DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH THE
U.S. BUREAU OF RECLAMATION

HYDROLOGIC INVESTIGATIONS
ATLAS HA-478 (SHEET 1 OF 2)

EXPLANATION

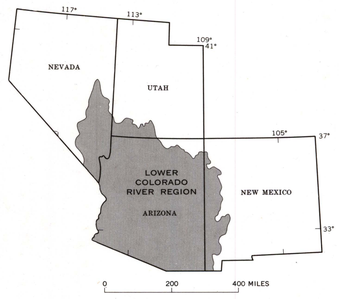
DISSOLVED SOLIDS, IN MILLIGRAMS PER LITER

SPECIFIC CONDUCTANCE, IN MICROMHOS AT 25°C

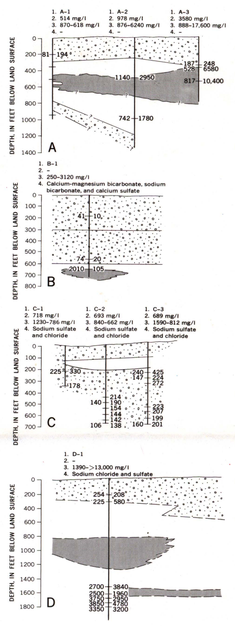
- Less than 1000 — Less than 1700
- 1000 to 3000 — 1700 to 5000
- More than 3000 — More than 5000
- Mountain areas or areas where data are lacking — Mountain areas or areas where data are lacking

Line pattern shown in Plateau Uplands where the N multiple-aquifer system underlies the D multiple-aquifer system and other water-bearing strata and contains water having less than 1000 mg/l dissolved solids. Wells other than those in the D, N, and C multiple-aquifer systems yield water that contains less than 3000 mg/l of dissolved solids, depending on the aquifer or combination of aquifers penetrated

- Limit of C multiple-aquifer system — *Dashed where approximately located*
- Limit of D multiple-aquifer system
- Limit of N multiple-aquifer system
- Boundary of area where wells that tap the Coconino Sandstone yield water that contains more than 25,000 mg/l of dissolved solids
- (B) Well(s) for which water-quality data are shown in sections
- Boundary of lower Colorado River region
- Subregion boundary



INDEX MAP OF THE LOWER COLORADO RIVER REGION



EXPLANATION

1. Well number
2. Dissolved-solids concentrations in water at discharge pipe
3. Range of dissolved solids in water sampled at different depths
4. Type of water

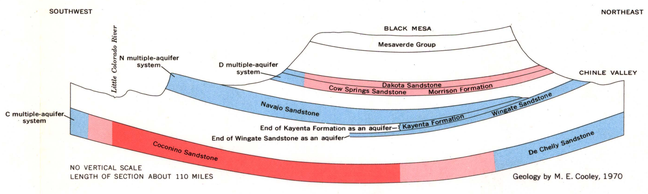
Sulfate (mg/l) | Chloride (mg/l)
254 | 208
225 | 580

Sampling point

MATERIALS PENETRATED

- Mainly sand and gravel; weakly to moderately cemented in places
- Gypsum and salt
- Mainly silt, silty clay and clay

SECTIONS SHOWING CHANGES IN THE CHEMICAL QUALITY OF THE WATER IN DIFFERENT MATERIALS PENETRATED BY WELLS IN THE BASIN AND RANGE LOWLANDS PROVINCE



EXPLANATION

DISSOLVED SOLIDS, IN MILLIGRAMS PER LITER — SPECIFIC CONDUCTANCE, IN MICROMHOS AT 25°C

- Less than 1000 — Less than 1670
- 1000 to 3000 — 1680 to 5010
- More than 3000 — More than 5010

DIAGRAMMATIC SECTION SHOWING THE GENERAL QUALITY OF WATER FROM THE D, N, AND C MULTIPLE-AQUIFER SYSTEMS IN THE PLATEAU UPLANDS PROVINCE

INTRODUCTION

This atlas presents data on the areal and vertical distribution of the dissolved-solids and fluoride concentrations in ground water for the lower Colorado River region, an area of about 140,000 square miles in parts of Arizona, Nevada, New Mexico, and Utah. 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. These data have been compiled as a part of the lower Colorado River region Type I framework study made in cooperation with the U.S. Bureau of Reclamation.

OCCURRENCE OF GROUND WATER

The occurrence of ground water in the lower Colorado River region is controlled by the geology and physiography of the three water provinces——the Basin and Range lowlands province, the Plateau uplands province, and the Central highlands province (see map). In this report the geologic and physiographic characteristics of the three provinces are discussed briefly in relation to the chemical quality of the ground water.

DISTRIBUTION OF DISSOLVED SOLIDS

BASIN AND RANGE LOWLANDS PROVINCE

This province is characterized by isolated north- to northwest-trending mountain ranges separated by broad alluvial-floored basins. The mountains are composed mainly of granite, gneiss, schist, quartzite, and volcanic rocks. The basin alluvium is composed of waterlaid deposits derived from the surrounding mountains and from volcanic activity. The older sedimentary rocks generally are more dense and cemented than the younger overlying deposits. The distribution of the deposits is controlled by the faulting and structural movement that affected the basins during their formation.

The water in the mountains generally contains less than 1,000 mg/l (milligrams per liter) dissolved solids, except where water issues from saline springs. The dissolved-solids concentrations in the ground water in the alluvium range from less than 100 to more than 100,000 mg/l and generally are less than 1,000 mg/l. In the basin alluvium, water that contains more than 1,000 mg/l dissolved solids——saline water——occurs mainly in the areas along and near the Gila River from Safford to Yuma, Ariz.; along the southernmost reach of the Colorado River; in the southeastern part of Nevada; and near Willcox, Casa Grande, and Tucson.

The dissolved-solids concentrations in the water from wells vary areally and with depth as different water-bearing units are penetrated. For example, a significant difference in the chemical quality of water in the different water-bearing units is apparent in the analyses from three wells near Casa Grande (section A). In this area the subsurface deposits are divided into three units——a lower sand and gravel unit, a silt and clay unit, and an upper sand and gravel unit (Hardt and Cattany, 1965). The well casings are perforated from the water table to the bottom of the well; therefore, the wells yield water from all the water-bearing units penetrated. Water samples taken at the discharge pipes and at different depths in the well bores show significant chemical-quality changes. The chloride concentrations in the water from well B-3 change from 248 mg/l at 350 feet to 6,580 mg/l at 375 feet below the land surface. The abrupt change in chloride concentration between 350 and 375 feet coincides with the contact between the upper sand and gravel unit and a gypsum and salt zone in the silt and clay unit. The chemical quality of the water from other wells in the lowlands (sections B, C, and D) is similar to that of the water in the wells near Casa Grande (section A).

In some places the dissolved-solids concentrations decrease with increasing depth, and a change in water type occurs. In the Willcox and Tucson areas, Pinal County, and in the Beardsley area the water type changes from a calcium bicarbonate to a sodium bicarbonate with increasing depth. In general, chemical analyses of the ground water in the Tucson area show a decrease in the amount of calcium relative to the amount of sodium with increasing depth in the upper water-bearing sand and gravel unit. The lower water-bearing unit contains sodium sulfate water south of Tucson and sodium bicarbonate water east of the Santa Cruz River, except where the unit is gypsiferous. Near Tucson, water to a depth of at least 2,000 feet in the lower unit generally contains less dissolved solids than the water in the upper unit. Along the southernmost reach of the Colorado River, water in the upper unit, which consists mainly of sand, silt, and clay, is slightly more saline than the water in the underlying gravel unit. Water in the gravel unit is generally more saline and contains more sodium chloride than the flow in the Colorado River. Electric logs of oil-test wells show that brackish water may be prevalent at depths of 2,000 or 3,000 feet below the land surface.

PLATEAU UPLANDS PROVINCE

This province includes a variety of landforms——canyons, buttes, mesas, and mountains. Although igneous and metamorphic rocks are the main rock types in the uplands, the sedimentary rocks form the most important aquifers. The sedimentary rocks are composed chiefly of sandstone, siltstone, claystone, and limestone. The sandstone and limestone units are capable of storing and transmitting water; whereas the siltstone and claystone units are highly impermeable and form confining beds——aquicludes——in most of the area.

The dissolved-solids concentrations in ground water vary areally and with depth and range from 90 to more than 60,000 mg/l in about 1,500 samples analyzed. Water in the Navajo, Wingate, Coconino, or De Chelly Sandstones on the Mogollon Slope, San Francisco Plateau, Navajo Uplands, and Defiance Plateau is the lowest in dissolved-solids content. The greatest dissolved-solids concentrations are in the water in the Black Mesa area north of the Little Colorado River; in places water in the Coconino Sandstone, in other water-bearing units in the consolidated rocks, and in the alluvium contains more than 5,000 mg/l dissolved solids.

In northeastern Arizona and northwestern New Mexico, most of the ground water occurs in the three multiple-aquifer systems——the D multiple-aquifer system, which consists of the Dakota Sandstone of Cretaceous age and the Morrison Formation and Cow Springs Sandstone of Jurassic age; the N multiple-aquifer system, which consists principally of the Navajo Sandstone of Jurassic and Triassic(?) age and the upper part of the Wingate Sandstone of Triassic age; and the C multiple-aquifer system, which consists principally of the Shinarump Member of the Chinle Formation of Triassic age and the Coconino, De Chelly, and Glorieta Sandstones of Permian age (Cooley and others, 1969). The chemical quality of the water in the three multiple-aquifer systems is shown in the diagrammatic section. Wells that tap the D multiple-aquifer system yield water that contains from 1,000 to 3,000 mg/l dissolved solids, and wells that tap the N multiple-aquifer system yield water that generally contains less than 1,000 mg/l dissolved solids. Wells that tap the C multiple-aquifer system yield water that contains from about 200 to more than 25,000 mg/l dissolved solids.

The principal constituents in the ground water in the uplands are bicarbonate, sulfate, calcium, sodium, and chloride. These constituents combine to form five general water types——calcium bicarbonate, sodium bicarbonate, sodium sulfate, calcium sulfate, and sodium chloride. Most water having less than 500 mg/l dissolved solids is classified as calcium bicarbonate or sodium bicarbonate, and most water having more than 500 mg/l is classified as sodium sulfate, calcium sulfate, or sodium chloride. Frequently, gradations occur between these chemical types, and much of the highly mineralized water is a bicarbonate sulfate type.

Concentrations of minor constituents——such as fluoride, nitrate, magnesium, silica, and iron——vary considerably in the ground water; except for the fluoride and nitrate, however, the concentrations are not objectionable for most uses. Nitrate concentrations are generally small in water from drilled wells and springs, but water from shallow dug wells may contain more than 45 mg/l nitrate.

In the Virgin River drainage basin in Utah many formations yield fresh water to wells. Among these are the Wahweap Sandstone of Cretaceous age, the Navajo Sandstone of Jurassic and Triassic(?) age, the Kaiparowits Formation of Cretaceous age, and limestones of Paleozoic age. Some of the limestone units contain salt water at depth. For example, samples from an oil well in T. 40 S., R. 13 W. showed 579 mg/l dissolved solids in the water between 410 and 1,440 feet; the well reportedly yielded salt water at a depth of 5,000 feet (Feltis, 1966).

Saline water occurs in several formations in the Virgin River drainage basin. Probably the most important are the Moenkopi Formation of Triassic age, the Carmel Formation of Jurassic age, and the Toroweap Formation and the Kaibab Limestone of Permian age, which yield salt water to wells and springs. Water from an oil well in the Moenkopi Formation in T. 41 S., R. 12 W. contains more than 84,000 mg/l of dissolved solids. Poor-quality water is to be expected in the Moenkopi in most areas because the formation contains interbedded evaporite deposits. La Verkin Hot Springs, which issue from the Kaibab Limestone, yield water containing more than 9,000 mg/l dissolved solids (Feltis, 1966).

Saline water is discharged into the Little Colorado River near its mouth from a group of springs in the Blue Spring area. The springs issue from the upper part of the Redwall Limestone of Mississippian age, and the water contains about 2,500 mg/l of dissolved solids.

CENTRAL HIGHLANDS PROVINCE

This province forms a topographic high that separates the Plateau uplands from the Basin and Range lowlands in most of the lower Colorado River region. The most prominent physiographic feature is the Mogollon Rim——an escarpment consisting mainly of Paleozoic sedimentary rocks——that extends from the White Mountains west-northwestward toward Jerome. The rim is the principal discharge area for ground water in the highlands, and many springs issue from the Coconino Sandstone and the underlying Supai Formation of Pennsylvanian and Permian age and the Redwall Limestone of Mississippian age. The intrusive igneous rocks——chiefly granite——are impervious and contain little space for the storage of water; in places, however, fractures developed along faults and joints provide open spaces for the storage of some ground water. Volcanic rocks crop out in much of the area, are permeable, and water moves readily through them and recharges the underlying ground-water reservoir. Thin alluvial deposits in a few small valleys also store ground water.

Springs along the Mogollon Rim and elsewhere in the Central highlands are the source of the perennial flow in the Gila, Salt, and Verde Rivers. Most of the available chemical-quality data indicate that the ground water generally contains less than 1,000 mg/l of dissolved solids. However, several springs yield saline water to streams; the most notable of these are Clifton Hot Springs near Clifton, Salt Banks on Salt River, White River Salt Springs near the confluence of the White and Black Rivers, and Verde Hot Springs near Childs (Feth and Hem, 1963). Clifton Hot Springs yield water from the alluvium along the San Francisco River. The water is a sodium chloride type and contains more than 9,000 mg/l dissolved solids. The high temperature and mineralization of the water indicate that it comes from a deep-seated source. Springs along the Salt River contribute large amounts of dissolved solids to the river. Salt Banks on Salt River yield sodium chloride water that contains more than 37,000 mg/l dissolved solids, and White River Salt Springs yield sodium chloride water that contains more than 8,000 mg/l dissolved solids. The Verde Hot Springs yield water of different chemical quality than that of the other saline springs. The water contains more than 3,000 mg/l dissolved solids and is of the sodium bicarbonate type.

Base from U.S. Geological Survey
State base maps 1:1,000,000

SCALE 1:1 000 000

25 0 25 50 75 100 MILES
25 0 25 50 75 100 KILOMETERS

DATUM IS MEAN SEA LEVEL

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D.C.—1973—W72218

Map showing generalized distribution of dissolved solids

QUALITY OF THE GROUND WATER IN THE LOWER COLORADO RIVER REGION, ARIZONA, NEVADA, NEW MEXICO, AND UTAH

By
L. R. Kister

1973

For sale by U.S. Geological Survey, price $1.00 per set