GEOHYDROLOGY AND POTENTIAL HYDROLOGIC EFFECTS OF SURFACE COAL MINING OF THE SAN AUGUSTINE COAL AREA AND ADJACENT AREAS, CATRON AND CIBOLA COUNTIES, NEW MEXICO

By Robert G. Myers

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MANUEL LUJAN, JR., *Secretary*

U.S. GEOLOGICAL SURVEY

Dallas L. Peck, *Director*

For additional information write to:

District Chief
U.S. Geological Survey
Water Resources Division
Pinetree Corporate Centre
4501 Indian School Rd. NE, Suite 200
Albuquerque, New Mexico 87110

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
inch	25.4	millimeter
inch per year	25.4	millimeter
foot	0.3048	meter
mile	1.609	kilometer
acre	4,047	square meter
foot per day	0.3048	meter per day
foot per day	0.000353	centimeter per second
foot squared per day	0.0929	meter squared per day
square mile	2.590	square kilometer
acre-foot	1,233	cubic meter
acre-foot per year	1,233	cubic meter per year
gallon	3.785	liter
gallon	0.003785	cubic meter
gallon per minute	0.0631	liter per second
gallon per day	0.00004382	liter per second
gallon per day per square foot	0.0408	meter per day
gallon per day per foot	0.124	square meter per day

Temperature in degrees Fahrenheit (°F) can be converted to degrees Celsius (°C) as follows:

$$°C = 5/9(°F - 32)$$

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929--a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

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ABSTRACT

The San Augustine Coal Area is located in northwestern Catron County and southwestern Cibola County in west-central New Mexico. Coal is present in the Cretaceous Dakota Sandstone and in the upper and lower members of the Moreno Hill Formation of the Cretaceous Mesaverde Group. The coal that is being considered for surface mining is in the Moreno Hill Formation. Aquifers are present in the Triassic Chinle Formation; Cretaceous units, including the main body of the Dakota Sandstone, the Mancos Shale and intertongued Dakota Sandstone, and Mesaverde Group; the Tertiary Baca Formation and Datil Group; and the Quaternary alluvium. The potentiometric surface of each aquifer is controlled by the surface-water drainage system and topography. The water in these aquifers generally is fresh (dissolved-solids concentrations less than 1,000 milligrams per liter) but locally is brackish (dissolved-solids concentrations 1,000 to 10,000 milligrams per liter). The aquifers in the Dakota Sandstone, Mesaverde Group, and Quaternary alluvium would be affected most by mining activities in the area. Wells and springs within the excavated area would be destroyed. The major effect of mine dewatering or the production of large quantities of water for mining activities could be the lowering of water levels in existing wells.

Zuni Salt Lake and a small cinder-cone lake that contain brine (dissolved-solids concentrations greater than 100,000 milligrams per liter) are in a maar about 18 miles northwest of Quemado, New Mexico. This area has long been used by Pueblo Indians for religious purposes and for the production of salt. On October 28, 1985, the specific conductance of the water was 221,000 microsiemens per centimeter at 25 degrees Celsius in Zuni Salt Lake and was 148,000 microsiemens per centimeter at 25 degrees Celsius in the cinder-cone lake. Sodium and chloride are the dominant ions in both lakes. Several sources of surface water and ground water feed these lakes. The surface water generally is fresh, but the ground water varies from fresh to brine. Coal-mining activities within the subbasins that contribute surface-water runoff to Zuni Salt Lake could decrease the quality of the salt produced, the discharge from Smith Spring, and the volume of water in Zuni Salt Lake. Any activity that lowers the potentiometric surface of ground water in the Cretaceous sedimentary rocks within the vicinity of the Zuni Salt Lake maar could decrease the flow from brackish seeps in the maar and decrease the quantity of water in the maar-floor alluvium.

INTRODUCTION

The San Augustine Coal Area (fig. 1) consists of 448,920 acres in northwestern Catron County and southwestern Cibola County in west-central New Mexico (U.S. Bureau of Land Management, 1984). The U.S. Bureau of Land Management is considering leasing coal deposits on Federal lands within the area. The San Augustine Coal Area is part of the Salt Lake Coal Field of Trumball (1959) and McLellan and others (1984). Most of the San Augustine Coal Area is located in the Carrizo Wash basin (Snead, 1979); a small part is in the southern Zuni River basin and the North Plains closed basin (fig. 1). Coal is present in the Cretaceous Dakota Sandstone and the lower and upper members of the Cretaceous Moreno Hill Formation (McLellan and others, 1984). Other possible resources of the area include uranium (Morgan, 1980), petroleum (Foster, 1964), salt (Bradbury, 1967; San Filipo, 1982), cinders, and geothermal resources (Levitte and Gambill, 1980). The major industry in the area is cattle ranching.

Except for Cibola County, no regional geohydrologic study of the various aquifers has been done in the study area. Site specific studies of the Zuni Salt Lake area have been done, but a study of the relation of the Zuni Salt Lake area to the regional aquifers has not been completed. In order to plan development of the area and its resources, a description of the regional geohydrology is required. The effects of any local or regional development within the study area that may affect the hydrology of the Zuni Salt Lake area requires an understanding of the relation of the regional geohydrology and Zuni Salt Lake area. Therefore, the U.S. Geological Survey, in cooperation with the U.S. Bureau of Land Management, has done a study of the regional geohydrology and water resources of the San Augustine Coal Area and adjacent areas and a study of the relation of the Zuni Salt Lake area to the regional aquifers.

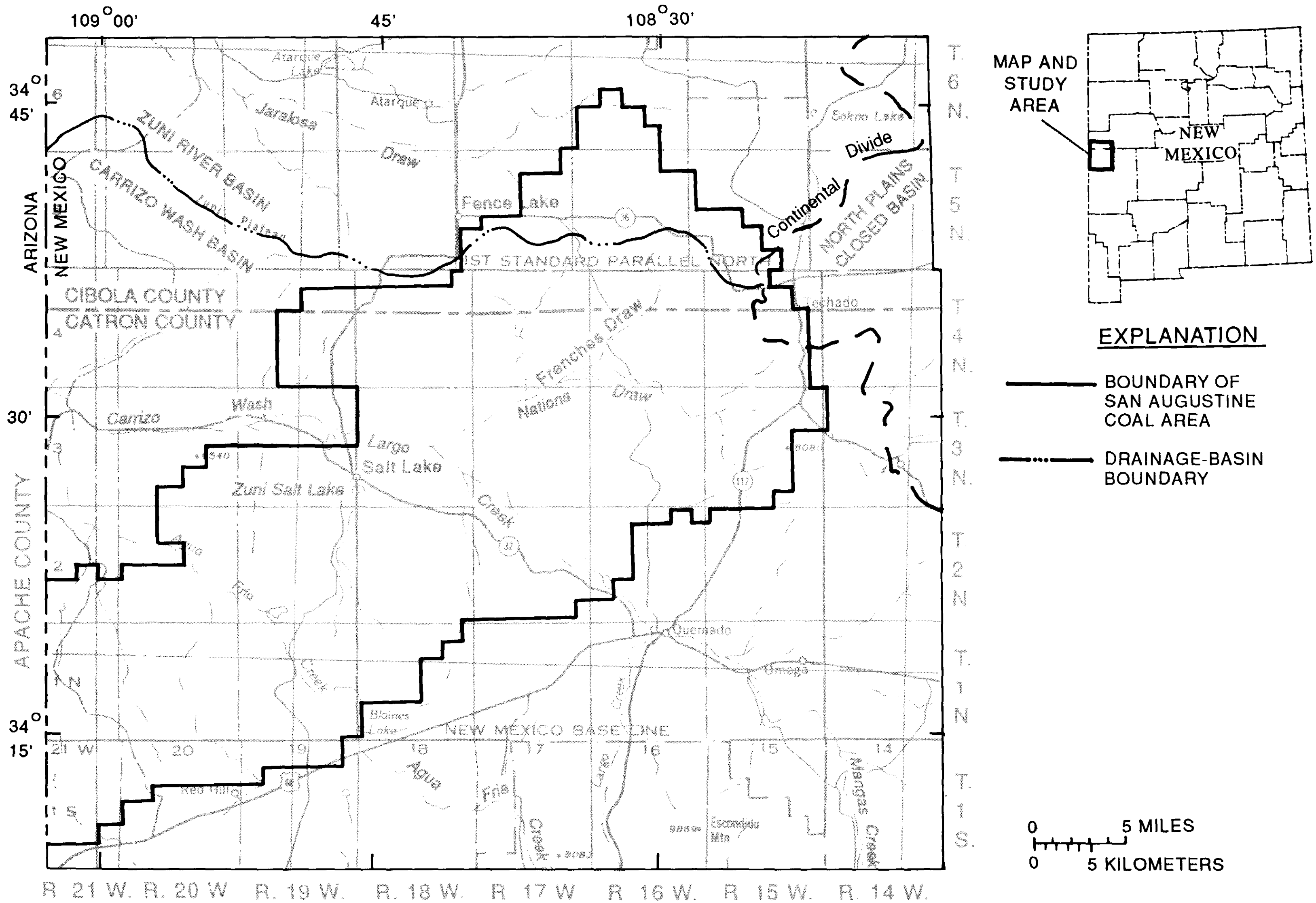
Purpose and Scope

This report describes the geohydrology of the San Augustine Coal Area and adjacent areas, and the possible effects of surface coal mining on the ground-water resources of the area and on Zuni Salt Lake. Coal that would be mined is in the Moreno Hill Formation of the Mesaverde Group. The report includes the compilation of geohydrologic data from published and unpublished sources, and the collection of new hydrologic data where none were available. No aquifer tests were conducted for this study.

Physiographic Description of the Study Area

The study area is characterized by mesas, broad valleys with ephemeral streams, and volcanic features. The altitude ranges from slightly less than 6,000 feet above sea level where Carrizo Wash crosses the New Mexico-Arizona State line on the west side of the study area to 9,869 feet above sea level at Escondido Mountain in the southeast part of the study area (fig. 1). The altitude of most of the area is less than 7,600 feet. The vegetation ranges from grasslands to piñon-juniper parklands (U.S. Bureau of Land Management, 1984).

The climate of the study area is semiarid with about 80 to 100 frost-free days per year. The average annual precipitation ranges from 9 to 15 inches (U.S. Bureau of Land Management, 1984). The maximum mean monthly temperature at Quemado is 67.7 degrees Fahrenheit in July; the minimum mean monthly temperature at Quemado is 30.0 degrees Fahrenheit in January (New Mexico Interstate Stream Commission and New Mexico State Engineer Office, 1975).



Base from U.S. Geological Survey, New Mexico, 1:500,000, 1980

Figure 1.--Location of San Augustine Coal Area, drainage basins, and study area.

System of Numbering Wells and Springs

The system of numbering wells and springs in New Mexico (fig. 2) is based on the common subdivision of public lands into sections. The well or spring number, in addition to designating the well or spring, locates its position to the nearest 10-acre tract in the land network. The number is divided by periods into four segments. The first segment denotes the township north or south of the New Mexico base line; the second denotes the range east or west of the New Mexico principal meridian; and the third denotes the section. The fourth segment of the number, which consists of three digits, denotes the 160-, 40-, and 10-acre tracts, respectively, in which the well or spring is situated. For this purpose, the section is divided into four quarters, numbered 1, 2, 3, and 4 in the normal reading order, for the northwest, northeast, southwest, and southeast quarters, respectively. The first digit of the fourth segment gives the quarter section, which is a tract of 160 acres. Similarly, the 160-acre tract is divided into four 40-acre tracts numbered in the same manner, and the second digit denotes the 40-acre tract. Finally, the 40-acre tract is divided into four 10-acre tracts, and the third digit denotes the 10-acre tract. Thus, well 03N.18W.31.113 is in the SW 1/4 of the NW 1/4 of the NW 1/4, section 31, Township 03 North, Range 18 West (fig. 2). If a well or spring cannot be located accurately within a 40-acre tract, zeros are used for both the second and third digits. The letters A, B, C, etc. are added to the last segment to designate succeeding wells or springs in the same 10-acre tract.

Where sections are irregularly shaped, the well or spring is located on the basis of a regular square section grid that is superimposed on the irregular section with the southeast corner and eastern section lines matching. The well or spring is then numbered by its location in the superimposed square grid.

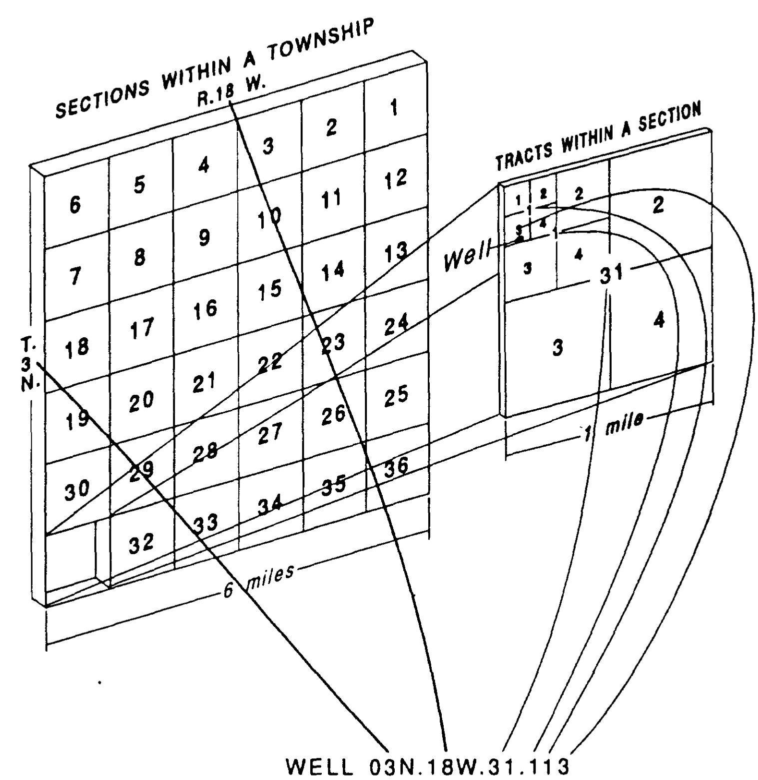


Figure 2.--System of numbering wells and springs in New Mexico.

Acknowledgments

The author acknowledges the assistance of numerous landowners in the area for providing access to their wells. The author thanks the Pueblo of Zuni and Mr. Rob Patterson of Rancho Alegre for allowing installation of recorders in the Zuni Salt Lake maar area.

REGIONAL GEOLOGIC SETTING

The study area is located in the Datil Section of the southern Colorado Plateau province (Fenneman, 1962; McLellan and others, 1984) on the Mogollon Slope, which dips gently toward the northeast. The area is characterized by several structural basins, sags, and upwarps. Rocks of Triassic, Jurassic, Cretaceous, Tertiary, and Quaternary age crop out throughout the study area (fig. 3). Current (1986) geologic investigations within some parts of the study area are redefining and renaming many of the Cretaceous and Tertiary units. The nomenclature for Cretaceous rocks used by several investigators within the study area is shown in figure 4. The broader definitions of some units and the geologic map of Dane and Bachman (1965) generally are used for continuity in this report because the current geologic investigations do not extend throughout the study area.

The structural features are the result of: Late Cretaceous to early Tertiary regional folding, thrust faulting, and volcanism; Oligocene volcanic activity and high-angle normal faulting in some areas; and tectonic activity after the Miocene deposition of the Fence Lake Formation from the northwest-flowing drainage of the Datil volcanic area, which caused a slight tilt to the northeast (McLellan and others, 1984). During the Cretaceous, a lobe of the Western Interior Seaway about 75 miles in diameter, known as Seboyeta Bay, expanded in a northerly, westerly, and southerly direction into western New Mexico (Hook and others, 1980). Eventually, Seboyeta Bay became indistinguishable from the Western Interior Seaway. Several periods of transgression and regression caused the intertonguing relation of the Cretaceous units within the study area.

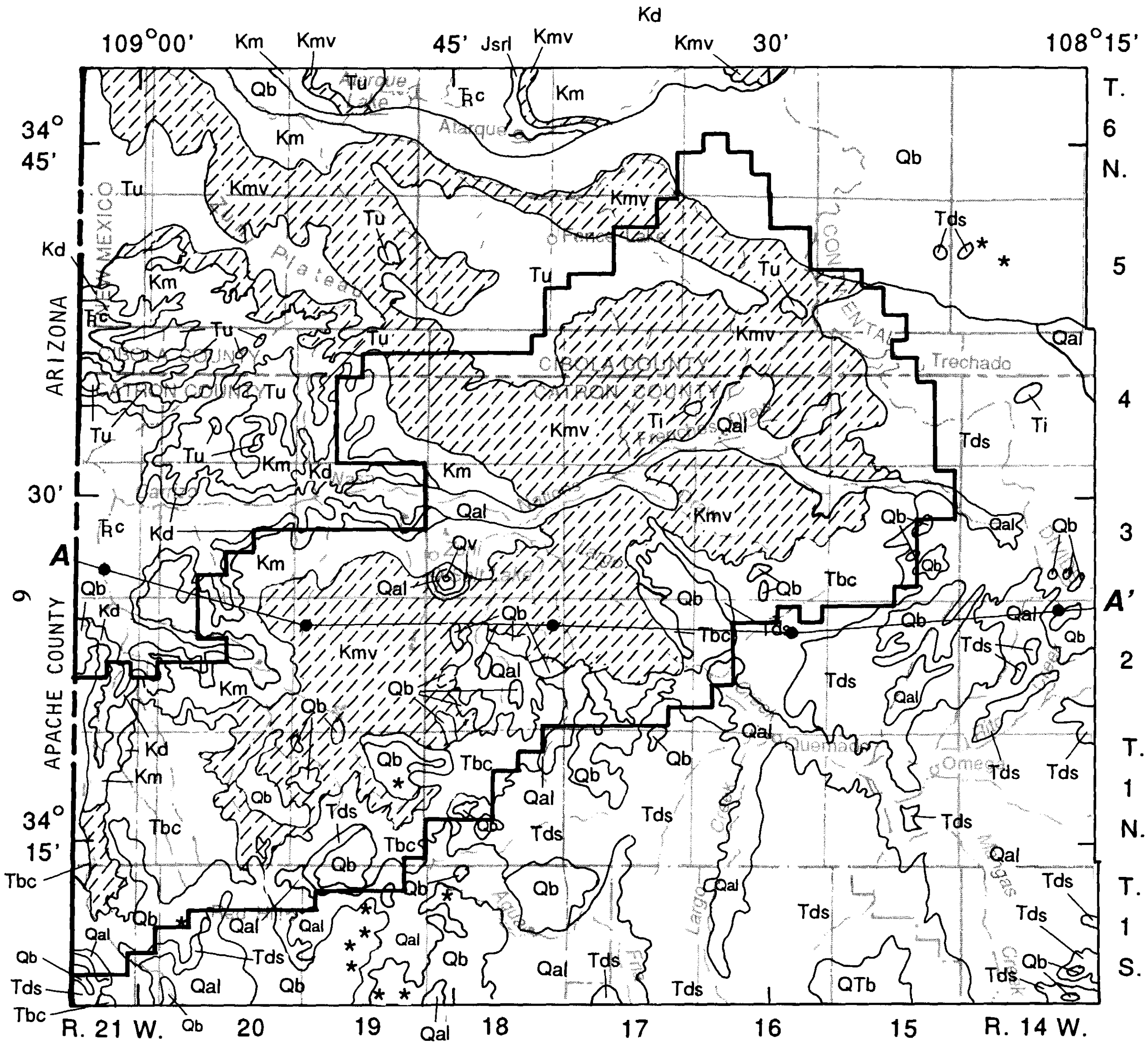
GEOHYDROLOGY

The aquifers described in this report are in the Triassic Chinle Formation; Cretaceous units, including the main body of the Dakota Sandstone, the Twowells and Paguate Tongues of the Dakota Sandstone, the Mancos Shale, and the Mesaverde Group; Tertiary units, including the Baca Formation, Datil Group, and Fence Lake Formation; and the Quaternary alluvium. Most of the aquifers in Triassic and Cretaceous rocks are semiconfined to confined aquifers. The potentiometric surfaces of most of the aquifers in the study area are controlled by the major surface-water drainage systems and the topography.

Most of the wells within the study area are stock or domestic wells that produce less than 10 gallons per minute. Records of selected wells, test holes, lakes, and springs are presented in table 1 (tables are in the back of the report).

The following terms are used to describe the dissolved-solids concentrations in water (Freeze and Cherry, 1979, p. 84): freshwater--dissolved-solids concentrations less than 1,000 milligrams per liter; brackish water--dissolved-solids concentrations between 1,000 and 10,000 milligrams per liter; saline water--dissolved-solids concentrations between 10,000 and 100,000 milligrams per liter; and brine--dissolved-solids concentrations greater than 100,000 milligrams per liter.

It was beyond the scope of this study to conduct aquifer tests. Any analysis of a test on existing wells would be complicated by the lack of lithologic and well-record data. In addition, many of the wells receive water from one or more aquifers. Aquifer tests of partially penetrating wells and wells completed in more than one aquifer would be of little use in determining the quantity of water within the aquifer. The data obtained from one well might not represent the hydrologic properties of the aquifer at another site within the study area because of the horizontal discontinuity of the interbedded lithologic units within the formation. Observation wells near the test wells also would be required to determine the storage coefficient within the aquifers. Personnel of the Salt River Project (1983) conducted two aquifer tests in the vicinity of Frenches Draw in the main body of the Dakota Sandstone and the Quaternary alluvium. The test in the main body of the Dakota Sandstone was conducted without observation wells. The New Mexico Bureau of Mines and Mineral Resources currently (1986) is developing a hydrogeologic model of the aquifers in Nations Draw in the vicinity of Frenches Draw (fig. 1).



Base from U.S. Geological Survey, New Mexico, 1:500,000, Dane and Bachman, 1965

0 — 5 MILES

0 — 5 KILOMETERS

VERTICAL SCALE GREATLY EXAGGERATED

DATUM IS SEA LEVEL

EXPLANATION

QUATERNARY	Qal	ALLUVIUM
	Qv	VOLCANICLASTICS
	Qb	BASALT FLOWS AND CINDER CONES (*)
QUATERNARY AND TERTIARY	QTb	BASALT TO BASALTIC ANDESITE
TERTIARY	Tu	FENCE LAKE FORMATION OR BIDAHOCHI FORMATION
	Ti	BASALTIC INTRUSIONS
	Tds	DATIL GROUP--Mostly volcaniclastics
	Tbc	BACA FORMATION
CRETACEOUS	Kmv	MESAVERDE GROUP
	Km	MANCOS SHALE AND INTERTONGUED DAKOTA SANDSTONE
	Kd	MAIN BODY OF THE DAKOTA SANDSTONE
JURASSIC	Jsrl	JURASSIC SEDIMENTARY ROCKS, UNDIFFERENTIATED
TRIASSIC	Ꝍc	CHINLE FORMATION
PERMIAN	Psa	SAN ANDRES LIMESTONE
	Pg	GLORIETA SANDSTONE
	Py	YESO FORMATION
	Pa	ABO FORMATION
PRECAMBRIAN	p€	PRECAMBRIAN ROCKS

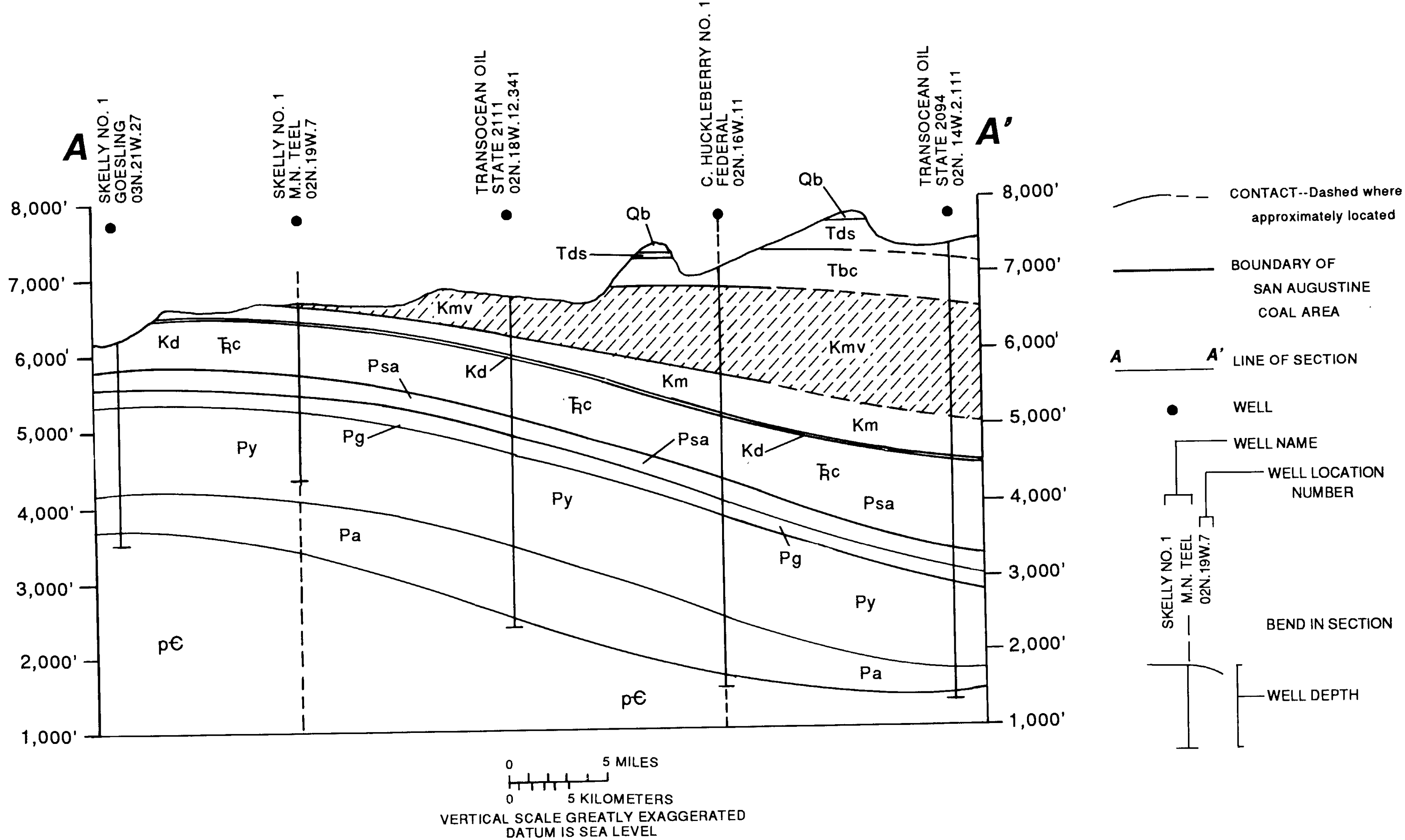


Figure 3.--Generalized geology of the study area (modified from Foster, 1964; and Dane and Bachman, 1965).

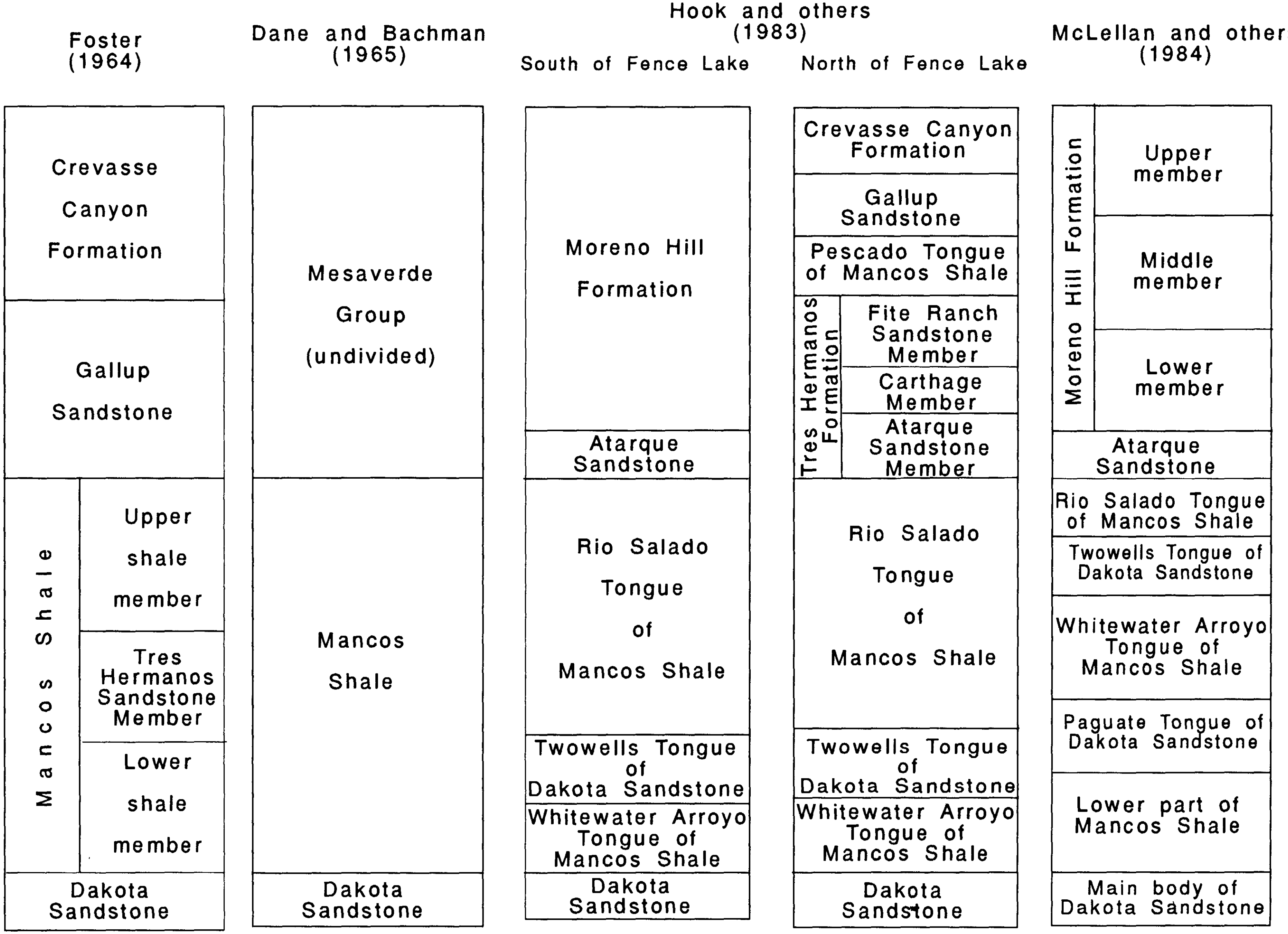


Figure 4.--Nomenclature for Cretaceous rocks of the study area.

Triassic Chinle Formation

The Triassic Chinle Formation underlies the Cretaceous Dakota Sandstone in the study area. An unconformity occurs between the Chinle Formation and the Dakota Sandstone. The Chinle Formation crops out in Carrizo Wash in the western part of the study area (fig. 3). The formation consists of reddish-brown to purple and light-greenish-gray to white claystone, shale, siltstone, and mudstone interbedded with thin lenses of poorly sorted sandstone and conglomerate (Willard and Weber, 1958; Foster, 1964; McLellan and others, 1984). About 60 percent of the formation within the study area is shale (Foster, 1964, p. 24). The maximum thickness of the Chinle Formation within the northern part of the study area and nearby Apache County, Arizona, is about 1,500 feet; the formation thins southwest of the study area in New Mexico and Arizona to 163 feet or less (Akers, 1964; Foster, 1964).

The Chinle Formation generally is a confining bed within the study area. Small quantities of water are produced from thin lenses of poorly sorted sandstone and conglomerate where the formation crops out in the Carrizo Wash basin in Arizona (Akers, 1964) and New Mexico. Some wells might obtain water from the Chinle Formation and the overlying Quaternary alluvium. Secondary porosity in the form of fractures can increase production in some areas. A few wells in the Zuni River basin are completed in the Chinle Formation in Township 06 North and Ranges 18 and 19 West (J.A. Baldwin, U.S. Geological Survey, written commun., 1986). Data, however, are insufficient to construct a potentiometric-surface map of the Chinle.

Recharge to the Chinle Formation is from precipitation on the outcrops and from flow in the stream channels where the formation is exposed. Some water also might leak upward from the underlying Permian San Andres Limestone and Glorieta Sandstone. The aquifer in the overlying main body of the Dakota Sandstone and Quaternary alluvium also might contribute water to the permeable material in the top of the Chinle Formation or to the fractures in the impermeable material of the Chinle Formation.

The water in the Chinle Formation ranges from freshwater in the Zuni River basin to brackish water in the Carrizo Wash basin. The specific conductance of water in the Zuni River basin ranges from 520 to 930 microsiemens (microsiemens per centimeter at 25 degrees Celsius) (tables 1 and 2). The dominant ions are sodium and bicarbonate. North of the study area, as the specific conductance of water from the Zuni River basin increases, the calcium concentration might be equal to or greater than sodium, and the sulfate concentration increases, but bicarbonate is still the dominant anion. The specific conductance of water in the Carrizo Wash basin ranges from about 2,200 microsiemens in New Mexico (tables 1 and 2) to 5,160 microsiemens in water from a well about 8 miles east of St. Johns, Arizona (Akers, 1964, p. 64, 65, 68). The dominant ions in water from the well in Arizona are sodium and sulfate.

Cretaceous Units

Dakota Sandstone

The fluvial to marine Cretaceous Dakota Sandstone overlies the Triassic Chinle Formation and underlies and intertongues with the Cretaceous Mancos Shale within the study area. About 20 to 60 feet of Dakota Sandstone crops out in the Carrizo Wash area (O'Brien, 1956; Crutcher, 1958; Foster, 1964). The thickness of the Dakota Sandstone ranges from 20 to 102 feet according to Foster (1964) and is as much as 190 feet according to Hook and others (1980). Hook and others (1980) and McLellan and others (1984) assigned two sandstone units in Foster's (1964) Mancos Shale to the Twowells Tongue and Paguate Tongue of the Dakota Sandstone; Foster's (1964) Dakota Sandstone is referred to as the "main body" in this report (fig. 4). The overlying Twowells Tongue of the Dakota Sandstone is separated from the underlying Paguate Tongue of the Dakota Sandstone by the Whitewater Arroyo Tongue of the Mancos Shale. The Dakota Sandstone is an interbedded, pale-orange to light-gray to white, very fine to medium-grained, sometimes conglomeratic, argillaceous, or silty sandstone with yellow, light-gray, and black calcareous or carbonaceous shale and some basal conglomerate (Foster, 1964). The lowest Cretaceous coal zone is present as thin beds in the main body of the Dakota Sandstone (McLellan and others, 1984).

Few wells are completed in the main body of the Dakota Sandstone in the Carrizo Wash basin (table 1). Most wells are in or near the outcrop area. Most of the wells completed in the Dakota Sandstone are in the Zuni River basin and North Plains closed basin (J.A. Baldwin, U.S. Geological Survey, written commun., 1986).

Secondary porosity in the form of fractures can increase the permeability of the Dakota Sandstone. Recharge to the main body of the Dakota Sandstone is from areas where the formation crops out. The altitude of the potentiometric surface of the aquifer in the main body of the Dakota Sandstone is shown in figure 5. The flow of ground water in the Dakota Sandstone in the Zuni River basin north of the Zuni Plateau is toward Jaralosa Draw and northwest toward Arizona. Data are insufficient to determine the direction of ground-water flow in the main body of the Dakota Sandstone in the Carrizo Wash basin.

Several wells in the study area are completed in the Twowells and Paguate Tongues of the Dakota Sandstone. Determining which tongues of the Dakota Sandstone the wells are completed in is difficult due to a lack of geologic and well-completion data. Because the Mancos Shale might contribute some water to these wells, they will be described in the following section about the Mancos Shale.

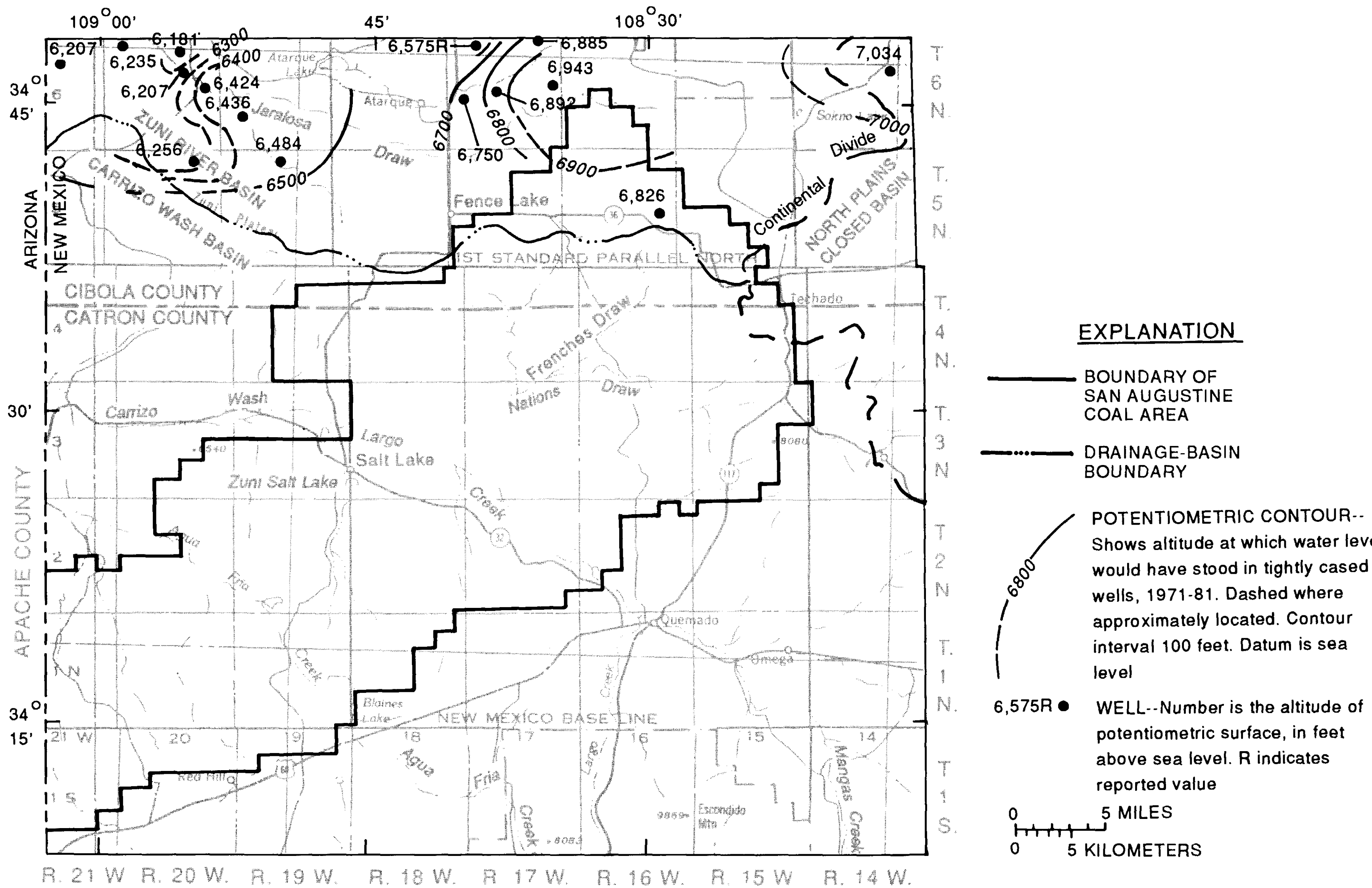
The Salt River Project (1983) completed and tested a flowing artesian well (04N.17W.36.121) in the main body of the Dakota Sandstone in 1983. The well is 1,080 feet deep and penetrates the main body of the Dakota Sandstone from 957 to 1,062 feet below land surface. The well flowed at a rate of 122 gallons per minute before the test was started. The well was pumped at 350 gallons per minute for 28.5 hours. Artesian flow resumed within 3 minutes after the test was completed. The transmissivity of the aquifer was estimated to be 5,300 gallons per day per foot (Salt River Project, 1983, p. 25) or 700 feet squared per day. The hydraulic conductivity was 50.5 gallons per day per square foot or 6.8 feet per day. Davis (1969, p. 70) reported that the horizontal hydraulic conductivity of sandstone generally ranges from 3.7×10^{-4} to 1.95 feet per day, whereas Morris and Johnson (1967, p. D18) reported that the average horizontal hydraulic conductivity of fine-grained sandstone ranges from 1.3×10^{-3} to 6.4 feet per day. Because no observation wells were completed in the confined aquifer in the main body of the Dakota Sandstone, a storage coefficient could not be determined from the aquifer test.

Risser and Lyford (1983, p. 19-20) reported the transmissivity of the Dakota Sandstone in the Pueblo of Laguna area north of the study area to be about 2,000 feet squared per day (15,000 gallons per day per foot) with an estimated hydraulic conductivity of 100 feet per day (750 gallons per day per square foot). Fractures in the Dakota Sandstone might account for the large transmissivity and hydraulic-conductivity values. North of the Pueblo of Laguna in the San Juan Basin, Stone and others (1983, p. 38) reported that the transmissivity of the Dakota Sandstone ranges from 49 to 105 feet squared per day (370 to 790 gallons per day per foot) and the hydraulic conductivity ranges from 0.0004 to 1.5 feet per day (0.003 to 11.2 gallons per day per square foot).

Water in the Dakota Sandstone is fresh to brackish in the Zuni River basin. The specific conductance of water ranges from 340 to 2,800 microsiemens (tables 1 and 2). In the North Plains closed basin, the water is fresh, and the specific conductance ranges from 290 to 441 microsiemens (tables 1 and 2). In the Carrizo Wash basin, water in the main body of the Dakota Sandstone is fresh; the specific conductance ranges from 500 to 850 microsiemens (tables 1 and 2). The dominant ions in water in the main body of the Dakota Sandstone throughout the study area generally are sodium and bicarbonate. Exceptions are in the areas near well 06N.20W.04.233 (sodium and sulfate) and well 06N.21W.10.222 (calcium and sulfate).

Mancos Shale

The marine Cretaceous Mancos Shale underlies the Mesaverde Group of Willard and Weber (1958) and Dane and Bachman (1965) or the Atarque Sandstone of Hook and others (1983); the Mancos overlies and intertongues with the Dakota Sandstone. The Mancos Shale is light- to dark-gray shale and siltstone with occasional yellow to light-tan quartzose sandstone (Willard and Weber, 1958). Foster (1964) divided the Mancos Shale into three units: a lower shale member, the Tres Hermanos Sandstone Member, and an upper shale member (fig. 4). Hook and others (1980) divided the Mancos Shale into the Whitewater Arroyo Tongue, which underlies the Twowells Tongue of the Dakota



Base from U.S. Geological Survey, New Mexico, 1:500,000, 1980

Figure 5.--Altitude of the potentiometric surface of the aquifer in the Dakota Sandstone.

Sandstone and overlies the Paguate Tongue of the Dakota Sandstone, and the "lower part" of the Mancos Shale, which underlies the Paguate Tongue of the Dakota Sandstone and overlies the main body of the Dakota Sandstone. Hook and others (1983) divided the Mancos Shale into two main tongues: (1) in the area south of Fence Lake, the Whitewater Arroyo Tongue between the overlying Twowells Tongue of the Dakota Sandstone and the underlying main body of the Dakota Sandstone; and (2) in the area north of Fence Lake, the Rio Salado Tongue between the overlying Atarque Sandstone Member of the Tres Hermanos Formation and underlying Twowells Tongue of the Dakota Sandstone (fig. 4). Where it pinches out, the Pescado Tongue of the Mancos Shale north of Fence Lake underlies the Gallup Sandstone and overlies the Tres Hermanos Formation (Hook and others, 1983). Foster (1964) indicated a maximum thickness of slightly more than 500 feet for all members of the Mancos Shale within the study area, which would be considerably less if the interbedded sandstone units were considered to be tongues of the Dakota Sandstone.

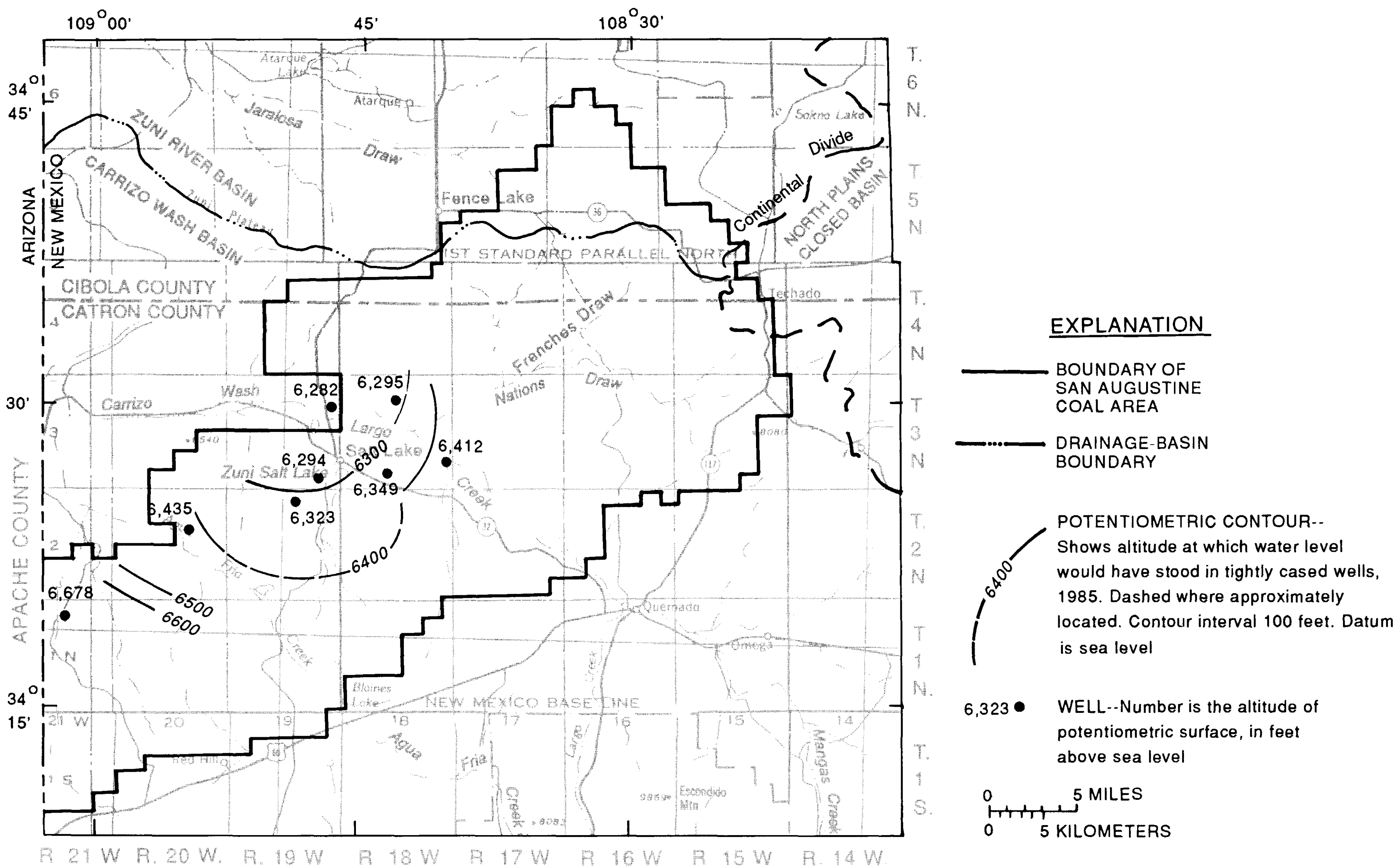
Willard (1957) and Willard and Weber (1958) showed Mancos Shale cropping out in the vicinity of Zuni Salt Lake and the Mancos Shale contact with the overlying Mesaverde Group to the south of Zuni Salt Lake. Dane and Bachman (1957, 1965) and Cummings (1968) showed the Mesaverde Group exposed up to and including part of the Zuni Salt Lake area. Willard (1957) and Willard and Weber (1958) also showed Mancos Shale cropping out in some of the drainages not shown by Dane and Bachman (1957, 1965). The Dane and Bachman (1957, 1965) and Cummings (1968) interpretations of the contact of the Mancos Shale with the overlying Mesaverde Group might be more accurate than those of Willard (1957) and Willard and Weber (1958) because outcrops of the Mesaverde Group --sandstone, shale, and mudstone with carbonaceous layers--are exposed in the wall of the Zuni Salt Lake maar. The difference in the mapping of the units could mean that some wells assigned to the Mancos Shale-Dakota Sandstone tongues might be completed partially or entirely in the Mesaverde Group, or that some wells assigned to the Mesaverde Group might be completed partially or entirely in the Mancos Shale-Dakota Sandstone tongues. It was beyond the scope of this study to determine the actual contact between and thickness of the Mesaverde Group and Mancos Shale.

In this report, the major sandstone beds of Foster (1964) are considered to be the Twowells and Paguate Tongues of the Dakota Sandstone. The Mancos Shale is considered an impermeable confining unit except in those areas where there are some thin sandstone lenses not assigned to the Dakota Sandstone and where secondary porosity is caused by fractures in the shale. Wells in this report listed as completed in both the Mancos Shale and Dakota Sandstone (tables 1 and 2) probably receive most of their water from the tongues of the Dakota Sandstone. Some of these wells and the wells completed only in the Mancos Shale receive water from the thin sandstone lenses or fractures in the Mancos Shale. Determining the source of the water is difficult because of the lack of well-completion and lithologic data.

The altitude of the potentiometric surface of the aquifer in the Mancos Shale and in the Paguate and Twowells Tongues of the Dakota Sandstone is shown in figure 6. In the Carrizo Wash basin, the direction of ground-water flow is toward Carrizo Wash and then west toward Arizona. The water is fresh to brackish. The specific conductance ranges from 900 to 3,500 microsiemens (tables 1 and 2).

Mesaverde Group

The marine to nonmarine Mesaverde Group (Dane and Bachman, 1965) overlies and intertongues with the Mancos Shale and underlies Tertiary formations within the study area. In the southern part of the study area, the Mesaverde Group has a maximum thickness of about 1,140 feet (Foster, 1964); in the northern part of the study area, the thickness ranges from about 200 to about 900 feet from west to east (McLellan and others, 1983; Campbell, 1984). Recent work in the northern part of the study area, especially by the New Mexico Bureau of Mines and Mineral Resources and the U.S. Geological Survey, is redefining the earlier divisions of the Mesaverde Group. Foster (1964) divided the Mesaverde Group into the lower Gallup Sandstone and the upper Crevasse Canyon Formation (fig. 4). South of Fence Lake, where the Pescado Tongue of the Mancos Shale pinches out, Hook and others (1983), McLellan and others (1983), and Molenaar (1983) divided the Mesaverde Group overlying the Rio Salado Tongue of the Mancos Shale into the lower marine Atarque Sandstone and the upper nonmarine coal-bearing Moreno Hill Formation. McLellan and others (1984) divided the Moreno Hill Formation into lower, middle, and upper members (fig. 4). North of Fence Lake, Hook and others (1983) and Molenaar (1983) divided the Mesaverde



Base from U.S. Geological Survey,
New Mexico, 1:500,000, 1980

Figure 6.--Altitude of the potentiometric surface of the aquifer in the Mancos Shale and Paguate and Twowells Tongues of the Dakota Sandstone.

Group overlying the Pescado Tongue of the Mancos Shale into the lower Gallup Sandstone and upper Crevasse Canyon Formation; the Mesaverde Group between the Pescado Tongue and the Rio Salado Tongue of the Mancos Shale is known as the Tres Hermanos Formation, which is divided into the lower marine Atarque Sandstone Member, the middle nonmarine Carthage Member, and the upper marine Fite Ranch Sandstone Member (fig. 4). The Fite Ranch Sandstone Member probably is not present within the study area.

The Mesaverde Group consists of yellow and reddish-brown sandstone, siltstone, mudstone, and conglomerate with gray shale (Willard, 1957; Willard and Weber, 1958). The coal beds, which are being considered for mining, are in the upper and lower members of the Moreno Hill Formation (McLellan and others, 1984).

More stock, domestic, and test wells are completed in the aquifer in the Mesaverde Group within the study area than in any other unit. In this report, the Mesaverde Group is considered as a single aquifer because many of the new formation and member names have not been extended throughout the study area. The numerous new stratigraphic boundaries do not appear to form regional hydrologic boundaries. Water locally is under semiconfined to confined conditions in the aquifer due to localized changes in lithology within the various formations and members. On a regional scale, the locally semiconfined and water-yielding zones are hydraulically connected. Secondary porosity in the form of fractures increases permeability in some areas.

The altitude of the potentiometric surface of the aquifer in the Mesaverde Group is shown in figure 7. The direction of ground-water flow in the aquifer is controlled by the surface-water drainage system and the topography. Ground water flows northeastward in the northeastern corner of the study area north of a high along the Continental Divide and north of Techado. The direction of ground-water flow in the Zuni River basin is toward Jaralosa Draw and northwest toward Arizona. The direction of ground-water flow in the Carrizo Wash basin is toward Frenches Draw, Carrizo Wash, and Largo Creek, and then west toward Arizona.

Recharge to the aquifer in the Mesaverde Group is from precipitation and runoff on the outcrops. Some water might come from the overlying Tertiary Baca Formation and Datil Group. Stone (1984) estimated the recharge of the Mesaverde Group overlain by 6 to 54 feet of Quaternary alluvium in the Frenches Draw area to be about 0.05 inch per year.

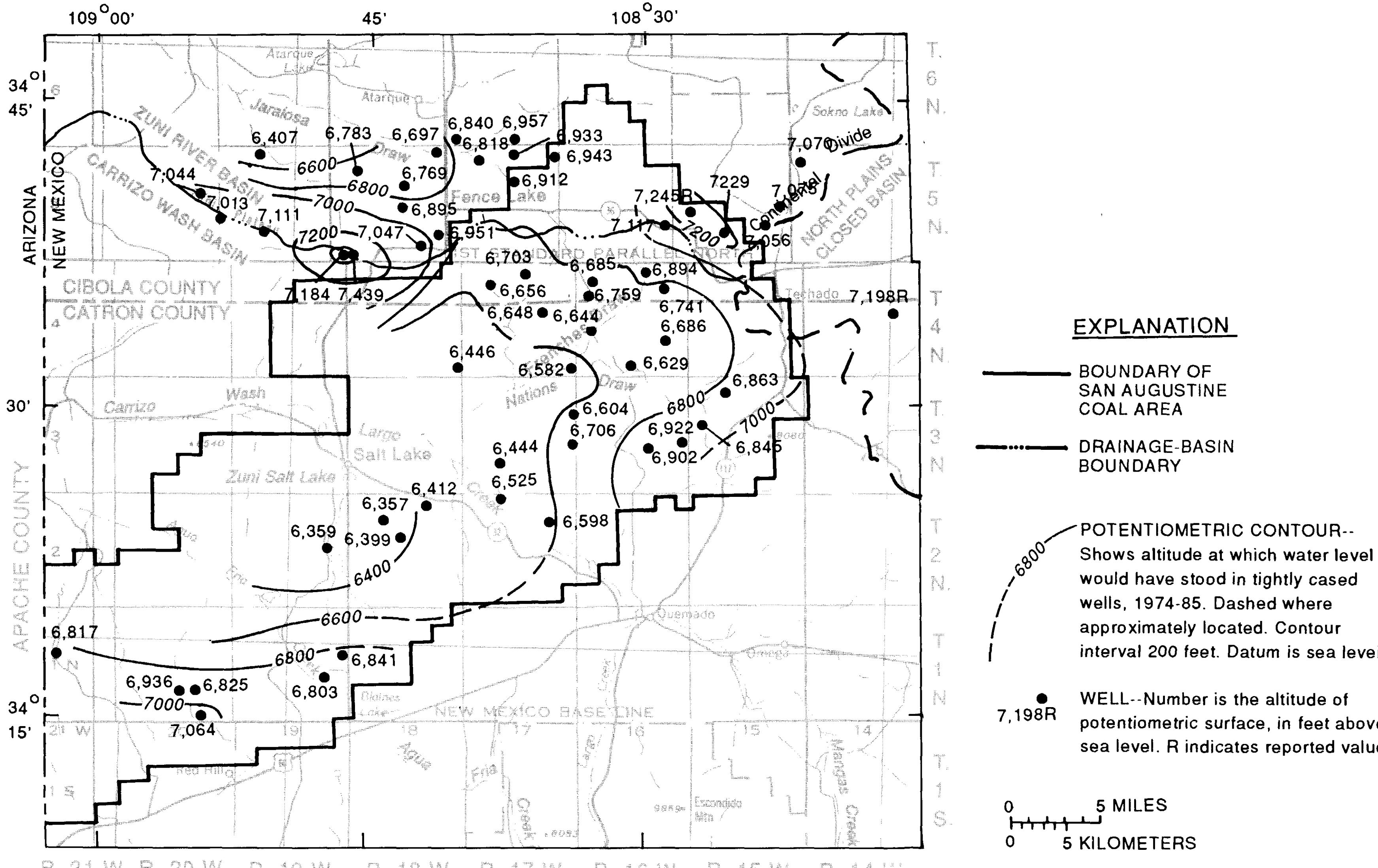
The water in the aquifer in the Mesaverde Group generally is fresh, though a few wells in the Carrizo Wash basin yield brackish water. The specific conductance of water in the North Plains closed basin ranges from 330 to 900 microsiemens (tables 1 and 2). In the Zuni River basin, the specific conductance of water ranges from 280 to 1,350 microsiemens (tables 1 and 2). In the Carrizo Wash basin, the specific conductance of water ranges from 350 to 2,000 microsiemens (tables 1 and 2). Water in the study area with smaller specific conductance mostly is from sandstone, whereas water with larger specific conductance is partially or totally derived from mudstone and shale, which might include coal or carbonaceous material.

The dominant ions in the water in the aquifer in the Mesaverde Group are calcium or sodium and sulfate or bicarbonate. The sulfate concentration usually increases with increases in specific conductance. Sulfate is the dominant anion in most of the water with a specific conductance more than 1,000 microsiemens; bicarbonate is the dominant anion in most of the water with a specific conductance less than 1,000 microsiemens.

Tertiary Units

Baca Formation

The Tertiary Baca Formation (Foster, 1964; Dane and Bachman, 1965) overlies the Cretaceous Mesaverde Group and underlies the Tertiary Datil Formation (Foster, 1964; Dane and Bachman, 1965) or the Datil Group (Weber, 1971; Osburn and Chapin, 1983). The Baca Formation crops out in the southern part of the study area (fig. 3). The formation consists of red, yellow, and gray sandstone, arkosic sandstone, and shale with numerous lenses



Base from U.S. Geological Survey, New Mexico, 1:500,000, 1980

Figure 7.--Altitude of the potentiometric surface of the aquifer in the Mesaverde Group.

of conglomerate (Foster, 1964). The Baca Formation might be as much as 700 feet thick (Trauger, 1967, p. 217). The formation thins toward the north and is absent in some areas where the Datil Group directly overlies the Mesaverde Group (Foster, 1964; Dane and Bachman, 1965).

The altitude of the potentiometric surface of the aquifer in the Baca Formation is shown in figure 8. Ground water flows west and north toward Largo Creek in the eastern part of the study area and north in the western part of the study area.

Recharge to the aquifer in the Baca Formation is from precipitation and runoff on the outcrop areas. Some water might come from the aquifer in the overlying Datil Group. Water from the Baca Formation also might recharge the underlying aquifer in the Mesaverde Group.

The aquifer in the Baca Formation yields small quantities of water to wells in several areas adjacent to the San Augustine Coal Area. Few hydrochemical data are available for water from the aquifer in the Baca Formation within the study area. The water in the Carrizo Wash basin generally is fresh. The specific conductance of the water ranges from 400 to 520 microsiemens (tables 1 and 2). The dominant ions of the water in the area of well 01S.19W.01.223 are sodium and bicarbonate.

Datil Group

The Tertiary Datil Group (Weber, 1971; Osburn and Chapin, 1983) overlies the Tertiary Baca Formation and the Cretaceous Mesaverde Group. The Datil Group is several thousand feet thick south of the study area, thins toward the north, and eventually disappears in the northern part of the study area. The Datil Group is only a few hundred feet thick throughout most of the study area. The Datil Group within the study area mostly consists of a volcanic sediment facies of reddish-gray or greenish-gray to gray mudstone, siltstone, sandstone, and conglomerate composed of volcaniclastics and locally thin beds of rhyolite tuff (Willard, 1957; Willard and Weber, 1958). This unit previously was known as the Tertiary Datil Formation (Foster, 1964; Dane and Bachman, 1965).

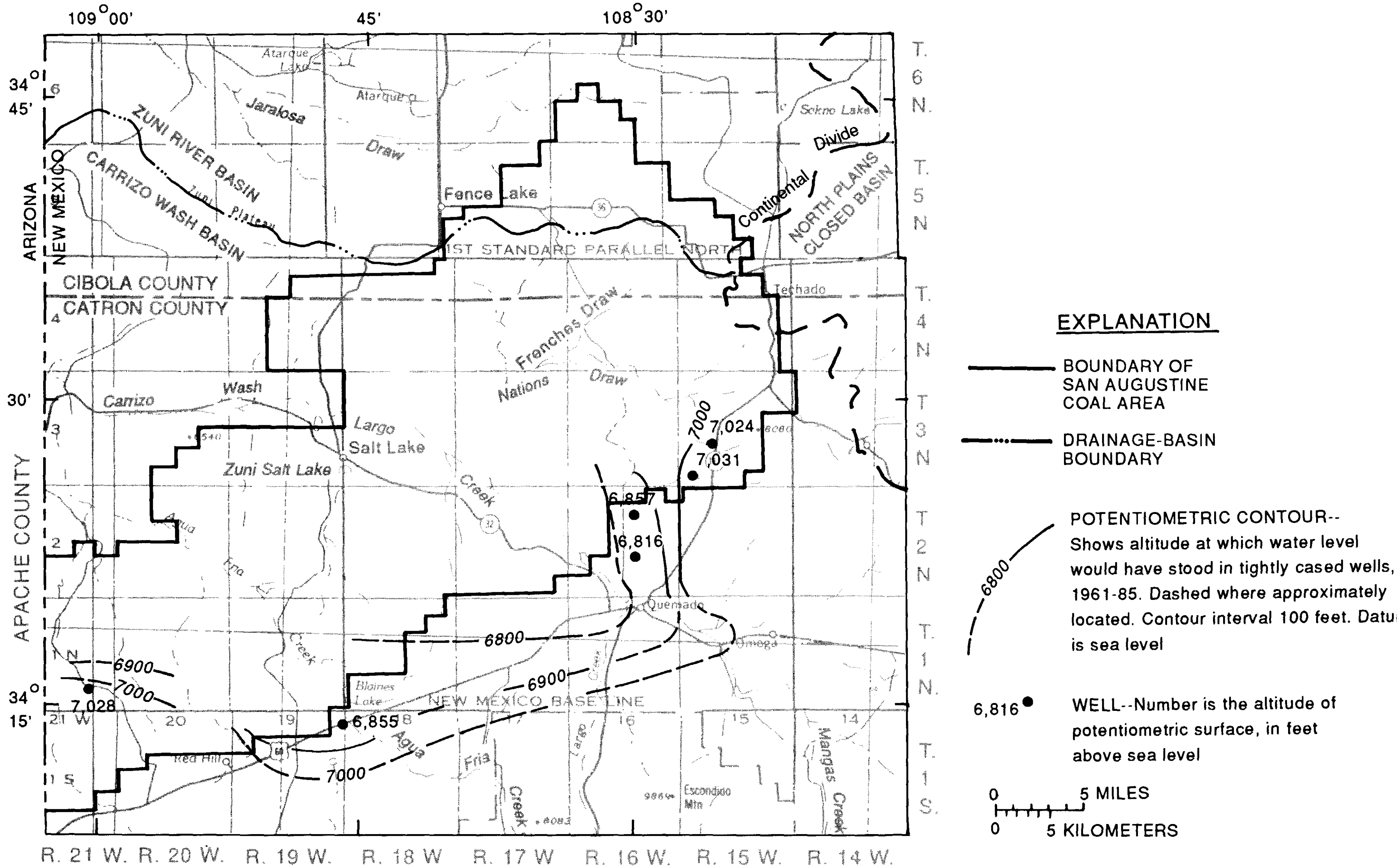
The aquifer in the Datil Group yields small quantities of water to wells to the south and east of the San Augustine Coal Area. The altitude of the potentiometric surface of the aquifer in the Datil Group is shown in figure 9. The direction of ground-water flow in the aquifer in the southeast part of the study area is toward Agua Fria Creek and Largo Creek.

Recharge to the aquifer is from precipitation and surface-water runoff on outcrop areas. Water from the Datil Group might recharge the aquifers in the underlying Baca Formation or in the Mesaverde Group in those areas where the Baca Formation is absent.

The water in the Carrizo Wash basin is fresh. The specific conductance of the water ranges from 320 to 860 microsiemens (tables 1 and 2). The dominant ions are sodium or calcium and bicarbonate.

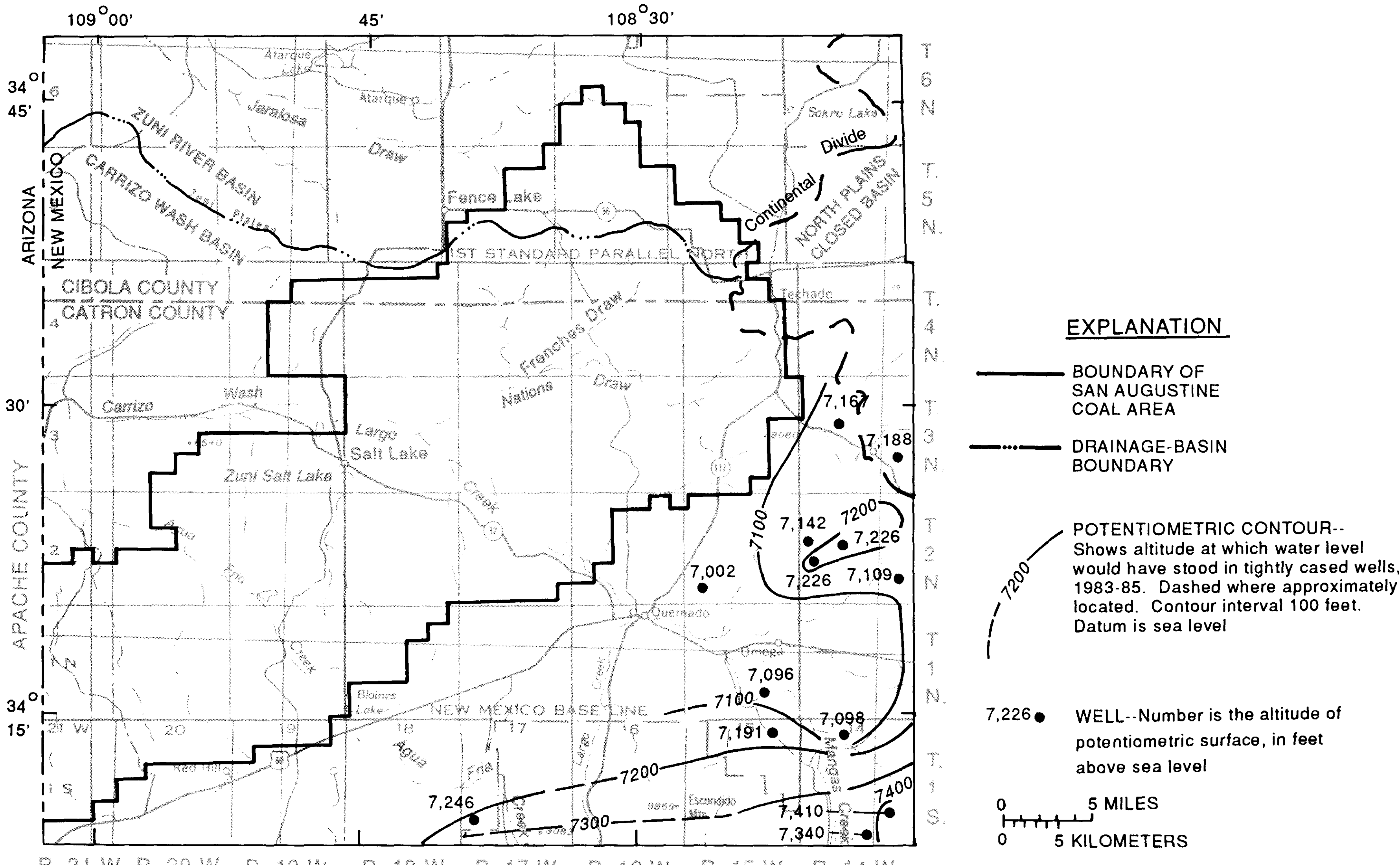
Fence Lake Formation

The Tertiary Fence Lake Formation overlies the Cretaceous Moreno Hill Formation of the Mesaverde Group in the northern part of the study area (McLellan and others, 1982; Campbell, 1984). This unit was previously considered to be part of the Tertiary Bidahochi Formation. An unconformity exists between the Fence Lake Formation and Moreno Hill Formation. The Fence Lake consists of fluvial sandstone and conglomerate and can be divided into a lower unit consisting of coarse conglomerate in a sandstone matrix with some sandstone lenses and an upper unit consisting of a poorly sorted sandstone with some lenses of conglomerate (McLellan and others, 1984). The Fence Lake Formation ranges in thickness from a featheredge to 221 feet (McLellan and others, 1984). This unit probably contains little or no water within the study area. J.A. Baldwin (U.S. Geological Survey, written commun., 1986) reported two wells completed in the Fence Lake Formation within the study area at 05N.18W.27.222 and 05N.20W.05.443. The well at 05N.20W.05.443 was dry. No hydrochemical data are available for the water from the Fence Lake Formation within the study area.



Base from U.S. Geological Survey,
New Mexico, 1:500,000, 1980

Figure 8.--Altitude of the potentiometric surface of the aquifer in the Baca Formation.



Base from U.S. Geological Survey, New Mexico, 1:500,000, 1980

Figure 9.--Altitude of the potentiometric surface of the aquifer in the Datil Group.

Quaternary Alluvium

Quaternary alluvium consisting of clay, silt, sand, and gravel is present in the washes and arroyos within the study area. The thickness is generally less than 200 feet (Salt River Project, 1983). Love and others (1984) studied the alluvial valleys in the northeastern part of the study area. They found that the drainage in the headwaters consists of narrow, steep gullies with incised channels and no flood plains. The steep gullies abruptly change to broad alluvial-fan and flood-plain valleys. The broad valleys are characterized by small and large discontinuous channels, fans, and reaches with no channels. Many of the valleys studied were underlain by at least 67 feet of alluvium.

Numerous wells are completed in the Quaternary alluvium and sometimes in the underlying consolidated lithologic units within the study area. Most of these wells are less than 60 feet deep. The extent of an aquifer in the alluvium and direction of ground-water flow are controlled by the surface-drainage channel. The direction of ground-water flow is downstream in the alluvium of the filled drainage channel.

Most of the recharge to the aquifers in the alluvium is from precipitation and runoff. Some small springs issuing from other aquifers also might recharge the alluvium. Stone (1984) estimated the recharge to the Quaternary alluvium in the Frenches Draw area to be 0.08 inch per year. Water from the aquifers in the alluvium recharges any underlying permeable Tertiary, Cretaceous, or Triassic rocks.

A 26-hour aquifer test of Quaternary alluvium in the vicinity of Frenches Draw was conducted on October 7 and 8, 1983, by personnel of the Salt River Project (Salt River Project, 1983). The production well was drilled and cased to a depth of 177 feet below land surface and screened from 137 to 177 feet below land surface. The static water level was 54.6 feet below land surface on October 7, 1983. Before surging the well, the static water level was 46.43 feet below land surface (Salt River Project, 1983, p. 36). The pumping rate was 350 gallons per minute for the first 4 hours of the test, but decreased to 250 gallons per minute for the remaining 22 hours of the test because of excessive drawdown in the pumped well. The water level at the end of the aquifer test was 118.9 feet below land surface. The average value of transmissivity was 9,640 gallons per day per foot (1,290 feet squared per day); the average storage coefficient was 2.5×10^{-4} (Salt River Project, 1983, p. 40). The storage coefficient indicates that the aquifer probably is under confined conditions.

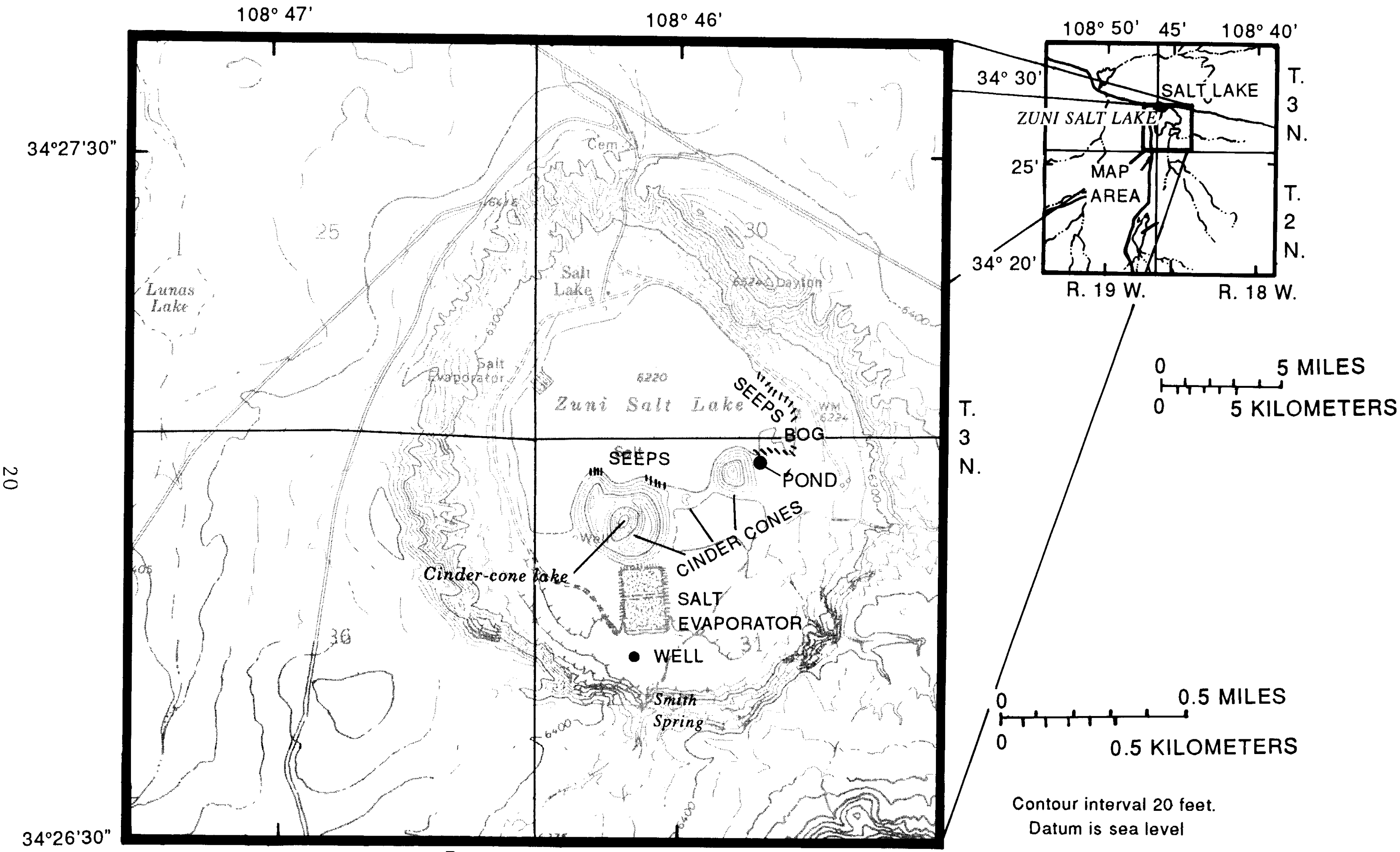
The water in the aquifers of the Quaternary alluvium usually is fresh, though some water is brackish where the alluvium is underlain by or adjacent to the Chinle Formation in the Carrizo Wash basin. The specific conductance of this water generally does not exceed 5,000 microsiemens (table 1).

Zuni Salt Lake Area

The Zuni Salt Lake area is about 18 miles northwest of Quemado, New Mexico (fig. 10). The predominant geohydrologic features of the Zuni Salt Lake area are Zuni Salt Lake maar, Zuni Salt Lake, brackish and brine seeps and springs on the edges of the lake, Smith Spring, the small cinder-cone lake, and the maar-floor Quaternary alluvium. Several of these features have religious significance for the Zuni Indians and some other Pueblo Indians in New Mexico.

Zuni Salt Lake Maar

Zuni Salt Lake maar, which is about 1.4 miles across at the widest point and covers about 1 square mile, was formed by volcanic and phreatic explosions in the late Pleistocene (Bradbury, 1967, 1971). An earlier basalt flow is exposed in the upper wall of the crater. The flow is characterized by a brecciated scoria at the base of the flow, horizontal lenticular vesicles in the main body of the flow, and flow textural features including small lava tubes on the top of the flow. This flow is shown as a dike by Cummings (1968). Following the formation of the maar, slumping occurred along the walls of the maar, as indicated by the dip of the air-fall tuff deposits away from the maar in some areas and slumped blocks of the basalt flow. A lava flow covered the maar floor after formation of



Base from U.S. Geological Survey,
Zuni Salt Lake, 1:24,000, 1972

Figure 10.--Zuni Salt Lake area.

the maar; the flow is buried beneath the present floor by cinder and sediment deposits (Bradbury, 1967). Three cinder cones then were formed at the south end of the maar. The largest of the three cones has a crater about 85 feet deep in the center and a small lake with a surface area of about 4.7 acres.

Zuni Salt Lake

Zuni Salt Lake is on the floor of a maar about 175 feet below the surrounding area. The lake varies in size, but generally is less than 0.7 mile north to south by 0.5 mile west to east. The surface area of the lake varies during the year in response to evaporation and runoff. The lake is restricted to the northern part of the maar by alluvial-fan deposits extending northward from the arroyo entering the south side of the maar at Smith Spring. The depth of water in Zuni Salt Lake usually is less than 4 feet, but the ooze on the bottom can be as much as 4 feet thick. Zuni Salt Lake has five major sources of water: (1) surface-water runoff from the surrounding basin, (2) brackish ground water from seeps and springs along the northeastern and southeastern edges of the lake, (3) brine springs and seeps along the southern edge of the lake issuing from the northern edge of the western cinder cone, (4) freshwater from the Quaternary alluvium and air-fall tuff south of the maar at Smith Spring, and (5) direct precipitation on the surface of the lake.

During normal runoff, about 4 square miles of drainage area contribute flow to the Zuni Salt Lake basin. During high runoff, some of the nearby basins overflow into the Zuni Salt Lake basin. The size of the contributing drainage area during high runoff is about 20 square miles. Most of this overflow is from the Cheap John Lake basin to the south of Zuni Salt Lake maar and water flows to the maar via the arroyo at Smith Spring. The runoff increases the lake water level and dilutes the brine of Zuni Salt Lake. Zuni Salt Lake has been a source of salt for prehistoric and historic people (Bradbury, 1967). Sediment from the runoff, however, deteriorates the quality of salt produced from the lake. The water in Zuni Salt Lake had an onsite specific conductance of 221,000 microsiemens on October 28, 1985. The dominant ions of the water were sodium and chloride.

Brackish water with an onsite specific conductance of about 1,800 to 2,200 microsiemens enters the lake from a large seep area along the northeastern to southeastern edges of the lake (fig. 10). Artesian and flowing artesian water to as much as 4 inches above land surface was noticed on May 14, 1986, in shallow piezometers used to sample the seep area to a depth of as much as 1 foot below land surface.

The northeastern end of the seep is shown as a spring by Cummings (1968). Water from this part of the seep area sometimes forms small boils in the northeast part of the lake as much as 60 feet from the lake shore. A windmill (03N.18W.30.433) produces water from a spring box near the northeastern edge of the lake. A bog exists just south of the windmill. At the southwestern end of the seep and east of the eastern cinder cone is a pond several feet deep (fig. 10). Water enters the pond from below and to as much as about 1 foot above the pond surface. Specific-conductance measurements made on May 14, 1986, indicated that the water entering the pond had a specific conductance of about 2,200 microsiemens, whereas the pond water had a specific conductance of about 3,800 microsiemens. The potentiometric contours of the aquifer in the Mesaverde Group (fig. 7) and the aquifer in the Paguate and Twowells Tongues of the Dakota Sandstone and Mancos Shale (fig. 6) show water flowing toward the maar. Water from the seep probably represents water from the Cretaceous sedimentary rocks. The dominant ions in water from the seep areas are sodium, chloride, and bicarbonate.

Brine seeps and springs also are present along the northern edge of the western cinder cone (fig. 10). The onsite specific conductance of the water from the seeps along the northwestern side of the cinder cone ranged from 146,400 to 148,800 microsiemens on May 14, 1986. The onsite specific conductance of the water from the seeps along the northeastern side of the cinder cone ranged from 133,600 to 134,000 microsiemens on May 14, 1986. The major sources of this water probably are the Permian sedimentary rocks underlying the maar and seepage through the cinders from the cinder-cone lake. The stock that formed the cinder cone probably fractured the underlying impermeable rocks, providing a conduit for the water from the Permian rocks to the maar.

Direct precipitation on the surface of Zuni Salt Lake might contribute as much as 110 acre-feet per year to the lake. This estimate is based on: (1) an average precipitation of 10.4 inches per year at Quemado, New Mexico (New Mexico Interstate Stream Commission and New Mexico State Engineer Office, 1975, p. 11), and (2) an average lake-surface area of 0.2 square mile or 128 acres.

Smith Spring

Freshwater enters the maar from Smith Spring, which had an onsite specific conductance of 1,100 microsiemens on May 14, 1985. The dominant ions of the spring water are sodium and bicarbonate. The flow generally is less than 5 gallons per minute. The source of the spring water is the shallow Quaternary alluvium and air-fall tuff in the arroyo south of the maar in the vicinity of Smith Spring. The water is perched on the basalt flow exposed at the top of the maar wall. The water enters the maar by fractures in the basalt and discharges from several points. Most of this water seeps into the alluvium in the floor of the maar before it reaches Zuni Salt Lake.

Cinder-Cone Lake

The cinder-cone lake is as much as 23 feet deep. The major sources of water for the lake are precipitation within the crater and brine springs in the cinder cone. The bottom of the lake is as much as 20 feet below the water table in the alluvium of the maar. According to Bradbury (1971), the water quality remains somewhat constant at the bottom of the lake, but varies with precipitation and the time of the year at the top of the lake. The water at the top of the lake had a specific conductance of 148,000 microsiemens on October 28, 1985. The dominant ions of the water were sodium and chloride.

Ground Water in the Maar-Floor Quaternary Alluvium

Ground water in the upper part of Quaternary alluvium in the Zuni Salt Lake maar is brackish; onsite specific conductance ranged from 1,800 to 2,330 microsiemens. The water sample having a specific conductance of 2,330 microsiemens was from a well (03N.18W.31.312) between the western cinder cone and the south wall of the maar (fig. 10). This well is about 48 feet deep, indicating that the thickness of brackish water in this area is at least about 40 feet. Water quality at depth is unknown. Four sources of the ground water in the maar are: (1) Smith Spring in the south wall of the maar; (2) surface-water runoff from outside the maar; (3) water from the Cretaceous sedimentary rocks; and (4) direct precipitation on the alluvium in the floor of the maar. Most of the water entering the alluvium of the maar floor is fresh.

POTENTIAL HYDROLOGIC EFFECTS OF SURFACE COAL MINING

The potential effects of the surface mining of coal on the hydrologic systems in the San Augustine Coal Area could be estimated most accurately from mine plans that would include the location of the excavations, the direction and rate of mine expansion, and duration of mining. The timing and location of excavations are particularly important in calculating the ground-water flow into the excavations and the changes of the potentiometric surface in any aquifers created by the excavation (Levings, 1983, p. 5 and 8; McClymonds, 1986, p. 9-13). Because no specific mine plans were available for the San Augustine Coal Area at the time of this study (1986), the potential effects described are based on knowledge of general surface-mining techniques. The following assumptions were used in the analysis: (1) all Federal and State regulations would be followed during mining and reclamation, (2) all of the coal mined would be from the Moreno Hill Formation of the Mesaverde Group, and (3) aquifers in stratigraphic units other than the Mesaverde Group also might be used as sources of water for mining activities.

The most significant effect of an excavation would be on the flow of water in the aquifer in the Mesaverde Group and in any aquifers in the overlying Quaternary alluvium if the excavation intersects the water table. Water entering the excavation would result in a lowering in the potentiometric surface in the mine area. The area affected would be a function of excavation geometry, aquifer characteristics, and time. The depression in the potentiometric surface would be greatest downgradient from the excavation where the ground-water flow would be intercepted. Wells and springs within the mined area would be destroyed.

Upstream from a mine boundary, surface-water runoff would not be affected. Downstream from a mine boundary, however, the surface-water runoff would be decreased because of runoff control required by law. The decrease in surface-water runoff downstream from a mine could decrease the recharge to aquifer outcrops downstream from a mine.

Dakota Sandstone

Coal mining in the Mesaverde Group could affect the aquifer in the Dakota Sandstone if the Dakota were used as a source of water for mining activities. The Salt River Project (1983) is considering the use of water in the aquifer in the main body of the Dakota Sandstone for surface mining in the northeastern part of the San Augustine Coal Area. The Paguate and Twowells Tongues of the Dakota Sandstone interbedded in the overlying Cretaceous Mancos Shale yield small quantities of water to wells. Withdrawal of water from the Paguate and Twowells Tongues could lower water levels in wells completed in these aquifers because of the small yield of the thin aquifers. The main body of the Dakota Sandstone would be the most likely source of supply. Because the main body of the Dakota Sandstone is a confined aquifer, the withdrawal of water could lower water levels in wells completed in the aquifer throughout a large area. Dewatering of the Mesaverde Group caused by mining would not, in itself, affect the Dakota Sandstone because it is separated from the Mesaverde Group by the mostly impermeable Mancos Shale. Some of the thin sandstone beds in the top of the underlying Triassic Chinle Formation might be hydraulically connected to the aquifer in the main body of the Dakota Sandstone.

To predict potential water-level declines in the main body of the Dakota Sandstone, a series of analyses was made using the Theis method (Todd, 1954, p. 90). The following equations of the Theis method of solution were used for the drawdown calculations:

$$u = \frac{1.87\ S\ r^2}{Tt} \tag{1}$$

and

$$h_o - h = \frac{114.6\ Q}{T}\ W(u) \tag{2}$$

where
- u is a dimensionless variable of integration;
- S is dimensionless storage coefficient;
- r is distance between pumped well and observation well, in feet;
- T is transmissivity, in gallons per day per foot;
- t is time since pumping started, in days;
- h_o-h is drawdown below land surface in observation well, in feet;
- Q is quantity of water pumped continuously, in gallons per minute; and
- $W(u)$ is well function from Lohman (1979, p. 16).

The Theis method of solution of the nonequilibrium equation for aquifer tests requires the following assumptions: (1) the aquifer is isotropic, homogeneous, and of infinite areal extent; (2) the well penetrates the entire thickness of the aquifer; (3) the well diameter is infinitesimal; (4) water removed from storage is discharged instantaneously with decline in hydraulic head; and (5) secondary openings, such as fractures, have homogeneous characteristics if sufficiently large volumes are considered (Todd, 1959, p. 90). All of these assumptions are not fully met by hydrologic conditions in the study area.

Theoretical drawdowns in wells at selected distances from a pumped well based on a reported value of transmissivity and assumed values of aquifer storage coefficient and pumping rate are shown in figures 11 through 13. The transmissivity value of 5,300 gallons per day per foot was obtained from an aquifer test conducted by the Salt River Project (1983, p. 25). According to Freeze and Cherry (1979, p. 60), sandstone similar to the main body of the Dakota Sandstone has a storage coefficient between 0.005 and 0.00005. Therefore, storage coefficients of 0.005 (fig. 11), 0.0005 (fig. 12), and 0.00005 (fig. 13) were used to estimate drawdowns for continuous pumping rates of 100, 200, 300, and 400 gallons per minute at wells 0.5 mile, 1 mile, 5 miles, and 10 miles from the pumped well. Mining activities might not require continuous pumpage. With discontinuous pumpage, projected water-level declines would be less than those shown in figures 11 through 13.

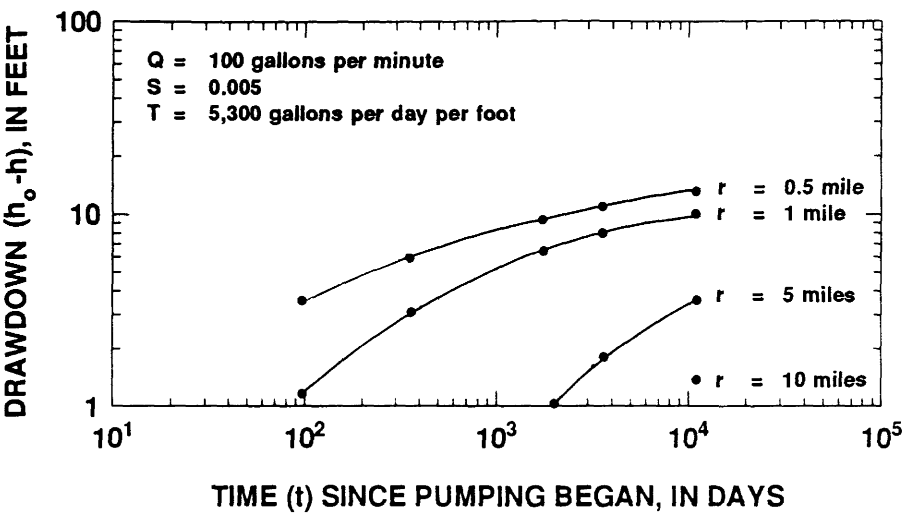
The quantity of water produced, in acre-feet, for continuous withdrawal rates of 100, 200, 300, and 400 gallons per minute for 1, 5, and 10 years is summarized in the following table:

Withdrawal rate (gallons per minute)	Water produced (acre-feet)		
	1 year	5 years	10 years
100	161	806	1,612
200	322	1,612	3,225
300	484	2,418	4,837
400	645	3,225	6,449

Zuni Salt Lake Area

Coal-mining activities in the surface-water drainages that contribute runoff to Zuni Salt Lake could change the quantity of runoff and sediment in the runoff to the lake, which would affect the quality of the salt that could be produced. Changes in the quantity of runoff would change recharge to the Quaternary alluvium south of the maar and discharge from Smith Spring.

The quantity of fresh, brackish, and brine water from the Cretaceous and older rocks that is entering and leaving the maar is not known. As indicated by the hydraulic gradient of the potentiometric surfaces of the aquifers in the Mesaverde Group (fig. 7) and Mancos Shale and Paguate and Twowells Tongues of the Dakota Sandstone (fig. 6), most of the fresh and brackish water probably comes from these two aquifers. It is possible that any activity that could lower water levels in these aquifers in the Zuni Salt Lake area also would decrease the quantity of water entering and leaving the maar, which could change the hydrologic environment of the area.



Q - Quantity of water pumped continuously

S - Storage coefficient

T - Transmissivity

r - Distance between pumped well and observation well

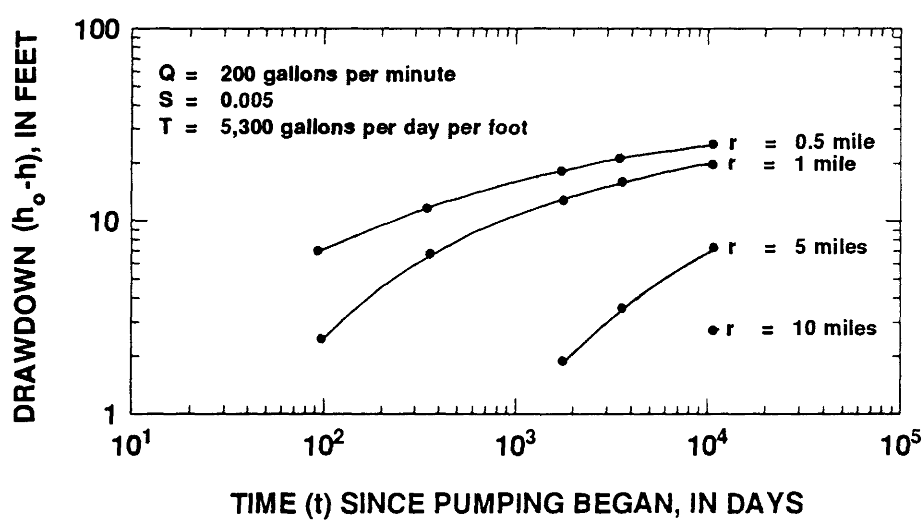
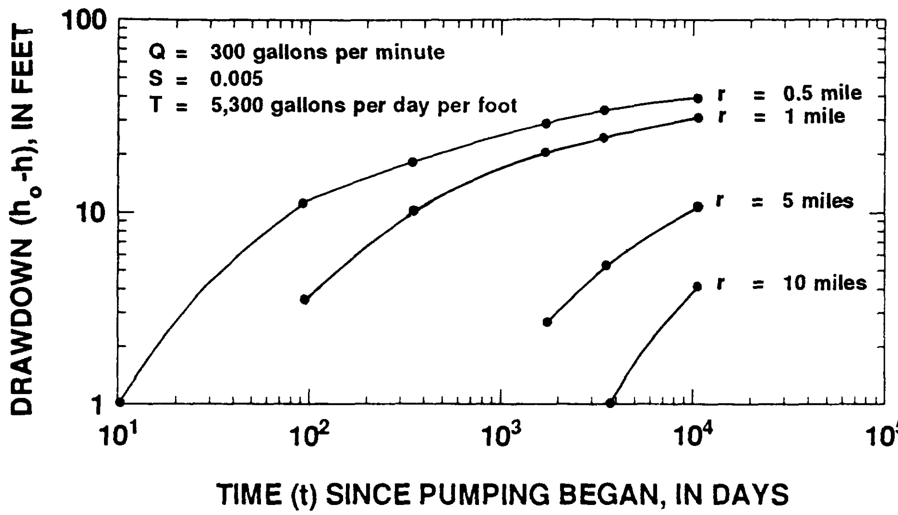


Figure 11.--Theoretical drawdowns in wells at selected distances (r) from a pumped well: storage coefficient of 0.005.



Q - Quantity of water pumped continuously
S - Storage coefficient
T - Transmissivity
r - Distance between pumped well and observation well

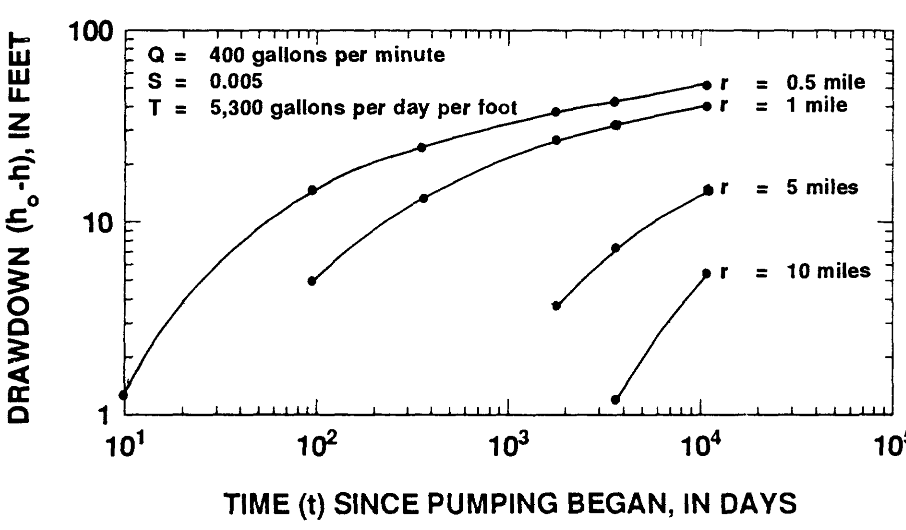
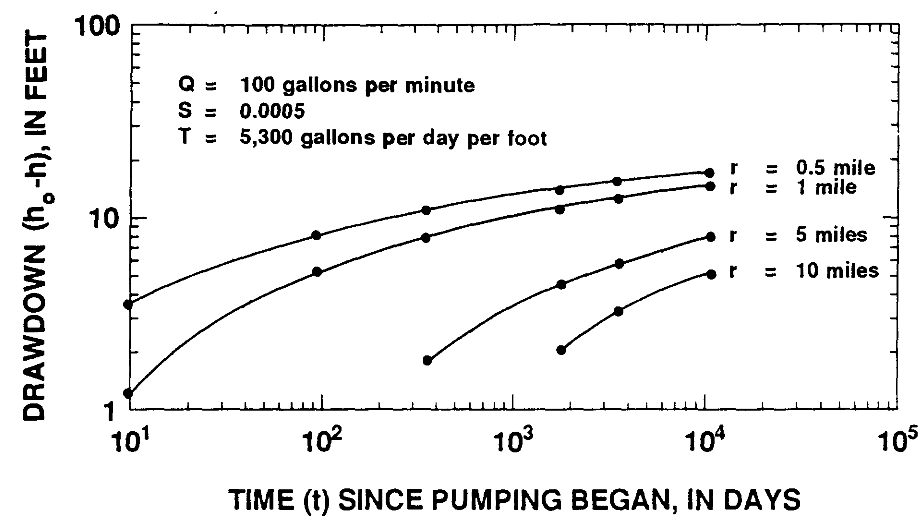


Figure 11.-- Concluded.



Q - Quantity of water pumped continuously

S - Storage coefficient

T - Transmissivity

r - Distance between pumped well and observation well

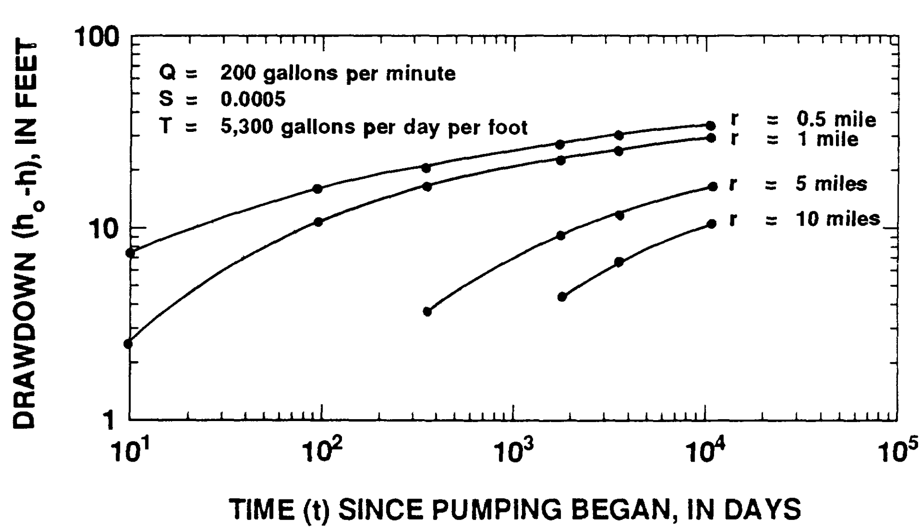
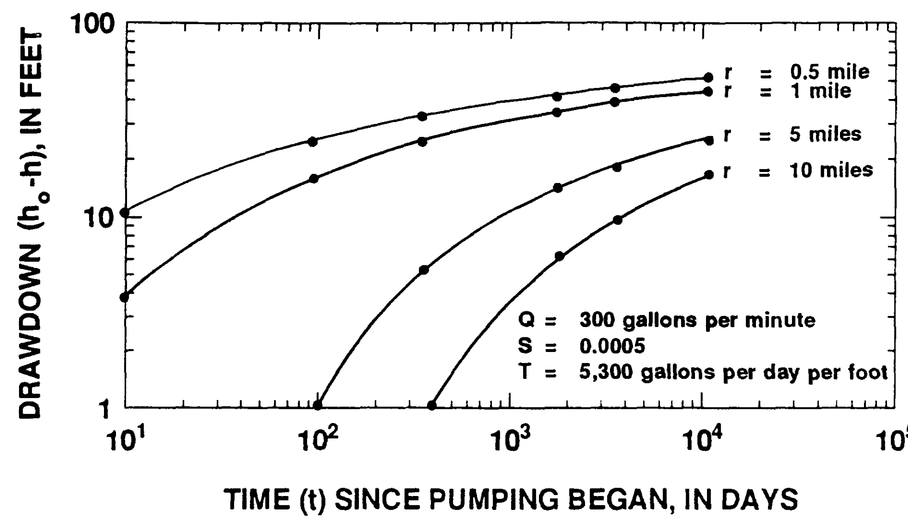


Figure 12.--Theoretical drawdowns in wells at selected distances (r) from a pumped well: storage coefficient of 0.0005.



Q - Quantity of water pumped continuously

S - Storage coefficient

T - Transmissivity

r - Distance between pumped well and observation well

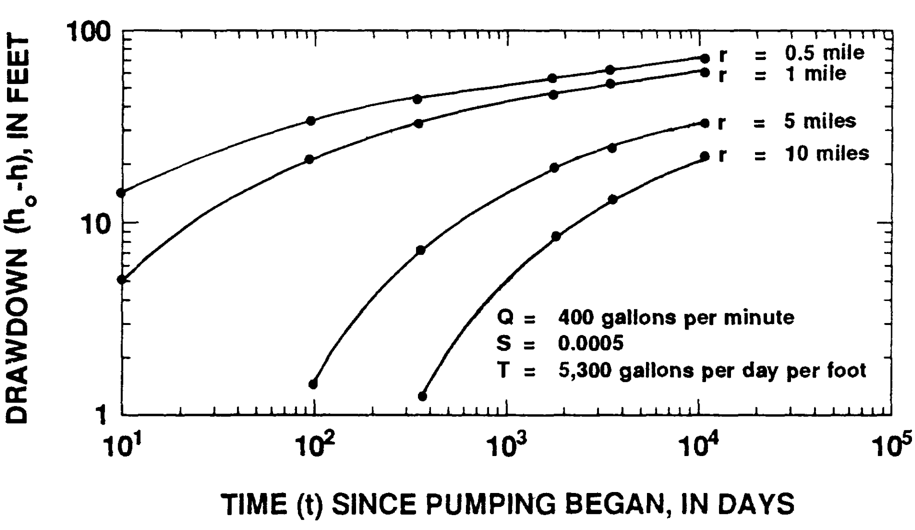
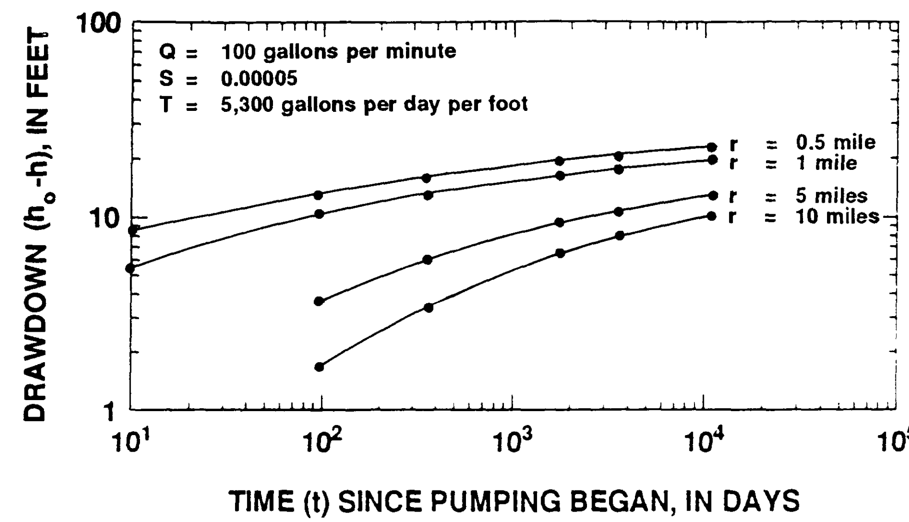


Figure 12.-- Concluded.



Q - Quantity of water pumped continuously

S - Storage coefficient

T - Transmissivity

r - Distance between pumped well and observation well

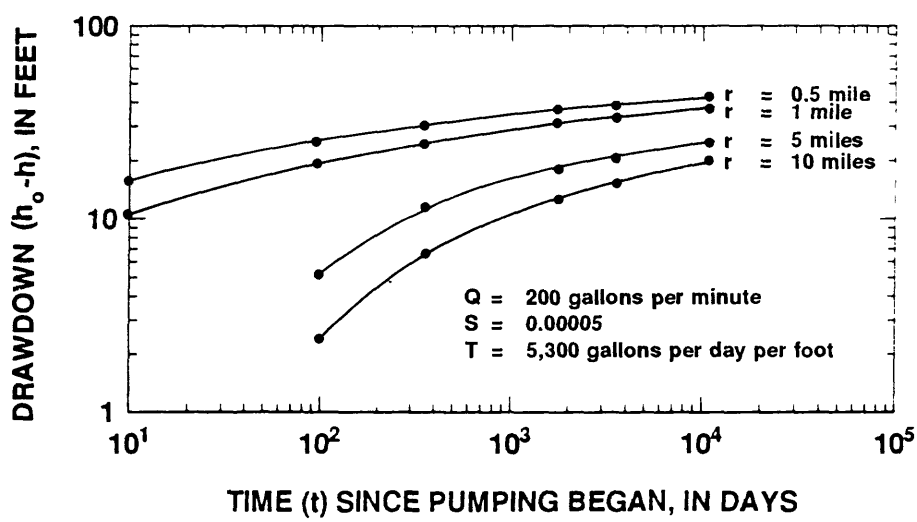
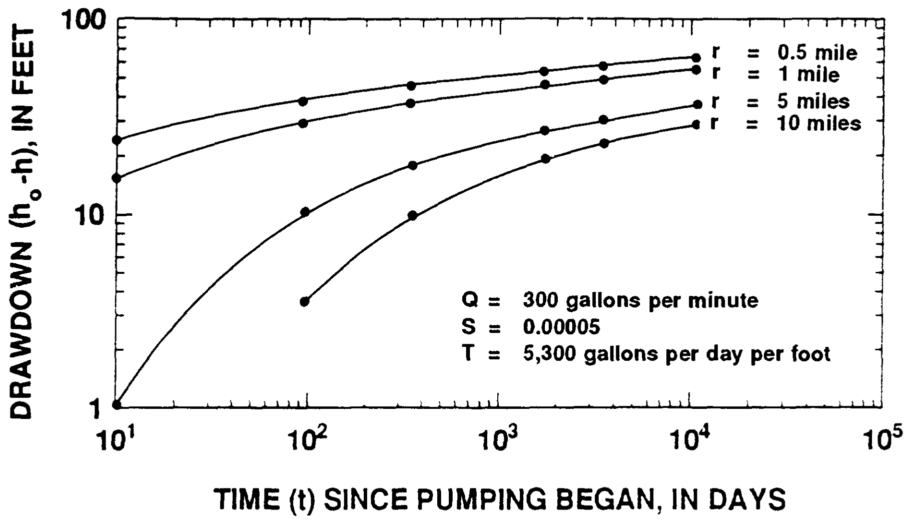


Figure 13.--Theoretical drawdowns in wells at selected distances (r) from a pumped well: storage coefficient of 0.00005.



Q - Quantity of water pumped continuously

S - Storage coefficient

T - Transmissivity

r - Distance between pumped well and observation well

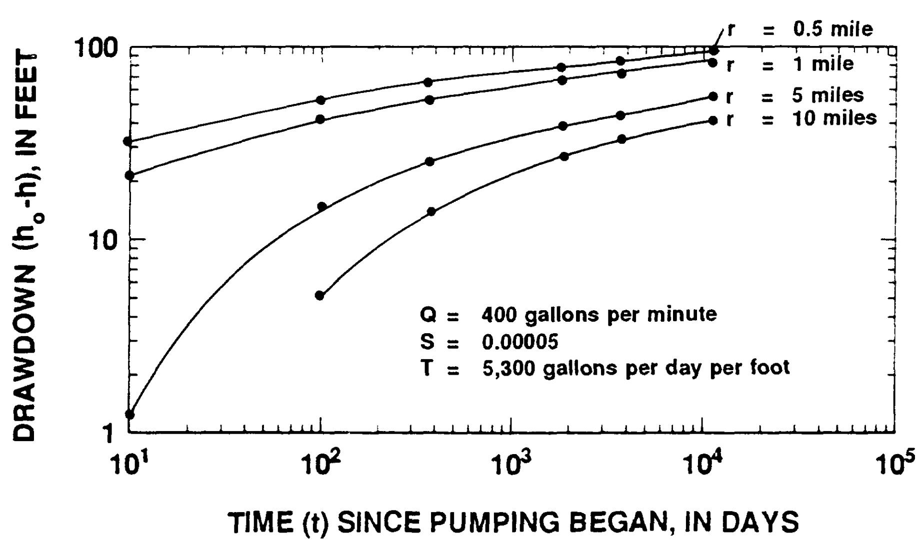


Figure 13.-- Concluded.

SUMMARY

The San Augustine Coal Area consists of 448,920 acres in northwestern Catron County and southwestern Cibola County in west-central New Mexico. The U.S. Bureau of Land Management is considering leasing coal deposits on Federal lands within the area. The coal is in the Cretaceous Dakota Sandstone and lower and upper members of the Moreno Hill Formation of the Cretaceous Mesaverde Group.

Aquifers within the San Augustine Coal Area and adjacent areas that might be affected by the surface mining of coal in the Moreno Hill Formation are in the Triassic Chinle Formation; Cretaceous units, including the main body of the Dakota Sandstone, Twowells and Paguate Tongues of the Dakota Sandstone and the Mancos Shale, and the Mesaverde Group; the Tertiary Baca Formation, Datil Group, and Fence Lake Formation; and the Quaternary alluvium. Most of the aquifers in Triassic and Cretaceous rocks are semiconfined to confined. The potentiometric surfaces of aquifers are controlled by the surface-water drainage system and the topography. The water in these aquifers generally is fresh (dissolved-solids concentrations less than 1,000 milligrams per liter) and occasionally brackish (dissolved-solids concentrations between 1,000 and 10,000 milligrams per liter). Personnel of the Salt River Project conducted two aquifer tests, one in the vicinity of Frenches Draw in the main body of the Dakota Sandstone and the other in Quaternary alluvium. The transmissivity of the main body of the Dakota Sandstone was estimated to be 700 feet squared per day and the hydraulic conductivity to be 6.8 feet per day. The average value of transmissivity of the Quaternary alluvium in the vicinity of Frenches Draw was 1,290 feet squared per day and the average storage coefficient was 0.00025. No other aquifer-test data were available for the study area.

Zuni Salt Lake varies in size, but generally is less than 0.7 mile north to south by 0.5 mile west to east. The depth of water in Zuni Salt Lake usually is less than 4 feet, but the ooze on the bottom can be as much as 4 feet thick. Zuni Salt Lake has five major sources of water: (1) surface-water runoff from the surrounding basin, (2) brackish ground water from seeps and springs along the northeastern and southeastern edges of the lake, (3) brine springs and seeps along the southern edge of the lake issuing from the northern edge of the western cinder cone, (4) freshwater from the Quaternary alluvium and air-fall tuff south of the maar from Smith Spring, and (5) direct precipitation on the surface of the lake.

The cinder-cone lake in the maar is as much as 23 feet deep. The major source of water for the cinder-cone lake is from precipitation within the crater and from brine springs in the cinder cone.

Water in the upper part of Quaternary alluvium in the Zuni Salt Lake maar is brackish. The ground-water quality at depth is unknown. Four sources of the ground water in the maar are: (1) Smith Spring in the south wall of the maar, (2) surface-water runoff from outside the maar, (3) water from the Cretaceous sedimentary rocks, and (4) direct precipitation on the alluvium in the floor of the maar. Most of the water entering the alluvium of the maar floor is fresh.

Because no mine plans were available, the potential hydrologic effects of coal mining were based on knowledge of typical surface-mining techniques and other assumptions. Effects of mining on the Moreno Hill Formation of the Mesaverde Group include: (1) the destruction of any wells or springs within the excavated area, (2) lowering of the potentiometric surface of aquifers in the Mesaverde Group and overlying Quaternary alluvium if the excavation intersects the water table, and (3) decrease of recharge to aquifer outcrops downstream from a mine because of the control of surface-water runoff in a mine area required by law. Dewatering of the Mesaverde Group and Quaternary alluvium would have little effect on the underlying aquifers, which are separated from overlying aquifers by the Mancos Shale.

The Dakota Sandstone has been proposed as a source of water for some mining operations. The effects of pumping water from the main body of the Dakota Sandstone for mine use would depend on the quantity of water produced and the length of time any wells are pumped.

Coal-mining activities within the basins that contribute surface-water runoff to Zuni Salt Lake could affect the quality of the salt produced, the quantity of flow from Smith Spring, and the volume of water in Zuni Salt Lake. Any activity that lowers the potentiometric surface of water in the Cretaceous sedimentary rocks within the vicinity of the Zuni Salt Lake maar could decrease the quantity of flow to brackish seeps in the maar and decrease the quantity of water in the maar-floor alluvium.

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Table 1.--*Records of selected wells, test holes, lakes, and springs*

[Qal, Quaternary alluvium; Tertiary: Tfl, Fence Lake Formation; Td, Datil Group; Tb, Baca Formation; Cretaceous: Kmv, Mesaverde Group; Kcc, Crevasse Canyon Formation; Kg, Gallup Sandstone; Km, Mancos Shale; Kd, Dakota Sandstone; TRc, Triassic Chinle Formation; Psg, Permian San Andres Limestone and Glorieta Sandstone; ?, uncertain; µS/cm, microsiemens per centimeter at 25 degrees Celsius. Use: D, domestic; I, irrigation; O, observation; S, stock; T, test hole; U, unused. R, reported; P, pumping; E, estimated; --, no data]

Location number	Well depth (feet)	Date well completed	Water level below land surface (feet)	Date measured	Altitude of land surface (feet)	Aquifer (major)	Specific conductance (µS/cm)	Temperature (degrees Celsius)	Use	Name and remarks
01S.14W.04.334	190	--	176.52	7-26-83	7,275	Td	--	--	S	East Mangas
01S.14W.06.112	101	--	41.68	7-25-83	7,167	--	--	--	S	New or Frio
01S.14W.06.411	--	--	--	--	--	--	247	14.5	S	
01S.14W.17.332	100	--	16.38	7-25-83	7,240	--	--	--	I	
01S.14W.18.132	--	--	70.64	7-06-79	7,250	--	--	--	S	
	80	--	70.36	7-26-83	7,250	--	--	--	S	
01S.14W.20.334	--	--	--	7-25-83	7,265	--	390	17.0	D	
01S.14W.23.233	200R	--	195.30	7-26-83	7,605	Td	--	--	S	
01S.14W.29.123	90	- -68	4.38	7-25-83	7,265	--	--	--	I	
01S.14W.34.412	350R	--	260.25	7-26-83	7,600	Td	--	--	S	Mitchell
01S.15W.02.433	130R	--	113.66	7-25-83	7,305	Td	--	--	U	
01S.15W.30.433	94	--	28.60	7-28-83	7,275	Td	--	--	S	
01S.18W.05.332	300	--	--	--	6,997	Td	408	18.0	S	
01S.18W.09.142	300	- -61	--	--	--	Td	800	18.0	--	Odell
01S.19W.01.220	--	--	107.60	5-15-61	7,020	Tb	--	--	S	
01S.19W.01.223	--	--	127.60	8-12-80	6,960	Tb	721	15.0	S	Cajon
	133	--	104.99	7-28-83	6,960	Tb	--	--	S	Cajon
01S.19W.34.442	--	--	--	7-28-83	7,035	--	470	17.0	S	
01S.20W.01.410	200R	3- -81	--	--	--	--	--	--	S	
01S.20W.08.443	310R	--	271.20	5-14-85	7,538	Tb	--	--	S	
01S.20W.20.442	--	--	--	--	--	--	450	15.0	--	
01S.20W.21.411	--	--	304R	6-26-79	7,554	--	460	16.0	--	East
01S.21W.25.244	--	--	304.31	7-28-83	7,554	Tb?, Td?	--	--	S	
	360	--	--	5-14-85	7,554	--	--	--	S	
01N.14W.22.144	121	--	112.61	7-26-83	7,187	Td?	--	--	S	Putnam
01N.15W.11.000	107	--	57	12-30-33	--	--	--	--	--	
01N.15W.11.432	80	--	34.23	5-17-85	7,082	Td?	--	--	S	

Table 1.--*Records of selected wells, test holes, lakes, and springs*--Continued

Location number	Well depth (feet)	Date well completed	Water level below land surface (feet)	Date measured	Altitude of land surface (feet)	Aquifer (major)	Specific conductance (µS/cm)	Temperature (degrees Celsius)	Use	Name and remarks
01N.15W.15.441	--	--	--	7-11-80	--	Td	435	15.0	--	San Ignacia Spring
01N.15W.16.113	33	--	18.73	5-17-85	6,931	Qal	--	--	S	
01N.15W.25.231	60	--	31.68P	7-25-83	7,128	Td	430	17.0	D	Mexican
01N.15W.26.144	--	--	--	7-11-80	--	Td	370	24.0	--	Nutria Spring
01N.16W.01.331	84	- -77	33.07	5-17-85	6,904	--	--	--	I	
01N.16W.03.000	123	--	110	12-20-33	--	--	--	--	--	
01N.16W.04.232	80R	--	23.69	7-19-83	6,880	--	670	18.0	D	Highway Department
01N.17W.08.120	412	5- -79	380R	5- -79	7,530	--	--	--	S	
01N.18W.16.332	211	--	178R	5-16-85	7,122	Tb	--	--	S	
01N.18W.31.332	97.5	--	69.68	5-23-85	6,935	--	--	--	S	
01N.18W.35.412	250	--	--	--	7.205	Td	500	15.0	--	Shay
01N.19W.13.443	--	--	50.37	5-22-85	6,891	Kmv	--	--	S	
01N.19W.23.324	--	--	64.67	5-22-85	6,868	Kmv	--	--	S	
01N.19W.27.413	--	--	158.96	5-22-85	7,130	Tb?	--	--	S	
01N.19W.32.111	91	--	Dry	5-22-85	7,251	--	--	--	U	
01N.20W.09.440	470R	11- -60	560.60R	--	6,835	Kmv	--	--	S	
01N.20W.27.120	200R	--	3.70	4-15-61	6,940	Kmv	370	14.5	S	
01N.20W.27.221	250R	4- 1-81	152.50	5-14-85	6,978	Kmv	--	--	S	
01N.20W.35.344	79.5	--	45.72	5-23-85	7,110	Kmv	--	--	S	
01N.21W.03.312	112	--	102.4	5-21-85	6,780	Km, Kd	3,500	16.00	S	Tom Phelps
01N.21W.16.000	15	--	--	--	--	Qal	--	--	--	
01N.21W.16.222	60	--	--	5-21-85	6,838	Kmv	2,000	--	S	
01N.21W.26.223	118	--	81.1	5-14-85	7,109	Tb	--	--	S	East
02N.14W.03.113	95R	--	--	5-15-85	7,412	Td	600	14.5	S	Preacher
02N.14W.16.321	106	--	98.47	5-15-85	7,324	Td	--	--	U	Cat
02N.14W.18.412	574	7- 6-83	340R	7- 6-83	7,482	Td	--	--	S	
02N.14W.19.322	223R	--	115.40	5-15-85	7,341	Td	--	--	D, S	Moore
02N.14W.25.133	168	--	--	7-26-83	7,260	Td	860	14.5	S	New
02N.14W.25.133	157	--	152.67	5-15-85	7,260	Td	790	15.5	S	New
02N.15W.05.000	--	--	--	8-03-79	--	Tb	--	12.5	--	Mariano Spring

Table 1.--*Records of selected wells, test holes, lakes, and springs*--Continued

Location number	Well depth (feet)	Date well completed	Water level below land surface (feet)	Date measured	Altitude of land surface (feet)	Aquifer (major)	Specific conductance (µS/cm)	Temperature (degrees Celsius)	Use	Name and remarks
02N.15W.23.132	--	--	--	5-15-85	7,328	--	430	14.0	S	
02N.15W.27.142	139R	--	--	5-15-85	7,248	Td	320	12.0	S	
02N.15W.30.342	220	--	206.45	5-15-85	7,208	Td	--	--	S	
02N.16W.10.133	104R	--	68.2	5-14-85	6,925	Tb	--	--	S	
02N.16W.12.110	354	8- -82	225R	8- -82	--	Tb?	--	--	--	
02N.16W.19.342	51	--	27.02	5-14-85	6,779	Tb?	--	--	U	
02N.16W.22.122	--	--	--	5-23-85	6,967	Tb	520	17.0	S	
02N.16W.27.134	223	--	111.7	5-23-85	6,928	Tb	--	--	S	
02N.16W.31.120	323	12- -79	154R	12- -79	--	Tb	--	--	S	
02N.16W.33.112	95	--	18.17	5-23-85	6,810	Tb?	700	--	S	
02N.17W.05.233	64R	--	30.35	5-14-85	6,555	Kmv	--	--	S	Little Wells
02N.17W.11.333	87	- -60	71.66	5-23-85	6,670	Kmv	1,000	--	S	New
02N.17W.13.242	--	--	--	3-21-81	--	Td	460	7.0	--	Spring
02N.18W.03.233	115R	--	86.56	5-21-85	6,499	Kmv	--	--	S	Lazy K Slash
02N.18W.07.140	160R	--	100R	--	6,545	Kmv	870	16.0	S	
02N.18W.07.141	--	--	192.72	5-16-85	6,550	Kmv	1,100	17.5	S	
02N.18W.16.114	265	--	250.93P	5-16-85	6,650	Kmv	840	15.5	S	Midway
02N.18W.26.344	--	--	397.65	5-21-85	6,947	--	--	--	S	
02N.19W.03.221	--	--	182.3	5-16-85	6,505	Km?, Kd?	--	--	S	
02N.19W.14.430	200R	--	160R	--	6,540	--	--	19.0	S	
02N.19W.14.441	--	--	151.08	5-16-85	6,510	Kmv	690	17.5	S	
02N.19W.25.110	200R	--	160R	--	6,525	Kmv	650	14.4	S	
02N.19W.29.430	200R	--	160R	--	6,660	Kmv	--	18.0	S	
02N.20W.07.131	40	--	--	12-22-33	--	--	--	--	--	
02N.20W.07.143	31	--	15.70	5-21-85	6,373	--	--	--	U	
02N.20W.08.344	50	--	28.44	5-21-85	6,406	TRc	3,000	18.0	S	Dipping Vat
02N.20W.15.100	25R	--	--	--	6,400	Qal	1,050	--	S	
02N.20W.15.241	64	--	29.60	5-21-85	6,465	Km, Kd	--	--	S	Rock House
02N.20W.29.413	--	--	--	8- 8-80	--	Td	575	13	--	Goat Spring
02N.21W.02.223	150	--	37	12-22-33	--	TRc	--	--	--	

Table 1.--*Records of selected wells, test holes, lakes, and springs*--Continued

Location number	Well depth (feet)	Date well completed	Water level below land surface (feet)	Date measured	Altitude of land surface (feet)	Aquifer (major)	Specific conductance (µS/cm)	Temperature (degrees Celsius)	Use	Name and remarks
02N.21W.22.423	44	--	23.88	5-23-85	7,358	--	--	--	S	
02N.21W.24.132	18	--	9.03	5-21-85	6,560	--	--	--	--	
02N.21W.24.141	14	--	--	12-22-33	--	Qal	--	--	--	
02N.21W.25.332	28	--	14.34	5-21-85	6,727	--	--	--	S	
02N.21W.36.120	24	--	15.70	5-16-61	6,680	--	400	13.8	S	
03N.14W.16.133	129R	--	101.80	5-15-85	7,269	Td	--	--	S	
03N.14W.24.311	268R	--	228	5-15-85	7,416	Td	--	--	S	
03N.15W.05.413	135R	--	72.07	5-21-85	6,935	Kmv	790	18.5	S	
03N.15W.22.111	--	--	--	3-24-81	--	Td	525	13	--	Cottonwood Spring
03N.15W.20.323	104	--	86.96	5-21-85	7,111	Tb	--	--	S	Webb
03N.15W.18.000	210	--	135	12-21-33	6,980	Kmv	--	--	--	
03N.15W.31.424	180R	--	142.97	5-14-85	7,174	Tb	--	--	S	
03N.16W.06.124	64R	--	--	--	6,670	Kmv	--	--	T	
03N.16W.22.331	116	--	88.16	5-21-85	6,990	Kmv	--	--	D, S	
03N.16W.24.142	111R	--	89.73	5-21-85	7,012	Kmv	--	--	S	Gaines
03N.17W.08.123	40R	--	29.96	5-14-85	6,510	--	1,200	--	S	
03N.17W.08.200	--	--	--	--	--	Kg	--	--	--	Garcia Spring
03N.17W.12.000	101R	--	54R	--	6,680	Kmv	--	--	T	
03N.17W.12.314	138	--	52.84	5-21-85	6,657	Kmv	670	15.0	S	
03N.17W.24.232	248	--	49.24	5-21-85	6,755	Kmv	--	--	S	
03N.17W.29.111	63	--	36.28	5-23-85	6,480	Kmv	--	--	S	
03N.18W.09.223	189	--	94.83	5-22-85	6,390	Km, Kd	900	17.0	S	
03N.18W.22.232	28R	--	20.42	5-14-85	6,394	--	--	--	S	Jerry
03N.18W.25.241	54	--	30.09	5-23-85	6,442	Km?, Kd?	--	--	S	Tapia
03N.18W.30.000	--	--	--	12-22-33	--	--	--	13	--	Spring
03N.18W.30.314	--	--	--	10-28-85	--	--	--	--	--	Zuni Salt Lake
03N.18W.30.433	3.36	--	72	5-14-85	6,224	Qal	1,850	16.0	U	
03N.18W.31.113	--	--	3.98	2-21-85	6,230	Qal	--	--	U	
	--	--	4.10	5-14-85	6,230	Qal	--	--	U	
	--	--	4.50	5-14-86	6,230	Qal	--	--	U	

Table 1.--*Records of selected wells, test holes, lakes, and springs*--Continued

Location number	Well depth (feet)	Date well completed	Water level below land surface (feet)	Date measured	Altitude of land surface (feet)	Aquifer (major)	Specific conductance (µS/cm)	Temperature (degrees Celsius)	Use	Name and remarks
03N.18W.31.114	--	--	--	10-28-85	--	--	--	--	--	Cinder-cone lake
03N.18W.31.312	47.65	--	8.34	5-14-85	6,248	Qal	--	--	U	
	47.65	--	5.94	5-14-86	6,248	Qal	2,330	--	U	
03N.18W.31.314	--	--	--	--	--	--	--	--	--	Smith Spring
03N.18W.33.233	119	--	115.78	5-23-85	6,465	Km?, Kd?	--	--	S	New
03N.19W.07.413	--	--	81.46	5-21-85	6,254	TRc	2,200	19.0	S	Mireles
03N.19W.12.411	112	--	17.20	5-22-85	6,299	Km, Kd	1,100	15.5	S	Leon
03N.19W.22.310	206	7- -79	160R	--	6,500E	Km, Kd	--	--	S	Tastes bad
03N.19W.35.231	--	--	156.45	5-16-85	6,450	Km?, Kd?	--	--	S	
03N.20W.07.434	134	--	72.33	5-21-85	6,104	TRc?	--	--	S	Allen
03N.20W.15.322	30	--	9.89	5-21-85	6,085	--	3,100	22.0	S	Chavez
04N.14W.10.211	--	- -24	--	--	7,340	Kd	--	--	S	
04N.14W.14.333	308	4-10-78	200	4-10-78	7,398	Kmv	--	--	S	
04N.14W.19.211	365	5- -82	260R	--	7,000E	--	--	--	S	
04N.15W.04.423	--	--	--	--	7,630	Td	350	15.5	U	
04N.15W.31.213A	191R	--	93.38	5-21-85	6,973	--	--	--	S	
04N.15W.31.213B	142	--	125.90	5-21-85	6,973	--	--	--	U	
04N.16W.03.321	260R	9-12-79	136R	9-12-79	6,980	Kmv	--	--	U	
04N.16W.04.241	--	--	279.32	12-17-80	6,970	Kmv	--	--	S	
04N.16W.07.000	--	--	86.56	8-20-83	--	Kmv	--	--	S	
04N.16W.07.212	230R	4- -71	184.86	2-11-81	6,870	Kmv	--	--	S	
04N.16W.07.223	90R	10-16-79	--	10-16-79	6,850	Kmv	--	--	U	
04N.16W.07.421	--	8- -80	82.58	2-11-81	6,840	Kmv	--	--	S	
04N.16W.07.434	245R	5-14-80	83R	5-14-80	6,845	Kmv	--	--	U	
04N.16W.10.131	272R	9- 8-79	143R	9- 8-79	6,920	Kmv	--	--	U	
04N.16W.10.331A	280R	--	141.17	12-17-80	6,860	Kmv	460	--	S, D	
04N.16W.10.331B	230R	--	--	--	6,840	Kmv	700	11.0	S	
04N.16W.11.332	--	--	154.34	12-17-80	6,894	Kmv	--	--	S	
04N.16W.19.242	155	--	53.33	2-11-81	6,700	--	--	--	S	
	155	--	56.28	8-20-83	6,700	Kmv	--	--	S	Cerro Prieto

Table 1.--*Records of selected wells, test holes, lakes, and springs*--Continued

Location number	Well depth (feet)	Date well completed	Water level below land surface (feet)	Date measured	Altitude of land surface (feet)	Aquifer (major)	Specific conductance (µS/cm)	Temperature (degrees Celsius)	Use	Name and remarks
04N.16W.26.141	130	--	108.71	5-14-85	6,795	Kmv	--	--	S	
04N.16W.27.144	280	--	200R	--	6,810	Kmv	--	--	U	
04N.16W.30.410	177	8-26-83	46.72	8-29-83	6,665	Qal	695	--	T	FL30
04N.16W.30.410A	186	--	52.76	10- 7-83	--	Qal	710	--	O	FL30-OB1
04N.16W.30.410B	205	--	49.95	10- 7-83	--	Qal	710	--	O	FL30-OB2
04N.16W.31.100	100R	--	46.40	9-28-83	6,643	Qal	820	--	S	L.S. Brown
04N.16W.31.111	79R	--	11	5-14-85	6,643	--	750	14.5	S	
04N.16W.31.411	262R	--	255R	--	6,690	Kmv	--	--	U	
04N.16W.33.300	390	--	88.83	9-27-83	6,718	Kmv	--	--	S	Apodaca
04N.17W.03.312	250R	5-20-80	227R	5-20-80	6,880	Kmv	--	--	U	
04N.17W.03.324A	--	--	100.32	10-13-80	6,820	Kmv	--	--	S	
04N.17W.03.324B	--	--	117	10-13-80	6,820	Kmv	--	13.5	--	
04N.17W.04.233	--	--	--	--	6,806	Kmv	1,550	14.0	S	
04N.17W.08.100	--	--	206.15P	1- 6-81	6,846	Kmv	--	--	S	Mendanoso
04N.17W.08.121	252R	--	189.90	10-15-80	6,846	Kmv	600	15.0	S	
04N.17W.10.200	435R	--	--	--	6,790	--	--	--	S	Lucero
04N.17W.10.211	435	--	--	--	6,797	Kmv	--	--	S	
04N.17W.14.143	250R	--	169R	--	6,810	Kmv	--	--	S	
04N.17W.23.114	250R	--	150R	--	6,740	Kmv	--	--	U	
04N.17W.23.200	--	--	97.25	1- 6-81	6,745	Kmv	1,000	--	S	Taylor
	--	--	97.39	8-20-83	--	--	--	--	--	
04N.17W.34.430	150	8-13-83	--	--	--	Qal	810	--	O	FL34M
04N.17W.36.111	41	--	38.49	9-28-83	6,620	Kmv	--	--	S	Dipping Vat
04N.17W.36.121	1,080	8-30-83	Flowing	8-30-83	--	Kd	665	--	T	FL36
04N.18W.05.144A	320	--	192.05	10-31-80	7,339	Kmv	--	--	S	
04N.18W.05.144B	320	--	164.24	10-31-80	7,339	Kmv	350	14.0	S	
04N.18W.05.212	--	--	135.79	10- 9-80	7,315	Kcc	520	14.5	S	
04N.18W.22.200	--	--	10R	--	6,394	Km?, Kd?	860	--	S	Jerry
04N.18W.28.12	--	--	--	8- 4-79	--	Kg	--	--	--	New Santa Rita Spring
04N.18W.29.124	23	--	11.45	5-22-85	6,620	--	2,100	16.5	U	

Table 1.--*Records of selected wells, test holes, lakes, and springs*--Continued

Location number	Well depth (feet)	Date well completed	Water level below land surface (feet)	Date measured	Altitude of land surface (feet)	Aquifer (major)	Specific conductance (µS/cm)	Temperature (degrees Celsius)	Use	Name and remarks
04N.18W.36.312	165R	--	120.05	11-20-80	6,566	Kmv	600	13.9	S	Escojeda
	189R	--	101.25	5-22-85	6,566	--	--	--	S	Escojeda
04N.19W.14.314A	--	--	108.56	10-29-80	6,622	--	4,500	15.0	S	
04N.19W.15.422	135R	--	135R	10-29-80	6,570	Km	4,000	--	S	
04N.19W.25.414	1,050	--	55.13	10-30-80	6,475	Psg	1,600	33.9	S	
	--	--	54.39	5-22-85	6,475	--	--	--	S	Pueblo
04N.19W.28.234	1,350	- -51	4.80	10-29-80	6,480	Psg	1,350	28.0	S	
05N.14W.06.334	--	--	327.22	12-18-80	7,397	Kmv	350	14.0	S	
05N.14W.15.334	--	--	--	--	7,845	Kd	441	17.0	S	
05N.15W.16.223	381	- -28	350R	--	7,365	Kd	290	15.0	S	
05N.15W.19.444	100	--	87R	12-04-80	7,332	Kmv	900	14.0	S	
05N.15W.24.113	362	--	329.78	12-18-80	7,405	Kmv	--	--	U	
05N.15W.26.100	760	--	300R	- -71	7,600	--	--	--	--	
05N.15W.26.133	--	--	336.43	12-16-80	7,392	Kmv	330	14.5	S, D	
05N.15W.28.431	--	--	261	12-16-80	7,490	Kmv	500	13.0	S	
05N.15W.31.200	720	- -71	440	- -71	7,600	--	400	--	S	
05N.15W.31.222A	710	--	320R	--	7,425	Kmv	340	15.0	D	
05N.15W.31.222B	--	--	406.66	12- 4-80	7,422	Kmv	--	--	U	
05N.16W.19.141	430R	--	--	--	7,298	Kd	700	13.0	D, S	
05N.16W.19.343	250	- -79	Dry	- -79	7,220	--	--	--	--	
05N.16W.21.242	800R	--	--	--	7,308	Kd	1,000	13.0	S	
05N.16W.22.213	254	- -79	Dry	- -79	7,310	--	--	--	U	
05N.16W.23.411	900R	9- -80	503.64	7-16-81	7,330	Kd	--	--	S	
05N.16W.25.121	300R	--	248	12- 4-80	7,365	Kmv	--	--	S	
05N.16W.30.321	250	- -79	Dry	- -79	7,300	--	--	--	U	
05N.16W.31.413	253	- -79	Dry	- -79	7,020	--	--	--	U	
05N.16W.31.441	300R	--	57.26	2-11-81	6,980	Kg	--	--	S	
05N.16W.36.431	--	--	--	--	7,200	Kmv	1,300	11.0	S	Spring
05N.17W.01.141	294	--	257.09	11-20-80	7,200	Kmv	--	--	U	
05N.17W.02.114	--	--	121.70	11-20-80	7,059	Kmv	--	--	U	
05N.17W.03.221	108	--	86.51	11-20-80	7,020	Kmv	--	--	U	

Table 1.--*Records of selected wells, test holes, lakes, and springs*--**Continued**

Location number	Well depth (feet)	Date well completed	Water level below land surface (feet)	Date measured	Altitude of land surface (feet)	Aquifer (major)	Specific conductance (µS/cm)	Temperature (degrees Celsius)	Use	Name and remarks
05N.17W.03.231	96	--	71.53	11-20-80	7,005	Kmv	--	--	U	
05N.17W.05.000	400	6- 4-81	O, R	--	6,980	--	--	--	T	Coal test
05N.17W.05.232	200	--	--	--	6,972	Kmv	450	15.0	D	
05N.17W.05.444	420	--	134.08	11-13-80	6,952	Kmv	525	15.0	S	
05N.17W.06.333	184	--	--	--	6,954	Kmv	280	12.0	S	
05N.17W.07.000	650	6- 3-81	12R	--	6,985	Kmv, Kd	--	--	T	Coal test
05N.17W.07.333	225R	--	--	--	7,000	Kmv	350	14.0	S	
05N.17W.09.000	360	6- 4-81	46R	--	6,980	--	--	--	T	Coal test
05N.17W.09.223	--	--	--	--	6,982	Kmv	465	14.0	--	
05N.17W.10.344	505	10- 5-71	112.50	11-19-80	7,025	Kmv	700	13.0	S	
05N.17W.13.132A	700	--	--	--	7,121	Kd	650	13.0	D	
05N.17W.13.132B	516	- -79	Dry	- -79	7,120	--	--	--	U	
05N.17W.14.443	750	--	--	--	7,128	Kd	650	16.0	S, D	
05N.17W.15.324A	232	--	--	--	7,060	Kmv	--	--	U	
05N.17W.15.324B	234	- -79	232R	- -79	7,060	Kmv	--	--	U	
05N.17W.24.324	250	- -79	Dry	- -79	7,225	--	--	--	U	
05N.17W.27.311	--	- -79	--	--	7,150	--	--	--	U	
05N.17W.29.131	365	--	347R	10-10-80	7,055	Kmv	550	15.0	D	
05N.17W.31.211	425	--	--	--	7,968	Kmv	450	12.5	S	
05N.17W.34.133	250	- -79	Dry	--	6,910	--	--	--	U	
05N.18W.01.000	365	6- 5-81	O, R	--	6,950	Kmv, Kd	--	--	T	Coal test
05N.18W.01.233	275	--	225	10- 4-80	6,922	Kmv	350	15.0	S	
05N.18W.03.000	340	6- 5-81	O, R	--	6,935	Kmv, Kd	--	--	T	Coal test
05N.18W.08.223	--	--	191.48	12-12-80	6,974	Kmv	340	20.0	S	
05N.18W.10.342	300	5-12-67	--	--	7,035	Kmv	350	15.0	S	
05N.18W.11.000	700	6- 3-81	O, R	--	6,875	Kmv, Kd	--	--	T	Coal test
05N.18W.12.212	170	--	--	--	6,972	Kmv	300	15.0	D	
05N.18W.13.222	180R	--	--	--	7,008	Kmv	310	14.0	D	
05N.18W.13.444	600	--	--	--	7,075	Kd	950	14.0	D	
05N.18W.15.111	300	--	275	12- 2-80	7,044	Kmv	370	17.0	S ,D	

Table 1.--*Records of selected wells, test holes, lakes, and springs*--Continued

Location number	Well depth (feet)	Date well completed	Water level below land surface (feet)	Date measured	Altitude of land surface (feet)	Aquifer (major)	Specific conductance (µS/cm)	Temperature (degrees Celsius)	Use	Name and remarks
05N.18W.15.444	200	--	175	12- 2-80	7,070	Kmv	440	13.0	S	
05N.18W.23.233	350	--	210R	1- 5-81	7,108	Kmv	--	--	S	
05N.18W.24.324	255	4-26-70	--	--	7,105	Kmv	500	14.0	S	
05N.18W.25.224	--	--	174.30	4-10-80	7,125	Kmv	--	--	U	
05N.18W.26.241	220	--	102.75	12-18-80	7,150	Kmv	--	--	U	
05N.18W.27.222	--	--	42.79	1- 6-81	7,192	Tfl	--	--	D	
05N.18W.28.122	400	6-12-74	310R	6-12-74	7,420	Kmv	--	--	D	
05N.18W.29.000	300	6-15-81	170R	--	7,470	Kmv	--	--	T	Coal test
05N.18W.29.000A	500	6-16-81	102R	--	7,465	--	--	--	T	Coal test
05N.18W.31.000	400	6-16-81	71R	--	7,510	Kmv	--	--	T	Coal test
05N.18W.33.000	400	6-17-81	59R	--	7,305	Kmv	--	--	T	Coal test
05N.19W.04.111	167	--	153.48	11-19-80	6,560	Kmv	--	--	U	
05N.19W.04.444A	200	--	144.80	11-12-80	6,629	Kd	--	--	U	
05N.19W.04.444B	--	--	--	--	6,629	Kd	500	17.0	S	
05N.19W.07.334	--	--	--	--	6,970	Kmv	390	13.0	--	Spring
05N.19W.19.000	500	6-13-81	42R	--	7,190	Kmv	--	--	T	Coal test
05N.19W.29.213	--	--	94.32	11-19-80	7,205	Kmv	--	--	S	
05N.19W.30.000	400	6-13-81	O, R	--	7,220	Kmv	--	--	T	Coal test
05N.20W.02.214	600	--	393.93	10-14-80	6,650	Kd	850	17.5	S	
05N.20W.05.000	340	6-12-81	O, R	--	6,895	--	--	--	T	Coal test
05N.20W.05.443	340	--	Dry	10-22-80	6,840	Tfl	--	--	U	
05N.20W.13.000	380	6-11-81	15R	--	7,140	Kmv	--	--	T	Coal test
05N.20W.14.242	--	--	140.83	9-26-80	7,185	Kcc	--	--	U	
05N.20W.24.122	180	4- -57	112.97	9-24-80	7,126	Kcc	500	15.0	S	
05N.20W.29.344	1,453	5- 8-50	264.44	9-24-80	6,527	Psg	1,300	23.0	S	
05N.21W.10.112A	208	7- -75	99.73	9-24-80	6,600	Kd	--	--	S, D	
05N.21W.10.112B	300	--	125	9- -75	6,600	Kd	500	15.0	S, D	
05N.21W.35.321	1,300	- -75	100R	- -75	6,236	Psg	1,300	16.5	S	
06N.14W.14.100	650	- -59	393	- -71	7,472	Kd	380	13.0	S	
06N.16W.32.222	228	--	--	--	7,170	Kmv	--	--	S	

Table 1.--*Records of selected wells, test holes, lakes, and springs*--Continued

Location number	Well depth (feet)	Date well completed	Water level below land surface (feet)	Date measured	Altitude of land surface (feet)	Aquifer (major)	Specific conductance (µS/cm)	Temperature (degrees Celsius)	Use	Name and remarks
06N.17W.02.342	128	- -00	124.78	4-21-80	7,010	Kd	--	--	S	
06N.17W.05.411	405	--	375R	7- 7-71	6,950	Kd	--	--	S	
06N.17W.13.342	--	--	164.86	1- 6-81	7,108	Kd	470	14.0	S	
06N.17W.16.331	--	--	135.76	11-13-80	7,028	Kd	450	14.0	S	
06N.17W.18.233	--	--	17.99	4-10-80	6,810	Qal	--	--	U	
06N.17W.18.321	--	--	26.55	10-31-80	6,815	Qal	--	--	D	
06N.17W.19.131	323R	--	180R	11-14-80	6,930	Kd	350	13.0	D	
06N.17W.20.442	--	--	--	--	6,990	Kd	400	14.5	S	
06N.17W.22.421	160R	--	40R	1- 6-81	7,000	Kmv	--	--	D	
06N.17W.27.123	--	--	146R	1- 6-81	6,952	Kmv	1,300	14.0	S	
06N.17W.30.111	240R	--	--	--	6,927	Kd	340	13.0	D	
06N.17W.30.214	--	--	--	--	6,955	Kd	445	14.5	S	
06N.17W.30.311	162R	--	--	--	6,960	Kd	380	15.0	D	
06N.17W.31.313	--	--	110.48	11-20-80	6,950	Kmv	600	13.0	D	
06N.17W.33.000	400	6- 5-81	O, R	--	6,945	Kmv, Kd	--	--	T	Coal test
06N.17W.33.212	10R	--	--	--	7,196	Qal	320	14.0	D, S	
06N.17W.34.433A	70R	--	50.78	11-30-80	6,988	Kmv	--	--	U	
06N.17W.34.433B	86	--	50.96	11-13-80	6,980	Kmv	1,350	13.0	S	
06N.17W.35.333	160	--	110.78	11-20-80	7,052	Kmv	--	--	U	
06N.18W.10.232	--	--	--	--	6,901	TRc	600	22.0	S	
06N.18W.23.124	128	--	49.28	11-12-80	6,800	TRc	--	--	U	
06N.18W.27.433	--	--	--	--	6,907	--	383	16.0	S	
06N.18W.30.214	--	--	--	--	6,620	Kmv	370	14.4	S	Spring
06N.19W.01.131	400	--	--	--	6,771	TRc	520	17.0	S	
06N.19W.13.413	--	--	--	--	6,738	TRc	930	20.0	S	
06N.19W.16.113	--	--	--	--	6,609	Kd	600	14.0	S	
06N.19W.24.311	40R	--	--	--	6,521	Kd	2,200	15.0	S	
06N.19W.24.421	90R	--	--	--	6,674	Kd	400	15.0	S	
06N.19W.29.231	252R	--	--	--	6,490	Kd	2,200	17.0	S	
06N.19W.30.233	--	--	98.88	11-11-81	6,535	Kd	--	--	S	

Table 1.--*Records of selected wells, test holes, lakes, and springs*--Concluded

Location number	Well depth (feet)	Date well completed	Water level below land surface (feet)	Date measured	Altitude of land surface (feet)	Aquifer (major)	Specific conductance (µS/cm)	Temperature (degrees Celsius)	Use	Name and remarks
06N.20W.04.233	--	--	--	--	6,250	Kd	2,800	14.0	S	
06N.20W.06.444	307	--	88.52	9-25-80	6,324	Kd	--	--	S	
06N.20W.10.213	--	--	93.37	10-01-80	6,274	Kd	2,100	15.5	S	
06N.20W.10.442	--	--	86.42	10-21-80	6,293	Kd	2,500	--	S	
06N.20W.14.412	200R	--	122.44	7-14-46	--	--	2,860	11.5	--	
	200R	--	128.44	10- 2-80	6,360	Kd	--	--	S	
06N.20W.31.132	355	--	338	10-22-80	6,762	Kd	1,800	14.5	U	
06N.21W.10.222	270R	9-22-47	150.68	9-30-80	6,358	Kd	900	18.0	S	

Table 2.--*Chemical analyses of water from selected wells, lakes, and springs*

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg. C, degrees Celsius; mg/L, milligrams per liter; fet, fixed-pH endpoint titration. Quaternary: Qb, basalt; Qal, alluvium; Tertiary: Tfl, Fence Lake Formation; Td, Datil Group; Tb, Baca Formation; Cretaceous: Kmv, Mesaverde Group; Kcc, Crevasse Canyon Formation; Kg, Gallup Sandstone; Km, Mancos Shale; Kd, Dakota Sandstone; TRc, Triassic Chinle Formation; Psg, Permian San Andres Limestone and Glorieta Sandstone. --, no data; >, greater than; <, less than]

Location number	Date of sample	Geo-logic unit	Spe-cific con-duct-ance (µS/cm)	Solids, residue at 180 deg. C, dis-solved (mg/L)	pH, lab (stand-ard units)	Temper-ature, water (deg. C)	Calcium, dis-solved (mg/L as Ca)	Magne-sium, dis-solved (mg/L as Mg)	Potas-sium, dis-solved (mg/L as K)	Sodium+ potas-sium, dis-solved (mg/L as Na)	Bicar-bonate, fet field (mg/L as HCO_3)	Car-bonate, fet field (mg/L as CO_3)	Alka-linity, lab (mg/L as $CaCO_3$)	Sulfate, dis-solved (mg/L as SO_4)	Chlo-ride-dis-solved (mg/L as Cl)	Fluo-ride, dis-solved (mg/L as F)	Nitro-gen, nitrate, dis-solved (mg/L as NO_3)	Sodium, dis-solved (mg/L as Na)
01N.15W.11.000	12-30-33	--	--	--	--	--	48	17.00	--	62	350	0.0	--	14	17	0.2	1.30	--
01N.15W.15.441	07-11-80	Td	435	--	--	19	41	16.00	0.6	--	--	--	--	4.8	6.1	2.1	--	46
01N.15W.26.144	07-11-80	Td	370	--	--	24	27	13.00	1.8	--	--	--	--	5.3	7.9	2	--	41
01N.15W.27.342	08-26-80	Qal	670	479	--	12	55	22.00	1.2	--	--	--	--	32	23	1.8	--	85
01N.16W.03.000	12-20-33	--	--	--	--	--	20	--	--	180	520	--	--	2	31	3.1	.40	--
01N.16W.03.214	06-27-79	--	1,040	--	--	24	27	11.00	1.7	200	630	--	--	12	33	2.3	--	200
	06-27-79	--	1,020	677	--	20	27	10.00	2.1	220	660	--	--	804	34	2.3	--	220
01N.16W.03.220	05-06-65	--	752	475	--	--	14	3.20	--	--	421	.0	--	15	29	2.6	.10	166
01N.17W.12.333	07-26-83	--	820	--	8.1	14	100	24.00	1.5	--	--	--	159	21	160	.4	--	33
01N.18W.35.412	05-18-82	Td	500	--	8.1	15	15	3.30	1.7	--	--	--	187	24	11	.4	--	79
01N.19W.27.420	07-13-83	--	453	--	8.5	18.5	9.5	2.60	1.9	--	--	--	207	20	10	.8	--	92
01N.20W.27.221	09-28-79	Kmv	--	316	--	19.8	34	16.00	3.1	59	--	--	--	40	5.8	.4	--	56
01N.21W.16.000	12-22-33	Qal	--	--	--	--	130	110.00	--	170	400	.0	--	650	69	1.2	30.00	--
01S.18W.05.332	05-18-82	Qal	408	--	8.9	18	5.2	.14	.4	--	--	--	152	35	13	1.3	--	91
01S.18W.09.142	05-18-82	Qal	800	--	9.1	18	7.2	1.20	.6	--	--	--	106	71	110	1.6	--	140
01S.19W.01.223	10-15-80	Tb	721	468	8	15	45	26.00	4.9	--	--	--	240	78	37	.4	--	76
01S.19W.09.124	08-12-80	Qal	480	313	--	18	2.4	.30	1.5	--	--	--	--	39	8	1.5	--	110
01S.20W.21.233	03-16-83	Qal	438	--	8	7	30	17.00	3.1	--	--	--	209	9.2	18	.4	--	42
01S.20W.21.411	06-26-79	--	460	243	--	16	26	16.00	3.4	45	240	--	--	19	10	.4	--	42
01S.21W.25.244	06-26-79	Qal	312	225	--	--	36	11.00	2	24	--	--	--	15	14	.3	--	22
	10-15-80	Qal	372	212	8	15	37	11.00	1.6	--	--	--	--	11	13	.3	--	23

Table 2.--*Chemical analyses of water from selected wells, lakes, and springs*--Continued

Location number	Date of sample	Geo-logic unit	Spe-cific con-duct-ance (µS/cm)	Solids, residue at 180 deg. C, dis-solved (mg/L)	pH, lab (stand-ard units)	Temper-ature, water (deg. C)	Calcium, dis-solved (mg/L as Ca)	Magne-sium, dis-solved (mg/L as Mg)	Potas-sium, dis-solved (mg/L as K)	Sodium+ potas-sium, dis-solved (mg/L as Na)	Bicar-bonate, fet field (mg/L as HCO_3)	Car-bonate, fet field (mg/L as CO_3)	Alka-linity, lab (mg/L as $CaCO_3$)	Sulfate, dis-solved (mg/L as SO_4)	Chlo-ride-dis-solved (mg/L as Cl)	Fluo-ride, dis-solved (mg/L as F)	Nitro-gen, nitrate, dis-solved (mg/L as NO_3)	Sodium, dis-solved (mg/L as Na)
02N.15W.05.000	08-03-79	Tb	--	293	--	12.6	43	9.00	1.8	39	--	--	--	17	16	0.5	--	37
02N.17W.13.242	03-12-81	Td	460	290	7.8	7	55	21.00	2.4	--	--	--	210	23	12	.4	--	17
02N.18W.07.141	07-18-85	Kmv	994	609	8.6	18.5	4.5	.35	1.3	--	--	--	436	62	24	1.4	--	240
02N.19W.14.441	07-18-85	Kmv	699	421	8.8	18.5	2.9	.40	1	--	--	--	307	43	8.5	.9	--	180
02N.20W.07.131	12-22-33	--	--	--	--	--	54	46.00	--	300	490	0.0	--	520	18	1	12.00	--
02N.20W.29.410	08-05-79	Kcc	--	293	--	12.6	24	14.00	2.9	64	--	--	--	49	9.6	.5	--	61
02N.20W.29.413	08-08-80	Kmv	575	310	--	13	22	16.00	3.4	--	--	--	--	52	9.5	.5	--	66
02N.21W.03.244	03-13-81	Kd	3,000	2,230	7.5	9	270	91.00	19	--	--	--	580	770	380	2.2	--	380
02N.21W.24.141	12-22-33	Qal	--	--	--	--	69	34.00	--	--	230	.0	--	180	9	.6	.40	36
03N.15W.18.000	12-21-33	Kmv	--	--	--	--	2	--	--	130	290	.0	--	30	12	2.1	.00	--
03N.15W.22.111	03-24-81	Td	525	345	7.9	13	69	18.00	.7	--	--	--	270	19	14	.7	--	28
03N.17W.08.200	07-19-79	Kg	--	747	--	--	12	2.80	1.6	240	--	--	--	180	19	1	--	240
03N.17W.10.223	07-25-83	--	710	--	8.4	16	--	--	1.4	--	--	--	337	58	9.2	2.3	--	170
03N.18W.22.130	07-17-79	Km	--	505	--	--	1.2	.10	.9	190	--	--	--	51	18	1.6	--	190
03N.18W.22.232	09-08-82	Kd	980	--	9	21.5	1.4	.10	.8	--	--	--	371	45	13	1.5	--	210
03N.18W.30.000	12-22-33	--	--	--	--	13	14	--	--	491	563	.0	--	175	340	.0	1.80	--
03N.18W.30.314	10-28-85	--	221,000	--	7.4	17.5	90	4,100.00	750	--	--	--	220	44,000	210,000	.5	--	110,000
03N.18W.30.433	07-18-85	Qal	1,960	1,160	8.8	21.5	12	7.00	8.1	--	--	--	411	150	290	1	--	430
03N.18W.31.114	10-28-85	--	148,000	--	7.6	14	600	1,900.00	310	--	--	--	196	10,000	72,000	.6	--	45,000
03N.18W.31.314	07-18-85	Qal	1,230	775	8.4	17.5	21	7.70	4.3	--	--	--	474	110	49	2.1	--	270
03N.18W.33.233	08-19-80	Km	1,290	762	--	17	5.2	1.00	1.5	--	--	--	--	150	120	2.4	--	270
03N.21W.15.322	03-13-81	TRc	3,460	--	7.8	8	180	91.00	25	--	--	--	220	850	510	2.1	--	460
04N.15W.04.423	12-16-80	Td	350	--	8	15.5	33	8.80	1.9	--	--	--	180	16	7	.3	--	40
04N.16W.10.331A	12-17-80	Kmv	533	--	8	--	22	5.10	1.8	--	--	--	190	68	5.7	.7	--	89

Table 2.--*Chemical analyses of water from selected wells, lakes, and springs*--Continued

Location number	Date of sample	Geo-logic unit	Spe-cific con-duct-ance (µS/cm)	Solids, residue at 180 deg. C, dis-solved (mg/L)	pH, lab (stand-ard units)	Temper-ature, water (deg. C)	Calcium, dis-solved (mg/L as Ca)	Magne-sium, dis-solved (mg/L as Mg)	Potas-sium, dis-solved (mg/L as K)	Sodium+ potas-sium, dis-solved (mg/L as Na)	Bicar-bonate, fet field (mg/L as HCO_3)	Car-bonate, fet field (mg/L as CO_3)	Alka-linity, lab (mg/L as $CaCO_3$)	Sulfate, dis-solved (mg/L as SO_4)	Chlo-ride-dis-solved (mg/L as Cl)	Fluo-ride, dis-solved (mg/L as F)	Nitro-gen, nitrate, dis-solved (mg/L as NO_3)	Sodium, dis-solved (mg/L as Na)
04N.16W.10.331B	12-17-80	Kmv	846	--	7.7	11	43	11.00	2.3	--	--	--	200	200	9.5	0 .6	--	120
04N.16W.31.111	07-26-83	--	720	--	7.9	13	28	13.00	2.3	--	--	--	462	2.9	6.3	1.4	--	150
04N.17W.03.324B	10-14-80	Kmv	1,900	--	8.3	13.5	6.4	.90	2.3	--	--	--	270	520	8.9	1.4	--	380
04N.17W.04.233	10-13-80	Kmv	1,550	--	8.3	14	7.6	.90	1.4	--	--	--	--	530	14	.4	--	330
04N.17W.08.121	10-14-80	Kmv	600	--	--	15	5.5	.70	1.3	--	--	--	--	44	10	.6	--	120
04N.17W.23.220	07-27-83	Kmv	--	--	7.8	16	140	27.00	4.1	--	--	--	322	500	6.4	.2	--	180
04N.18W.03.442	10-31-80	Kmv	800	--	8	13	50	32.00	8.7	--	--	--	230	66	63	.6	--	57
04N.18W.05.144B	11-18-80	Kmv	350	--	7.7	14	47	8.90	.7	--	--	--	160	21	15	.7	--	14
04N.18W.28.122	08-04-79	Kg	--	532	--	--	13	2.70	1.1	160	--	--	--	140	9.1	.4	--	160
04N.18W.28.211	10-30-80	Kg	900	--	8.2	13	16	3.40	1.1	--	--	--	310	150	8.6	.5	--	200
04N.18W.36.312	11-20-80	Kg	600	--	>9	14	1.8	.50	.6	--	--	--	280	100	7.9	1	--	170
04N.19W.14.314A	10-29-80	Kg	4,370	--	8	15	180	49.00	6.2	--	--	--	--	2,100	23	.8	--	770
04N.19W.15.422	10-29-80	Km	4,490	--	8	--	61	12.00	5.4	--	--	--	--	1,900	20	.7	--	900
04N.19W.25.414	10-30-80	Psg	1,600	--	7.2	34	150	31.00	13	--	--	--	--	280	68	.0	--	150
04N.19W.25.424	08-04-79	Kg	--	950	--	33.8	130	29.00	13	180	--	--	--	310	68	3.4	--	170
04N.19W.28.234	10-29-80	Psg	1,440	--	7.3	28	180	41.00	9.7	--	--	--	--	280	63	1	--	88
	11-20-80	Psg	1,300	--	7	29	180	40.00	9.3	--	--	--	420	290	63	.9	--	86
05N.14W.06.334	12-18-80	Kmv	406	--	7.9	14	27	9.90	3.7	--	--	--	160	25	14	.6	--	48
05N.14W.15.330	08-10-79	--	--	260	--	--	29	11.00	2.8	45	--	--	--	22	12	.3	--	42
05N.14W.15.334	12-03-80	Kd	450	--	7.7	17	31	11.00	3.5	--	--	--	200	22	9.1	.4	--	46
05N.15W.16.223	12-03-80	Km	290	--	8	15	24	7.50	4	--	--	--	160	18	9	.4	--	42
05N.15W.19.444	12-04-80	Kmv	1,130	--	7.8	14	110	31.00	5.4	--	--	--	250	95	120	.4	--	78
05N.15W.26.133	12-16-80	Kmv	330	--	8.4	14.5	5.3	1.30	1.3	--	--	--	170	17	4.2	.4	--	87
05N.15W.28.431	12-16-80	Kmv	500	--	9.1	13	2.2	.30	1.2	--	--	--	280	2.9	9	3.1	--	140
05N.15W.31.222A	12-04-80	Kmv	340	--	8.5	15	3.6	.60	2.1	--	--	--	190	16	6.3	.5	--	87

Table 2.--*Chemical analyses of water from selected wells, lakes, and springs*--Continued

Location number	Date of sample	Geo-logic unit	Spe-cific con-duct-ance (µS/cm)	Solids, residue at 180 deg. C, dis-solved (mg/L)	pH, lab (stand-ard units)	Temper-ature, water (deg. C)	Calcium, dis-solved (mg/L as Ca)	Magne-sium, dis-solved (mg/L as Mg)	Potas-sium, dis-solved (mg/L as K)	Sodium+ potas-sium, dis-solved (mg/L as Na)	Bicar-bonate, fet field (mg/L as HCO_3)	Car-bonate, fet field (mg/L as CO_3)	Alka-linity, lab (mg/L as $CaCO_3$)	Sulfate, dis-solved (mg/L as SO_4)	Chlo-ride-dis-solved (mg/L as Cl)	Fluo-ride, dis-solved (mg/L as F)	Nitro-gen, nitrate, dis-solved (mg/L as NO_3)	Sodium, dis-solved (mg/L as Na)
05N.16W.19.141	11-19-80	Km	700	--	7.9	13	4.7	26.00	1.6	--	--	--	270	59	4.1	0.8	--	100
05N.16W.21.242	11-19-80	Kd	1,000	--	8.6	13	2.3	.20	1.2	--	--	--	410	78	5.4	7.5	--	240
05N.16W.23.411	06-13-88	Kd	550	357	8.7	15.5	4	1.20	1.6	--	--	--	--	40	12	1.7	0.01	140
05N.16W.36.431	12-17-80	Kmv	1,300	--	7.7	11	110	57.00	2.8	--	--	--	370	430	14	.4	--	140
05N.17W.05.232	11-13-80	Kmv	450	--	8.7	15	2.6	.60	1.2	--	--	--	200	45	7	.9	--	120
05N.17W.05.444	11-06-80	Kmv	525	--	9	15	1.6	.30	.9	--	--	--	250	49	4.7	.9	--	140
05N.17W.06.333	11-06-80	Kmv	327	--	8.2	12	11	3.60	2.1	--	--	--	--	19	5.4	.4	--	56
05N.17W.07.333	11-20-80	Kmv	350	--	7.8	14	41	10.00	1.9	--	--	--	130	34	7.8	.8	--	16
05N.17W.09.223	11-06-80	Kmv	465	--	7.9	14	14	2.90	2.3	--	--	--	220	43	5.2	.5	--	110
05N.17W.10.344	11-20-80	Kmv	700	--	8.4	13	4.2	.60	1	--	--	--	240	74	5.5	.6	--	150
05N.17W.13.132A	11-19-80	Kd	650	--	9	13	2.8	.60	1	--	--	--	260	50	4.3	1.6	--	140
05N.17W.14.443	11-19-80	Kd	650	--	9	16	1.3	.10	.5	--	--	--	280	34	2.5	1.1	--	150
05N.17W.29.131	10-10-80	Kmv	550	--	--	15	30	6.00	2.4	--	--	--	--	72	11	.7	--	79
05N.17W.31.211	10-20-80	Kg	450	--	8	12.5	13	2.40	2.2	--	--	--	190	22	7.6	.6	--	80
05N.18W.01.233	11-05-80	Kmv	350	--	8.7	15	3.4	.70	1.3	--	--	--	150	22	12	.5	--	80
05N.18W.08.223	11-12-80	Kmv	340	--	7.9	20	42	10.00	1.3	--	--	--	150	19	16	.4	--	20
05N.18W.10.342	11-05-80	Kmv	414	--	7.8	15	47	10.00	2	--	--	--	--	22	15	.4	--	22
05N.18W.12.212	11-05-80	Kmv	336	--	8.1	15	31	7.80	2.1	--	--	--	--	28	6.9	.5	--	24
05N.18W.13.222	11-06-80	Kmv	351	--	7.8	14	40	9.00	1.8	--	--	--	--	32	10	.6	--	15
05N.18W.13.444	11-19-80	Km	950	--	8.6	14	3.7	.60	1.2	--	--	--	300	170	33	3.7	--	230
05N.18W.15.111	12-02-80	Kmv	456	--	8	17	62	11.00	1.8	--	--	--	160	28	29	.5	--	16
05N.18W.15.444	12-02-80	Kmv	532	--	8.1	13	32	9.30	2.5	--	--	--	220	42	10	.6	--	67
05N.18W.24.324	01-07-81	Kmv	500	--	7.8	14	57	13.00	1.8	--	--	--	130	27	37	.5	--	15
05N.19W.04.444A	11-12-80	Kmv	500	--	8.7	17	1.9	.20	.8	--	--	--	240	30	8.3	.5	--	130
05N.19W.07.334	10-14-80	Kmv	371	--	7.6	13	50	8.40	.8	--	--	--	--	9.9	13	.6	--	8

Table 2.--*Chemical analyses of water from selected wells, lakes, and springs*--Continued

Location number	Date of sample	Geologic unit	Specific conductance (μS/cm)	Solids, residue at 180 deg. C, dissolved (mg/L)	pH, lab (standard units)	Temperature, water (deg. C)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Potassium, dissolved (mg/L as K)	Sodium+ potassium, dissolved (mg/L as Na)	Bicarbonate, fet field (mg/L as HCO_3)	Carbonate, fet field (mg/L as CO_3)	Alkalinity, lab (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Nitrogen, nitrate, dissolved (mg/L as NO_3)	Sodium, dissolved (mg/L as Na)
05N.20W.02.214	10-14-80	Kd	825	--	8.5	17.5	2.9	0.70	1.1	--	--	--	--	120	18	1.1	--	190
05N.20W.24.122	09-24-80	Km	500	--	--	15	73	11.00	1.7	--	--	--	--	23	32	.4	--	7
05N.20W.29.344	09-26-80	Psg	1,350	--	--	23	140	34.00	9.7	--	--	--	--	250	60	2	--	69
05N.21W.10.112B	10-01-80	Km	500	--	--	15	50	12.00	2.1	--	--	--	--	24	24	.4	--	18
05N.21W.35.321	09-24-80	--	1,300	--	--	16.5	54	42.00	10	--	--	--	--	290	60	1.5	--	75
06N.10W.06.121	08-28-78	Kg	539	300	--	15	56	26.00	2.6	--	--	--	--	39	2.7	1.1	--	23
06N.17W.13.342	01-06-81	Kmv	470	--	8.1	14	24	10.00	3.8	--	--	--	180	39	7.6	.3	--	56
06N.17W.16.331	11-13-80	Kmv	450	--	8	14	39	17.00	5.2	--	--	--	210	37	12	.3	--	40
06N.17W.19.131	11-14-80	Kmv	350	--	7.9	13	12	3.10	2.4	--	--	--	160	21	5.8	.3	--	67
06N.17W.20.442	11-13-80	Kmv	400	--	8	14.5	33	15.00	5.1	--	--	--	180	27	9	.3	--	34
06N.17W.27.123	01-06-81	Kmv	1,300	--	8.3	14	7	1.70	1.5	--	--	--	380	180	20	5	--	270
06N.17W.30.111	11-06-80	Kmv	418	--	7.3	13	38	13.00	3.6	--	--	--	--	32	6.1	.2	--	31
06N.17W.30.214	11-13-80	Kmv	455	--	7.9	14.5	42	19.00	4.9	--	--	--	200	34	12	.3	--	30
06N.17W.30.311	11-07-80	Kmv	380	--	8	15	32	14.00	5.5	--	--	--	180	35	5.8	.3	--	31
06N.17W.31.313	11-20-80	Kmv	600	--	8.6	13	46	15.00	2.7	--	--	--	240	41	7.1	.3	--	48
06N.17W.33.212	11-21-80	Kmv	320	--	7.9	14	30	20.00	4.1	--	--	--	170	.8	2.9	2.1	--	8
06N.17W.34.433A	11-06-80	Kmv	1,511	--	7.8	13	83	19.00	3.2	--	--	--	--	380	23	.2	--	230
06N.18W.10.232	10-29-80	TRc	629	--	8.8	17	1.3	<.00	2.4	--	--	--	280	35	11	.6	--	150
06N.18W.27.433	11-12-80	Qb	383	--	8	16	34	14.00	4.3	--	--	--	180	35	5.7	.3	--	32
06N.18W.30.214	10-31-80	Qb	421	--	7.8	14.5	37	13.00	3.5	--	--	--	--	37	6.5	.4	--	29
06N.19W.01.131	11-06-80	Tfl	520	--	8	17	26	3.90	6.5	--	--	--	210	71	12	.6	--	100
06N.19W.13.413	11-05-80	Qb	930	--	8	20	17	2.50	3.7	--	--	--	230	240	16	.3	--	200
06N.19W.16.113	10-29-80	Qb	655	--	8.1	14	60	17.00	4	--	--	--	--	78	30	.5	--	47
06N.19W.24.311	11-05-80	Kmv	2,200	--	7.7	15	370	100.00	6	--	--	--	200	1,300	16	.6	--	130
06N.19W.24.421	11-05-80	Kmv	480	--	7.8	15	46	18.00	5	--	--	--	--	62	7	.3	--	23

Table 2.--*Chemical analyses of water from selected wells, lakes, and springs*--Concluded

Location number	Date of sample	Geologic unit	Specific conductance (µS/cm)	Solids, residue at 180 deg. C, dissolved (mg/L)	pH, lab (standard units)	Temperature, water (deg. C)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Potassium, dissolved (mg/L as K)	Sodium+ potassium, dissolved (mg/L as Na)	Bicarbonate, fet field (mg/L as HCO_3)	Carbonate, fet field (mg/L as CO_3)	Alkalinity, lab (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride- dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Nitrogen, nitrate, dissolved (mg/L as NO_3)	Sodium, dissolved (mg/L as Na)
06N.19W.29.231	11-11-80	Km	2,200	--	7.9	17	120	39.00	5.3	--	--	--	210	1,000	18	0.7	--	410
06N.20W.04.233	10-15-80	Kd	2,566	--	7.4	14	230	62.00	5.6	--	--	--	--	1,100	19	.5	--	330
06N.20W.10.213	10-01-80	Qal	2,129	--	7.3	15.5	190	53.00	6.2	--	--	--	--	810	12	.5	--	250
06N.20W.14.412	07-14-46	Km	2,860	--	--	11.5	310	87.00	--	320	520	0.0	--	1,300	18	.2	3.10	--
06N.20W.31.132	10-21-80	Kmv	1,800	--	8	14.4	16	3.60	12	--	--	--	170	670	47	.7	--	390
06N.21W.10.222	09-30-80	Kd	900	--	--	18	99	31.00	3.2	--	--	--	--	240	31	.4	--	49

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