DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH THE
ARIZONA DEPARTMENT OF WATER RESOURCES

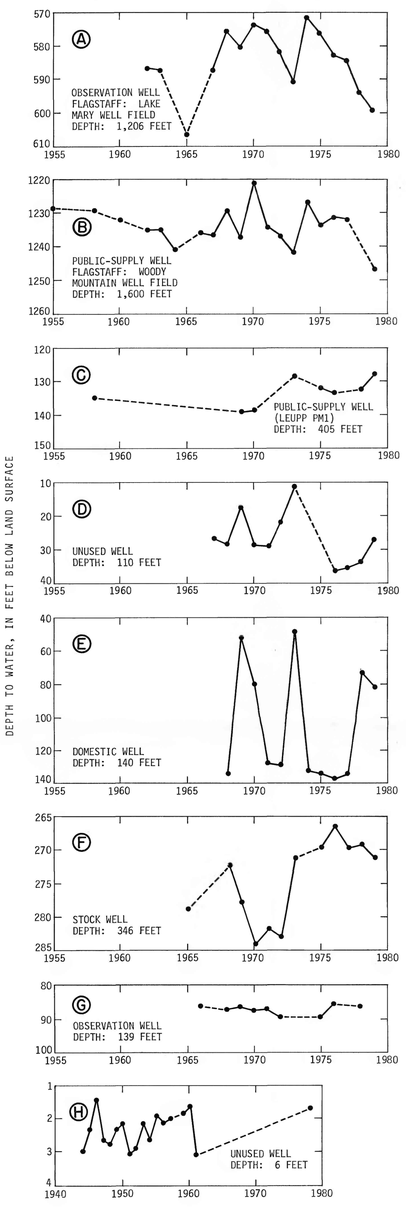
WATER-RESOURCES INVESTIGATIONS
OPEN-FILE REPORT 81-914
SHEET 1 OF 2

WELL DEPTH, DEPTH TO WATER, ALTITUDE OF THE WATER LEVEL, AND SPRING DISCHARGE

Composite stratigraphic column for the San Francisco Peaks area

System	Group, formation, or member	Letter symbol for geologic unit
Quaternary	Alluvium Glacial outwash	Qal Qg
Quaternary and Tertiary	Volcanic rocks	QTv
Triassic	Chinle Formation Petrified Forest Member Shinarump Member Moenkopi Formation	Trc Trcp Trcs Rm
Permian	Kaibab Limestone Toroweap Formation Coconino Sandstone Hermit Shale	Pk Pt Pc Ph
Permian and Pennsylvanian	Supai Group	PPs
Mississippian	Redwall Limestone	Mr
Devonian	Temple Butte Limestone	Dtb
Cambrian	Muav Limestone	Cm

HYDROGRAPHS OF THE WATER LEVEL IN SELECTED WELLS SHOWN ON THE MAP
[Dashed line indicates an inferred water level]



AREA OF REPORT (SHADED)

EXPLANATION

4400 — POTENTIOMETRIC CONTOUR—Shows approximate altitude at which water level would have stood in tightly cased well that penetrates the Coconino Sandstone and (or) Supai Group. Short dashed where uncertain. Contour interval 100 and 200 feet. Datum is mean sea level

3P-352 / Pc / 658 / 495M(1963) / 3715 — WELL IN WHICH DEPTH TO WATER WAS MEASURED IN 1978-79—First entry, 3P-352, is well name or number assigned by the Navajo Tribe; well numbers are not shown for off-reservation sites. Second entry, Pc, is principal geologic formation from which the well obtains its water (see composite stratigraphic column for explanation of letter symbol). Third entry, 658, is depth of well in feet. Fourth entry, 495M(1963), is depth to water in feet below land surface [M, depth to water measured; R, depth to water reported; E, depth to water estimated; (1963), year in which water level was determined if other than 1978-79]. Fifth entry, 3715, is altitude of the water level in feet above mean sea level

Mr / 48,000E(1950) / 3165 — SPRING FOR WHICH DISCHARGE WAS DETERMINED IN 1978-79—First entry, Mr, is principal geologic formation from which the spring issues (see composite stratigraphic column for explanation of letter symbol). Second entry, 48,000E(1950), is discharge of spring in gallons per minute [M, discharge measured; E, discharge estimated; (1950), year in which discharge was determined if other than 1978-79]. Third entry, 3165, is altitude of the land surface in feet above mean sea level

A — WELL FOR WHICH A HYDROGRAPH IS SHOWN

GENERALIZED DIRECTION OF GROUND-WATER FLOW IN THE COCONINO SANDSTONE AND (OR) SUPAI GROUP

ARBITRARY BOUNDARY OF GROUND-WATER AREA

INTRODUCTION

The San Francisco Peaks area includes about 2,300 mi^2, of which about 500 mi2 is in the Navajo Indian Reservation, in north-central Arizona. Groundwater development has been slight except for the public-supply wells for Flagstaff and domestic wells in Fort Valley, Pitman Valley, and the area west of Elden Mountain. The public water supply for Flagstaff is primarily from Upper Lake Mary but is supplemented by ground water from wells near Woody Mountain and Lower Lake Mary and from wells and springs in the Inner Basin. In 1978 about 2,000 acre-ft of ground water was withdrawn for public, industrial, domestic, and stock supplies in the San Francisco Peaks area.

The hydrologic data on which these maps are based are available, for the most part, in computer-printout form and may be consulted at the Arizona Department of Water Resources, 99 East Virginia, Phoenix, and at U.S. Geological Survey offices in: Federal Building, 301 West Congress Street, Tucson; Valley Center, Suite 1880, Phoenix; and 2255 North Gemini Drive, Building 3, Flagstaff. Material from which copies can be made at private expense is available at the Tucson, Phoenix, and Flagstaff offices of the U.S. Geological Survey. Only the springs for which discharge data are available are shown on the maps, and only selected wells are shown in areas of high well density.

GEOHYDROLOGY

The San Francisco Peaks area is underlain by a bedded sequence of sedimentary rocks, which generally is overlain by volcanic rocks in the southern part of the area. In places the sedimentary and volcanic rocks are overlain by glacial outwash and alluvium. Ground water is present in most of the geologic units (see composite stratigraphic column), and some of the units are hydraulically connected. Generally, the water occurs under water-table conditions; locally, however, the water is under artesian pressure and rises above the zone of saturation where tapped by wells. Well yields probably are more dependent on pump type and size than on aquifer characteristics. In places the Kaibab Limestone, Moenkopi Formation, Chinle Formation, volcanic rocks, glacial outwash, and alluvium contain perched ground water, which may be as much as 2,000 ft above the water table. The water is perched on the poorly permeable cherty limestone in the Kaibab Limestone, siltstone, mudstone, and clay beds in the Moenkopi and Chinle Formations, or on unfractured volcanic rocks, which impede downward movement.

In the eastern part of the area most wells obtain water from the Coconino Sandstone and sandstone beds in the upper part of the Supai Group. Near Leupp, the Kaibab Limestone is hydraulically connected to the sandstone beds in the underlying Coconino and Supai; siltstone beds in the lower part of the Supai restrict the vertical movement of water between the units above the siltstone beds and the units below. Near Leupp, the depth to water ranges from 75 to 140 ft below the land surface and increases westward and northward. The depth to water is more than 1,900 ft below the land surface near Sunset Crater and almost 1,600 ft in the Wupatki National Monument. The contours near the well in sec. 6, T. 25 N., R. 9 E., may indicate greater depth to water than actually occurs in that area owing to possible structural anomalies. Wells that penetrate the Coconino and Supai are 154 to 2,400 ft deep except for one well in T. 27 N., R. 9 E., which is 3,624 ft deep and bottoms in the Redwall Limestone; well yields are 4 to 560 gal/min. In the Coconino and Supai ground-water movement generally is northward. Between Cameron and the Coconino Rim, siltstone beds in the Supai are fractured owing to folding and faulting, and water in the overlying sandstone moves downward through the fractures into the underlying Redwall and Muav Limestones. Along the Little Colorado River north of the Coconino Rim, many springs issue from the Redwall and Muav Limestones. Some wells along the Little Colorado River obtain water from the alluvium, volcanic rocks, Shinarump Member of the Chinle Formation, or Moenkopi Formation. The depth to water in these units generally is less than 100 ft below the land surface, and most wells yield less than 50 gal/min. In and near the Wupatki National Monument springs issue from perched zones in the Moenkopi Formation and discharge less than 5 gal/min.

In the southwestern part of the area most wells and springs obtain water from the alluvium or volcanic rocks. The depth to water in these units ranges from 0 to more than 900 ft below the land surface, and wells are from 6 to 1,175 ft deep. Well yields and spring discharges from the alluvium and volcanic rocks range from less than 1 to 70 gal/min and fluctuate in response to precipitation, snowmelt, and runoff; occasionally, the wells and springs are dry. Most domestic wells yield less than 30 gal/min. West of Elden Mountain and near Babbitt Lake, some wells obtain water from the Chinle or Moenkopi Formations. Depth to water is 40 to more than 200 ft below the land surface, wells are 60 to 243 ft deep, and wells yield less than 20 gal/min. In the Inner Basin most wells and springs obtain water from the glacial outwash. The depth to water in the glacial outwash ranges from 0 to about 150 ft below the land surface, wells are 215 to 502 ft deep, and wells yield 300 to 859 gal/min. Near Flagstaff, Parks, and Babbitt Lake, some wells obtain water from the Kaibab Limestone. In the Kaibab Limestone water bodies are perched from about 30 to more than 400 ft below the land surface, wells are 47 to 437 ft deep, and wells generally yield less than 20 gal/min. Although the upper part of the Supai Group is at least partly saturated in most of the area, a well that penetrates the Supai near Parks was dry at a depth of 2,570 ft. Near Flagstaff, several deep wells obtain water from the Coconino Sandstone and Supai Group. Depth to water in the Coconino and Supai is 600 to more than 2,100 ft below the land surface, wells are 987 to 2,350 ft deep, and wells yield 30 to 860 gal/min.

In the northern part of the area several springs issue from the Redwall and Muav Limestones, but there are no known producing wells. At the north boundary, Blue Spring, which issues from the Redwall Limestone, flows into the Little Colorado River. In 1950 the discharge was estimated to be 107 ft^3/s or 48,000 gal/min. Blue Spring and several nearby springs sustain the base flow of the river at its mouth. Between 1952 and 1979, 14 discharge measurements were made of the combined discharge. The measured discharges ranged from 217 to 232 ft^3/s (97,400 to 104,000 gal/min) and averaged 223 ft^3/s (100,000 gal/min).

SELECTED REFERENCES

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Sellers, W. D., and Hill, R. H., eds., 1974, Arizona climate 1931-1972: Tucson, University of Arizona Press, 616 p.

U.S. Environmental Protection Agency, 1976 [1978], Quality criteria for water: U.S. Environmental Protection Agency publication, 256 p.

_____1977a, National interim primary drinking water regulations: U.S. Environmental Protection Agency Report, EPA-570/9-76-003, 159 p.

_____1977b, National secondary drinking water regulations: Federal Register, v. 42, no. 62, March 31, 1977, p. 17143-17147.

CONVERSION FACTORS

For readers who prefer to use the International System of Units (SI) rather than inch-pound units, the conversion factors for the terms used in this report are listed below:

Multiply inch-pound unit	By	To obtain SI unit
foot (ft)	0.3048	meter (m)
square mile (mi^2)	2.590	square kilometer (km^2)
acre-foot (acre-ft)	0.001233	cubic hectometer (hm^3)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

5 0 5 MILES
5 0 5 KILOMETERS

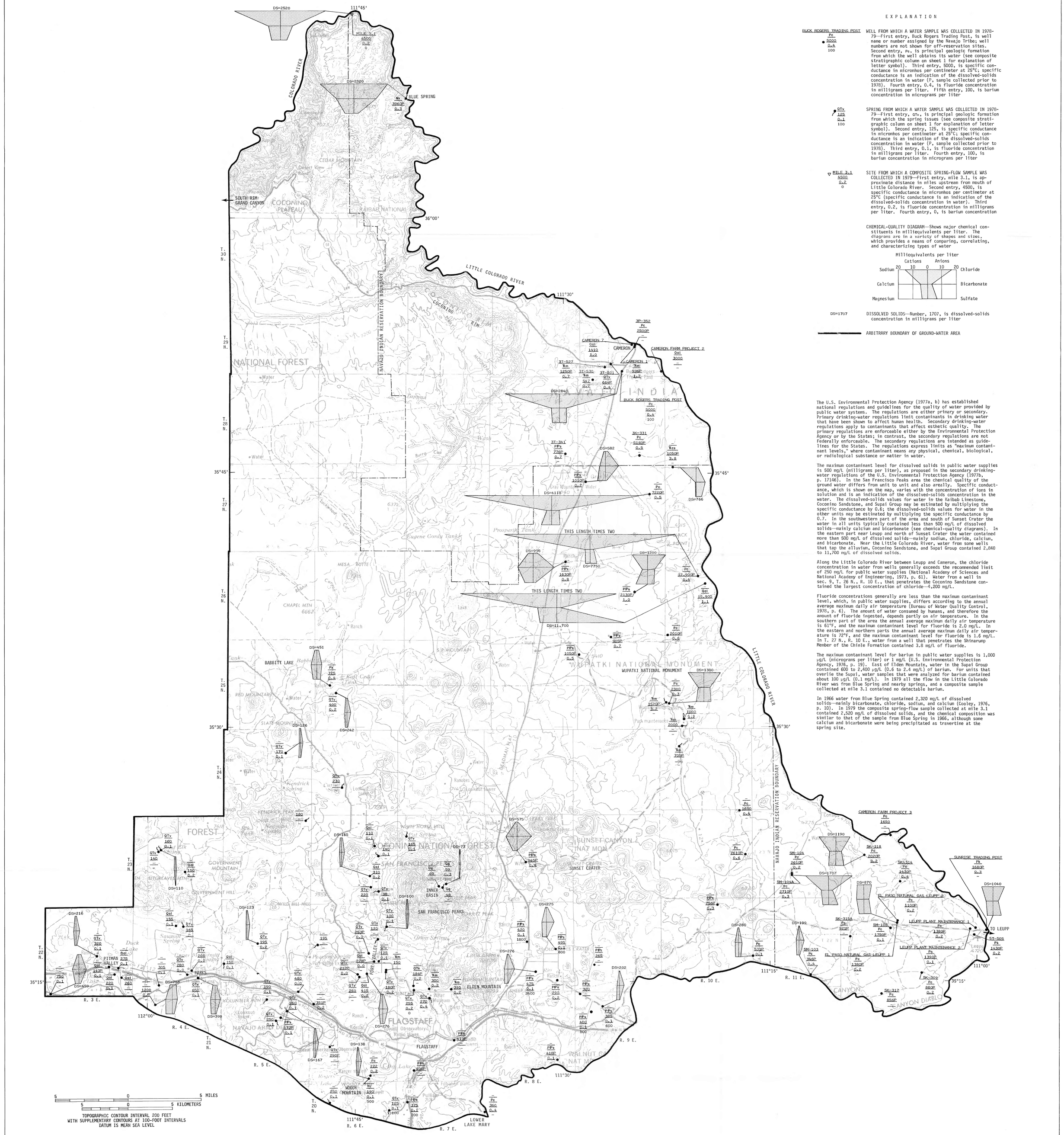
TOPOGRAPHIC CONTOUR INTERVAL 200 FEET
WITH SUPPLEMENTARY CONTOURS AT 100-FOOT INTERVALS
DATUM IS MEAN SEA LEVEL

BASE FROM U.S. GEOLOGICAL SURVEY
FLAGSTAFF 1:250,000, 1954-70,
MARBLE CANYON 1:250,000, 1956-63,
WILLIAMS 1:250,000, 1956

WELL DEPTH, DEPTH TO WATER, ALTITUDE OF THE WATER LEVEL, SPRING DISCHARGE,
AND HYDROGRAPHS OF THE WATER LEVEL IN SELECTED WELLS

MAPS SHOWING GROUND-WATER CONDITIONS IN THE SAN FRANCISCO PEAKS AREA, COCONINO COUNTY, ARIZONA—1979

BY
CYNTHIA L. APPEL AND DONALD J. BILLS



EXPLANATION

BUCK ROGERS TRADING POST
Pc
5000
0.4
100

WELL FROM WHICH A WATER SAMPLE WAS COLLECTED IN 1978-79—First entry, Buck Rogers Trading Post, is well name or number assigned by the Navajo Tribe; well numbers are not shown for off-reservation sites. Second entry, Pe, is principal geologic formation from which the well obtains its water (see composite stratigraphic column on sheet 1 for explanation of letter symbol). Third entry, 5000, is specific conductance in micromhos per centimeter at 25°C; specific conductance is an indication of the dissolved-solids concentration in water (P, sample collected prior to 1978). Fourth entry, 0.4, is fluoride concentration in milligrams per liter. Fifth entry, 100, is barium concentration in micrograms per liter

QTv
125
0.1
100

SPRING FROM WHICH A WATER SAMPLE WAS COLLECTED IN 1978-79—First entry, QTv, is principal geologic formation from which the spring issues (see composite stratigraphic column on sheet 1 for explanation of letter symbol). Second entry, 125, is specific conductance in micromhos per centimeter at 25°C; specific conductance is an indication of the dissolved-solids concentration in water (P, sample collected prior to 1978). Third entry, 0.1, is fluoride concentration in milligrams per liter. Fourth entry, 100, is barium concentration in micrograms per liter

MILE 3.1
4500
0.2
0

SITE FROM WHICH A COMPOSITE SPRING-FLOW SAMPLE WAS COLLECTED IN 1979—First entry, mile 3.1, is approximate distance in miles upstream from mouth of Little Colorado River. Second entry, 4500, is specific conductance in micromhos per centimeter at 25°C (specific conductance is an indication of the dissolved-solids concentration in water). Third entry, 0.2, is fluoride concentration in milligrams per liter. Fourth entry, 0, is barium concentration

CHEMICAL-QUALITY DIAGRAM—Shows major chemical constituents in milliequivalents per liter. The diagrams are in a variety of shapes and sizes, which provides a means of comparing, correlating, and characterizing types of water

DS=1707

DISSOLVED SOLIDS—Number, 1707, is dissolved-solids concentration in milligrams per liter

ARBITRARY BOUNDARY OF GROUND-WATER AREA

The U.S. Environmental Protection Agency (1977a, b) has established national regulations and guidelines for the quality of water provided by public water systems. The regulations are either primary or secondary. Primary drinking-water regulations limit contaminants in drinking water that have been shown to affect human health. Secondary drinking-water regulations apply to contaminants that affect esthetic quality. The primary regulations are enforceable either by the Environmental Protection Agency or by the States; in contrast, the secondary regulations are not Federally enforceable. The secondary regulations are intended as guidelines for the States. The regulations express limits as "maximum contaminant levels," where contaminant means any physical, chemical, biological, or radiological substance or matter in water.

The maximum contaminant level for dissolved solids in public water supplies is 500 mg/L (milligrams per liter), as proposed in the secondary drinking-water regulations of the U.S. Environmental Protection Agency (1977b, p. 17146). In the San Francisco Peaks area the chemical quality of the ground water differs from unit to unit and also areally. Specific conductance, which is shown on the map, varies with the concentration of ions in solution and is an indication of the dissolved-solids concentration in the water. The dissolved-solids values for water in the Kaibab Limestone, Coconino Sandstone, and Supai Group may be estimated by multiplying the specific conductance by 0.6; the dissolved-solids values for water in the other units may be estimated by multiplying the specific conductance by 0.7. In the southwestern part of the area and south of Sunset Crater the water in all units typically contained less than 500 mg/L of dissolved solids—mainly calcium and bicarbonate (see chemical-quality diagrams). In the eastern part near Leupp and north of Sunset Crater the water contained more than 500 mg/L of dissolved solids—mainly sodium, chloride, calcium, and bicarbonate. Near the Little Colorado River, water from some wells that tap the alluvium, Coconino Sandstone, and Supai Group contained 2,840 to 11,700 mg/L of dissolved solids.

Along the Little Colorado River between Leupp and Cameron, the chloride concentration in water from wells generally exceeds the recommended limit of 250 mg/L for public water supplies (National Academy of Sciences and National Academy of Engineering, 1973, p. 61). Water from a well in sec. 9, T. 26 N., R. 10 E., that penetrates the Coconino Sandstone contained the largest concentration of chloride—4,200 mg/L.

Fluoride concentrations generally are less than the maximum contaminant level, which, in public water supplies, differs according to the annual average maximum daily air temperature (Bureau of Water Quality Control, 1976, p. 6). The amount of water consumed by humans, and therefore the amount of fluoride ingested, depends partly on air temperature. In the southern part of the area the annual average maximum daily air temperature is 61°F, and the maximum contaminant level for fluoride is 2.0 mg/L. In the eastern and northern parts the annual average maximum daily air temperature is 72°F, and the maximum contaminant level for fluoride is 1.6 mg/L. In T. 27 N., R. 10 E., water from a well that penetrates the Shinarump Member of the Chinle Formation contained 3.8 mg/L of fluoride.

The maximum contaminant level for barium in public water supplies is 1,000 µg/L (micrograms per liter) or 1 mg/L (U.S. Environmental Protection Agency, 1976, p. 19). East of Elden Mountain, water in the Supai Group contained 600 to 2,400 µg/L (0.6 to 2.4 mg/L) of barium. For units that overlie the Supai, water samples that were analyzed for barium contained about 100 µg/L (0.1 mg/L). In 1979 all the flow in the Little Colorado River was from Blue Spring and nearby springs, and a composite sample collected at mile 3.1 contained no detectable barium.

In 1966 water from Blue Spring contained 2,320 mg/L of dissolved solids—mainly bicarbonate, chloride, sodium, and calcium (Cooley, 1976, p. 10). In 1979 the composite spring-flow sample collected at mile 3.1 contained 2,520 mg/L of dissolved solids, and the chemical composition was similar to that of the sample from Blue Spring in 1966, although some calcium and bicarbonate were being precipitated as travertine at the spring site.

BASE FROM U.S. GEOLOGICAL SURVEY
FLAGSTAFF 1:250,000, 1954-70,
MARBLE CANYON 1:250,000, 1956-63,
WILLIAMS 1:250,000, 1956

SPECIFIC CONDUCTANCE AND FLUORIDE AND BARIUM CONCENTRATIONS

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