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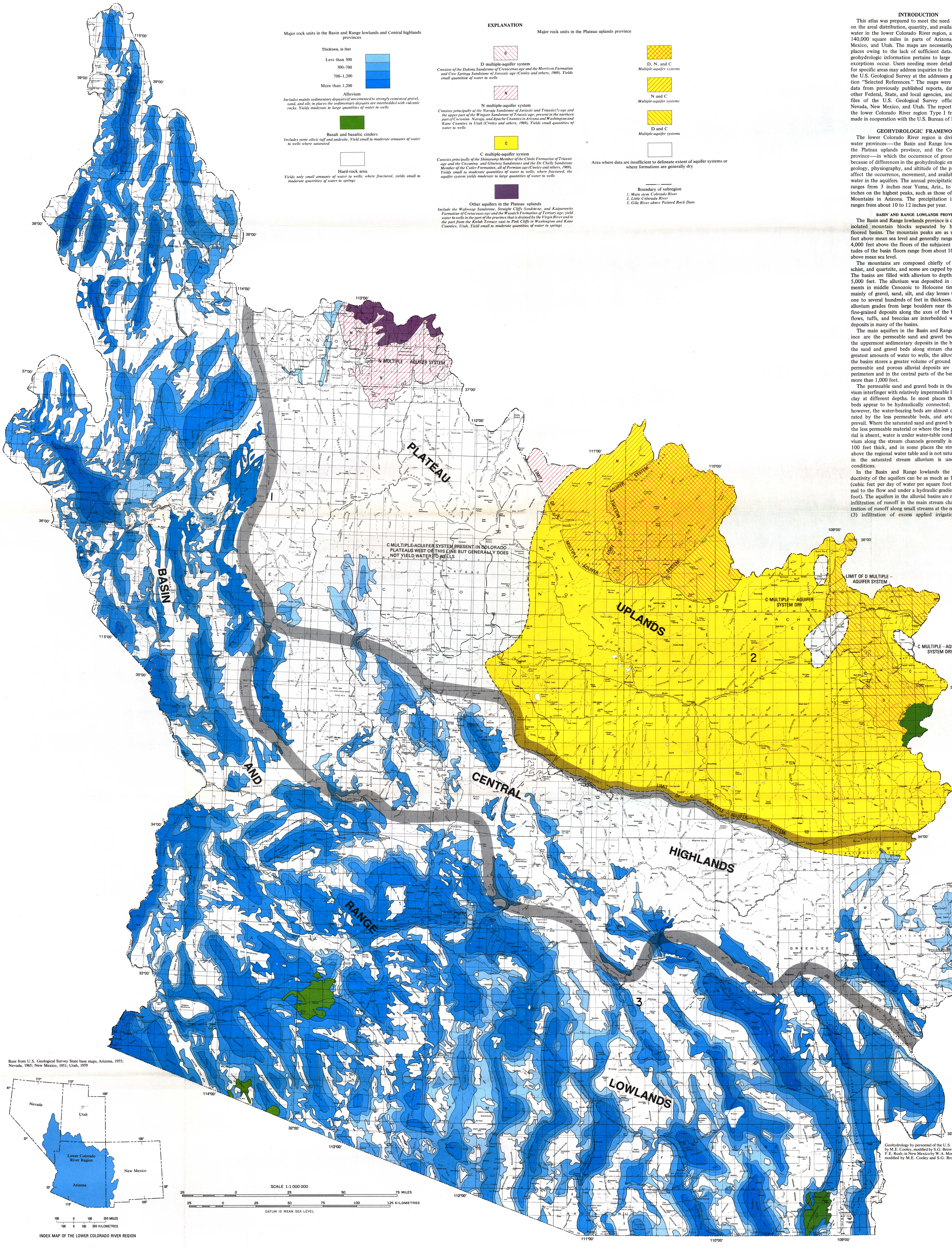

EXPLANATION

Major rock units in the Basin and Range lowlands and Central highlands provinces

Thickness, in feet

- Less than 300
- 300–700
- 700–1,200
- More than 1,200

Alluvium

Includes mainly sedimentary deposits of uncemented to strongly cemented gravel, sand, and silt; in places the sedimentary deposits are interbedded with volcanic rocks. Yields moderate to large quantities of water to wells

Basalt and basaltic cinders

Includes some silicic tuff and andesite. Yield small to moderate amounts of water to wells where saturated

Hard-rock area

Yields only small amounts of water to wells; where fractured, yields small to moderate quantities of water to springs

Major rock units in the Plateau uplands province

D

D multiple-aquifer system

Consists of the Dakota Sandstone of Cretaceous age and the Morrison Formation and Cow Springs Sandstone of Jurassic age (Cooley and others, 1969). Yields small quantities of water to wells

N

N multiple-aquifer system

Consists principally of the Navajo Sandstone of Jurassic and Triassic(?) age and the upper part of the Wingate Sandstone of Triassic age; present in the northern part of Coconino Navajo, and Apache Counties in Arizona and Washington and Kane Counties in Utah (Cooley and others, 1969). Yields small quantities of water to wells

C

C multiple-aquifer system

Consists principally of the Shinarump Member of the Chinle Formation of Triassic age and the Coconino and Glorieta Sandstones and the De Chelly Sandstone Member of the Cutler Formation, all of Permian age (Cooley and others, 1969). Yields small to moderate quantities of water to wells; where fractured, the aquifer system yields moderate to large quantities of water to wells

Other aquifers in the Plateau uplands

Include the Wahweap Sandstone, Straight Cliffs Sandstone, and Kaiparowits Formation of Cretaceous age and the Wasatch Formation of Tertiary age; yield water to wells in the part of the province that is drained by the Virgin River and in the part from the Kolob Terrace east to Pink Cliffs in Washington and Kane Counties, Utah. Yield small to moderate quantities of water to springs

D, N, and C
Multiple-aquifer systems

N and C
Multiple-aquifer systems

D and C
Multiple-aquifer systems

Area where data are insufficient to delineate extent of aquifer systems or where formations are generally dry

Boundary of subregion
1, Main stem Colorado River
2, Little Colorado River
3, Gila River above Painted Rock Dam

Base from U.S. Geological Survey State base maps, Arizona, 1955; Nevada, 1965; New Mexico, 1951; Utah, 1959

INDEX MAP OF THE LOWER COLORADO RIVER REGION

Geohydrology by personnel of the U.S. Geological Survey: In Arizona by M.E. Cooley, modified by S.G. Brown; in Nevada by T.E. Eakin and F.E. Rush; in New Mexico by W.A. Mourant; in Utah by Donald Price, modified by M.E. Cooley and S.G. Brown

MAP SHOWING GENERALIZED GEOHYDROLOGIC FRAMEWORK

INTRODUCTION

This atlas was prepared to meet the need for information on the areal distribution, quantity, and availability of ground water in the lower Colorado River region, an area of about 140,000 square miles in parts of Arizona, Nevada, New Mexico, and Utah. The maps are necessarily generalized in places owing to the lack of sufficient data. In general the geohydrologic information pertains to large areas, and local exceptions occur. Users needing more detailed information for specific areas may address inquiries to the district chief of the U.S. Geological Survey at the addresses given in the section "Selected References." The maps were prepared using data from previously published reports, data collected by other Federal, State, and local agencies, and data from the files of the U.S. Geological Survey offices in Arizona, Nevada, New Mexico, and Utah. The report is the result of the lower Colorado River region Type I framework study made in cooperation with the U.S. Bureau of Reclamation.

GEOHYDROLOGIC FRAMEWORK

The lower Colorado River region is divided into three water provinces—the Basin and Range lowlands province, the Plateau uplands province, and the Central highlands province—in which the occurrence of ground water differs because of differences in the geohydrologic environment. The geology, physiography, and altitude of the provinces greatly affect the occurrence, movement, and availability of ground water in the aquifers. The annual precipitation in the region ranges from 3 inches near Yuma, Ariz., to as much as 35 inches on the highest peaks, such as those of the Chiricahua Mountains in Arizona. The precipitation in the lowlands ranges from about 10 to 12 inches per year.

BASIN AND RANGE LOWLANDS PROVINCE

The Basin and Range lowlands province is characterized by isolated mountain blocks separated by broad alluvium-floored basins. The mountain peaks are as much as 10,000 feet above mean sea level and generally range from 1,000 to 4,000 feet above the floors of the subjacent basins; the altitudes of the basin floors range from about 100 to 4,500 feet above mean sea level.

The mountains are composed chiefly of granite, gneiss, schist, and quartzite, and some are capped by volcanic rocks. The basins are filled with alluvium to depths of as much as 5,000 feet. The alluvium was deposited in several environments in middle Cenozoic to Holocene time and consists mainly of gravel, sand, silt, and clay lenses that range from one to several hundreds of feet in thickness. In general, the alluvium grades from large boulders near the mountains to fine-grained deposits along the axes of the basins. Volcanic flows, tuffs, and breccias are interbedded with the alluvial deposits in many of the basins.

The main aquifers in the Basin and Range lowlands province are the permeable sand and gravel beds that occur in the uppermost sedimentary deposits in the basins. Although the sand and gravel beds along stream channels yield the greatest amounts of water to wells, the alluvium throughout the basins stores a greater volume of ground water. The least permeable and porous alluvial deposits are along the basin perimeters and in the central parts of the basins at depths of more than 1,000 feet.

The permeable sand and gravel beds in the saturated alluvium interfinger with relatively impermeable lenses of silt and clay at different depths. In most places the water-bearing beds appear to be hydraulically connected; in some places, however, the water-bearing beds are almost completely separated by the less permeable beds, and artesian conditions prevail. Where the saturated sand and gravel beds occur above the less permeable material or where the less permeable material is absent, water is under water-table conditions. The alluvium along the stream channels generally is not more than 100 feet thick, and in some places the stream alluvium is above the regional water table and is not saturated; the water in the saturated stream alluvium is under water-table conditions.

In the Basin and Range lowlands the hydraulic conductivity of the aquifers can be as much as 130 feet per day (cubic feet per day of water per square foot of aquifer normal to the flow and under a hydraulic gradient of 1 foot per foot). The aquifers in the alluvial basins are recharged by (1) infiltration of runoff in the main stream channels, (2) infiltration of runoff along small streams at the mountain fronts, (3) infiltration of excess applied irrigation water from surface-water sources, (4) underflow from upstream basins, and (5) possibly by some direct penetration of precipitation. The amount of runoff in the Basin and Range lowlands is very small, and, therefore, the amount of recharge to the ground-water reservoir from this source also is very small; recharge occurs regularly and predictably only along the Colorado River, where surface water released by dams infiltrates into the adjacent permeable rocks. Data from the upper Santa Cruz River basin indicate that 3–6 percent of the precipitation that falls on the mountains becomes ground-water recharge through infiltration of runoff (B. N. Aldridge and S. G. Brown, written commun., 1969). The relation between the amount of precipitation that falls on the mountains and the amount that is recharged to the ground-water reservoir in the upper Santa Cruz basin probably is typical for most basins in the lowlands province. Only a small amount of the precipitation that falls on the valley floors is recharged to the ground-water reservoir.

Part of the ground water that is applied to the land for irrigation is returned to the ground-water reservoir by infiltration. A large part of the surface water that flows through unlined canals and a smaller part that is applied to fields infiltrates to the ground-water reservoir in some areas, such as in the Wellton-Mohawk area along the lower Gila River, the Yuma Mesa area southeast of Yuma, the Salt River Project area, the Safford area, and the San Carlos project in the Casa Grande area in Arizona. In most other areas, however, the amount of infiltration from this source probably is negligible. If the applied irrigation water is ground-water pumpage, then the part that returns to the subsurface by infiltration is a credit against pumpage and does not constitute the addition of new water to the system.

In some basins the ground-water reservoir is recharged by underflow from upstream basins. The interbasin movement of ground water is recharge to the lower basin but is discharge from the upper basin.

The natural direction of ground-water movement in alluvial basins generally is from the margins toward the axis of the basin, along the axis in the direction of the slope of the land surface, and parallel to the surface drainage. The rate of ground-water movement probably ranges from a few feet to several hundreds of feet per year. Ground-water development modifies both the direction and rate of movement; the degree of modification depends mainly on the pumping pattern and on the volume of ground water removed. Along the Colorado River, water enters and leaves the permeable rocks in response to changes in stage of the river, lowering of ground-water levels by pumping, and infiltration of river water applied for irrigation. In Nevada the ground water in a regional system consisting of 13 basins—some of which are topographically closed basins—moves southward and is discharged through springs in White River, Pahranagat, and upper Moapa Valleys.

Ground water may be discharged by direct evaporation in areas where the water table is near the land surface, such as in parts of the Willcox basin in Arizona. In many of the alluvial basins in the southern part of the Basin and Range lowlands, however, the water table is now sufficiently deep to prevent significant evaporation. Where the depth to water is greater than about 10 feet, evaporation of ground water is negligible; therefore, discharge by evaporation probably is not significant except in a few places along stream channels. A large part of the precipitation that may otherwise become runoff or ground water is lost by direct evaporation from the land surface.

Millions of acre-feet of water per year is transpired from the ground-water reservoir by phreatophytes. About 1.2 million acre-feet of water per year is transpired by phreatophytes in the drainage of the Colorado River and its tributaries below Hoover Dam. In many areas the growth of these plants is quite dense—for example, along the Colorado River between Davis and Imperial Dams and between Bylas and Coolidge Dam along the Gila River. Several studies are being conducted on the possible salvage of water by the eradication of these plants.

PLATEAU UPLANDS PROVINCE

The Plateau uplands province includes a variety of landforms—plateaus, canyons, buttes, mesas, and volcanic mountains. The altitude ranges from about 4,000 to 13,000 feet above mean sea level but generally is between 5,000 and 7,000 feet above mean sea level. The annual precipitation in the uplands ranges from less than 10 to 30 inches. The uplands is underlain chiefly by consolidated sedimentary rocks that consist mainly of sandstone, siltstone, claystone, and limestone. The sandstone and limestone form the chief aquifers in the area; the siltstone and claystone are nearly impermeable and form confining beds throughout most of the area. Where water-bearing beds of sandstone and limestone alternate with the confining beds, the water in the aquifers is under artesian pressure.

In the Plateau uplands province most of the ground water occurs in three multiple-aquifer systems—the D, N, and C multiple-aquifer systems (Cooley and others, 1969). The Wahweap Sandstone, Straight Cliffs Sandstone, Kaiparowits Formation, and Wasatch Formation also yield water in parts of the uplands.

Fracturing of the consolidated sedimentary rocks in the C multiple-aquifer system greatly influences the occurrence, yield, and movement of ground water. Most of the fractures are alined northwest, north, and northeast. The fracture pattern is one of general divergence from the San Francisco Mountain area near Flagstaff, Ariz., and extends from the White Mountains to the Kaibab Plateau and the western Grand Canyon region. The width of the fractures ranges from the thickness of a sheet of paper to several feet. The largest well yields from the C multiple-aquifer system occur in places where the aquifer system is extensively fractured, such as in the Flagstaff and St. Johns-Joseph City-Show Low areas. The C multiple-aquifer system generally does not yield water to wells west and north of Flagstaff; however, a few deep wells obtain small amounts of water from the aquifer system.

For the most part, the multiple-aquifer systems do not transmit water readily, and the hydraulic conductivity generally is less than 1.3 feet per day. Both the N and C multiple-aquifer systems are more than 500 feet thick over large areas; the D multiple-aquifer system and other consolidated-rock aquifers generally are less than 200 feet thick. The low hydraulic conductivity of these aquifers precludes rapid movement of ground water and large yields to wells.

In the Virgin River drainage in Utah and northern Arizona the N multiple-aquifer system and the Wahweap Sandstone, Straight Cliffs Sandstone, Wasatch Formation, and Kaiparowits Formation yield small amounts of water to wells and springs. Along the Virgin River in Utah and in the Peach Springs-Truxton area, upper Aubrey Valley, and Rose Well area in Arizona, the alluvium yields small to moderate amounts of water to wells. The volcanic rocks yield small amounts of ground water to wells in places where they are underlain by impervious material. In other areas water percolates through the volcanic rocks into the underlying formations, and the volcanic rocks yield little or no water to wells. Some ground water is present in the alluvium along the Little Colorado River and its principal tributaries; however, the alluvium generally is fine grained and of limited areal extent and does not store or yield large amounts of water to wells.

The multiple-aquifer systems are recharged in their areas of outcrop by infiltration of runoff. Probably more than 80 percent of the recharge enters the aquifers in the White Mountains, the Mogollon Slope, the San Francisco Plateau, the Kaibab Plateau, the Navajo Uplands, and the Defiance Plateau. The recharge areas are generally more than 6,000 feet above mean sea level, where the precipitation is more than 15 inches per year. The D multiple-aquifer system probably receives its recharge in the central part of the Black Mesa area, the N multiple-aquifer system receives its recharge principally in the Navajo Uplands area, and the C multiple-aquifer system receives its recharge in the Defiance Plateau and the Mogollon Slope areas.

In the uplands province ground-water movement in the D, N, and C multiple-aquifer systems generally is toward the Little Colorado River, but west of Flagstaff the general direction of ground-water movement probably is toward the Colorado River and its tributaries. North of Gallup in the New Mexico part of the uplands, movement is northward toward the San Juan River. The water in the N aquifer generally moves southwestward toward the Little Colorado River except in the northeastern part of Black Mesa where the flow is northeastward toward the San Juan River. Most water in the more deeply buried C aquifer in Arizona moves southwestward toward the Little Colorado River and discharges into the river at Blue Springs above the confluence of the Colorado and Little Colorado Rivers and farther downstream; northeast of the Defiance Plateau, ground water in the C aquifer moves northward toward the San Juan River.

Ground water is discharged through springs where the water table intersects the land surface or where water from deep artesian aquifers finds an outlet through fractures. Some ground water may be discharged by seepage into stream channels where the water table intersects the streambed. Ground water provides base flow to some streams, and during periods of high runoff these same streams may furnish ground-water recharge to the aquifers.

CENTRAL HIGHLANDS PROVINCE

The Central highlands province is a mountainous area that separates the Plateau uplands from the Basin and Range lowlands in most of the lower Colorado River region. The altitude ranges from 2,500 to 11,000 feet above mean sea level, and the precipitation ranges from 16 to 40 inches per year. The igneous and metamorphic rocks that form the core of the Central highlands are exposed extensively but do not store appreciable amounts of ground water. Where the rocks are fractured, however, they store small amounts of water, and springs issue from fractured zones. Along the base of the Mogollon Rim, a prominent feature in the Central highlands, many springs issue from the C multiple-aquifer system and the underlying Supai Formation of Pennsylvanian and Permian age and the Redwall Limestone of Mississippian age. The rim is the principal discharge area for ground water in the highlands. Volcanic rocks crop out in much of the highlands; the volcanic rocks are permeable, and water moves readily through them and recharges the underlying ground-water reservoir. In a few basins alluvial deposits provide storage for ground water. Big Sandy Valley, Chino Valley, Verde River valley, Tonto basin, the San Carlos River valley, and the Globe-Miami area contain sufficient thicknesses of saturated alluvium for the development of small water supplies.

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PRELIMINARY MAPS SHOWING GROUND-WATER RESOURCES IN THE LOWER COLORADO RIVER REGION, ARIZONA, NEVADA, NEW MEXICO, AND UTAH

By
S. G. Brown
1976

For sale by Branch of Distribution, U.S. Geological Survey, Box 25286, Federal Center, Denver, CO 80225, price $2.50 per set