Section 2

Ground Water

Use and Availability

Key Message

Ground water is a renewable, yet finite, resource—and it is usually taken for granted. It is generally pumped from the subsurface in the absence of a sound understanding of how much remains available for sustainable use. Overwithdrawal of ground water supplies can lead to dried-up wells and springs, shrinking wetlands, reduced stream flows and lake levels, saltwater intrusion in coastal areas, and land subsidence. These impacts have serious economic ramifications, which are only worsened when coupled with drought conditions. Unless we employ more effective ways to manage the way we use ground water, current practices of withdrawing ground water at unsustainable rates will ultimately have significant social, economic, and ecological costs.

Our land-use decisions and water-use policies must consider the interrelationship between ground water and surface water supplies and the capacity of individual watersheds to sustain existing, as well as future, water uses. To ensure the long-term availability of water and aquifer yields, we as a nation must use water more efficiently and better tailor our land- and water-use planning to effectively bridge the gap between water law and science.

Photo: California Department of Water Resources

Left: Ground water pumping in the Arizona desert has caused the land to subside in some basins.
Right: The United States uses more than 83 billion gallons of fresh ground water each day for private and public water supplies, irrigation, livestock, manufacturing, mining, and other purposes. (USGS, 2004)

Getting a Grip on Ground Water Use

> *"The solution involves charting a new course for the future based on wise policies, then making a commitment to stay the course. It can be done. In the process, there is a role for every individual and for local, state, and federal governments."*
>
> Robert Glennon | *Water Follies: Groundwater Pumping and the Fate of America's Fresh Waters*

why ground water Use and Availability matter…

Potable fresh water is fast becoming a highly sought-after commodity—it is being called "blue gold." Yet the fact that *all the water we have right now is all the water we will ever have* is not reflected in our demand for and use of water. As a nation, we can no longer put off the job of answering the essential and definitive questions of supply and demand: Will we have enough water, and what will it cost? Global consumption of water is doubling every 20 years, more than twice the rate of our population growth. (Barlow and Clarke, 2002) According to the U.S. Census Bureau, the U.S. population has passed the 301 million mark (2007) and is expected to grow to 404 million by the year 2050. (U.S. Census Bureau, 2004)

Given that the population continues to grow while the volume of fresh water does not, we need to rethink our approach to water use so that we can effectively reconcile hydrologic, legal, economic, and ecosystem realities with population growth. It is essential that we make a concerted move toward long-term water planning and conservation so that we are not using water supplies faster than they can be renewed.

Land-use activities that lead to overuse of water supplies or loss of a water supply due to contamination are key factors in water availability. In the United States, a tremendous amount of growth has occurred in areas with limited, if not inadequate, sources of suitable water. With increasing growth into and development of rural areas, demands on ground water supplies continue to escalate. In addition to increasing demand for ground water, this expanded growth and development reduces the area available for infiltration and aquifer recharge, resulting in further loss of ground water volumes.

Many of our land-use activities create potential sources of ground water contamination (e.g., septage from onsite septic systems; fertilizers, pesticides, and other lawn chemicals from farmland, golf courses, gardens, and lawns; underground storage tank releases from gas stations and heating oil tanks; and stormwater runoff from roads, parking lots, and rooftops). In many parts of the country—even in water-rich areas—we are depleting and diverting our ground water resources, often to supplement diminishing surface water supplies.

Clearly, climate and weather patterns are circumstances over which we have no control but that have a

"The people have a right to clean air, pure water, and to the preservation of the natural, scenic, historic and aesthetic values of the environment. Pennsylvania's public natural resources are the common property of all the people, including generations yet to come. As trustee of these resources, the Commonwealth shall conserve and maintain them for the benefit of all the people."

Pennsylvania State Constitution | Article I Section 27

direct bearing on water availability—less precipitation means less ground water recharge. Drought and long-term climate change pose an added layer of water supply uncertainty (e.g., the potential for long-term drought) and diminished surface water and ground water recharge.

The Agriculture Factor

While agricultural water use issues are are not a featured topic in this report, we cannot discuss water use without addressing the fact that irrigation is one of the largest users of ground water in the United States—137 billion gallons per day in 2000. According to Hutson et al. (2005), "Since 1950, irrigation has accounted for about 65 percent of total water withdrawals, excluding those for thermoelectric power. Historically, more surface water than ground water has been used for irrigation. However, the percentage of total irrigation withdrawals from ground water has continued to increase, from 23 percent in 1950 to 42 percent in 2000. The number of acres irrigated with sprinkler and micro-irrigation systems has continued to increase and now comprises more than one-half the total irrigated acreage."

Photo: Copyright © Bruce Molnia, Terra Photographics

Pivot Point Irrigation on the Oklahoma/Texas border.

WATER TRIVIA IS NOT TRIVIAL

The United States uses more than 83 billion gallons of fresh ground water each day for private and public water supplies, irrigation, livestock, manufacturing, mining, and other purposes. (USGS 2004)

We rely on water not just for our own survival, but also for the production of our food and day-to-day goods and services and our economic well-being. The three primary water-use sectors are municipal (e.g., domestic uses in urban and rural areas), industrial (e.g., mining, manufacturing), and agricultural (e.g., irrigation, livestock).

USEPA's *Water Trivia Facts (www.epa.gov/safewater/kids/water_trivia_facts.html)* provide some sobering examples of how much water we use for specific functions. Here are a few examples:

- The average residence uses more than 100,000 gallons per year (indoors and outside), or roughly 275 gallons per day.
- The average automatic dishwasher uses 9 to 12 gallons of water.
- It takes 62,600 gallons of water to produce one ton of steel.
- 300,000,000 gallons of water are used to produce a single day's supply of newsprint.
- 400 gallons of water are used during the raising/production of a single chicken.
- It takes 39,090 gallons of water to manufacture one new car, including new tires.

CORN ETHANOL AND WATER USE

Ethanol fuel from corn has been presented as a key component in helping lessen U.S. dependence on foreign oil. However, there are concerns about the environmental impacts of increased production of corn and processing the corn into ethanol, not the least of which is increased water use. For ethanol production, water use is twofold: (1) growing corn, which requires both rainfall and irrigation; and (2) converting corn to ethanol inside a plant, which requires four to five gallons of water per gallon of ethanol produced.

Photo: The Bliss Agency

How much water will it take to produce enough ethanol to displace one gallon of regular gasoline? The numbers vary widely depending on the climate in which the corn is grown, the conversion method used, and the efficiency of the ethanol produced. Here are some quick facts:

- It takes about 19 pounds of corn grain to produce one gallon of ethanol.
- In the high plains region it takes about 1,000 gallons of water to grow 19 pounds of corn (1,150-1,300 gallons, including soil moisture, rainfall, and irrigation).
- Once inside the ethanol plant, it takes 4 to 5 gallons of water to convert the grain to ethanol.
- Because ethanol is less fuel-efficient than gasoline, it could take as much as 1.5 gallons of ethanol to displace 1 gallon of gas.

Therefore, it could take as much as 1,500 gallons of water to produce enough ethanol to displace 1 gallon of regular gas, depending on where the corn is grown, the methods of conversion used, and the fuel efficiency of ethanol.

Potential Problems

- Increased corn prices, whether through subsidy or natural market, can cause an increase in corn grown in less suitable climates, creating even greater competition for water resources.
- Competing water needs.
- Rising food and livestock feed prices.

Needs

- More research on corn and water use.
- Factor water use into energy decisions.
- More research into biofuels that need less water to grow and convert into ethanol.

The Ogallala

The Ogallala Aquifer lies under portions of the eight states, including South Dakota, Nebraska, Wyoming, Colorado, Kansas, Oklahoma, New Mexico, and Texas. In 2006, the U.S. consumed roughly 5 billion gallons of biofuels (mostly ethanol, which equates to about 7.5 trillion gallons of water. Increasing ethanol production will increase water use. A large percentage of this water will be pumped from underground aquifers such as the Ogallala, drawing down our already overtaxed water supplies. If we severely draw down aquifers such as the Ogallala in order to produce corn ethanol, is it really a renewable resource?

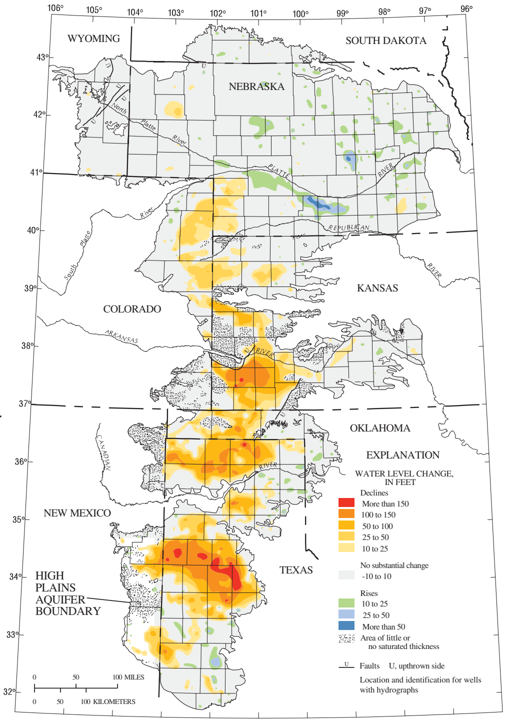

Figure 1. This map shows water-level changes in the High Plains aquifer from predevelopment to 2003 (based on water levels from 3,792 wells). The changes ranged from between a rise of 86 feet to a decline of 223 feet. Red indicates the largest declines.

Source http://pubs.usgs.gov/fs/2004/3097/

The Ground Water–Dependent Ecosystems Factor

Ground water plays a vital, but often poorly understood, role in sustaining both surface and subsurface ecosystems. It provides an essential source of water and creates critical habitat conditions for a broad range of species and ecosystems representing a distinct and varied component of the earth's biological diversity. Ground water-dependent ecosystems include wetlands, forests, springs, rivers, lakes, and caves, as well as deep-rooted plant communities, for which access to ground water is critical to maintaining ecosystem viability and biodiversity.

Ground water discharges on land and even at sea as springs and seeps. It provides baseflow to wetlands and rivers, maintaining aquatic ecosystems during dry months. Where the water table is relatively close to the surface, trees tap ground water directly. Hydrogeologists, ecologists, and water managers still have much to learn about how, when, and where ecosystems are dependent on ground water. For example, our understanding of wetland hydrology will be improved if the relationships between ground water and wetlands are more clearly established.

The Nature Conservancy (TNC) has been working to improve this understanding and develop effective approaches for protecting ground water for biodiversity conservation. In its *Pacific Northwest: Groundwater and Biodiversity* fact sheet, TNC describes the ground water-dependent ecosystems it is studying in

THE IMPORTANCE OF SUBTERRANEAN BIODIVERSITY

The caves of the world may be found in many places, such as glaciers and lava fields, but the major cave-bearing landscape is karst, a term for lands where bedrock has been hollowed out over the ages from the slow enlargement of cracks by acidic rainwater. Karst landscapes are found on every continent, and the ground water they contain is critical to the world's water reserves.

Facts about Karsts:

- Karst habitats comprise 20% of the earth's land surface.
- One-quarter of the world gets its fresh water from karst aquifers.
- Scientists estimate 60,000 species of cave-dwelling animals worldwide, with 10% in North America.
- An estimated 90% of subterranean life has not yet been described.
- Animals found only in caves and ground water habitat represent more than half of the imperiled species in the United States, but fewer than 4% have federal protection.
- Caves harbor a rich diversity of freshwater fishes, amphipods, and crayfishes, which are among the world's most endangered animals.
- Cave animals live much longer than their surface counterparts—sometimes 10 times longer.

Source: The Nature Conservancy. SubterraneanConservation. http://www.nature.org/initiatives/programs/caves/ (accessed July 2007).

Photo: Horton H. Hobbs III, Wittenberg University

The Caney Creek Mountain Cave crayfish, or* Cambarus aculabrum*, inhabits only one site in the world. This small, albino, cave-dwelling crayfish has an overall body length reaching about 3.75 inches. Like many other cave creatures, or troglobites, it is specially adapted to its dark surroundings, exhibiting such features as reduced eyes, lack of pigmentation, a reduced metabolic rate, delayed reproduction, and reduced egg production. This crayfish feeds on organic matter carried in by cave streams or left by other animals such as bats. Some say it can live as long as 75 years, but it is extremely sensitive to the quality of the water in which it lives. It is adapted to the clean, filtered water of underground streams and must have dissolved oxygen in the water for respiration. Contamination of water by sewage, animal waste, petroleum products, or any number of chemicals can deplete oxygen concentrations and suffocate the cave crayfish.

Source: http://www.nature.org/initiatives/programs/caves/animals/ Visited July 2007.

the Pacific Northwest, but these observations apply in principle to all such ecosystems:

> *Ground water provides a vital source of water and creates critical habitat conditions for a broad range of species and ecosystems in the Pacific Northwest. Ground water input into rivers creates refuges of cool water that can be critical during hot summer seasons. Some ecosystems, such as fens or springs, receive no other water except ground water. Good water quality, essential to the survival of spring mollusks and other aquatic species, can be provided by ground water.*
>
> *The pressure from humans on ground water is expected to increase as communities are turning more and more to ground water to meet their needs. Human activities have the potential to alter the supply or quality of ground water, which, in turn, can affect how ground water supports biodiversity. Excessive ground water pumping can reduce cool water discharge into streams or lakes and pesticides and fertilizers have the potential to contaminate ground water supplies.*

"If sustainable development is to mean anything, such development must be based on an appropriate understanding of the environment—an environment where knowledge of water resources is basic to virtually all endeavors."

Report on Water Resources Assessment
WMO/UNESCO, 1991

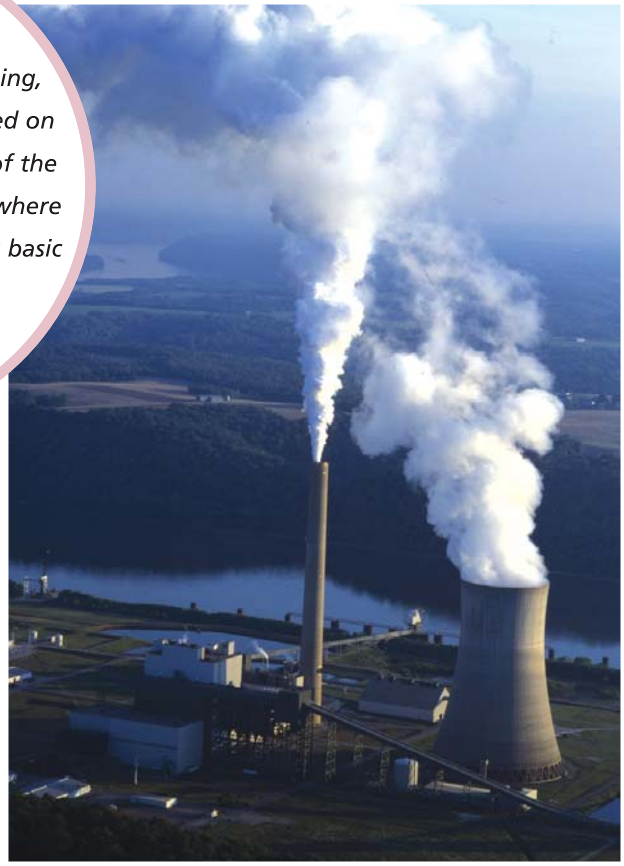

Photo: Copyright © Michael Collier

In Westport, Kentucky, the Ohio River provides the large amount of water required by this coal-fired power plant. While plants such as these typically use surface water, water demand from these operations has an impact on the ground water/surface water environment and total water demand.

The Energy Factor

Another critical factor to consider in the competition for water use is energy production, which requires a reliable, abundant, and predictable supply of water. Electricity production is second only to agriculture as the largest user of water in the United States. The Sandia National Lab, a research arm of the Department of Energy, reports that many newer energy technologies will be more water-intensive.

For example, a biofuels (e.g., ethanol) and hydrogen transportation fuel economy will require significantly more water than one based on fossil fuels, and power-plant siting will face more constraints if the water needed for cooling, advanced scrubbing, and CO_2 removal is not available. Yet, according to Sandia, there is currently no national research program directed specifically at understanding the relationship between energy production and water use.

GROUND WATER WITHDRAWAL AND AVAILABILITY IN THE NATURAL SYSTEM

Ground water and surface water have a uniquely interdependent relationship and are essentially a single resource. In the natural hydrologic cycle, water is constantly on the move. Within the ground water system, water typically moves very slowly and is replenished by recharge from precipitation and to some extent discharge from surface water bodies. In the natural system, water leaves the ground water system through discharge to surface waters and evapotranspiration.

Human activities impact the amount and rate of water movement within a given ground water system. When ground water is withdrawn for human uses, natural flow patterns are altered, affecting the amount of water in the system, leaving the system, and enter-

THE EFFECTS OF GROUND WATER WITHDRAWALS ON SURFACE WATER

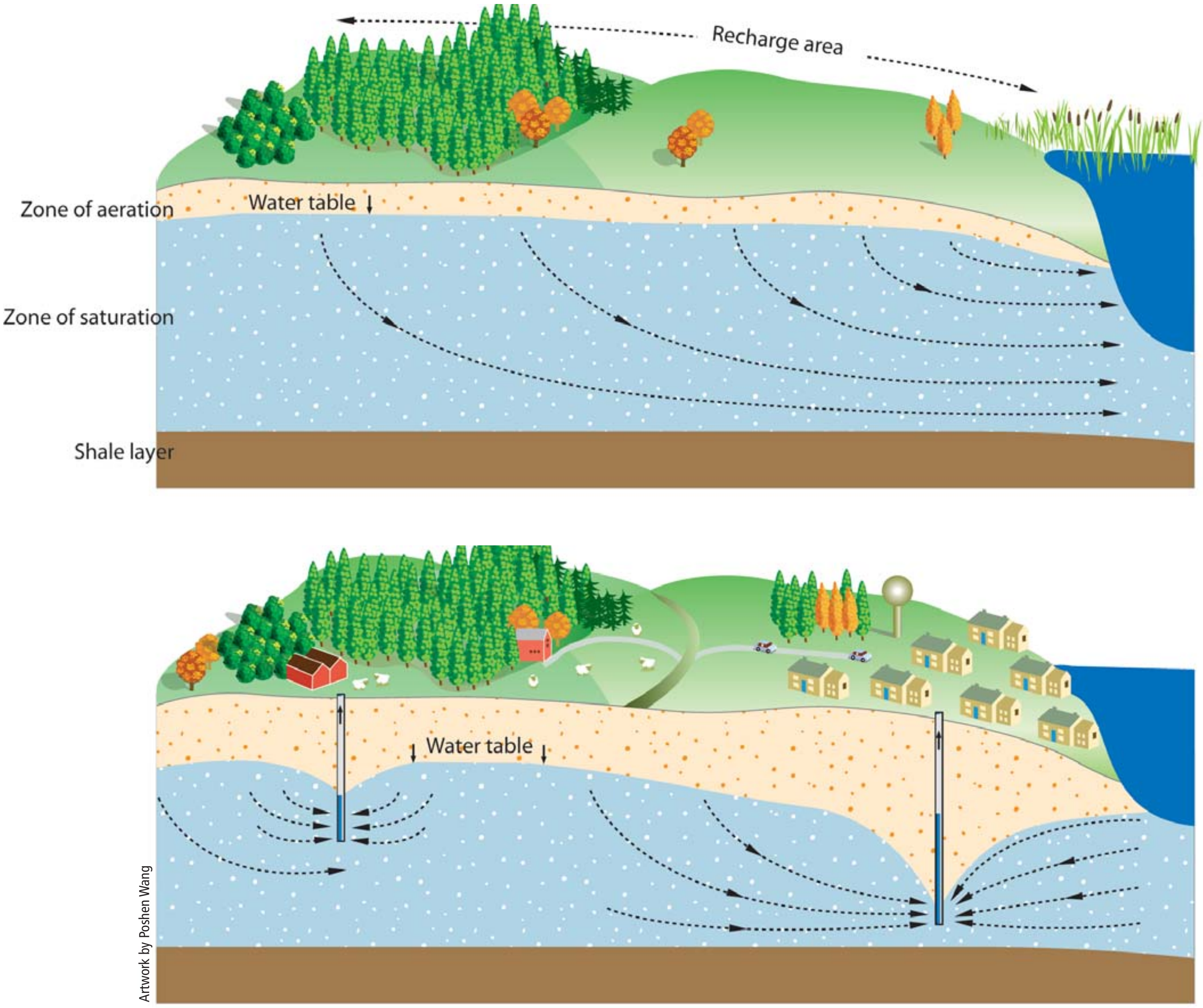

***FIgure 2.** Withdrawing water from shallow aquifers near surface water bodies can diminish the available surface water supply by capturing some of the ground water flow that otherwise would have discharged to surface water or by inducing flow from surface water into the surrounding aquifer system. Furthermore, changes in the direction of flow between the two water bodies can affect transport of contaminants associated with the moving water. Although a stream is used in this example, the results apply to all surface water bodies, including lakes and wetlands.*

ing the system. Withdrawal also affects the rate of ground water movement within the system. Pumping ground water from a well also lowers ground water levels at or near the well and diverts the water from its natural movement to a discharge area (e.g., a stream). (See Figure 2.)

Each system is unique, based on hydrogeology and external factors, such as amount and timing of precipitation, location and size of surface waters in the system, and rate of evapotranspiration. All of this calls for the use of an accounting system called a "water budget." (See Figure 3.)

Like balancing a checkbook, we need to be able to account for the amount of ground water entering, leaving, and being stored in our aquifers so that we have an accurate picture of the volume of water

Key Term

GROUND WATER SUSTAINABILITY

Development and use of ground water in a manner that can be maintained for an indefinite time without causing unacceptable environmental, economic, or social consequences. (Alley et al., 1999)

HOPE SPRINGS FROM THE ARROYO SECO WATERSHED'S WATER BUDGET

The Tongva people, the settlers who first established villages on the rim of the Arroyo Seco River, called the region *Hahamongna* ("Flowing Waters, Fruitful Valley"). The significance of water has not diminished in the 46.6 square mile Arroyo Seco watershed, located within the larger Los Angeles River watershed and spanning five jurisdictions in southern California, including the Angeles National Forest and the cities of Pasadena, South Pasadena, and Los Angeles. But today, the waters aren't necessarily flowing, nor is the valley so fruitful.

Over the years, water consumption in the region has increased dramatically. Development has altered and stressed the natural water cycle throughout the Arroyo Seco watershed. The most significant change is that there is no longer a balance in the water budget. Furthermore, creeks and rivers throughout the watershed are contaminated with algae, fecal coliform, trash, and runoff from commercial activities, which has resulted in the designation of the upper portion of the watershed as a Superfund site and the closure of nine Pasadena wells. Water users in the Arroyo Seco watershed now depend on a mix of surface water from the river, ground water, and imported supplies for local use.

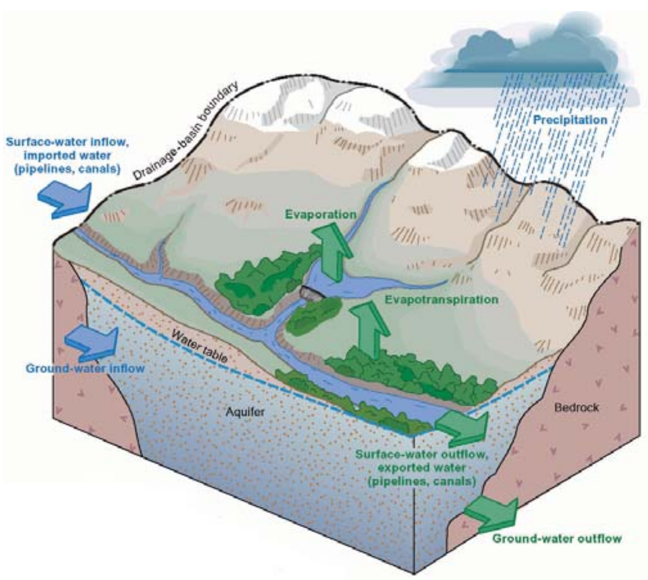

Figure 3. What is a water budget?
Hydrologists use water budgets to account for flow and storage changes in natural systems that contain water. Systems of interest can be features such as rivers, lakes, drainage basins, the land surface, or aquifers. Water budgets for each of these systems use the following formula:

(WATER INFLOW) – (WATER OUTFLOW) = (CHANGE IN WATER STORAGE)

Source: http://pubs.usgs.gov/circ/circ1223/pdf/C1223.pdf

In December 2003, the Arroyo Seco Foundation produced *A Water Budget for the Arroyo Seco Watershed,* an effort made possible by the Watershed Management Program of the CALFED Bay-Delta Program and created by federal and state agencies to develop and implement a long-term comprehensive plan to restore ecological health and improve water management for beneficial uses of the Bay-Delta System. The program was established in 1998 to work at a watershed level with the communities that use or benefit from the ecosystem.

The water budget has helped set in motion a framework to quantify precipitation, runoff, recharge, evaporation, transpiration, and human uses of water within the watershed so that the public and planners understand the effects of future management options. The information provided in the document can be used to refine, test and assess specific watershed management alternatives. The hope is that the water budget and refined models will provide the context for an informed, prescriptive approach to planning and the development of local codes and ordinances to help "balance the budget."

As the document states: "The Arroyo Seco Watershed Budget is a tool to promote a better understanding of local water use and better management of the water resources of the Arroyo Seco. The approach used here is a relatively simple, straightforward evaluation of all the components of the hydrologic cycle and human interaction with it." It also points out that more detailed and sophisticated techniques are needed to refine this budget.

Source: http://www.arroyoseco.org/AS_Water_Budget.pdf

"From a sustainability perspective, the key point is that pumping decisions today will affect surface-water availability; however, these effects may not be fully realized for many years."

U.S. Geological Survey | Sustainability of Ground-Water Resources

available to meet our needs at a sustainable level now and in the future. Yet, as a nation, we lack the fundamental data necessary to adequately understand our ground water resources and develop a water budget, let alone make informed decisions regarding its use and management. The "Ground Water Resource Characterization and Monitoring" section of this document lists some of the critical data needed to assess and determine ground water availability and to develop a water budget.

HOW OVERPUMPING TAKES A TOLL ON GROUND AND SURFACE WATER

In the relatively short period of time in human history that we have had the technology to access ground water sources, we have had significant impacts on hydrologic systems, and hence water availability. Ground water depletion is primarily caused by unsustainable ground water pumping, or overpumping, and is occurring in many areas of the country. Some of the negative effects of overpumping include:

- **Dried-up wells –** Ground water levels fall when the volume of water extracted exceeds the volume of water available through recharge. As a result, existing wells need to be drilled deeper to find new water supplies, new wells need to be drilled, or an alternative source of water must be located. In many instances this may require that water be purchased, hauled, or stored from an offsite source, or connected to new or existing municipal or water district supply pipelines, if possible.

Photo: Copyright © Larry Fellows, Arizona Geological Survey

These earth fissures in the desert appear to stop at the edge of a cultivated field. The high ground water use for irrigation pulls ground water from the whole of the aquifer, affecting overlying lands.

PRIORITIES FOR GROUND WATER MANAGEMENT

- **Sustainable long-term yields from aquifers.**
- **Effective use of the large volume of water stored in aquifers.**
- **Preservation of ground water quality.**
- **Preservation of the aquatic environment by prudent abstraction of ground water.**
- **Integration of ground water and surface water into a comprehensive water and environmental management system.**

Source: USGS, 1999

"A key challenge for achieving ground water sustainability is to frame the hydrologic implications of various alternative management strategies in such a way that they can be properly evaluated."

U.S. Geological Survey | Sustainability of Ground-Water Resources

- **Reduced flows to rivers, lakes, springs, and wetlands –** With overpumping, the movement of ground water from shallow aquifers to rivers, lakes, springs, and wetland areas is diminished, leading to decreased streamflows, lower water levels in lakes, and shrinking wetlands. At its extreme, overpumping can lead to total loss of flow to surface waters and associated riparian areas, not to mention lost water sources for people, animals, and vegetation.
- **Degraded water quality –** Overdrafting of ground water in coastal areas (or anywhere deep saline ground water exists) can lead to the migration, or "intrusion," of salt water into freshwater aquifers. Once salt water mixes with freshwater, either treating the water or locating and developing an alternative water supply are the only options, however costly.
- **Land subsidence –** Overdrafting of ground water can cause the loss of subsurface support, causing subsidence at the ground surface and resulting in any number of costly structural consequences, including damage to highways, buildings, wells, and pipelines. *(http://ga.water.usgs.gov/edu/gwdepletion. html)*

Photo: USGS

Sinkholes can be classified as geologic hazards, sometimes causing extensive damage to structures and roads and resulting in costly repairs. Sinkholes can also threaten water supplies by draining unfiltered water from streams, lakes and wetlands directly into the aquifers.

CHANGES IN KANSAS RIVERS AND STREAMS: 1961 – 1994

Source: Marios Sophocleous, Kansas Geological Survey

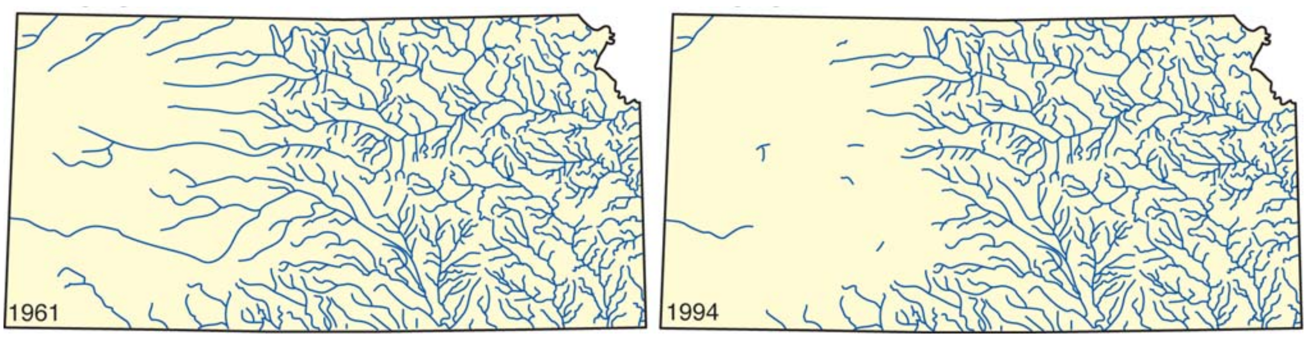

Figure 4. *Kansas rivers and streams changed between 1961 and 1994 due to high ground water pumping rates that caused the loss of perennial streams by 1994 in western Kansas. That area is underlain by the High Plains aquifer, which has been heavily pumped to support irrigation. Over time, the pumping "captured" surface water flows.*

In response to drastically declining water levels in the High Plains aquifer in western Kansas (200 feet or more than 50 percent of the aquifer thickness in some places), local ground water-management districts were authorized by the Kansas Legislature in 1972 to manage the resource. In 1982, the Kansas Legislature passed a law requiring minimum desirable streamflows. Management policies vary in the districts, including planned depletion, zero depletion, and modified sustainable yield. In some locations, new wells are not allowed. Local, state, and regional planning efforts continue to manage collectively the ground water and surface water resources in the High Plains aquifer area.

Minnesota's streams, lakes, and wetlands are vulnerable to this kind of change, and signs of such change are evident in some areas. Looking for ways to minimize the impact of human intervention (i.e., ground water withdrawal), Minnesota uses the Kansas experience as a means for addressing its own similar water issues.

Source: http://files.dnr.state.mn.us/waters/groundwater_section/sustainability/GW-SWinteraction.pdf

FARMERS TAKE A HIT IN THE SOUTH PLATTE RIVER BASIN'S BATTLE FOR WATER

Although agriculture is Colorado's third-largest industry, irrigated farms that rely on ground water stand to be among the first water-shortage victims for several reasons. For one thing, according to Colorado's August 2006 *Statewide Water Supply Initiative Water Demand Forecast,* total water demand in the Colorado basin is expected to increase 95 percent by 2030.

A 2003 Colorado law required that farmers along the South Platte come up with a permanent plan by 2006 to replace the water they'd pumped. The law was prompted by a 2002 drought, when South Platte River users, such as cities, utilities, farmers, and others who relied on surface water supplies, successfully sued the state to limit how much well owners could pump. Without an approved plan, irrigation wells were forced to shut down during periods of low flow (within the South Platte) to ensure that sufficient surface water would be available to provide irrigators holding priority, or "senior," water rights their share first. The constant interplay between the shallow aquifer that supplies the wells and the river was the basis for this relentless tug of war—and unsustainable ground water pumping gradually reduced the flow in the river.

But the replacement plan didn't solve the problem. Since the 2003 law was enacted, nearly one-third of irrigation wells have stopped pumping because farmers lacked the means to replace pumped water. Land once worth more than $2,000 an acre (with water) has plummeted in value. Farmers who hold surface water rights are also struggling and, strapped for cash, many are selling off their rights to urban interests.

The situation became critical in 2006. The April 1 forecast for snowmelt and runoff in the South Platte River Basin of northeastern Colorado gave area residents hope that conditions would be adequate to meet water demands for urban, industrial, and agricultural uses—so the farmers went ahead and planted. Not long afterward, however, it became clear that the billions of gallons of water expected to melt out of the mountain snowpack and run off into the basin had, due to hot winds and drought conditions, vaporized or melted faster than expected and soaked rapidly into the ground.

By early May, more than 200 ground water–dependent farmers came face to face with disaster.

Irrigation, primarily from ground water, brings lush green crops to an otherwise arid region, but this method forfeits much of the water to evaporation.

Flow levels in streams and rivers took a nosedive, and roughly 440 irrigation wells were ordered shut down, cutting off the lifeline to thousands of acres of such high-dollar crops as sugar beets, onions, sweet corn, broccoli, melons, and sod.

Efforts were made to secure an emergency fix for the water-starved crops, but some of the interests that rely solely on the river's surface-water supplies couldn't agree with the proposal because they felt it would stress the river too much. To provide short-term relief, water was pumped up and over the continental divide.

The Central Colorado Water Conservancy District has been working on a plan to help farmers offset the amount of water used by the deep irrigation wells. The district's strategies include building new reservoirs and purchasing water rights from towns, but the logistics of accomplishing this could take years. The loss of ground water has been extremely costly. As for the farmers whose wells were shut down, the losses are in the millions of dollars—in land, planted crops, livelihoods, and overwhelming debt.

In June 2007, a task force appointed by the governor was given the job of creating a water plan for lawmakers to consider in September 2007. According to Jerd Smith, writing in the *Rocky Mountain News* (June 30, 2007), "Any solutions likely will have to serve farmers and fast-growing cities equally, and may focus on better managing the river's scare supplies, as well as improving reservoir systems on the Eastern Plains.

Overpumping and Drought—the Dangerous Duo

In recent years, drought has hit many parts of the country besides the West. And while many folks in "water-rich" states try to ignore it, some state governments are getting very worried about water supply...and the potential for conflict over access to water. For example, overpumping of ground water to meet rapid population growth has aggravated the saltwater intrusion problem in many cities along the Atlantic coast. In more than a few southeastern states, severe precipitation deficits, low streamflows, and dried out soils have devastated farm productivity and challenged water managers. As in many parts of the water-poor West, the battle for water begins when there is not enough to go around.

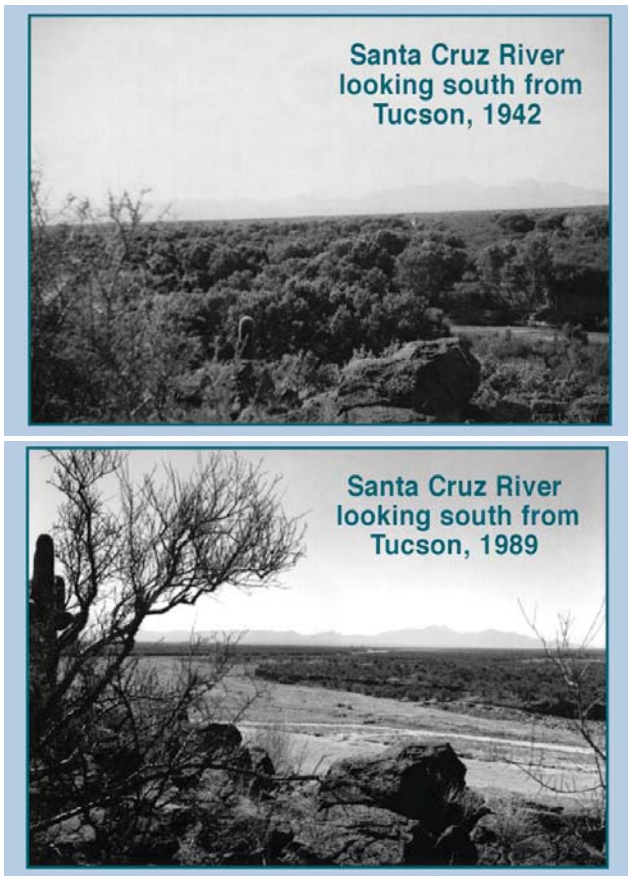

Photo: Robert Webb, USGS

Perennial streams, springs, and wetlands in the Southwestern United States are highly valued as a source of water for humans and for the plant and animal species they support. Development of ground water resources since the late 1800s has resulted in the elimination or alteration of many perennial stream reaches, wetlands, and associated riparian ecosystems. For example, this 1942 photo (top) of a reach of the Santa Cruz River south of Tucson, Arizona, shows stands of mesquite and cottonwood trees along the river. A replicate photograph of the same site in 1989 (bottom) shows that the riparian trees have largely disappeared. Data from nearby wells indicate that the water table has declined more than 100 feet due to pumping, which appears to be the principal reason for the decrease in vegetation.

Source: USGS.

In *Mirage: Florida and the Vanishing Water of the Eastern United States* (2007), author Cynthia Barnett points out that drought coupled with overallocation of water resources and the lack of water conservation practices can add up to water shortages—even in water-rich Eastern states. She says that many of these areas were already overpumping ground water resources to meet demands before drought became an issue. She notes that water managers in a majority of the states believe they will see shortages within a decade, and that is without drought. "But nowhere in the country," she says, "are water shortages more puzzling and prophetic than in notoriously wet Florida." In Florida, ground water is routinely being pumped from aquifers faster than the state's rainfall can refill them.

DETERMINING MINIMUM FLOWS/SUSTAINABLE YIELDS OF AQUIFERS

One of the ways in which a state or other jurisdiction can protect and conserve its water resources is through the establishment of a minimum flows and levels (MFLs) program. Establishing such a program is important in planning for adequate water supplies for future generations while protecting current water resources from significant harm. An MFL program recognizes the concept of a "three-dimensional watershed" where ground water, surface water, soil moisture, and atmospheric deposition are components of a system that must be protected, conserved, and managed as a whole. Therefore, to maintain and sustain the functions and processes of the overall aquatic system, minimum flows and levels must be developed for lakes, streams, rivers, wetlands, springs, and aquifers.

What Are MFLs?

MFLs are minimum water levels and/or flows deemed necessary to prevent significant harm to the water resources or ecology of an area due to water withdrawals for both consumptive and nonconsumptive uses (including the quantities of water necessary to support navigation, recreation, and fish and wildlife

Photo: Alan Cressler, USGS

A ground water pump wellhead, on Colonels Island, near Brunswick, Georgia, in 1999. Before the widespread use of pressure transducers to measure artesian water levels, a tower was necessary to measure the water level at wellhead; the tower was removed in 2000.

habitats). MFLs define how often and for how long high, average, and low water levels and/or flows should occur to prevent significant harm. Three to five MFLs are usually defined for each aquatic system—minimum infrequent high, minimum frequent high, minimum average, minimum frequent low, and minimum infrequent low.

MFLs are established and adopted by a regulatory authority to protect water resources from significant harm resulting from permitted water withdrawals. Some states, such as Florida, require the establishment of MFLs by law and/or by the state's comprehensive water management plan.

Why Are MFLs Important?

MFLs help in determining the ability of aquifers, springs, wetlands, streams, rivers, and their human and aquatic communities to adjust to changes in hydrologic conditions. MFLs allow for an acceptable level of change to occur. If the use of water resources is not adequately managed, it can result in shifts in hydrologic conditions that can, in turn, cause significant economic and ecological harm. MFLs serve as a minimum threshold for hydrologic conditions.

How Are MFLs Determined?

MFLs are determined on the basis of hydrographic information for surface waters, aquifer yield, topography, soil, and vegetation data collected within plant and animal communities, as well as other data pertinent to water resources and the best judgment of hydrogeologists and hydrographic engineers familiar with the water bodies and watersheds in question.

How are MFLs Applied?

MFLs apply to decisions affecting consumptive-use permit applications, declarations of water shortages, and assessments of water supply sources. Computer simulation models for surface and ground waters are used to evaluate the effects of existing and/or proposed consumptive uses and the likelihood that they might cause significant harm. In Florida, for example, each of the state's five water management district governing boards are required to develop recovery or prevention strategies in cases where a water body currently does not or will not meet an established MFL. Water uses that cause any MFL to be violated are not permitted.

AN EMERGING WATER STORAGE TECHNIQUE

In the face of concern about the depletion of ground water reserves, aquifer storage and recovery (ASR) has emerged in some states as a water-storage technique. ASR involves injecting water into an aquifer through wells or by surface spreading and infiltration and then pumping it out when needed. The aquifer essentially functions as a water "bank," whereby deposits are made in times of surplus, typically during the rainy season, and withdrawals occur when available water falls short of demand.

While most ASR wells being used today recharge underground sources of drinking water, there is also considerable discussion about expanding ASR for purposes of storing and recovering treated surface water, untreated ground water, or treated wastewater, which would otherwise go unused.

The ASR type of ground water augmentation is up for debate because of concerns about aquifer contamination and human health. Some states see ASR as a welcome water storage solution, while others are concerned that specific characteristics of the aquifer or the water to be injected could contaminate aquifers used for drinking water.

For example, the State of Washington Department of Ecology, recognizes the following benefits:

- Substantial amounts of water can be stored deep underground. This may reduce the need to construct large and expensive surface reservoirs.
- ASR systems are considered to be more environmentally friendly than surface reservoirs. They also offer more protection from tampering.
- ASR may restore and expand the function of an aquifer that has experienced long-term declines in water levels due to heavy pumping necessary to meet growing urban and agricultural water needs. *(http://www.ecy.wa.gov/programs/wr/asr/asr-home.html)*

In contrast, the Wisconsin Department of Natural Resources (WIDNR) has identified the following concerns, based on the results of two ASR pilot projects it conducted (as required by the state legislature):

- An aquifer system has its own natural equilibrium, and the addition of treated water disturbs that equilibrium. Monitoring results from both Wisconsin ASR pilot projects confirmed that geochemical reactions between injected lake water and bedrock aquifer material are occurring and that potential contaminants such as arsenic, manganese, and nickel may be mobilized into the ground water system.

> *"Innovative approaches that have been undertaken to enhance the sustainability of ground-water resources typically involve some combination of use of aquifers as storage reservoirs, conjunctive use of surface water and ground water, artificial recharge of water through wells or surface spreading, and the use of recycled or reclaimed water."*
>
> U.S. Geological Survey | Sustainability of Ground-Water Resources

FLORIDA'S WATER MANAGEMENT DISTRICTS FOCUS ON AN ARRAY OF WATER ISSUES

Why would Florida, a state that gets approximately 55 inches of rain each year, have water problems? As in many places, the problem often has to do with whether water is where it is needed when it is needed. In Florida, rain falls mostly in the northern part of the state, but 78 percent of the population lives in the southern part of the state. Florida has experienced population growth from 1.9 million in 1940 to 15 million today—more than a 600 percent increase in just 50 years.

The other serious water issue facing coastal communities in south Florida is saltwater intrusion—the byproduct of continued development and increased ground water pumping. Brackish ground water has been drawn further inland by pumping of wells, mixing with and tainting the quality and taste of freshwater aquifers it encounters.

The state has established five water management districts to address various water issues through permit programs. The three most common permits deal with how much water is used (consumptive use permits), well construction (well construction permits), and the effects of new development on water resources (environmental resource permits).

Watersheds and other natural, hydrologic, and geographic features determine district boundaries. The districts' responsibilities include, but are not limited to, flood protection, water use, well construction and environmental resource permitting, water conservation, education, land acquisition and management, water resource supply and development, and data collection and analysis.

- Hydraulic control is difficult to maintain. It is difficult to recapture the injected water and predict the speed and extent of water movement.

WIDNR concluded that these pilot tests demonstrate the need for careful environmental monitoring and development of a thorough understanding of the local hydrogeological and geochemical systems that are affected by the use of ASR techniques.

As noted by the National Ground Water Association in its assessment of aquifer storage and recovery, "The principal need with regard to the recharge of drinking water is to develop guidance for ASR legislation and regulations, possibly a model ASR code, so that issues and regulatory experiences in states with operating ASR systems are more readily available to those states that may wish to develop their own ASR regulatory framework."

WE CAN HAVE OUR WATER AND DRINK IT TOO

If we don't assess water availability in a systemwide context, we may well find ourselves in future jeopardy. Problems caused by water scarcity can be expensive, convoluted, and debilitating. In the interest of working toward a water-secure future, we will need to strike a functional balance between the amount of ground water we use, and the amount that we can pump without economic or environmental damage.

Have we learned enough about ground water hydrology and how pumping affects our water systems and our prospects for a healthy environment to stir us to heed this call to action? There are actually many positive signs that states, communities, environmental organizations, businesses, and individuals are on the case.

One sign is that the concept of water conservation is easily understood by most people, particularly people who experience water shortages firsthand (e.g., Western states) and on a routine basis. Most states have water conservation programs, as do many communities throughout the country.

Another sign is the increase in the application of Low Impact Development (LID) practices, which provide ways to maintain and enhance ground-water recharge. But to have our water and drink it too, we will need buy-in from local land-use decision makers, developers, and communities so that this knowledge translates into practical application.

"Because any use of ground water changes the subsurface and surface environment (that is, the water must come from somewhere), the public should determine the tradeoff between ground-water use and changes to the environment and set a threshold for what level of change becomes undesirable."

U.S. Geological Survey | Sustainability of Ground-Water Resources

A prairie rain garden in Maplewood, Minnesota. The town is encouraging residents to plant rain gardens so that rainwater can be routed to the garden, filtered naturally by the plants and soils of the garden, and then allowed to recharge the aquifer locally. A rain garden is a relatively small area of plantings near the drain spout of a building or a paved area that collects stormwater that might otherwise be diverted, eliminating natural recharge potential and often collecting additional pollutants as it travels through urban environments.

Source: http://www.ci.maplewood.mn.us/index.asp?Type=B_BASIC&SEC=%7BF2C03470-D6B5-4572-98F0-F79819643C2A%7D

Recommended Actions

To USEPA:

- **Support state efforts to develop guiding principles that state and local water-planning and water-use entities should take into consideration when conserving the integrity of watersheds and ensuring adequate water supplies.**
- **Require better integration between surface and ground water programs and ensure that the national water strategy addresses both quality and quantity issues, including interaction between surface and ground water.**

To USGS and State Geological Surveys:

- **Continue to conduct research and provide information—at a scale that is useful to states and local entities—about such matters as the safe, or sustainable, yield of aquifers (and methods for determining that yield); water-use data; and delineating boundaries and water budgets of three-dimensional watersheds, including scientifically based and cost-effective methods of quantifying interaction between ground water and surface water.**

To Governors and State Legislatures:

- **Authorize water supply planning at the state level and encourage water supply planning at regional and local levels to conserve the integrity of watersheds and ensure adequate water supplies.**
- **Consider adopting ground water protection and management laws that:**
  - Recognize and manage the impact of ground water withdrawals on surface water.
  - Link development to sustainable availability of water and other water supply infrastructure.
  - Allow for and encourage techniques such as transfer-of-development rights for the purpose of ground water conservation and protection.
  - Ensure coordination among agencies responsible for water quality and water use in order to determine watershed water budgets and base water withdrawal and recharge policies.
  - Regulate the interbasin transfer of water in order to protect ecosystem integrity.
  - Require water conservation practices for all new construction (e.g., agricultural, industrial, residential) by changing plumbing codes so that they require water conservation.

To State Agencies:

- **Ensure coordination among water-quality and water-use agencies/programs and associated surface water and ground water policies/programs. Benefits of this strategy can include:**
  - Integration of ground water resource characterization and monitoring into state water-monitoring strategies.
  - Development and implementation of water-reuse policies.
  - Development of tools and policies to match water sources of various quality with the most suitable use (e.g., domestic, agricultural, industrial).

To Local Governments:

- **Conduct water resources planning for long-term resource sustainability, focusing on 5- to 50-year water availability projections and plans. Incorporate this information into local comprehensive and infrastructure plans, zoning, and other local ordinances, as well as incentive programs, including:**
  - Ordinances that tie development to sustainable water availability.
  - Ordinances and best management practices (BMPs) that provide for sustainable ground water recharge and improved stormwater management practices.
  - Transfer-of-development rights and development of property tax incentive programs to encourage land owners and developers to maintain recharge areas as open spaces, helping to achieve ground water protection and conservation goals.
  - Ordinances and plumbing codes designed to conserve water through improved efficiency, water reuse, water rationing, and gray water-use requirements.

Section 2 References: Ground Water Use and Availability

Alley, W. M., T. E. Reilly, O. L. Franke. 1999. *Sustainability of Ground-Water Resources,* USGS Circular 1186, U.S. Geological Survey.

Barlow, M., T. Clarke. 2002. *Blue Gold: The Fight to Stop the Corporate Theft of the World's Water.* New York: The New Press.

Barnett, Cynthia. 2007. M*irage: Florida and the Vanishing Water of the Eastern United States.* Ann Arbor: University of Michigan Press.

Glennon, Robert. 2002. *Water Follies: Groundwater Pumping and the Fate of America's Fresh Waters.* Washington, DC: Island Press.

Hutson, S., N. Barber, J. Kenny, K. Linsey, D. Lumia, and M. Maupin. 2004. E*stimated Use of Water in the United States in 2000.* USGS Circular 1268 (released March 2004, revised April 2004, May 2004, February 2005). Available at: *http://pubs.er.usgs.gov/usgspubs/cir/cir1268*) (accessed February 19, 2007).

Jones, L. E, D. C. Prowell, M. L. Maslia. *Hydrogeology and Water Quality (1978) of the Floridan Aquifer System at U.S. Geological Survey Test Well 26, on Colonels Island, Near Brunswick, Georgia.* USGS Water-Resources Investigations Report 02-4020, 44 pages. Available at: h*ttp://ga.water.usgs.gov/publications/abstracts/wrir02-4020.html*

McGuire, V. L. 2004. *Water-Level Changes in the High Plains Aquifer, Predevelopment to 2003*. USGS Fact Sheet 2004–3097. Available at: *http://pubs.usgs.gov/fs/2004/3097/*

NGWA Issue Assessment: Aquifer Storage and Recovery. *http://www.ngwa.org/public/releases/iaaquifer.aspx* (accessed July 2007).

Sandia Labs. Available at: *www.sandia.gov/energy-water/nexus_overview.htm* (accessed July 2007).

The Nature Conservancy. Fact sheet: *Pacific Northwest: Groundwater and Biodiversity. http://www.nature.org/wherewe work/northamerica/states/oregon/files/groundwater_fact_sheet.pdf* (accessed July 2007).

U.S. Census Bureau. 2007. *www.census.gov/main/www/popclock.html*

U.S. Census Bureau. 2004. "U.S. Interim Projections by Age, Sex, Race, and Hispanic Origin." *http://www.census.gov/ipc/www/usinterimproj/*.

USGS. 2002. *Report to Congress: Concepts for National Assessment of Water Availability and Use.* Circular 1223. Available at: *http://pubs.usgs.gov/circ/circ1223/pdf/C1223.pdf*

USGS. 1998. *Ground Water and Surface Water: A Single Resource.* U.S. Geological Survey Circular 1139.

Photo: Alex Marentes

A water well in the middle of the desert south of Socorro, New Mexico.