568 gallons in 1985, and down to 545 gallons in 1990.

Table 1 gives the absolute volume of water withdrawn for irrigation water use, showing that in 1980, some 150 billion gallons a day went for irrigation; in 1985, this fell to an estimated 137 bgd, which remains the best estimate for 1990.

"Irrigation water use" figures include all water artificially applied to farm and horticultural crops, as well as water used to irrigate private and public golf courses. The use of irrigation, especially in technologically advanced forms of "protected agriculture," meaning greenhouses, hydroponics, and similar modifications, results in far higher productivities of biomass per acre of production. In these advanced modes, there is much more biomass output per gallon of water, e.g., with drip irrigation, instead of furrow irrigation.

For example, you can expect to triple crop output by using advanced drip irrigation, instead of furrow irrigation, for such crops as cotton. One acre-inch of water will produce 20 pounds of cotton with furrow irrigation; and with drip irrigation, 59 pounds. The difference for sorghum is 4,600 pounds per acre with furrow irrigation, and 8,500 pounds per acre with drip irrigation. For watermelons, the ratio of yield goes up from 20-25 tons per acre, to 25-35 tons per acre.

However, the decline in total volume of irrigation water in the United States does not represent a sweeping shift over into advanced irrigation modes, with higher output ratios per water volume applied. In fact, less water is being used for irrigation overall. Table 1 shows that the average volume of water applied per acre in the United States dropped from 2.9 acre-feet in 1985, down to 2.7 acre-feet in 1990. Only in a few locations are advanced hydroponics in use, and many of the largest are operations run by Cargill, Chiquita, and other international commodities cartel giants that dominate key links in the food chain for private profiteering, not public benefit.

Therefore, the decline in use of irrigation is a marker of a declining U.S. agriculture sector. This shift is acknowledged in a backhanded way in a new study by the National Research Council of the National Academy of Sciences, entitled "A New Era for Irrigation," due out in October. The NRC notes a decline in the total U.S. land area irrigated, from a peak of 52 million acres in 1994.

The impact to the consumer of the downgrading of the U.S. agriculture sector, specifically irrigated production, is masked temporarily by the huge increase, over the 1980s-1990s, of imported fruits, vegetables, and juices. Since 1985, the United States has been a net importer even of onions (that is, tonnage of imports exceeds exports). As of the late 1980s, Mexico supplied 35% of the U.S. consumption of the six fresh winter vegetables (October through June)—tomatoes, bell peppers, cucumbers, eggplant, snap beans, and squash. This flow has increased over the 1990s, representing a de facto use of Mexican water for provision of the U.S. consumer market basket. Huge quantities of fruit juice base are now coming into the United States from Europe, Turkey, and even South Africa.

Declining water usage is not conservation

Does declining per-capita water usage in the U.S. economy mean that future water supplies will be adequate? Is this a form of "saving water for the future," as the radical environmentalists (at *National Geographic,* Turner Broadcasting, the World Wide Fund for Nature, et al.) claim?

Just the opposite is true. The U.S. Geological Survey statistics showing the "drying out" of the economy, correspond to a decline in maintenance, replacement, and expansion of U.S. water supply infrastructure, that is now showing up in the form of regional water crises in many locations around the country. It is the lack of infrastructure and technology that is causing ecological decay and degradation of the U.S. water resource base.

In the following sections, we give a brief survey of the nation's regional water problems, then look at what should be done to remedy these situations, and, finally, we identify the forces preventing sensible water infrastructure and ecology development.

Major problem areas in U.S. water supply

by Marcia Merry Baker

The water problems present in various regions in the United States range from trouble at the source, through to the end-user stage. At the source, there are regions with severe water supply shortages, or others, with flooding and uncontrolled "oversupply"; at the treatment phase, there are thousands of locations where filtration, purification, sewage and discharge treatment, and other essential processes are inadequate; and finally, thousands of miles of distribution pipes, and thousands of storage reservoirs, pumps, and other parts of urban water systems need to be refurbished. We begin here, with a national overview of the geography of freshwater supply problems.

Figure 7 shows the boundaries of the 18 hydrologic regions in the coterminous 48 states of the United States, and indicates two general zones of water problem areas. The hydrologic regions are delineated with heavy boundary lines, and named and numbered according to the standard system used since the 1960s by the U.S. Geologic Survey. An hydrologic region refers to a natural drainage basin that contains either the drainage area of a major river (e.g., the Lower Mississippi, region No. 8), or the combined drainage area of two or more rivers (e.g., South Atlantic-Gulf, region No. 3, which has numerous rivers draining out to sea, including the James, the Potomac, and the Tombigbee).

FIGURE 7
United States: 18 hydrologic regions, and areas of water supply problems

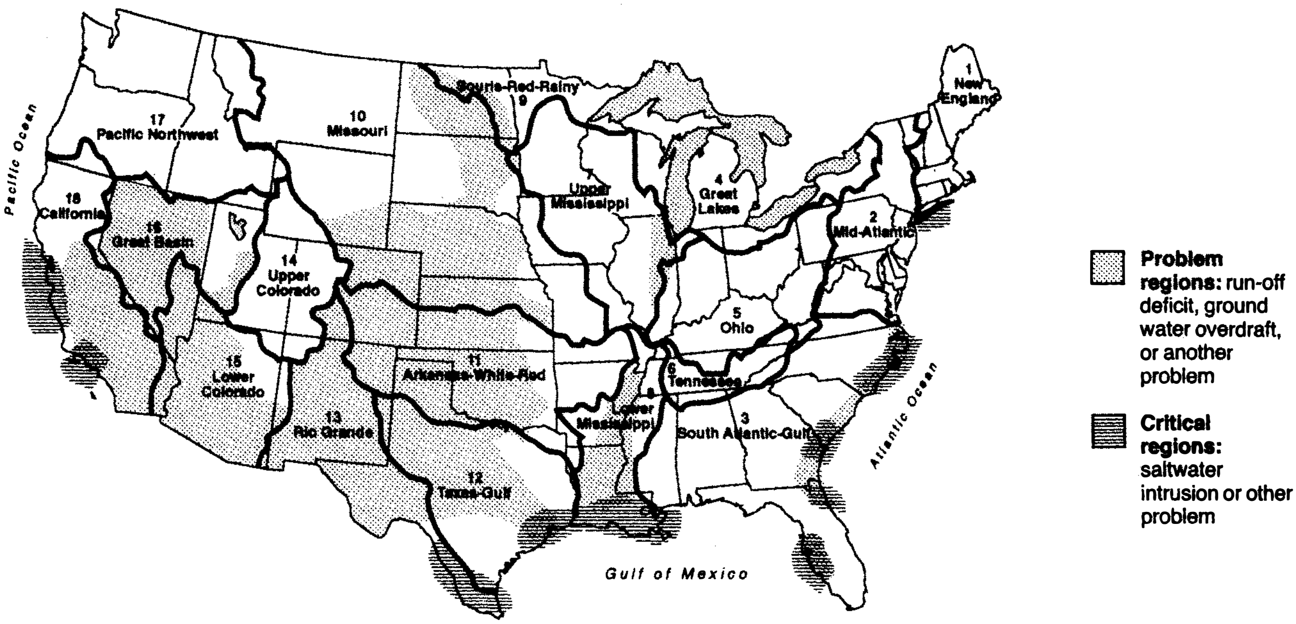


Table 2 presents the list of the 18 hydrologic regions, and gives statistics on supply and use of water in each region.

The lightly shaded zones of Figure 7 indicate the areas where there are generally problems of water shortage, such as runoff deficit, groundwater overdraft, or similar problems. The darker, cross-hatched zones show regions with saltwater intrusion, and similar problems of both water supply and quality.

There are two patterns immediately apparent: the western states have large areas subject to water shortages; and the Pacific, Atlantic, and Gulf coastal regions are subject to saltwater intrusion into freshwater coastal wells and aquifers. These reflect "natural causes" at work, but the problems are man-made.

Mismanagement of the national water budget

Most people think of rivers, lakes, aquifers, and water wells as resources fixed by nature, to be either conserved or consumed. On the contrary. The only relatively fixed feature of the water cycle in North America is the overall annual precipitation (see **Figure 8**).

In all of North America, the annual precipitation amounts to an estimated average of 4,200 billion gallons a day (bgd). Of that, about 1,200 bgd reaches the 48 states, where man's intervention over the past 200 years has directly affected what water engineers call the *average dependable supply of runoff.*

In recent decades, this dependable supply has totalled about 515 bgd for the United States. It is not a fixed figure, but the result of man's activities to clear channels, drain swamps, prevent evaporation, and create storage capacity.

As of the mid-1960s, the United States, with over 190 million people, was using overall about 308 bgd, which was 60% of the average dependable supply of 515 bgd. This supply reflected the dam-building of the interwar period—the Grand Coulee and the Hoover dams, the Colorado River development, the Tennessee Valley Authority, and the post-war California Water Plan (adopted in 1957).

In the 1950s and 1960s, there were engineering plans to continue large-scale water projects to provide for the future. It was projected then that the 1990 U.S. population would be about 250 million, and the economic base would require 588 bgd of average dependable water supply. Projects for the provision of new water included some continued river basin improvements—finishing what remained of the undone dams, levees, etc.; but otherwise, featured such advanced plans as the continental-scale water diversion program called the North American Water and Power Alliance (Nawapa, see following article), and nuclear-powered desalination facilities for the coastal areas. Had these latter programs been pursued, we would not have the water problems that are common today. But these projects were blocked.

Therefore, when the U.S. population in 1990 did reach some 252 million, there were many regions where water supplies were inadequate, even though the economy was only using about 408 bgd, and not the previously projected 588 bgd. We will look at certain of these regions more closely. But first, look at the national rainfall patterns.

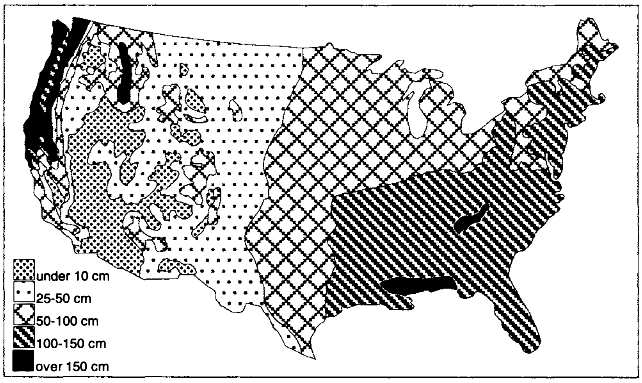
A Figure 8 shows, most of the 48 states receive 20-40

TABLE 2
Water resources, by standard hydrologic regions, for the 48 coterminous states

Region	Total average runoff	Estimated dependable runoff	Per capita: Dependable runoff	Per capita: Use, 1990
	(bgd)		(gal daily)	
1. New England	67	22	1,719	370
2. Mid-Atlantic	84	36	867	508
3. South Atlantic-Gulf	197	75	2,159	962
4. Great Lakes	75	69	3,223	1,510
5. Ohio	125	48	2,193	1,390
6. Tennessee	41	14	3,579	2,350
7. Upper Mississippi	65	31	1,457	977
8. Lower Mississippi	79	25	3,488	2,510
9. Souris-Red-Rainy	6.2	3	4,464	439
10. Missouri	54	30	2,986	3,730
11. Arkansas-Red-White	73	20	2,424	1,870
12. Texas-Gulf	32	17	1,115	886
13. Rio Grande	5	3	1,346	2,670
14. Upper Colorado	13	13	20,800	11,300
15. Lower Colorado	3.2	3	632	1,630
16. Great Basin	7.5	9	4,125	3,300
17. Pacific Northwest	210	70	7,855	4,070
18. California	62	28	951	1,200
Total	**1,200**	**515**	**2,041**	**1,340**

Source: U.S. Geologic Survey Circular 1081. (1993)

FIGURE 8
United States: annual precipitation



inches (60-150 cm) of rainfall a year, but one-third of the country has less than 20 inches (under 50 cm) of annual precipitation, mostly in the dry western states. The discontinuing of development of water supply infrastructure has resulted in water crises in the arid regions.

Supply problem regions

In the right-hand columns of Table 2, the dependable runoff and average use for 1990 are stated in per-capita terms, both in gallons per day (gpd). In most of the eastern regions, the per-capita daily use is less than the dependable runoff, e.g., 1) New England, 2) Mid-Atlantic, 3) South Atlantic-Gulf, and so forth. In some of the mountainous regions, of both east and west, the daily use per capita is far less than the dependable runoff, e.g., 6) Tennessee, 11) Arkansas-White Red, 14) Upper Colorado.

Now look at the arid regions. In region No. 18, California, the per-capita use of 1,200 gpd is more than the 951 gpd per capita of dependable runoff. This indicates both that water needs are being supplied from outside the region, and also that there are serious overdrafts in underground water—that is, water is being taken from wells and aquifers at a faster rate than it is being replaced.

Region No. 15, the Lower Colorado, is similar. It principally includes the state of Arizona. In 1990, the per-capita use rate was about 1,630 gpd, in contrast to the per-capita dependable runoff, which was 632 gpd.

Region No. 13, the Rio Grande, likewise shows 2,670 gpd per-capita daily use, in contrast to the 1,346 gpd per-capita dependable runoff. This region is shown in more detail below. First, look at water problems in a few states.

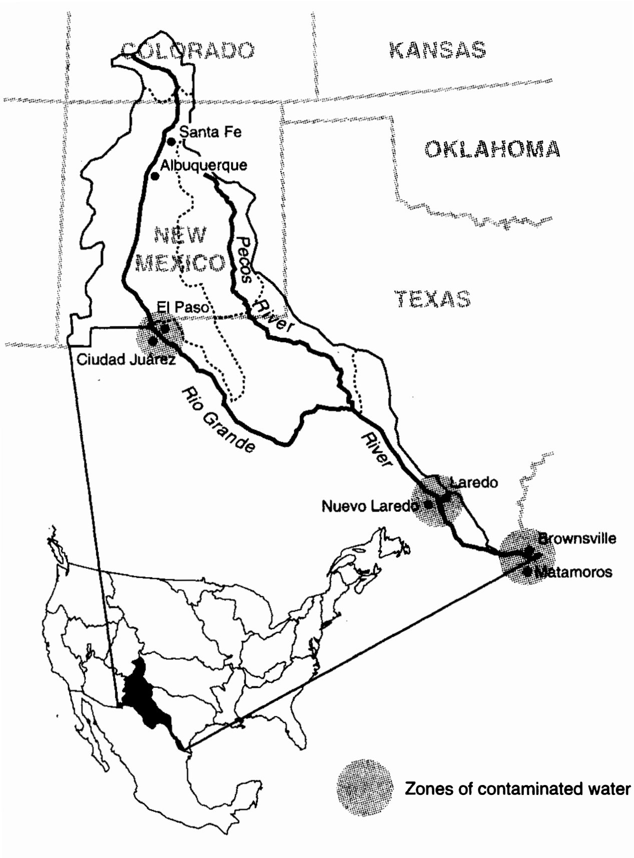
- California: Eleven of the state's 50 major aquifers are in overdraft; the state has been obtaining 40% of its annual water needs from pumping groundwater. To avert this, a joint study was begun in 1988, by the Metropolitan Water District of Southern California and the federal Department of Energy, for nuclear-powered desalination. But the workable engineering plans were subsequently cancelled, which, along with non-construction of the Nawapa water diversion project, contributed to the current ecological decline of the water resource base in California.
- Missouri: This state, Iowa, and others in the region, were hard hit by "Great Flood of '93," and many lesser floods, because of the lack of completion of the upper Mississippi/ Missouri river basins projects, including dams, levees, farm field ponds and tilling.
- Florida: The water supplies for Miami, Tampa, Jacksonville, and many other population centers are threatened by saltwater intrusion into the groundwater sources, because of heavy pumping. Nuclear-powered desalination would contribute flows to correct this imbalance. In addition, former NASA engineers have a successful Miami test facility (built 1982) in operation for treating waste-water with electron beams.
- New York: Long Island supplies are threatened because the underlying aquifer has been mined to the point of saltwater intrusion. Other coastal areas to the south, notably, Virginia Beach, Virginia, are facing the same type of crisis.

Rio Grande hydrologic region water crisis

Figure 9 shows the Rio Grande hydrologic region in more detail. This region, plus southern California and Arizona, includes the U.S.-Mexico border zone of *maquiladoras*—

FIGURE 9

Zones of contaminated water in the Rio Grande Hydrologic Region



slave-labor factories; it has become a biological breakdown zone because of lack of safe and sufficient water. Waterborne diseases, such as dysentery and hepatitis, are spreading, and cholera has appeared. Some of the major locations of contaminated water along the 700-mile Rio Grande U.S.-Mexico border are shown on the map—El Paso-Ciudad Juárez, Laredo-Nuevo Laredo, and Brownsville-Matamoros.

Hundreds of thousands of people are living in conditions where there is no sewage treatment, and no safe water. El Paso County, Texas, for example, had, in 1992, five times the national average rate of hepatitis A—a disease related to fecal contamination and filthy water.

A recent report from the U.S. Federal Reserve Bank in Dallas, Texas, praised this Tex-Mex maquiladora zone for its economic "grandeur," as proof of the success of the North American Free Trade Agreement. They refer to the continuing population influx, which serves as a pool of low-wage labor. From 1989 to 1996, for example, the border town of Reynosa, saw its population double to 550,000. There are 126 *maquiladora* plants there now, employing 50,000 people. The typical wage for a textile worker is $5 a day.

An Associated Press story in July described the town: "Reynosa's outskirts are dotted with colonias overflowing with families who live without drinkable water, electricity, and sewage. Hospitals and schools are crammed, and numerous streets remain unpaved."

In 1975, based on its prior surveys, the U.S. Geologic Survey explictly forewarned against any more population influx, or expansion of economic activity in the Rio Grande region, until and unless new volumes of water were secured, and new treatment systems were built. The 1975 USGS warning said, "Water quality is a serious problem in the lower Rio Grande Valley and precludes or inhibits expanded use of the valley under present conditions. . . . 20% of the lower valley population is not served by a public water supply system. This situation is likely to be aggravated by the increasing population in that area. . . . No additional water supply is currently available for the majority of [anticipated, modest] population increase."

The engineers' warnings were ignored.

Decrepit distribution systems

The Rio Grande region is a biological holocaust zone because of water shortages, lack of water treatment, and absence of proper distribution systems. In many other regions, where volumes of supplies are relatively ample, nevertheless, the treatment phase is decrepit, and/or the delivery system is faulty. Look just at the disrepair of urban distributions systems. Washington, D.C. is typical.

An estimated 1.2 million feet out of the 6.8 million total feet of the District of Columbia's water pipes need to be replaced. They are over 100 years old. The corrosion, and niches in the outdated distribution system, create conditions for bacteria to flare up, which is what happened this June, at the onset of warm summer temperatures. Also, the District has not routinely flushed the system out, so "biofilms" of bacteria have formed in many pipes. Chlorine infusions temporarily reduce the bacteria, but will not solve the problem.

Nationwide, the water delivery systems involve some 436,000 miles of pipe. Depending on the location, significant percentages of these pipes are old and worn out—they are prone to breakage, harbor bacteria, leak, and generally cause uncertainty of water supply and a threat to public health.

An estimated 48% of the nation's water main systems is cast-iron; the percentage in older cities is 70-90%. In many of the major cities on the East Coast, and a few in the Midwest, pipes over 140 years old are in use.

As of the 1990s, the breakage rate was about one break for every 3.7 miles of water main. Thus, over 117,000 miles of water piping sustain breaks each year. But U.S. public works projects replace only 2,300 miles of pipe per year in total—less than 2% of the lines that experience breaks.

Most water district utilities replace only about a dozen miles of pipe a year. At the current rate of replacement and repair, this translates into the prospect of taking more than 200 years to rebuild each area's water distribution system. In reality, these systems won't hold out that long.