from Lester R. Brown, *Plan B 2.0 Rescuing a Planet Under Stress and a Civilization in Trouble* (NY: W.W. Norton & Co., 2006).

3

Emerging Water Shortages

Africa's Lake Chad, once a landmark for astronauts circling the earth, is now difficult for them to locate. Surrounded by Chad, Niger, and Nigeria—three countries with some of the world's fastest-growing populations—the lake has shrunk by 95 percent since the 1960s. The soaring demand for irrigation water in that area is draining dry the rivers and streams the lake depends on for its existence. As a result, Lake Chad may soon disappear entirely, its whereabouts a mystery to future generations.[1]

Every day, it seems, we read about lakes disappearing, wells going dry, or rivers failing to reach the sea. But these stories typically describe local situations. It is not until we begin to compile the numerous national studies—such as an 824-page analysis of the water situation in China, a World Bank study of the water situation in Yemen, or a detailed U.S. Department of Agriculture (USDA) assessment of the irrigation prospect in the western United States—that the extent of emerging water shortages worldwide can be grasped. Only then can we see the extent of water overuse and the decline it can bring.[2]

The world is incurring a vast water deficit—one that is large-

ly invisible, historically recent, and growing fast. Because much of the deficit comes from aquifer overpumping, it is often not apparent. Unlike burning forests or invading sand dunes, falling water tables are often discovered only when wells go dry.

This global water deficit is recent, the result of demand tripling over the last half-century. The drilling of millions of irrigation wells has pushed water withdrawals beyond the recharge of many aquifers. The failure of governments to limit pumping to the sustainable yield of aquifers means that water tables are now falling in countries that contain more than half the world's people.[3]

Among the more visible manifestations of water scarcity are rivers running dry and lakes disappearing. A politics of water scarcity is emerging between upstream and downstream claimants both within and among countries. Water scarcity is now crossing borders via the international grain trade. Countries that are pressing against the limits of their water supply typically satisfy the growing need of cities and industry by diverting irrigation water from agriculture, and then importing grain to offset the loss of productive capacity.

The link between water and food is strong. We each drink on average nearly 4 liters of water per day in one form or another, while the water required to produce our daily food totals at least 2,000 liters—500 times as much. This helps explain why 70 percent of all water use is for one purpose—irrigation. Another 20 percent is used by industry, and 10 percent goes for residential purposes. With the demand for water growing in all three categories, competition among sectors is intensifying, with farmers almost always losing.[4]

Falling Water Tables

Scores of countries are overpumping aquifers as they struggle to satisfy their growing water needs, including each of the big three grain producers—China, India, and the United States. These three, along with a number of other countries where water tables are falling, are home to more than half the world's people. (See Table 3–1.)[5]

There are two types of aquifers: replenishable and nonreplenishable (or fossil) aquifers. Most of the aquifers in India and the shallow aquifer under the North China Plain are replen-

Table 3–1. *Countries Overpumping Aquifers in 2005*

Country	Population (million)
China	1,316
India	1,103
Iran	70
Israel	7
Jordan	6
Mexico	107
Morocco	31
Pakistan	158
Saudi Arabia	25
South Korea	48
Spain	43
Syria	19
Tunisia	10
United States	298
Yemen	21
Total	3,262

Source: See endnote 5.

ishable. When these are depleted, the maximum rate of pumping is automatically reduced to the rate of recharge.

For fossil aquifers, such as the vast U.S. Ogallala aquifer, the deep aquifer under the North China Plain, or the Saudi aquifer, depletion brings pumping to an end. Farmers who lose their irrigation water have the option of returning to lower-yield dryland farming if rainfall permits. In more arid regions, however, such as in the southwestern United States or the Middle East, the loss of irrigation water means the end of agriculture.

Falling water tables are already adversely affecting harvests in some countries, including China, the world's largest grain producer. A groundwater survey released in Beijing in August 2001 revealed that the water table under the North China Plain, which produces over half of that country's wheat and a third of its corn, is falling faster than earlier reported. Overpumping has

largely depleted the shallow aquifer, forcing well drillers to turn to the region's deep fossil aquifer, which is not replenishable.[6]

The survey, conducted by the Geological Environmental Monitoring Institute (GEMI) in Beijing, reported that under Hebei Province in the heart of the North China Plain, the average level of the deep aquifer was dropping nearly 3 meters (10 feet) per year. Around some cities in the province, it was falling twice as fast. He Qingcheng, head of the GEMI groundwater monitoring team, notes that as the deep aquifer is depleted, the region is losing its last water reserve—its only safety cushion.[7]

His concerns are mirrored in a World Bank report: "Anecdotal evidence suggests that deep wells [drilled] 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." In unusually strong language for a Bank report, it foresees "catastrophic consequences for future generations" unless water use and supply can quickly be brought back into balance.[8]

The U.S. embassy in Beijing reports that wheat farmers in some areas are now pumping from a depth of 300 meters, or nearly 1,000 feet. Pumping water from this far down raises pumping costs so high that farmers are often forced to abandon irrigation and return to less productive dryland farming.[9]

Falling water tables, the conversion of cropland to nonfarm uses, and the loss of farm labor in provinces that are rapidly industrializing are combining to shrink China's grain harvest. The wheat crop, grown mostly in semiarid northern China, is particularly vulnerable to water shortages. After peaking at 123 million tons in 1997, the harvest has fallen in five of the last eight years, coming in at 95 million tons in 2005, a drop of 23 percent.[10]

The U.S. embassy also reports that the recent decline in rice production is partly a result of water shortages. After peaking at 140 million tons in 1997, the harvest dropped in four of the following eight years, falling to an estimated 127 million tons in 2005. Only corn, China's third major grain, has thus far avoided a decline. This is because corn prices are favorable and because the crop is not as irrigation-dependent as wheat and rice are.[11]

Overall, China's grain production has fallen from its historical peak of 392 million tons in 1998 to an estimated 358 million tons in 2005. For perspective, this drop of 34 million tons exceeds

the annual Canadian wheat harvest. China largely covered the drop-off in production by drawing down its once vast stocks until 2004, at which point it imported 7 million tons of grain.[12]

A World Bank study indicates that China is overpumping three river basins in the north—the Hai, which flows through Beijing and Tianjin; the Yellow; and the Huai, the next river south of the Yellow. Since it takes 1,000 tons of water to produce one ton of grain, the shortfall in the Hai basin of nearly 40 billion tons of water per year (1 ton equals 1 cubic meter) means that when the aquifer is depleted, the grain harvest will drop by 40 million tons—enough to feed 120 million Chinese.[13]

Of the leading grain producers, only China has thus far experienced a substantial decline in production. Even with a worldwide grain crunch and climbing grain prices providing an incentive to boost production, it will be difficult for China to regain earlier grain production levels, given the loss of irrigation water.[14]

Serious though emerging water shortages are in China, they are even more serious in India simply because the margin between actual food consumption and survival is so precarious. In a survey of India's water situation, Fred Pearce reported in the *New Scientist* that the 21 million wells drilled in this global epicenter of well-drilling are lowering water tables in most of the country. In North Gujarat, the water table is falling by 6 meters (20 feet) per year.[15]

In Tamil Nadu, a state with more than 62 million people in southern India, wells are going dry almost everywhere. According to Kuppannan Palanisami of Tamil Nadu Agricultural University, falling water tables have dried up 95 percent of the wells owned by small farmers, reducing the irrigated area in the state by half over the last decade.[16]

As water tables fall, well drillers are using modified oil-drilling technology to reach water, going as deep as 1,000 meters in some locations. In communities where underground water sources have dried up entirely, all agriculture is rain-fed and drinking water is trucked in. Tushaar Shah, who heads the International Water Management Institute's groundwater station in Gujarat, says of India's water situation, "When the balloon bursts, untold anarchy will be the lot of rural India."[17]

At this point, the harvests of wheat and rice, India's princi-

pal food grains, are still increasing. But within the next few years, the loss of irrigation water could override technological progress and start shrinking the harvest in some areas, as it is already doing in China.[18]

In the United States, the USDA reports that in parts of Texas, Oklahoma, and Kansas—three leading grain-producing states—the underground water table has dropped by more than 30 meters (100 feet). As a result, wells have gone dry on thousands of farms in the southern Great Plains. Although this mining of underground water is taking a toll on U.S. grain production, irrigated land accounts for only one fifth of the U.S. grain harvest, compared with close to three fifths of the harvest in India and four fifths in China.[19]

Pakistan, a country with 158 million people that is growing by 3 million per year, is also mining its underground water. In the Pakistani part of the fertile Punjab plain, the drop in water tables appears to be similar to that in India. Observation wells near the twin cities of Islamabad and Rawalpindi show a fall in the water table between 1982 and 2000 that ranges from 1 to nearly 2 meters a year.[20]

In the province of Baluchistan, water tables around the capital, Quetta, are falling by 3.5 meters per year. Richard Garstang, a water expert with the World Wildlife Fund and a participant in a study of Pakistan's water situation, said in 2001 that "within 15 years Quetta will run out of water if the current consumption rate continues."[21]

The water shortage in Baluchistan is province-wide. Sardar Riaz A. Khan, former director of Pakistan's Arid Zone Research Institute in Quetta, reports that six basins have exhausted their groundwater supplies, leaving their irrigated lands barren. Khan expects that within 10–15 years virtually all the basins outside the canal-irrigated areas will have depleted their groundwater supplies, depriving the province of much of its grain harvest.[22]

Future irrigation water cutbacks as a result of aquifer depletion will undoubtedly reduce Pakistan's grain harvest. Countrywide, the harvest of wheat—the principal food staple—is continuing to grow, but more slowly than in the past.[23]

Iran, a country of 70 million people, is overpumping its aquifers by an average of 5 billion tons of water per year, the

water equivalent of one third of its annual grain harvest. Under the small but agriculturally rich Chenaran Plain in northeastern Iran, the water table was falling by 2.8 meters a year in the late 1990s. New wells being drilled both for irrigation and to supply the nearby city of Mashad are responsible. Villages in eastern Iran are being abandoned as wells go dry, generating a flow of "water refugees."[24]

Saudi Arabia, a country of 25 million people, is as water-poor as it is oil-rich. Relying heavily on subsidies, it developed an extensive irrigated agriculture based largely on its deep fossil aquifer. After several years of using oil money to support wheat prices at five times the world market level, the government was forced to face fiscal reality and cut the subsidies. Its wheat harvest dropped from a high of 4.1 million tons in 1992 to 1.2 million tons in 2005, a drop of 71 percent.[25]

Craig Smith writes in the *New York Times*, "From the air, the circular wheat fields of this arid land's breadbasket look like forest green poker chips strewn across the brown desert. But they are outnumbered by the ghostly silhouettes of fields left to fade back into the sand, places where the kingdom's gamble on agriculture has sucked precious aquifers dry." Some Saudi farmers are now pumping water from wells that are 4,000 feet deep, nearly four fifths of a mile (1 mile equals 1.61 kilometers).[26]

A 1984 Saudi national survey reported fossil water reserves at 462 billion tons. Half of that, Smith reports, has probably disappeared by now. This suggests that irrigated agriculture could last for another decade or so and then will largely vanish, limited to the small area that can be irrigated with water from the shallow aquifers that are replenished by the kingdom's sparse rainfall. It is a classic example of an overshoot-and-collapse food economy.[27]

In neighboring Yemen, a nation of 21 million, the water table under most of the country is falling by roughly 2 meters a year as water use outstrips the sustainable yield of aquifers. In western Yemen's Sana'a Basin, the estimated annual water extraction of 224 million tons exceeds the annual recharge of 42 million tons by a factor of five, dropping the water table 6 meters per year. World Bank projections indicate the Sana'a Basin—site of the national capital, Sana'a, and home to 2 million people—will be pumped dry by 2010.[28]

In the search for water, the Yemeni government has drilled test wells in the basin that are 2 kilometers (1.2 miles) deep—depths normally associated with the oil industry—but they have failed to find water. Yemen must soon decide whether to bring water to Sana'a, possibly by pipeline from coastal desalting plants, if it can afford it, or to relocate the capital. Either alternative will be costly and potentially traumatic.[29]

With its population growing at 3 percent a year and with water tables falling everywhere, Yemen is fast becoming a hydrological basket case. Aside from the effect of overpumping on the capital, World Bank official Christopher Ward observes that "groundwater is being mined at such a rate that parts of the rural economy could disappear within a generation."[30]

Israel, even though it is a pioneer in raising irrigation water productivity, is depleting both of its principal aquifers—the coastal aquifer and the mountain aquifer that it shares with Palestinians. Israel's population, whose growth is fueled by both natural increase and immigration, is outgrowing its water supply. Conflicts between Israelis and Palestinians over the allocation of water in the latter area are ongoing. Because of severe water shortages, Israel has banned the irrigation of wheat.[31]

In Mexico—home to a population of 107 million that is projected to reach 140 million by 2050—the demand for water is outstripping supply. Mexico City's water problems are well known. Rural areas are also suffering. For example, in the agricultural state of Guanajuato, the water table is falling by 2 meters or more a year. At the national level, 51 percent of all the water extracted from underground is from aquifers that are being overpumped.[32]

Since the overpumping of aquifers is occurring in many countries more or less simultaneously, the depletion of aquifers and the resulting harvest cutbacks could come at roughly the same time. And the accelerating depletion of aquifers means this day may come soon, creating potentially unmanageable food scarcity.

Rivers Running Dry

While falling water tables are largely hidden, rivers that are drained dry before they reach the sea are highly visible. Two rivers where this phenomenon can be seen are the Colorado, the

major river in the southwestern United States, and the Yellow, the largest river in northern China. Other large rivers that either run dry or are reduced to a mere trickle during the dry season are the Nile, the lifeline of Egypt; the Indus, which supplies most of Pakistan's irrigation water; and the Ganges in India's densely populated Gangetic basin. Many smaller rivers have disappeared entirely.[33]

As the world's demand for water has tripled over the last half-century and as the demand for hydroelectric power has grown even faster, dams and diversions of river water have drained many rivers dry. As water tables have fallen, the springs that feed rivers have gone dry, reducing river flows.[34]

Since 1950, the number of large dams, those over 15 meters high, has increased from 5,000 to 45,000. Each dam deprives a river of some of its flow. Engineers like to say that dams built to generate electricity do not take water from the river, only its energy, but this is not entirely true since reservoirs increase evaporation. The annual loss of water from a reservoir in arid or semiarid regions, where evaporation rates are high, is typically equal to 10 percent of its storage capacity.[35]

The Colorado River now rarely makes it to the sea. With the states of Colorado, Utah, Arizona, Nevada, and, most important, California depending heavily on the Colorado's water, the river is simply drained dry before it reaches the Gulf of California. This excessive demand for water is destroying the river's ecosystem, including its fisheries.[36]

A similar situation exists in Central Asia. The Amu Darya—which, along with the Syr Darya, feeds the Aral Sea—is now drained dry by Uzbek and Turkmen cotton farmers upstream. With the flow of the Amu Darya cut off, only the diminished flow of the Syr Darya keeps the Aral Sea from disappearing entirely.[37]

China's Yellow River, which flows some 4,000 kilometers through five provinces before it reaches the Yellow Sea, has been under mounting pressure for several decades. It first ran dry in 1972, and since 1985 it has often failed to reach the sea.[38]

The Nile, site of another ancient civilization, now barely makes it to the sea. Water analyst Sandra Postel, in *Pillar of Sand*, notes that before the Aswan Dam was built, some 32 billion cubic meters of water reached the Mediterranean each year.

After the dam was completed, however, increasing irrigation, evaporation, and other demands reduced its discharge to less than 2 billion cubic meters.[39]

Pakistan, like Egypt, is essentially a river-based civilization, heavily dependent on the Indus. This river, originating in the Himalayas and flowing westward to the Indian Ocean, not only provides surface water, it also recharges aquifers that supply the irrigation wells dotting the Pakistani countryside. In the face of growing water demand, it too is starting to run dry in its lower reaches. Pakistan, with a population projected to reach 305 million by 2050, is in trouble.[40]

In Southeast Asia, the flow of the Mekong is being reduced by the dams being built on its upper reaches by the Chinese. The downstream countries, including Cambodia, Laos, Thailand, and Viet Nam—countries with 168 million people—complain about the reduced flow of the Mekong, but this has done little to curb China's efforts to exploit the power and the water in the river.[41]

The same problem exists with the Tigris and Euphrates Rivers, which originate in Turkey and flow through Syria and Iraq en route to the Persian Gulf. This river system, the site of Sumer and other early civilizations, is being overused. Large dams erected in Turkey and Iraq have reduced water flow to the once "fertile crescent," helping to destroy more than 90 percent of the formerly vast wetlands that enriched the delta region.[42]

In the river systems just mentioned, virtually all the water in the basin is being used. Inevitably, if people upstream get more water, those downstream will get less.

Disappearing Lakes

As river flows are reduced or even eliminated entirely and as water tables fall from overpumping, lakes are shrinking and in some cases disappearing. As my colleague Janet Larsen notes, the lakes that are disappearing are some of the world's best known—including Lake Chad in Central Africa, the Aral Sea in Central Asia, and the Sea of Galilee (also known as Lake Tiberias).[43]

Many U.S. lakes have not fared well either. In California, Owens Lake, which covered 200 square miles when the last century began, has disappeared. After the Owens River was divert-

ed to thirsty Los Angeles in 1913, the lake lasted little more than a decade.[44]

California's Mono Lake, geologically the oldest lake in North America and a popular feeding stop for migratory water birds, is a more recent victim of Los Angeles's seemingly unquenchable thirst. Mono Lake has experienced a 35-foot drop in its water level since 1941, when the diversion of water from its tributaries to Los Angeles began.[45]

Reuters reporter Megan Goldin writes that "walking on the Sea of Galilee is a feat a mere mortal can accomplish," due to receding shores. When I first saw the Jordan River as it enters Israel from Syria, its frailty was obvious. Indeed, in many countries it would be called a creek or a stream. And yet it has the primary responsibility for supplying water to the Sea of Galilee, which it enters at the north end and exits on the south end, continuing southward some 105 kilometers before emptying into the Dead Sea.[46]

With the Jordan's flow further diminished as it passes through Israel, the Dead Sea is shrinking even faster than the Sea of Galilee. Over the past 40 years, its water level has dropped by some 25 meters (nearly 80 feet). As a result of diversions from the Jordan River as it flows southward in Israel as well as fast-falling water tables on the Jordanian side, the Dead Sea could disappear entirely by 2050.[47]

Of all the shrinking lakes and inland seas, none has gotten as much attention as the Aral Sea. Its ports, once centers of commerce in the region, are now abandoned, looking like the ghost mining towns of the American West. Once one of the world's largest freshwater bodies, the Aral has lost four fifths of its volume since 1960. Ships that once plied its water routes are now stranded in the sand of the old seabed—with no water in sight.[48]

The seeds for the Aral Sea's demise were sown in 1960, when Soviet central planners in Moscow decided the region embracing the Syr Darya and Amu Darya basins would become a vast cotton bowl to supply the country's textile industry. As cotton planting expanded, so too did the diversion of water from the two rivers that fed the Aral Sea. As the sea shrank, the salt concentrations climbed until the fish died. The thriving fishery that once produced 50,000 tons per year

disappeared, as did the jobs on the fishing boats and in the fish processing factories.[49]

With the 65-billion-cubic-meter annual influx of water from the two rivers now down to 1.5 billion cubic meters a year, the prospect for reversing the shrinkage is not good. With the sea's shoreline now up to 250 kilometers (165 miles) from the original port cities, there is a vast area of exposed seabed. Each day the wind lifts thousands of tons of sand and salt from the dry seabed, distributing the airborne particles on the surrounding grasslands and croplands and damaging them.[50]

At a 1990 Soviet Academy of Sciences conference on the future of the Aral Sea, there was an aerial tour for foreign guests. Flying over this area in a World War II–vintage single-engine biplane a few hundred feet above the dry, salt-covered seabed, I noted that it looked like the surface of the moon. There was no vegetation, no sign of any life, only total desolation.[51]

The disappearance of lakes is perhaps most pronounced in China. In western China's Qinhai province, through which the Yellow River's main stream flows, there were once 4,077 lakes. Over the last 20 years, more than 2,000 have disappeared. The situation is far worse in Hebei Province, which surrounds Beijing. With water tables falling fast throughout this region, Hebei has lost 969 of its 1,052 lakes.[52]

Lakes are disappearing in other Asian countries as well, including India, Pakistan, and Iran. For example, numerous lakes have disappeared in India's Kashmir Valley. Lake Dal, at one time covering 75 square kilometers, has shrunk to 12 square kilometers. With water tables falling in so much of India, many lakes are disappearing and others are shrinking fast.[53]

Population is also outgrowing the water supply in Mexico. Lake Chapala, the country's largest, is the primary source of water for Guadalajara, which is home to 5 million people. Expanding irrigation in the region has reduced water volume in the lake by 80 percent.[54]

Lakes are disappearing on every continent and for the same reasons: excessive diversion of water from rivers and overpumping of aquifers. No one knows exactly how many lakes have disappeared over the last half-century, but we do know that thousands of them now exist only on old maps.

Farmers Losing to Cities

Water conflicts among countries dominate the headlines. But within countries it is the jousting for water between cities and farms that preoccupies local political leaders. The economics of water use do not favor farmers in this competition, simply because it takes so much water to produce food. For example, while it takes only 14 tons of water to make a ton of steel worth $550, it takes 1,000 tons of water to grow a ton of wheat worth $150. In countries preoccupied with expanding the economy and creating jobs, the policy decision to make agriculture the residual claimant comes as no surprise.[55]

Many of the world's largest cities are located in watersheds where all available water is being used. Cities in such watersheds, such as Mexico City, Cairo, and Beijing, can increase their water consumption only by importing water from other basins or taking it from agriculture. Literally hundreds of the world's cities are now meeting their growing needs by taking irrigation water from farmers. Among the U.S. cities doing so are San Diego, Los Angeles, Las Vegas, Denver, and El Paso. A USDA study of 11 western states found that annual sales of water rights during 1996 and 1997 averaged 1.65 billion tons, enough to produce 1.65 million tons of grain.[56]

World Bank calculations for densely populated South Korea, a relatively well watered country, indicate that growth in residential and industrial water use there could reduce the supply available for agriculture from 13 billion to 7 billion tons in 2025. The Bank also projects that between 2000 and 2010, China's urban water demand will increase from 50 billion to 80 billion tons, a growth of 60 percent. Industrial water demand, meanwhile, will go from 127 billion to 206 billion tons, up 62 percent. Several hundred cities are looking to the countryside to satisfy their future water needs. In the region around Beijing, this shift has been under way since 1994, when farmers were banned from drawing on the reservoirs that supplied the city.[57]

As China attempts to accelerate the economic development of the upper Yellow River basin, emerging industries upstream get priority in the use of water. And as more water is used upstream, less reaches farmers downstream. In unusually dry years, the Yellow River fails to reach Shandong, the last province en route to the sea.[58]

Farmers in Shandong, who have traditionally received roughly half of their irrigation water from the Yellow River and half from wells, are now losing water from both sources. Irrigation water losses in a province that produces one fifth of China's corn and one seventh of its wheat help explain why China's grain harvest is declining.[59]

Literally hundreds of cities in other countries are meeting their growing water needs by taking some of the water that farmers count on. In western Turkey, for example, the city of Izmir now relies heavily on well fields from the neighboring agricultural district of Manisa.[60]

In the U.S. southern Great Plains and Southwest, where virtually all water is now spoken for, the growing water needs of cities and thousands of small towns can be satisfied only by taking water from agriculture. A monthly magazine from California, *The Water Strategist*, devotes several pages to a listing of water sales in the western United States during the preceding month. Scarcely a day goes by without another sale. Eight out of 10 sales are typically by either individual farmers or their irrigation districts to cities and municipalities.[61]

Colorado, with a fast-growing population, has one of the world's most active water markets. Growing cities and towns of all sizes in a state with high immigration are buying irrigation water rights from farmers and ranchers. In the upper Arkansas River basin, which occupies the southeastern quarter of the state, Colorado Springs and Aurora (a suburb of Denver) have already bought water rights to one third of the basin's farmland. Aurora has purchased rights to water that was once used to irrigate 9,600 hectares (23,000 acres) of cropland in the Arkansas valley.[62]

Far larger purchases are being made by cities in California. In 2003, San Diego bought annual rights to 247 million tons (200,000 acre-feet) of water from farmers in the nearby Imperial Valley—the largest rural/urban water transfer in U.S. history. This agreement covers the next 75 years. In 2004, the Metropolitan Water District, which supplies water to 18 million southern Californians in several cities, negotiated the purchase of 137 million cubic meters of water per year from farmers for the next 35 years. Without irrigation water, the highly productive land owned by these farmers is wasteland. The farmers who are sell-

ing their water rights would like to continue farming, but city officials are offering far more for the water than the farmers could possibly earn by using it to irrigate crops.[63]

In many countries, however, farmers are not compensated for a loss of irrigation water. In 2004, for example, Chinese farmers along the Juma River downstream from Beijing discovered that the river had stopped flowing. A diversion dam had been built near the capital to take river water for Yanshan Petrochemical, a state-owned industry. Although the farmers protested bitterly, it was a losing battle. For the 120,000 villagers downstream from the diversion dam, the loss of water could cripple their ability to make a living from farming.[64]

Whether it is outright government expropriation, farmers being outbid by cities, or cities simply drilling deeper wells than farmers can afford, the world's farmers are losing the water war. They are faced with not only a shrinking water supply in many situations but also a shrinking share of that shrinking supply. Slowly but surely, cities are siphoning water from the world's farmers even as they try to feed some 70 million more people each year.[65]

Scarcity Crossing National Borders

Historically, water scarcity was a local issue. It was up to national governments to balance water supply and demand. Now this is changing as scarcity crosses national boundaries via the international grain trade. Since producing one ton of grain takes 1,000 tons of water (1,000 cubic meters), as noted earlier, importing grain is the most efficient way to import water. Countries are, in effect, using grain to balance their water books. Similarly, trading in grain futures is in a sense trading in water futures.[66]

After China and India, there is a second tier of countries with large water deficits—Algeria, Egypt, Iran, Mexico, and Pakistan. Three of these—Algeria, Egypt, and Mexico—already import much of their grain. However, in a parallel move with China, water-short Pakistan abruptly turned to the world market in 2004 for imports of 1.5 million tons of wheat. Its need for imports is likely to climb in the years ahead.[67]

The Middle East and North Africa—from Morocco in the west through Iran in the east—has become the world's fastest-

growing grain import market. The demand for grain is driven both by rapid population growth and by rising affluence, much of the latter derived from the export of oil. With virtually every country in the region pressing against its water limits, the growing urban demand for water can be satisfied only by taking irrigation water from agriculture.[68]

Egypt, with some 74 million people, has become a major importer of wheat in recent years, vying with Japan—traditionally the leading wheat importer—for the top spot. It now imports 40 percent of its total grain supply, a number that edges steadily upward as its population outgrows the grain harvest produced with the Nile's water.[69]

Algeria, with 33 million people, imports more than half of its grain, which means that the water embodied in the imported grain exceeds the use of water for all purposes from domestic sources. Because of its heavy dependence on imports, Algeria is particularly vulnerable to disruptions, such as grain export embargoes.[70]

Overall, the water required to produce the grain and other farm products imported into the Middle East and North Africa last year equaled the annual flow of the Nile River at Aswan. In effect, the region's water deficit can be thought of as another Nile flowing into the region in the form of imported grain.[71]

It is often said that future wars in the Middle East will more likely be fought over water than oil, but the competition for water is taking place in world grain markets. The countries that are financially the strongest, not necessarily those that are militarily the strongest, will fare best in this competition.

Knowing where grain import needs will be concentrated tomorrow requires looking at where water deficits are developing today. Thus far, the countries importing much of their grain have been smaller ones. Now we are looking at fast-growing water deficits in both China and India, each with more than a billion people.[72]

Each year the gap between world water consumption and the sustainable water supply widens. Each year the drop in the water table is greater than the year before. Both aquifer depletion and the diversion of water to cities will contribute to the growing irrigation water deficit and hence to a growing grain deficit in many water-short countries.

A Food Bubble Economy

As noted earlier, overpumping is a way of satisfying growing food demand that virtually guarantees a future drop in food production when aquifers are depleted. Many countries are in essence creating a "food bubble economy"—one in which food production is artificially inflated by the unsustainable mining of groundwater.

The effects of overdrafting were not obvious when farmers began pumping on a large scale a few decades ago. The great attraction of pumping groundwater in contrast to large-scale surface water systems is that farmers can apply the water to crops precisely when it is needed, thereby maximizing water use efficiency. Groundwater is also available during the dry season, enabling many farmers in mild climatic regions to double crop.

To illustrate, yields of foodgrains in the Punjab on land irrigated from wells was 5.5 tons per hectare, while yields on land irrigated from canals averaged 3.2 tons per hectare. Similar data for the southern state of Andhra Pradesh also showed a strong advantage in pumped irrigation, with foodgrain yields averaging 5.7 tons per hectare compared with 3.4 tons on land irrigated with canal water.[73]

In the United States, 37 percent of all irrigation water comes from underground; the other 63 percent comes from surface sources. Yet three of the top grain-producing states—Texas, Kansas, and Nebraska—each get 70–90 percent of their irrigation water from the Ogallala aquifer, which is essentially a fossil aquifer with little recharge. The high productivity of groundwater-based irrigation means that the food production losses will be disproportionately large when the groundwater runs out.[74]

At what point does water scarcity translate into food scarcity? In which countries will the irrigation water losses from aquifer depletion translate into a drop in grain production? David Seckler and his colleagues at the International Water Management Institute, the world's premier water research group, summarized this issue well: "Many of the most populous countries of the world—China, India, Pakistan, Mexico, and nearly all the countries of the Middle East and North Africa—have literally been having a free ride over the past two or three decades by depleting their groundwater resources. The penalty

for mismanagement of this valuable resource is now coming due and it is no exaggeration to say that the results could be catastrophic for these countries and, given their importance, for the world as a whole."[75]

Since expanding irrigation helped triple the world grain harvest from 1950 to 2000, it comes as no surprise that water losses can shrink harvests. With water for irrigation, many countries are in a classic overshoot-and-decline mode. If countries that are overpumping do not move quickly to reduce water use and stabilize water tables, then an eventual drop in food production is almost inevitable.[76]