GROUND-WATER RESOURCES FOR THE FUTURE

Desert Basins of the Southwest

Ground water is among the Nation's most important natural resources. It provides drinking water to urban and rural communities, supports irrigation and industry, sustains the flow of streams and rivers, and maintains riparian and wetland ecosystems. In many areas of the Nation, the future sustainability of ground-water resources is at risk from over use and contamination. Because ground-water systems typically respond slowly to human actions, a long-term perspective is needed to manage this valuable resource. This publication is one in a series of fact sheets that describe ground-water-resource issues across the United States, as well as some of the activities of the U.S. Geological Survey that provide information to help others develop, manage, and protect ground-water resources in a sustainable manner.

Ground-water resources in the Southwest are among the most overused in the United States. Natural recharge to aquifers is low and pumping in many areas has resulted in lowering of water tables. The consequences of large-scale removal of water from storage are becoming increasingly evident. These consequences include land subsidence; loss of springs, streams, wetlands and associated habitat; and degradation of water quality. Water managers are now seeking better ways of managing ground-water resources while looking for supplemental sources of water.

This fact sheet reviews basic information on ground water in the desert basins of the Southwest. Also described are some activities of the U.S. Geological Survey (USGS) that are providing scientific information for sustainable management of ground-water resources in the Southwest. Ground-water sustainability is defined as developing and using ground water in a way that can be maintained for an indefinite time without causing unacceptable environmental, economic, or social consequences (Alley and others, 1999).

Figure 1. The desert basins in the Southwest, shown in the darker brown, extend over parts of California, Nevada, Utah, Arizona, and New Mexico.

Occurrence of Ground Water in the Southwestern Basins

Much of the landscape in the southwestern United States (fig. 1) consists of valleys separated by mountain ranges. The mountain ranges are composed of a variety of rocks, many of which contain water-filled fractures, but do not yield large quantities of water to wells. Most of the valleys, however, are basins containing water-filled layers of gravel, sand, silt, and clay. Though these sediments are as much as 10,000 feet thick, commonly only the upper few thousand feet of sediments are aquifers that contain water of good quality that can be readily extracted by wells. Water in these aquifers occurs in small pores between the grains of sediment (fig. 2). The pores are completely saturated below the water table, but are only partially saturated above the water table where they cannot readily release water.

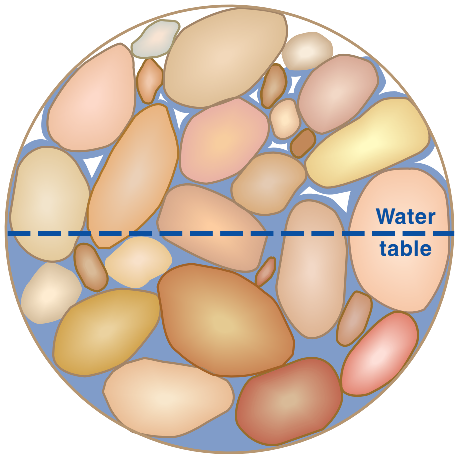

Figure 2. Ground water in the basins of the Southwest occurs in pore spaces between grains of gravel, sand, and clay sediments.

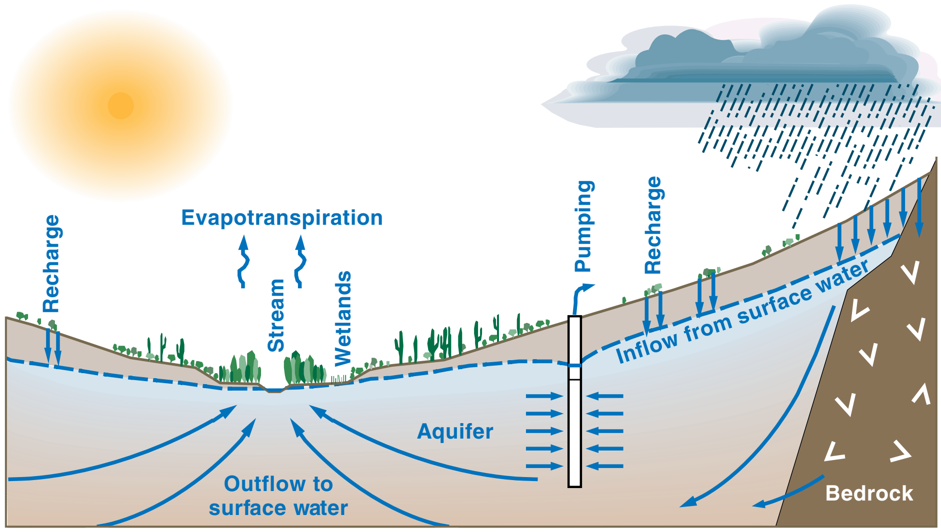

Figure 3. Hydrology of a desert basin drained by a stream. Most recharge to the aquifer occurs at higher elevations, which receive more rainfall than lower elevations. Ground water flows to the central part of the basin where it may discharge to springs, wetlands, streams, or evapotranspiration. Ground-water pumping has the local effect of removing water from storage in the aquifer and the eventual effect of reducing outflow to surface-water features and riparian plants.

Most recharge to the aquifers occurs at higher elevations from rainfall and snowmelt runoff in the mountains. Water seeps into the aquifers through sand and gravel near the edges of the basins under normally dry washes that flow during infrequent periods of runoff and by subsurface flow from water-filled fractures beneath the mountains (fig. 3).

Ground water flows from basin edges toward lower elevations in the central parts of the basins. Movement of ground water is slow, with typical velocities ranging from tens to thousands of feet per year. Water eventually discharges from aquifers to springs, streams, wetlands, playas, plants, and adjacent basins. Because of the slow movement, ground water can be in basins for tens of thousands of years before discharging.

Many of the basin aquifers contain large quantities of water. For example, in a basin in which the upper 1,000 feet of saturated sediments contain 15 percent removable water and having an average width and length of 15 miles and 25 miles respectively, the volume of water is 36 million acre-feet. That volume of water, if it could be practically pumped, would amount to a 2,000-year supply for a population of 100,000 having a per capita water use of 160 gallons per day.

Ground-Water Use in the Desert Southwest

Ground water has long been a critical resource to humans in the Southwest. The earliest access to ground water was at springs and in stream channels where it seeps to the surface. Later access was through shallow dug wells (fig. 4), low-capacity drilled wells, and finally, high-capacity large-diameter drilled wells with turbine pumps. The high-capacity deep-well turbine pumps came into widespread use in the mid 1940's and resulted in large increases in ground-water use in desert basins. For example, ground-water use in Arizona more than doubled from 1945–53, when turbine pumps were installed for irrigation and public supply (fig. 5).

Ground-water use in some parts of the Southwest has declined as projects to import surface water from distant sources have been implemented. In many areas of the Southwest, however, surface-water supplies are limited and ground water remains a critical resource.

Consequences of Ground-Water Use

Ground-water use has the positive aspect of providing water for human needs including public supply, agriculture, and industry. On the other hand, ground-water use in areas where recharge is limited can have negative consequences. Concerns where withdrawals exceed recharge include loss of available ground-water supply, land subsidence, degradation of water quality, and loss of riparian habitat.

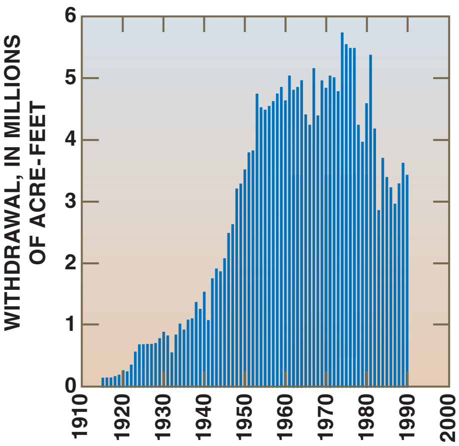

Figure 5. Annual ground-water withdrawals in Arizona, 1915–90.

Figure 4. Gonzales' well, Dome Rock Mountains, Yuma County Arizona, 1917. Ground-water resources were important to travelers in the Southwest in the early 1900's.

Loss of Available Supply

Any withdrawal of ground water results in removal of water from storage. Large-scale withdrawals in many areas in the Southwest have resulted in widespread lowering of water tables (fig. 6). The amount of the lowering reflects a quantity of ground water that is no longer available. Several other aspects of lowered water tables affect future water availability. First, lowering of water tables results in increased costs to lift water a greater distance. For some water uses such as agriculture, pumping costs from deep aquifers could be prohibitively high. Second, lowered water tables can result in loss of well productivity. In most basins, shallower sediments are less compacted and more readily release water to wells than deeper sediments. Lowered water tables can result in the need to drill more and deeper wells to maintain a desired rate of ground-water withdrawal.

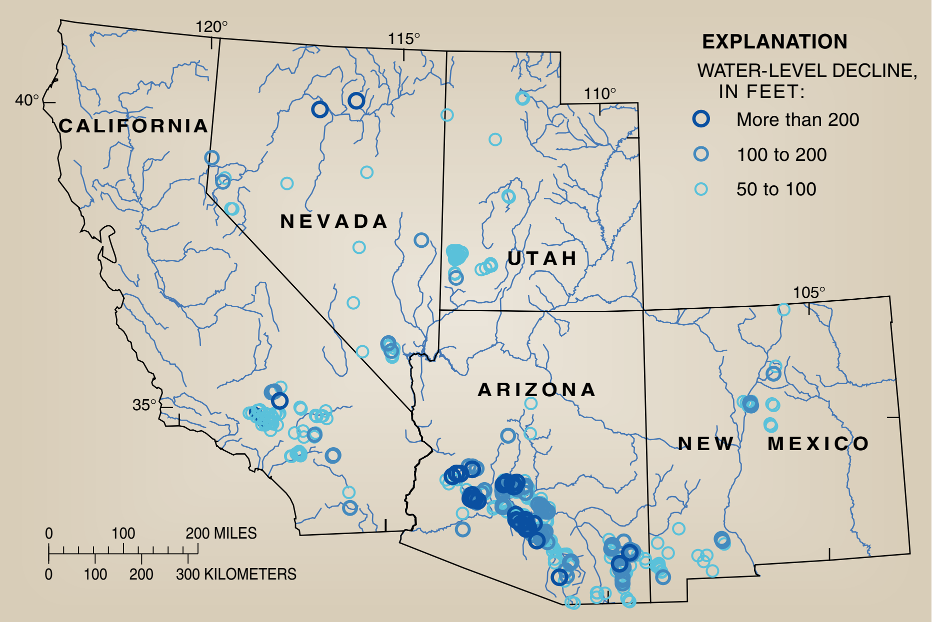

Figure 6. Locations in the basins of southern California, Nevada, Utah, Arizona, and New Mexico where significant ground-water level declines have been measured. In some areas, water levels have recovered in response to reduction in pumping and increased recharge efforts.

Land Subsidence

Land subsidence is the sinking of the land surface. A major cause of land subsidence in the Southwest is slow drainage of water from the clay and silt sediments in or next to aquifers (Galloway and others, 1999). As water levels in the aquifers decline, the slow drainage from the clay and silt layers cause them to compact, and the land surface to be lowered. Uneven land subsidence can change the slope of the land surface and can cause earth fissures (fig. 7), resulting in damage to buildings, pipelines, canals, drainage ditches, roads, railroads, dams, and bridges. Some locations in the Southwest having significant amounts of land subsidence are:

Location	Subsidence, in feet
Lancaster, California	6
Near Mendota, California	29
Las Vegas, Nevada	6
Eloy, Arizona	15
West of Phoenix, Arizona	18

Degradation of Water Quality

Many basins in the Southwest contain the highest quality water at shallower depths. Initial development of ground-water resources commonly focuses on first pumping the water of highest quality from the shallowest part of the aquifer. Continued pumping then can result in degradation of water quality over time as more water of lower quality is pumped from deeper parts of aquifers.

Figure 7. Earth fissure related to land subsidence, south-central Arizona.

Loss of Riparian Habitat

As shown in figure 3, under natural conditions most recharge in basins occurs at higher elevations, resulting in ground-water flow toward discharge points near the center of the basins. Many of the discharge points are springs, streams, and wetlands. The discharge of ground water to the surface sustains abundant plant and animal life in otherwise harsh environments. When ground water is withdrawn by humans, the immediate effect is the removal of water from storage in the area of the withdrawal. However, after continued withdrawal, the effects in an aquifer spread from the area of withdrawal and decrease the amount of discharge from the aquifer (Winter and others, 1998). Ground-water withdrawals in excess of the amount of discharge can result in the loss of an entire riparian system. For example, a mesquite bosque was present along the Santa Cruz River south of Tucson, Arizona, in 1942 (fig. 8 on following page, the photograph to the left). By 1989, the large riparian trees were gone (fig. 8, the photograph to the right). Ground-water levels in the area declined by more than 100 feet in that period, resulting in a loss of the ground water that had sustained the riparian plants.

Figure 8. Views of the Santa Cruz River looking south from the same location on Martinez Hill, south of Tucson, Arizona. In the 1942 photograph to the left, the flood plain is covered with a mesquite bosque, valued for its wild bird population. In the 1989 photograph to the right, the bosque no longer exists.

Southwest Ground-Water Resources Project

The U.S. Geological Survey has a program for continuing evaluation of the ground-water resources of the United States. Part of this program is the study of major ground-water issues in different regions of the country. In the Southwest, the major issue under investigation is the interaction of ground water and surface water. The study will provide water managers with better information on interaction of ground water and surface water and relations of that interaction to sustainability of ground-water resources. The project is focused on the desert basins of the Southwest shown on figure 1. Major study components include (1) regional synthesis; (2) effects of climate variability on recharge to and discharge from ground-water systems; (3) effects of development of ground-water resources on sustainability of riparian systems; (4) development of improved methods of estimating recharge to desert basins; and (5) development of improved methods of simulating interaction of ground water and surface water in arid and semi-arid regions.

Regional Synthesis

Hydrologic and geologic data are collected by federal, state, and local agencies to monitor water supply and hydrologic conditions. Compilation of that information and evaluation of long-term data sets are assisting in characterization of areas in terms of the interactions of ground water and surface water, the potential for future overdraft, and the impact on riparian systems in the Southwest. Land-use data also will be used to analyze the relation between land-use changes and hydrologic conditions.

Climate Variability and Ground Water

This study is quantifying the responses of different aquifers to climate variations at various time scales. For selected areas in the Southwest, time series of precipitation, streamflow, ground-water levels and discharge, and tree-ring thicknesses will be analyzed by various mathematical methods to quantify the relations between climate variations and ground-water resource availability.

Ground-Water Development and Riparian Systems

The effect of ground-water availability on riparian ecosystems is being studied at three sites in riparian habitats in California, Arizona, and New Mexico. The study is using a multidisciplinary approach centered on at least six riparian tree species to determine the sustainability of riparian systems with respect to ground-water and surface-water development in the Southwest.

Improved Methods of Estimating Recharge

The quantity of ground-water recharge to alluvial basins in the Southwest is one of the least known factors in the water budget. Several studies are currently being conducted to assist in quantifying recharge estimates. A network of four sites along streams in California, Nevada, Arizona, and New Mexico has been established to evaluate methods to estimate recharge. The methods include: geochemical analysis, thermal tracing, Darcian flow measurements, geophysical surveys, and channel loss.

Improved Methods of Simulating Interaction of Ground Water and Surface Water

Existing computer programs can be used to simulate interaction of ground water and surface water, but the methods used are not ideal for streams that go dry frequently or that are underlain by a thick unsaturated zone. For use in the desert Southwest and other arid regions, the Southwest Ground-Water Resources Project is developing better methods of simulating loss of water from ephemeral streams and movement of that water to the underlying aquifer.

Obtaining More Information on Ground-Water Resources in the Southwest

In addition to the Southwest Ground-Water Project, District Offices of the U.S. Geological Survey in California, Nevada, Utah, Arizona, and New Mexico collect data and conduct studies on ground-water resources in each state. Links to pages on the World Wide Web with information on District programs and the Southwest Ground-Water Resources Project can be found at site http://water.usgs.gov/ogw/

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