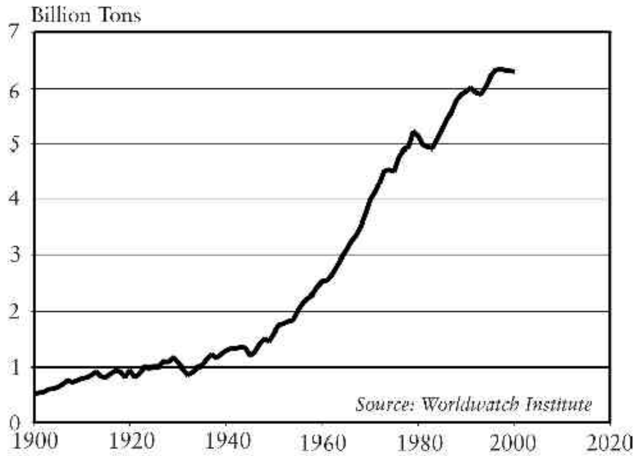

Figure 2–1. *World Carbon Emissions from Fossil Fuel Burning, 1900–2000*

hectares of forest per year. Forests store easily 20 times as much carbon per hectare as does land in crops. If the net loss of forests can be eliminated, this source of carbon emissions will disappear. In the northern hemisphere, the forested area is actually increasing by 3.6 million hectares a year. The big challenge is to arrest and reverse the deforestation in developing countries.[8]

At the start of the Industrial Revolution in 1760, the atmospheric CO_2 concentration was estimated at 280 parts per million (ppm). By 2000, it had reached 370 ppm, a rise of 32 percent from pre-industrial levels. (See Figure 2–2.) The buildup of atmospheric CO_2 from 1960 to 2000 of 54 ppm far exceeded the 36 ppm rise from 1760 to 1960.[9]

Atmospheric CO_2 levels have risen each year since annual measurements began in 1959, making this one of the most predictable of all environmental trends. Physics textbooks point out that as atmospheric CO_2 levels rise, so will the earth's temperature, and this is exactly what is happening. As noted earlier, the 14 warmest years since recordkeeping began have all come since 1980. Over the last three decades, global average temperature has risen from 13.99 degrees Celsius in 1969–71 to 14.43 degrees in 1998–2000, a gain of 0.44 degrees Celsius (0.8 degrees Fahrenheit).[10]

The dramatic rise in the earth's temperature since 1980 can be clearly seen in Figure 2–3. Not only is it rising rapidly, but it is

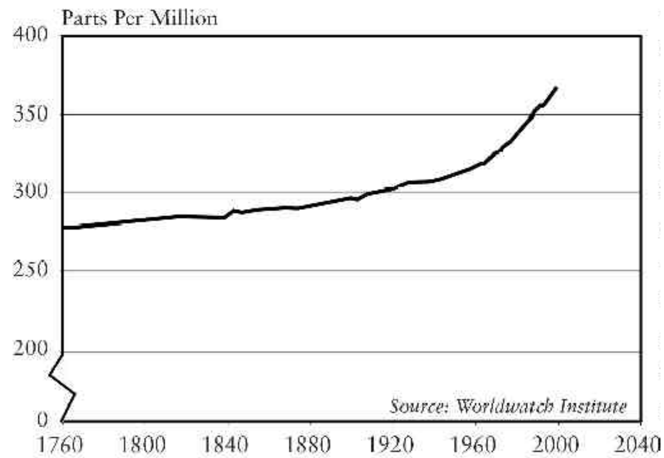

Figure 2–2. *Atmospheric Concentrations of Carbon Dioxide, 1760–2000*

projected to rise even faster in the next century. If CO_2 concentrations in the atmosphere double pre-industrial levels by the end of this century, reaching 560 ppm, the temperature is projected to rise by 1.4–5.8 degrees Celsius. Rising temperatures lead to more extreme climatic events—record heat waves, the melting of ice, rising sea level, and more destructive storms.[11]

Projected temperature rises will not be distributed evenly over the earth's surface, but will be greater over land areas than over the oceans and also greater in the higher latitudes than in the equatorial regions. Inland regions in northern latitudes can expect some of the biggest temperature jumps. A taste of what is to come can be seen in the July 1995 heat wave in Chicago, when temperatures reached 38–41 degrees Celsius (100–106 degrees Fahrenheit) on five consecutive days. Although Chicago is a modern industrial city with extensive air conditioning, this heat wave claimed more than 500 lives. And because Chicago is in the center of the U.S. Corn Belt, the intense heat also helped shrink the 1995 U.S. corn harvest by some 15 percent or $3 billion.[12]

The Ice Is Melting

Ice melting is one of the most visible manifestation of global warming. Sometimes the evidence that mountain glaciers are melting takes novel forms. In late 1991, hikers in the southwestern Alps on the

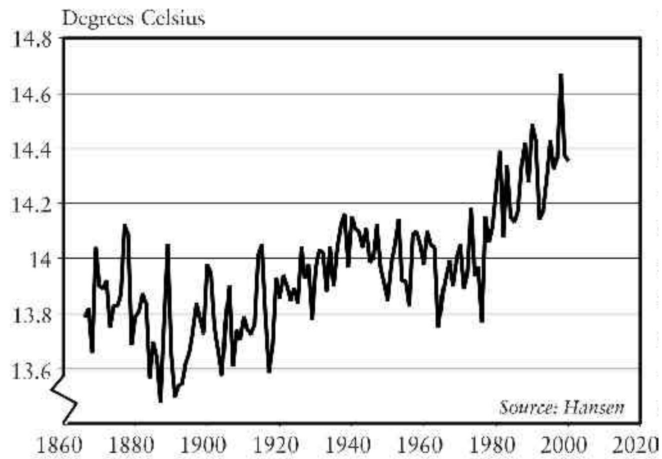

Figure 2–3. *Average Temperature at the Earth's Surface, 1866–2000*

Austrian-Italian border discovered an intact male human body protruding from a glacier. Apparently trapped in a storm more than 5,000 years ago and quickly covered with snow and ice, his body was remarkably well preserved. In 1999, another body was found in a melting glacier in the Yukon Territory of western Canada. As I noted at the time, our ancestors are emerging from the ice with a message for us: the earth is getting warmer.[13]

In the Arctic Ocean, sea ice is melting fast. As recently as 1960, the Arctic sea ice was nearly 2 meters thick. In 2001, it averaged scarcely a meter. Over the last four decades, the ice sheet has thinned by 42 percent and it has shrunk in area by 6 percent. Together, this thinning and shrinkage have reduced the Arctic Ocean ice mass by nearly half. This rapid melting is expected to continue. A recent study by two Norwegian scientists projects that within 50 years the Arctic Ocean could be ice-free during the summer.[14]

In 2000, four U.S. scientists published an article in *Science* reporting that the vast Greenland ice sheet is starting to melt. Lying largely within the Arctic Circle, Greenland is gaining some ice in higher elevations on its northern reaches, but it is losing much more at lower elevations, particularly along its southern and eastern coasts. This huge island of 2.2 million square kilometers (three times the size of Texas) is experiencing a net loss of 51 billion cubic meters of water each year, an amount approaching two thirds of the annual flow of the Nile River as it enters Egypt.[15]

The Antarctic peninsula is also losing ice. In contrast to the North Pole, which is covered by the Arctic Sea, the South Pole is covered by the continent of Antarctica, a land mass roughly the size of the United States. Its continent-sized ice sheet, which is on average 2.3 kilometers (1.5 miles) thick, is relatively stable. But the ice shelves, the portions of the ice sheet that extend into the surrounding seas, are fast disappearing.[16]

A team of U.S. and British scientists reported in 1999 that the ice shelves on either side of the Antarctic peninsula are in full retreat. From roughly mid-century through 1997, these areas lost 7,000 square kilometers as the ice sheet disintegrated. But then within scarcely one year they lost another 3,000 square kilometers. Delaware-sized icebergs that have broken off are a threat to ships in the area. The scientists attribute the accelerated ice melting to a regional temperature rise of 2.5 degrees Celsius (4.5 degrees Fahrenheit) since 1940.[17]

These are not the only examples of melting. Lisa Mastny of Worldwatch Institute, who reviewed some 30 studies on this topic, reports that mountain glaciers are melting worldwide—and at an accelerating rate. (See Table 2–1.) The snow/ice mass is shrinking in the world's major mountain ranges: the Rocky Mountains, the Andes, the Alps, and the Himalayas. In Glacier National Park in Montana, the number of glaciers has dwindled from 150 in 1850 to fewer than 50 today. The U.S. Geological Survey projects that the remaining glaciers could disappear within 30 years.[18]

In Europe's Alps, the shrinkage of the glacial volume by more than half since 1850 is expected to continue, with these ancient glaciers largely disappearing over the next half-century. Shrinkage of ice masses in the Himalayas has accelerated alarmingly. In eastern India, the Dokriani Bamak glacier, which retreated by 16.5 meters between 1992 and 1997, drew back by a further 20 meters in 1998 alone.[19]

A research report by Lonnie Thompson of Ohio State University indicates that the ice cap on Kilimanjaro could disappear within 15 years. This upset Tanzania's Minister of Tourism, Zokia Meghji, who told parliament that the projected melting was exaggerated, as he tried to allay fears about the effects on the country's lucrative tourism industry. In response, Thompson pointed out that his report was simply based on an extrapolation of the recent historical

Table 2–1. *Selected Examples of Ice Melt Around the World*

Name	Location	Measured Loss
Arctic Sea Ice	Arctic Ocean	Has shrunk by 6 percent since 1978, with a 14-percent loss of thicker, year-round ice. Has thinned by 40 percent in less than 30 years.
Greenland Ice Sheet	Greenland	Has thinned by more than a meter a year on its southern and eastern edges since 1993.
Glacier National Park	Rocky Mtns., United States	Since 1850, the number of glaciers has dropped from 150 to fewer than 50. Remaining glaciers could disappear completely in 30 years.
Larsen B Ice Shelf	Antarctic Peninsula	Calved a 300-square-kilometer iceberg in early 1998. Lost 1,714 square kilometers during the 1998–99 season, and 300 square kilometers during the 1999–2000 season.
Dokriani Bamak Glacier	Himalayas, India	Retreated by 20 meters in 1998, compared with 16.5 meters over the previous five years.
Tien Shan Mountains	Central Asia	Twenty-two percent of glacial ice volume has disappeared in the past 40 years.
Caucasus Mountains	Russia	Glacial volume has declined by 50 percent in the past century.
Alps	Western Europe	Glacial volume has shrunk by more than 50 percent since 1850. Glaciers could be reduced to only a small fraction of their present mass within decades.
Kilimanjaro	Tanzania	Ice cap shrunk by 33 percent from 1989 to 2000. Could disappear by 2015.
Quelccaya Glacier	Andes, Peru	Rate of retreat increased to 30 meters a year in the 1990s, up from only 3 meters a year; will likely disappear before 2020.

Source: Updated from Lisa Mastny, "Melting of Earth's Ice Cover Reaches New High," Worldwatch News Brief (Washington, DC: Worldwatch Institute: 6 March 2000).

trend.[20]

Researchers are discovering that a modest rise in temperature of 1–2 degrees Celsius in mountainous regions can dramatically alter the precipitation mix, increasing the share falling as rain while decreasing the share coming down as snow. The result is more flooding during the rainy season, a shrinking snow/ice mass, and less snowmelt to feed rivers during the dry season.[21]

These "reservoirs in the sky," where nature stores fresh water for use in the summer as the snow melts, have been there ever since irrigation began, supplying farmers with water for several thousand years. Now suddenly, in a matter of years, they are shrinking and some could disappear entirely, sharply reducing the water supply for irrigation and for cities.

If the massive snow/ice sheet in the Himalayas—which is the third largest in the world, after the Antarctic and Greenland ice sheets—continues to melt, it will affect the water supply of much of Asia. All of the region's major rivers—the Indus, Ganges, Mekong, Yangtze, and Yellow—originate in the Himalayas. Melting in this area could alter the hydrology of several Asian countries, including Pakistan, India, Bangladesh, Thailand, Viet Nam, and China. Less snowmelt in the summer dry season to feed rivers could worsen the hydrological poverty already afflicting so many in the region.[22]

We don't have to sit idly by as this scenario unfolds. There may still be time to stabilize atmospheric CO_2 levels before carbon emissions lead to unmanageable climate change. There is an abundance of wind, solar, and geothermal energy to harness for running the world economy. (See Chapter 5.) If we were to cut income taxes and offset this by incorporating a carbon tax that reflected the cost of climate disruption in the price of fossil fuels, investment would quickly shift from fossil fuels to these climate-stabilizing energy sources.

Sea Level Rising

Sea level is a sensitive indicator of global warming since it is affected by both thermal expansion and the melting of land-based glaciers. The respective contributions to sea level rise of thermal expansion and ice melting are estimated to be roughly the same.[23]

During the twentieth century, sea level rose by 10–20 centimeters (4–8 inches), more than half as much as it had risen during the preceding 2,000 years. If the earth's temperature continues to rise, further acceleration is in prospect. The model used in the Intergovernmental Panel on Climate Change 2001 Assessment projects that sea level could rise by as much as 1 meter during the twenty-first century.[24]

Rising sea level has numerous consequences. The most obvious is inundation as the oceans expand at the expense of continents. Another is saltwater intrusion. As sea level rises, salt water may invade coastal freshwater aquifers. This intrusion is exacerbated by the falling water tables that now plague coastal regions in many countries, including Israel, Pakistan, India, and China. A third effect is beach erosion: as waves break further inland, they erode the beach, compounding the effect of rising sea level.[25]

The most easily measured effect of rising sea level is the inundation of coastal areas. Donald F. Boesch, with the University of Maryland's Center for Environmental Sciences, estimates that for each millimeter rise in sea level, the shoreline retreats an average of 1.5 meters. Thus if sea level rises by 1 meter, the coastline will retreat by 1,500 meters, or nearly a mile.[26]

With a 1-meter rise in sea level, more than a third of Shanghai would be under water. For China as a whole, 70 million people would be vulnerable to a 100-year storm surge. The rice-growing river floodplains and deltas of Asia would be particularly vulnerable. A World Bank analysis shows that Bangladesh would be hardest hit, losing half of its rice production—the food staple of its 140 million people. (See Figure 2–4.) At current rice prices, this would cost Bangladesh $3.2 billion. Residents of the densely populated river valleys of Asia would be forced into already crowded interiors. Rising sea level could create millions of climate refugees in Bangladesh, China, India, Indonesia, the Philippines, and Viet Nam.[27]

Two thirds of the Marshall Islands and Kiribati would be under water. The United States would lose 36,000 square kilometers (14,000 square miles) of land, with the middle Atlantic and Mississippi Gulf states losing the most. And large portions of lower Manhattan and the Capitol Mall in Washington, D.C., would be flooded during a 50-year storm surge. A 1-meter rise in Japan would mean that 2,340 square kilometers of the country would be below high tide. Four million Japanese would be affected, many of them driven from their homes.[28]

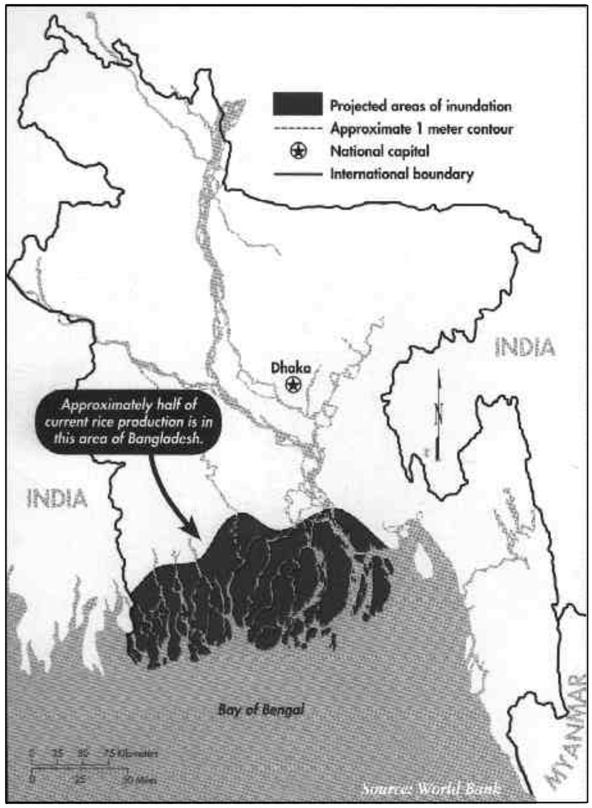

Figure 2–4. *A 1-Meter Rise in Sea Level Would Cut Bangladesh's Rice Production Approximately in Half*

Coastal real estate prices are likely to be one of the first economic indicators to reflect the rise in sea level. People with heavy investments in beachfront properties will suffer most. A half-meter rise in sea level in the United States could bring losses ranging from $20 billion to $150 billion. Beachfront properties, much like nuclear power plants, are becoming uninsurable—as many homeowners in Florida, for example, have discovered.[29]

Many developing countries already coping with population growth and intense competition for living space and cropland are now facing the prospect of rising sea level and substantial land losses. Some of those most directly affected have contributed the least to the buildup in atmospheric CO_2 that is causing this problem.

Rising sea level will pose difficult and costly choices. Consider, for example, the effort and cost involved in relocating a million Chinese from the area to be inundated by the Three Gorges Dam. This would be trivial compared with the tens of millions, and eventually hundreds of millions in Asia, who would have to be relocated as the ocean rises if we continue with business as usual. Climate refugees may come to dominate the international flow of migrants since they are losing not just land, but food supplies and livelihoods.[30]

More than 90 percent of the world's ice is in the Antarctic ice sheet, which, partly because of its size, is comparatively stable. The other 10 percent, however, is in the Greenland ice sheet and mountain glaciers, which are more vulnerable to climate change. Now that the Greenland ice sheet has started to melt, we must ask, What if this trend continues? Greenland's ice sheet is up to 2 kilometers (1.2 miles) thick in some areas. In an article in *Science*, NASA scientists calculate that if the Greenland ice sheet were to disappear entirely, sea level would rise by a staggering 7 meters (23 feet), markedly shrinking the earth's land area and engulfing many coastal cities.[31]

For the first time since civilization began, sea level has begun to rise at a measurable rate. It has become an indicator to watch, a trend that could force a human migration of almost unimaginable dimensions, and one that will shape the human prospect. It also raises questions of intergenerational responsibility that humanity has never before faced.

More Destructive Storms

Rising temperatures and the power of storms are directly related. As sea surface temperatures rise, particularly in the tropics and subtropics, the additional heat radiating into the atmosphere causes more destructive storms. Higher temperatures mean more evaporation. Water that goes up must come down. What is not clear is exactly where the additional water will fall.[32]

More extreme weather events are of particular concern to countries in the hurricane or typhoon belt. Among those most directly affected by increased storm intensity are China, Japan, and the Philippines in the western Pacific, India and Bangladesh in the Bay of Bengal, and the United States and the Central American and Caribbean countries in the western Atlantic.

Munich Re, which insures insurance companies, has maintained detailed, worldwide data on natural catastrophes—principally storms, floods, and earthquakes—over the last half-century. The company defines a great natural catastrophe as one that overwhelms the capacity of a region to help itself, forcing it to depend on international assistance. During the 1960s, economic losses from these large-scale catastrophes totaled $69 billion; during the 1990s, they totaled $536 billion, nearly an eightfold increase.[33]

Recent years have seen some extraordinarily destructive tropical storms. Among them was Hurricane Andrew, which cut a large swath across the state of Florida in 1992. Storm alerts held the loss of human life to 65, but Andrew destroyed 60,000 homes and other buildings, inflicting some $30 billion in damage. In addition to the buildings it destroyed, it also took down seven insurance companies, as mounting claims left them insolvent.[34]

Six years later, Hurricane Georges—a powerful storm with winds of close to 200 miles per hour—was stalled off the coast of Central America by a high-pressure system that blocked its normal path to the north. It claimed 4,000 lives and inflicted a staggering $10 billion worth of damage on El Salvador and Nicaragua. Damage on this scale, which approached the combined gross domestic products of the two countries, set economic development back by a generation. A storm that hit Venezuela in mid-December 1999 caused enormous flooding and landslides, claimed 20,000 lives, and registered economic losses of $15 billion—second only to Hurricane Andrew.[35]

In late September 1999, Typhoon Bart hit Japan's densely populated island of Kyushu. Its toll in human life was held to only 26, but it did $5 billion worth of damage. Countries such as Japan, China, and the Philippines are in a particularly vulnerable location, fully exposed to all the power that storms generated over the tropical Pacific can muster.[36]

Winter storms are also becoming more destructive in the northern hemisphere. S.J. Lambert, writing in the *Journal of Geophysical Research*, has analyzed the frequency of intense winter storms in this hemisphere over the last century. From 1920 until 1970, there were roughly 40 storms a year. But then as temperatures started to climb, so did the frequency of storms. Since 1985, the northern hemisphere has experienced close to 80 storms a year—a doubling in less than a generation. Over the past decade or so, Western Europe has been hit by numerous storms of record destructiveness. In 1987, the United Kingdom and France bore the brunt of a winter storm that claimed 17 lives and caused $3.7 billion worth of damage. In 1999, Western Europe was hit by three unusually powerful winter storms: Anatole, Martin, and Lothar. They claimed 150 lives and did $10.3 billion worth of damage. Lothar, which hit the continent during the holiday season on December 26, left $7.5 billion of damage in France, Germany, and Switzerland.[37]

Damage from storms is mounting both because of greater population density and because the investment per person in housing or other structures that are vulnerable to storm damage is greater than ever. There is also a disproportionately large gain in construction in coastal regions, which are much more vulnerable to storms and storm surges.

The bottom line is that storms are increasing both in number and in destructiveness. More powerful storms mean more damage. A doubling of the number of winter storms in the northern hemisphere within less than a generation, coupled with increasing severity, yields a dramatic rise in storm-related damage.

At this point, no one knows quite how this trend will unfold in the twenty-first century, but it seems likely that if we continue with business as usual and CO_2 levels continue to rise, the destructiveness in the future will dwarf that in the present—just as the destructiveness in the present is far greater than that of the recent past. The risk is that the cost of coping with these ever more destructive, human-induced catastrophes could overwhelm some societies, leading to their economic decline.

Rivers Drained Dry

We live in a water-challenged world, one that is becoming more so each year as 80 million additional people stake their claims to the earth's water resources. Even now, many people in developing countries lack enough water to satisfy basic needs for drinking, bathing, and producing food.

By 2050, India is projected to add 563 million people and China 187 million. Pakistan, one of the world's most arid countries, is projected to add over 200 million, going from 141 million today to 344 million. Egypt, Iran, and Mexico are slated to increase their populations by half or more by 2050. In these and other water-short countries, continuing population growth is sentencing hundreds of millions of people to hydrological poverty—a local form of impoverishment that is difficult to escape.[38]

One manifestation of emerging water scarcity is dry rivers. Several of the world's major rivers now either run dry part of the year, failing to reach the sea, or have little water left when they get there.[39]

As noted earlier, the Amu Darya in Central Asia, one of two rivers that feeds the Aral Sea, is now largely drained dry by Turkmen and Uzbek cotton farmers. With this river failing to reach the sea at times and the flow of the Syr Darya reduced to a shadow of its past flow, the Aral Sea is shrinking beneath the relentless sun in this semiarid region. Since 1960, the sea has dropped 12 meters (40 feet); its area has shrunk by 40 percent and its volume by 66 percent. Towns that were once coastal are now 50 kilometers from the water. If recent trends continue, the sea will largely disappear within another decade or two—existing only on old maps, a geographic memory.[40]

As the sea has shrunk, the salt concentrations in its water have increased to where fish can no longer survive. As a result, the fishery—which yielded 60,000 tons (130 million pounds) of fish per year as recently as 1960—is now dead.[41]

In 1990, the Soviet Academy of Sciences organized a conference in Nukus, a town near the Aral Sea, entitled "The Aral Sea: An Environmental Catastrophe." After attending the meeting, I joined other guests on an air tour over the sea and the former seabed. I later wrote in *World Watch* magazine, "From the air, the exposed floor of the Aral Sea looks like a moonscape. No plant or animal life is visible. From a few hundred feet above the ground, in an ancient canvas-winged, single-engine bi-plane, the signs of a dying ecosystem are evident. Fishing villages that once stood by the shoreline are abandoned and lie miles from the receding waters. Like ghost mining towns out of the American West, they reinforce the image of a dying ecosystem and a dying economy."[42]

When rivers go dry, the marine ecosystems within the rivers are destroyed. The estuaries as sometimes affected as well. For example, when the Colorado River was flowing into the Gulf of California, it supported a large fishery and several hundred Cocopa Indian families. Today this fishery is but a remnant of its former self.[43]

Upstream diversions for cities, industry, and irrigation from China's Yellow River are multiplying. After flowing uninterruptedly for thousands of years, this cradle of Chinese civilization ran dry in 1972, failing to reach the sea for some 15 days. In the following years, it ran dry intermittently until 1985. Since then, it has run dry for part of each year. In 1997, a drought year, the Yellow River did not connect with the sea for 226 days.[44]

In fact, during much of 1997, the river did not even make it to Shandong Province, the last of the eight provinces it flows through en route to the sea. Shandong, producing a fifth of China's corn and a seventh of its wheat, is more important agriculturally to China than Iowa and Kansas together are to the United States. Half of the province's irrigation water used to come from the Yellow River, but this supply is now shrinking. The other half comes from an aquifer whose water level is falling by 1.5 meters a year.[45]

As more and more water is diverted to industries and cities upstream, less is available downstream. Beijing is permitting the poverty-ridden upstream provinces to divert water for their development at the expense of agriculture in the lower reaches of the basin.

One of the hundreds of projects to divert water from the Yellow River in the upper reaches is a canal that will take water to Hohhot, the capital of Inner Mongolia, starting in 2003. This will help satisfy swelling residential needs as well as those of expanding industries, including the all-important wool textile industry that is supplied by the region's vast flocks of sheep. Another canal will divert water to Taiyuan, the capital of Shanxi Province, a city of 4 million that now rations water.[46]

The growing upstream claims on the Yellow River mean that one day it may no longer reach Shandong Province at all, cutting the province off from roughly half of its irrigation water. The resulting prospect of massive grain imports and growing dependence on U.S. grain, in particular, leads to sleepless nights for political leaders in Beijing.[47]

Another river that is leading to sleepless nights is the Nile, because its waters must be allocated not among provinces, as in China, but among countries. Ten countries share the Nile River basin, but just three—Egypt, Sudan, and Ethiopia—dominate. Eighty-five percent of the Nile's flow originates in Ethiopia, but the lion's share is used by Egypt. Most of the rest is used in Sudan. Once the claims of these two countries are satisfied, little water is left when it enters the Mediterranean.[48]

Egypt, where it almost never rains, is wholly dependent on the Nile. Without this lifeline, Egypt would not exist. Even if all the water in the Nile River were available to Egypt, it would still have to import some grain just to feed its current population. But it is already importing 40 percent of its grain, and its population, now 68 million, is projected to nearly double to 114 million by 2050. The population of Sudan, which is growing even faster, is projected to increase from 31 million today to 64 million by 2050, more than doubling its water needs.[49]

Ethiopia, where most of the precipitation falls that feeds the Nile, is growing faster still. With each family averaging nearly six children, its population is projected to triple from 63 million at the end of 2000 to 186 million by 2050. Thus far, Ethiopia has built only 200 very small dams that enable it to use 500 million cubic meters of the Nile's 84-billion-cubic-meter flow, or less than 1 percent. But the Ethiopian government is planning to use much more of the water to expand food production and provide electricity as it tries to lift its people out of poverty.[50]

The Nile, like the Yellow River, has wide disparities in income between the upper and lower reaches of the basin. It is difficult to argue that Ethiopia, with an annual income of scarcely $100 per person, should not use the upper Nile waters for its own development, even though it would be at the expense of Egypt, which has an annual income of over $1,000 per person. If the basin countries do not quickly stabilize their populations, they risk becoming trapped in hydrological poverty.[51]

Other river basins where competition for water is intensifying include the Jordan, the Ganges, and the Mekong. The competition over the river Jordan between Israel, Jordan, and the Palestinians is well known. The Jordan, which flows from Lebanon into Israel, where it joins the Sea of Galilee and eventually empties into the Dead Sea, is being overtaxed. As a result, the water level in the Sea of Galilee is gradually falling and the Dead Sea is shrinking.[52]

If India, which shares the Ganges with Bangladesh, were to use all the water that it wants, the Ganges might not even reach Bangladesh during the dry season. But fortunately a treaty has been signed that allocates an agreed-upon amount of water to Bangladesh. Competition in the Mekong River basin is also intensifying. As China builds dams on its upper reaches, less water is left for Cambodia, Laos, and Viet Nam—countries whose rice cultures depend on the Mekong water.[53]

Falling Water Tables

Even as major rivers are running dry, water tables are falling on every continent as the demand for water outruns the sustainable yield of aquifers. Overpumping is a new phenomenon, largely confined to the last half-century. Only since the development of powerful diesel and electric pumps have we had the capacity to pull water out of aquifers faster than it is replaced by precipitation.

Overpumping is now widespread in China, India, and the United States—three countries that together account for nearly half of the world grain harvest. Water tables are falling under the North China Plain, which produces 25 percent of China's grain harvest; under the Indian Punjab, the breadbasket of India; and under the southern Great Plains of the United States.[54]

Hydrologically, there are two Chinas—the humid south, which includes the Yangtze River basin and everything south of it, and the arid north, which includes the Yellow River basin and everything to the north. The south, with 700 million people, has one third of the nation's cropland and four fifths of its water. The north, with 550 million people, has two thirds of the cropland and one fifth of the water. The water per hectare of cropland in the north is one eighth that of the south.[55]

Northern China is drying out as the demand for water outruns the supply, depleting aquifers. In 1999 the water table under Beijing fell by 1.5 meters (5 feet). Since 1965, the shallow water table under the city has fallen by some 59 meters or nearly 200 feet. The deep aquifer that some wells draw from may have fallen even more. A 2001 World Bank report says, "Anecdotal evidence suggests that deep wells around Beijing now have to reach 1,000 meters (more than half a mile) to tap fresh water, adding dramatically to the cost of supply." Falling water tables under the capital remind China's leaders of the shortages that lie ahead as the country's aquifers are depleted.[56]

The North China Plain, a region that stretches from just north of Shanghai to well north of Beijing, embraces five provinces: Hebei, Henan, and Shandong, and the city provinces of Beijing and Tianjin. At the end of 1997, official data show that these five provinces had 2.6 million wells, the bulk of them for irrigation. During that year, 99,900 wells were abandoned, apparently because they ran dry as the water table fell. Some 221,900 new wells were drilled. In the two major cities, Beijing and Tianjin, the number of wells abandoned exceeded the number of new wells drilled. This wholesale abandonment of wells has no precedent. The drilling of so many new wells reflects the desperate quest for water as the water table falls.[57]

Although earlier data showed the water table dropping by an average of 1.5 meters (5 feet) a year under the North China Plain, these recent data on well abandonment and new well drilling suggest that it now could be falling much faster in some places. Overpumping is greatest in the Hai River basin, immediately to the north of the Yellow River basin. This area, which includes Beijing and Tianjin, both large industrial cities, is home to over 100 million people.[58]

Water use in the basin currently totals 55 billion cubic meters annually, while the sustainable supply totals only 34 billion cubic meters, leaving an annual deficit of 21 billion cubic meters to be satisfied by groundwater mining. When this aquifer is depleted, water pumping will necessarily drop to the sustainable yield, cutting the basin's water supply by nearly 40 percent. Given rapid urban and industrial growth in the area, and agriculture's relegation to third place in the line for water, irrigated agriculture in the basin could largely disappear by 2010—forcing a shift to less productive rain-fed agriculture. The 2001 World Bank report concluded that north China's fast deteriorating water situation could have "catastrophic consequences for future generations unless water use and supply could quickly be brought back into balance."[59]

In addition to losses of irrigation water from aquifer depletion, farmers are faced with a diversion of irrigation water to cities and industry. Between now and 2010, when China's population is projected to grow by 126 million, the World Bank projects that the nation's urban water demand will increase from 50 billion cubic meters to 80 billion, a growth of 60 percent. Industrial water demand, meanwhile, is projected to increase from 127 billion cubic meters to 206 billion, an expansion of 62 percent. In much of northern China, this growing demand for water is being satisfied either by investing in water efficiency or by taking irrigation water from agriculture.[60]

Under India's Punjab, where the double cropping of high-yielding winter wheat and summer rice produces a grain surplus for shipment to other states, the water table is falling. Dropping by an estimated 0.6 meters per year, it is forcing farmers with shallow wells to drill deeper.[61]

In the southern Great Plains of the United States, irrigated agriculture is based largely on water pumped from the Ogallala aquifer, which is essentially a fossil aquifer with little recharge. As the water table falls and the aquifer is depleted, farmers are forced to abandon irrigated agriculture, returning to dryland farming. In several states that dominate U.S. food production, including Colorado, Kansas, Oklahoma, and Texas, the irrigated area is slowly shrinking as the Ogallala is depleted.[62]

An economic analysis of the water situation in the high plains of Texas, where much of the state's irrigated cropland is located, concluded that crop production in the region will decline steadily as water supplies shrink. The big losers between 2000 and 2025 will be irrigated feedgrains, including both corn and sorghum. The area in wheat, a dryland crop, will expand slightly. Overall, grain production is projected to decline 17 percent. A similarly detailed analysis for nearby states, such as Oklahoma and Kansas, would likely also show production declines for the more water-dependent crops.[63]

In southern Texas, El Paso and its sister city across the border in Mexico, Juarez, both draw their water from the same aquifer. As population in the two fast-growing cities has climbed, demand has outstripped the sustainable yield of the aquifer. David Hurlbut, analyst with the Public Utility Commission of Texas, believes that because of their failure to address the water supply issue effectively, the two cities are moving toward hydrological bankruptcy.[64]

With continuing population growth, the world water situation can only get worse. Even with today's 6.1 billion people, the world has a huge water deficit. Using data on overpumping for China, India, Saudi Arabia, North Africa, and the United States, Sandra Postel, author of *Pillar of Sand*, calculates the annual overpumping of aquifers at 160 billion cubic meters or 160 billion tons. Using the rule of thumb that it takes 1,000 tons of water to produce 1 ton of grain, this 160-billion-ton water deficit is equal to 160 million tons of grain—or half the U.S. grain harvest.[65]

At average world grain consumption of just over 300 kilograms or one third of a ton per person a year, 160 million tons of grain would feed 480 million people. In other words, 480 million of the world's 6.1 billion people are being fed with grain produced with the unsustainable use of water. We are feeding ourselves with water that belongs to our children.[66]

Facing Water Scarcity

An estimated 70 percent of the water consumed worldwide, including that diverted from rivers and pumped from underground, is used for irrigation, while some 20 percent is used by industry and 10 percent for residential purposes. In the increasingly intense competition for water among these three sectors, the economics of water do not favor agriculture. In China, 1,000 tons of water can be used to produce 1 ton of wheat, worth perhaps $200, or to expand industrial output by $14,000—70 times as much. In a country that is desperately seeking economic growth and the jobs it generates, the gain in diverting water from agriculture to industry is obvious. The economics of water also helps explain the increasingly common sale of irrigation water rights by U.S. farmers in the West to cities.[67]

Urbanization, industrialization, and ecosystem maintenance also expand the demand for water. As developing-country villagers, traditionally reliant on the village well, move to urban high-rise apartment buildings with indoor plumbing, their residential water use can easily triple. Industrialization takes even more water than urbanization.

Rising affluence in itself generates additional demands for water. For example, as people move up the food chain, consuming more beef, pork, poultry, eggs, and dairy products, they use more grain. A U.S. diet rich in livestock products requires four times as much grain per person as a rice-based diet in a country like India. Using four times as much grain means using four times as much water.[68]

Once a localized phenomenon, water scarcity is now crossing national borders via the international grain trade. The world's fastest-growing grain import market is North Africa and the Middle East, an area that includes Morocco, Algeria, Tunisia, Libya, Egypt, and the countries eastward through Iran. Virtually every country in this region is simultaneously experiencing water shortages and rapid population growth.[69]

As the demand for water in the region's cities and industries rises, it is typically satisfied by diverting water from irrigation. The loss in food production capacity is then offset by importing grain from abroad. Since 1 ton of grain represents 1,000 tons of water, this is the most efficient way for water-deficit countries to import water.

In 2000, Iran imported 7 million tons of wheat, eclipsing Japan—for decades the world's leading wheat importer. In 2001, Egypt is also projected to move ahead of Japan. Iran and Egypt, each with nearly 70 million people and adding more than a million a year, are both facing acute water scarcity.[70]

The water required to produce the grain and other foodstuffs imported into North Africa and the Middle East in 2000 was roughly equal to the annual flow of the Nile River. Stated otherwise, the fast-growing water deficit of this region is equal to another Nile flowing into the region in the form of imported grain.[71]

It is now often said that future wars in the region will more likely be fought over water than oil. Perhaps, but given the difficulty in winning a water war, the competition for water seems more likely to take place in world grain markets. The countries that will "win" in this competition will be those that are financially strongest, not those that are militarily strongest.[72]

The world water deficit, as measured by the overpumping of aquifers, grows larger each year, making it progressively more difficult to manage. If countries everywhere decided this year to halt overpumping and to stabilize water tables, the world grain harvest would fall by some 160 million tons, or 8 percent, and grain prices would go off the top of the chart. The longer countries delay in facing this issue, the wider the water deficit becomes and the greater the eventual adjustment will be.

Unless governments in water-short countries act quickly to stabilize population and to raise water productivity, their water shortages may soon become food shortages. The risk is that the fast-growing ranks of water-short countries with rising grain import needs, including potentially the population giants China and India, will overwhelm the export capacity of the grain-surplus countries—the United States, France, Canada, and Australia. And this in turn will destabilize world grain markets.

The water situation is deteriorating rapidly in many countries, but it is the fast-growing water deficit in China that is likely to affect the entire world. The combination of 12 million additional people per year, urbanization, a projected economic growth rate of 7 percent, and the continuing movement of Chinese consumers up the food chain virtually ensures that the demand for water will continue to outstrip the supply for years to come. These trends also suggest that China's need for imported grain could soon start to climb, much as its imports of soybeans have in recent years. Between 1995 and 2000, China went from being self-sufficient in soybeans to being the world's largest buyer, importing over 40 percent of its supply.[73]

Water shortages can be ameliorated by raising water prices to reduce wastage and thus increase the efficiency of water use, but in China this is not always easy. An announcement in early 2001 that the government was planning to raise water prices in stages over the next five years was a welcome step in the right direction. But for Beijing, this option is fraught with political risks because the public response to increasing the price of water, which often has been free in the past, is akin to that when gasoline prices go up in the United States.[74]

Other recent announcements from Beijing indicate that the government has officially abandoned its long-standing policy of grain self-sufficiency. China has also announced that, in the intensifying competition for water, cities and industry will get priority—leaving agriculture as the residual claimant.[75]

As noted, China is not alone in facing water shortages. Other countries where water scarcity is raising grain imports or threatening to do so include India, Pakistan, Mexico, and dozens of smaller countries. But only China—with nearly 1.3 billion people and an $80 billion annual trade surplus with the United States—has the near-term potential to disrupt world grain markets. In short, falling water tables in China could soon mean rising food prices for the entire world.[76]