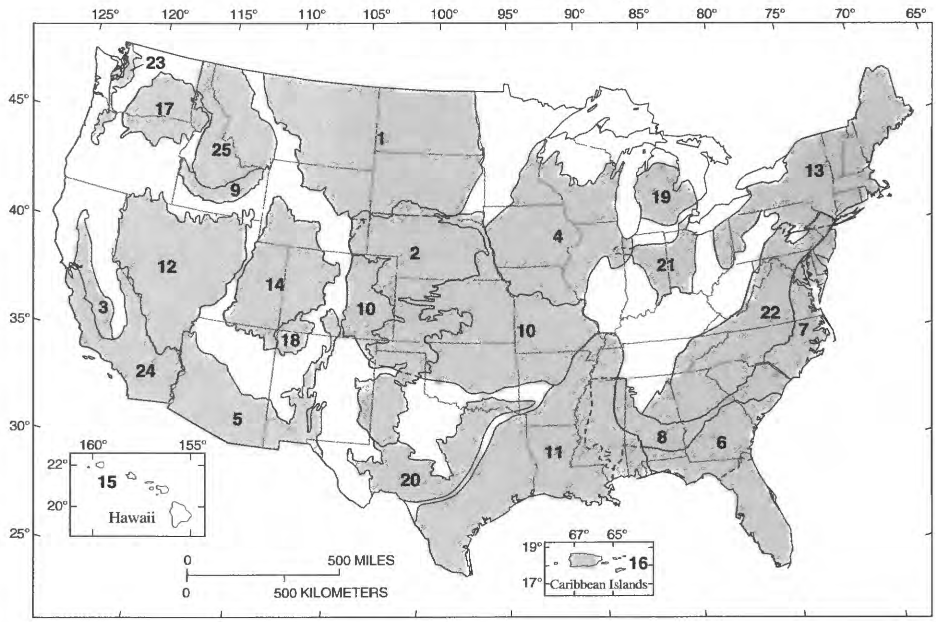
Fact Sheet

United States Geological Survey
Ground-Water Studies

The USGS provides maps, reports, and information to help others meet their needs to manage, develop, and protect America's water, energy, mineral, and land resources. We help find natural resources needed to build tomorrow, and supply scientific understanding needed to help minimize or mitigate the effects of natural hazards and environmental damage caused by human activities. The results of our efforts touch the daily lives of almost every American.

Ground water is among the Nation's most important natural resources. It is the source of about 40 percent of the water used for public supply and provides drinking water for more than 97 percent of the rural population who do not have access to public water-supply systems. Between 30 and 40 percent of the water used for the multi-billion-dollar agricultural industry comes from ground water. Withdrawals of ground water are expected to rise in the coming century as the population increases and available sites for surface reservoirs become more limited.

Wise management of ground-water resources requires knowledge of the distribution and characteristics of water-bearing rocks and sediments. Complicating this management task is the susceptibility of some ground-water resources to contamination by industrial, domestic, and agricultural chemicals and byproducts. Evaluating and dealing with these threats of ground-water contamination require improved knowledge of the occurrence and manner of movement of ground water in the subsurface.



EXPLANATION

Regional aquifer study areas

1 Northern Great Plains
2 High Plains
3 Central Valley, California
4 Northern Midwest
5 Southwest alluvial basins
6 Floridan
7 Northern Atlantic Coastal Plain
8 Southeastern Coastal Plain
9 Snake River Plain
10 Central Midwest
11 Gulf Coastal Plain
12 Great Basin
13 Northeast glacial aquifers
14 Upper Colorado River basin
15 Oahu, Hawaii
16 Caribbean Islands
17 Columbia Plateau
18 San Juan Basin
19 Michigan Basin
20 Edwards–Trinity
21 Midwestern basins and arches
22 Appalachian valleys and piedmont
23 Puget–Willamette Lowland
24 Southern California alluvial basins
25 Northern Rocky Mountain intermontane basins

Figure 1. Locations of regional aquifer systems studied by the USGS as part of a comprehensive program to define the hydrology and geology of extensive aquifer systems and to establish a framework of background information that can be used for regional assessment and detailed local studies of ground-water resources.

Ground-Water Protection and Management

The U.S. Geological Survey (USGS) is the principal source of scientific and technical expertise in the earth sciences within the Federal Government. The USGS does not manage or regulate ground water, but for more than 100 years, the USGS has provided water managers and policymakers with technically sound and unbiased data and reports that describe the location, quantity, and quality of ground water.

Ground-water investigations are carried out by more than 150 USGS field offices throughout the 50 States, Puerto Rico, and the trust territory. Regional ground-water studies (fig. 1) are especially important for understanding long-term resource issues and providing background information over multistate areas. Many projects are initiated in cooperation with State and local agencies, which provide part of the funding. The USGS provides a national infrastructure for consistently measuring and understanding ground-water resources and for sharing this information with all parties.

Included in this infrastructure is a nationwide network of observation wells in which the level of ground water is measured on a regular schedule to detect significant changes that might be produced by short- or long-term changes in precipitation, droughts, or pumpage. More than 26,000 stations were part of this network in fiscal year 1994. Data from these wells become part of a national water-information system that can be accessed by the public.

New Techniques and Approaches to Ground-Water Studies

The USGS has been in the forefront of devising new techniques or adapting existing techniques to solve practical problems in the study of ground water. Some examples of recent technical developments and innovations by the USGS in the field of ground water are as follows:

- A mathematical model of ground-water flow that has become the most widely used computer-based model in the ground-water industry.
- Techniques to identify and date recently recharged water that are useful in characterizing the susceptibility of hydrogeologic environments to contamination.
- Widely used geochemical models that can be used to improve estimates of the direction and rate of ground-water flow and to predict the transport and fate of inorganic contaminants.
- Geophysical methods for determining the hydraulic properties of fractured rocks. Predicting the movement of water and contaminants through fractured rocks has been one of the most challenging problems in hydrogeology.

Studies Related to the Effects of Ground-Water Withdrawals

USGS projects dealing with ground-water withdrawals range in scope from monitoring water levels in wells to regional studies involving geophysics, geology, and mathematical modeling. Selected examples of the several hundred such studies conducted by the USGS in recent years are described below.

Land Subsidence

Land subsidence due to the pumping of ground water occurs in nearly every State. It causes damage to buildings, roads, bridges, and canals; increases the incidence of coastal flooding; and can permanently reduce the capacity of aquifers to store water. Documented costs of subsidence are known to exceed $250 million per year within just Houston and Galveston, Texas, New Orleans, Louisiana, Santa Clara County, California, and the San Joaquin Valley, California.

Drawing on a nationwide network of experienced scientists, the USGS has made long-term measurements of subsidence that resulted from ground-water withdrawal in a variety of environments and has developed predictive models that are used today throughout the world. For example, USGS scientists assisted the Bureau of Reclamation (BOR) in the design and alignment of canals in the Central Arizona Project and the Central Valley Project of California to ensure that these multimillion-dollar structures would not fail as a result of surface cracking and changes in land-surface configuration.

Seawater Intrusion

Many communities in coastal areas have been or potentially can be affected by seawater intrusion caused by heavy pumpage of ground water. This seawater intrusion threatens major sources of freshwater relied upon by coastal communities for their water needs. The USGS, in cooperation with other agencies, has been determining the geologic and human factors that control seawater intrusion.

For example, in Ventura County, California, the USGS has determined that the extent of lateral seawater intrusion into the upper part of the ground-water system is less than previously thought. Previous investigators mistakenly attributed measured elevated chloride concentrations from some wells to seawater intrusion. However, these elevated chloride concentrations were determined to be caused by downward leakage of seawater and agriculture return water from overlying undeveloped shallow deposits through failed wells or ineffective well seals. In addition, the current investigators discovered that the potential for future seawater intrusion into the deeper aquifer from outcrops of the aquifer in submarine canyons is greater than originally thought. In response to the USGS findings, water agencies in the area are taking steps to control leaking wells and to develop alternative management strategies to control seawater intrusion.

Consumptive Use of Lower Colorado River Water

Accounting for consumptive use of lower Colorado River water in the States of Arizona, California, and Nevada is required by the U.S. Supreme Court Decree of 1964, *Arizona* v. *California*. Water pumped from some wells outside the flood plain of the river has not previously been included in the accounting because the subsurface limits of the aquifer that is hydraulically connected to the river were not defined. To aid the BOR in implementing the Decree, the USGS developed a method to identify wells outside the flood plain that yield water that will be replaced by water from the river. The USGS used hydrologic principles, results of previous hydrologic and geologic studies, and newly obtained gravity data to determine the extent and thickness of the river aquifer, which comprises sediments and sedimentary rocks that are hydraulically connected to the river. The method provides a uniform criterion of identification for all users that pump water from wells completed in the river aquifer.

Water Levels in the High Plains Aquifer

About 30 percent of the ground water used for irrigation in the United States is pumped from the High Plains aquifer of the Midwest (fig. 2). This intense development led the USGS to undertake in 1978 the first comprehensive assessment of the ground-water resources of the High Plains aquifer. USGS scientists found significant declines from predevelopment water levels in many areas. The largest declines were in the central and the southern High Plains, where declines locally exceeded 100 feet. Declines were much smaller and less extensive in the northern High Plains, where extensive irrigation has been practiced for a shorter time. In a few parts of the northern High Plains, increases in water levels were caused by seepage from surface-water diversions.

The USGS prepared a series of models to evaluate the effects of estimated future ground-water pumpage under a variety of development alternatives projected to 2020. Water levels declined in all the alternatives; for some alternatives, well yields were reduced significantly. Continued monitoring by the USGS has shown that water levels have continued to decline in the last 13 years at many localities but at a slower annual rate than before 1980; the decrease in the rate of water-level decline has resulted, in part, from water-conservation practices and a reduction in irrigated acreages in parts of the High Plains.

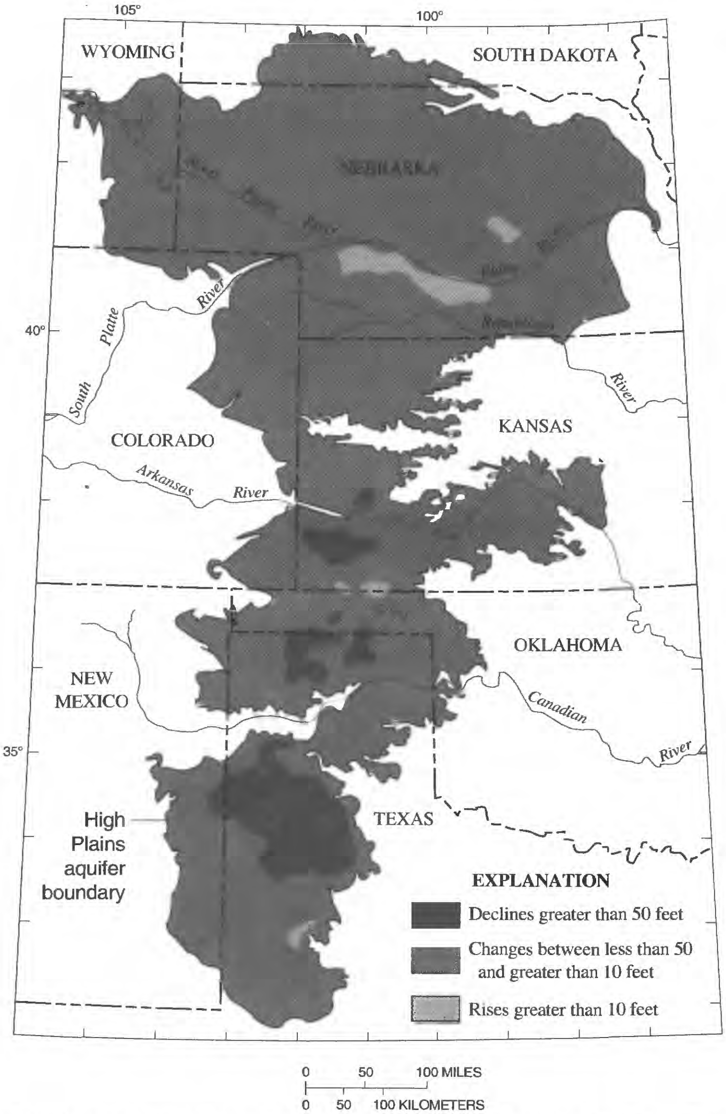


Figure 2. High Plains aquifer system and water-level changes, from predevelopment through 1993.

Untapped Ground Water

Large amounts of ground water are present within basin-fill deposits and underlying fractured carbonate rocks in the Great Basin of Nevada and Utah. Currently (1995), this water is the subject of disputes over water rights in 18 separate basins. In 1991, the USGS did the first modeling of the deeply buried regional flow system in the underlying rocks. Previous studies in that area had concentrated on the shallow basin-fill aquifers, although the deeper, regional carbonate system was recognized as a potentially vast, undeveloped water resource.

On the basis of USGS analyses, areas and amounts of recharge and discharge have been delineated, and estimates of the future effects of intensive ground-water development within areas of the carbonate province have been made. The objective information generated by the USGS provides a common factual base for negotiation of the water-rights issues.

Simulation of Conditions in the Biscayne Aquifer

The Biscayne aquifer is a highly permeable surficial formation and is the only source of drinking water for about 3 million people in southern Florida. The USGS has modelled the flow of water through the Biscayne aquifer to study the effects of water withdrawals, actual or potential sources of contamination, and drought or excessive precipitation. The hydrologic system that includes the aquifer has been complicated by the construction of an extensive system of canals and levees that are used for flood control and to manage the water needs of agricultural and urban areas in southern Florida. In recent years, the role of the aquifer in maintaining or modifying the ecosystem balances in Everglades National Park has become a focus for study.

Existing digital models were modified to permit representation of the unique hydrologic regime in this area where shallow sheets of surface water move sluggishly southward during the wet seasons followed by much more limited surface flows in the dry seasons. Also, the extensive system of canals and levees had to be included in the model to achieve realistic results. Output of the model has been used in locating new well fields, in assessing the potential for contamination of this shallow aquifer, and for testing water delivery alternatives for the Everglades.

Studies Related to Toxic Substances in Ground Water

Ground water plays a key role in the transport and eventual fate of contaminants in the environment. Ground water has been contaminated in some areas as a result of waste-disposal practices or accidental spills. Treatment of contaminated ground water can be expensive; in some cases, deterioration of ground-water quality may be virtually irreversible. In the evaluation of potential waste-disposal sites, the projected magnitude of transport of contaminants by ground water is always a primary concern.

The USGS aims to provide a firm basis for remediation and prevention of ground-water contamination by studying the hydrologic processes taking place at typical sites where contaminants have entered the ground water. The collection of data over long periods is especially important in these studies. Although it is not the role of the USGS to locate new waste-disposal sites, the data it provides from the study of processes are vital in the search for safe disposal sites for toxic materials. Three examples of USGS studies in toxic-waste hydrology are described below.

Crude-Oil Spill

USGS studies of a crude-oil spill from a broken pipeline in Bemidji, Minnesota, have indicated that large concentrations of petroleum-type hydrocarbons can be attenuated or removed from ground water through biodegradation. The size of the plume containing hydrocarbons at the top of the local water table has changed little during the 9 years of the study (1984-93). The chemistry of the plume components has been changing with time; however, biodegradation of the hydrocarbons has kept them within 450 feet downgradient from the oil source. Another factor that helped contain the plume is the presence of silt layers of low hydraulic conductivity near the oil at the top of the aquifer. This long-term study provides perhaps the best-documented case that natural attenuation is an effective treatment approach at some sites provided careful attention is paid to the hydrogeologic setting and the chemistry of the contaminants.

Gasoline Spill

The USGS studied hydrologic conditions at a small isolated spill of gasoline in Galloway Township, southern New Jersey, to learn details of the biology and chemistry of these materials in shallow ground water. Degradation of the contaminants by bacteria is an important process at the site; the process was studied under varying conditions and with different additives to determine efficient remediation schemes. In addition, USGS researchers modified a computer model of ground-water flow to apply it to gas flow in the zone above the water table. The model can be used to determine the optimal placement of wells and pumping rates so as to extract the contaminants with the greatest efficiency at a site undergoing remediation.

Low-Level Radioactive Waste

Historically in the United States, low-level radioactive waste from nuclear reactors, industry, hospitals, and medical research has been buried at a few centralized sites. Under laws passed in the 1980's, States must find new sites for low-level radioactive waste either individually or in compacts with other States. The USGS, in cooperation with the Nuclear Regulatory Commission and the States involved, studied the shallow ground-water conditions at several of the earlier sites and recommended guidelines for the location of new sites.

Currently (1995), the effectiveness of shallow burial trenches above the water table in arid regions containing the wastes is being studied by the USGS at an experimental facility near Beatty, Nevada. In humid regions, the water table is higher and ground-water flow paths are shorter than in arid regions. Results of studies by the USGS in humid regions have been used by States and compacts to conclude that new sites will have to incorporate engineering enhancements not required when earlier sites consisting of shallow trenches were constructed in the 1960's.

Ground-Water Atlas of the United States

An important product of regional ground-water studies of the USGS is the *Ground-Water Atlas of the United States*, which is a comprehensive summary of the Nation's ground-water resources and a basic reference on its major aquifers. The *Atlas* will be useful to Federal, State, and local officials with responsibilities for water allocation, waste disposal, and wellhead protection. The complete *Atlas* will consist of an introductory chapter and 13 descriptive chapters, each covering a multistate region of the country. As of early 1995, three chapters had been published, and three are in press.

References

Appel, C.A., and Reilly, T.E., 1994, Summary of selected computer programs produced by the U.S. Geological Survey for simulation of ground-water flow and quality: U.S. Geological Survey Circular 1104, 98 p.

Sun, Ren Jen, and Johnston, R.H., 1994, Regional aquifer-system analysis program of the U.S. Geological Survey, 1978–1992: U.S. Geological Survey Circular 1099, 126 p.

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Additional earth science information can be found by accessing the USGS "Home Page" on the World Wide Web at "http://www.usgs.gov" or by calling 1-800-H2O-9000 (1-800-426-9000).

For more information on all USGS reports and products (including maps, images, and computerized data), call 1-800-USA-MAPS.