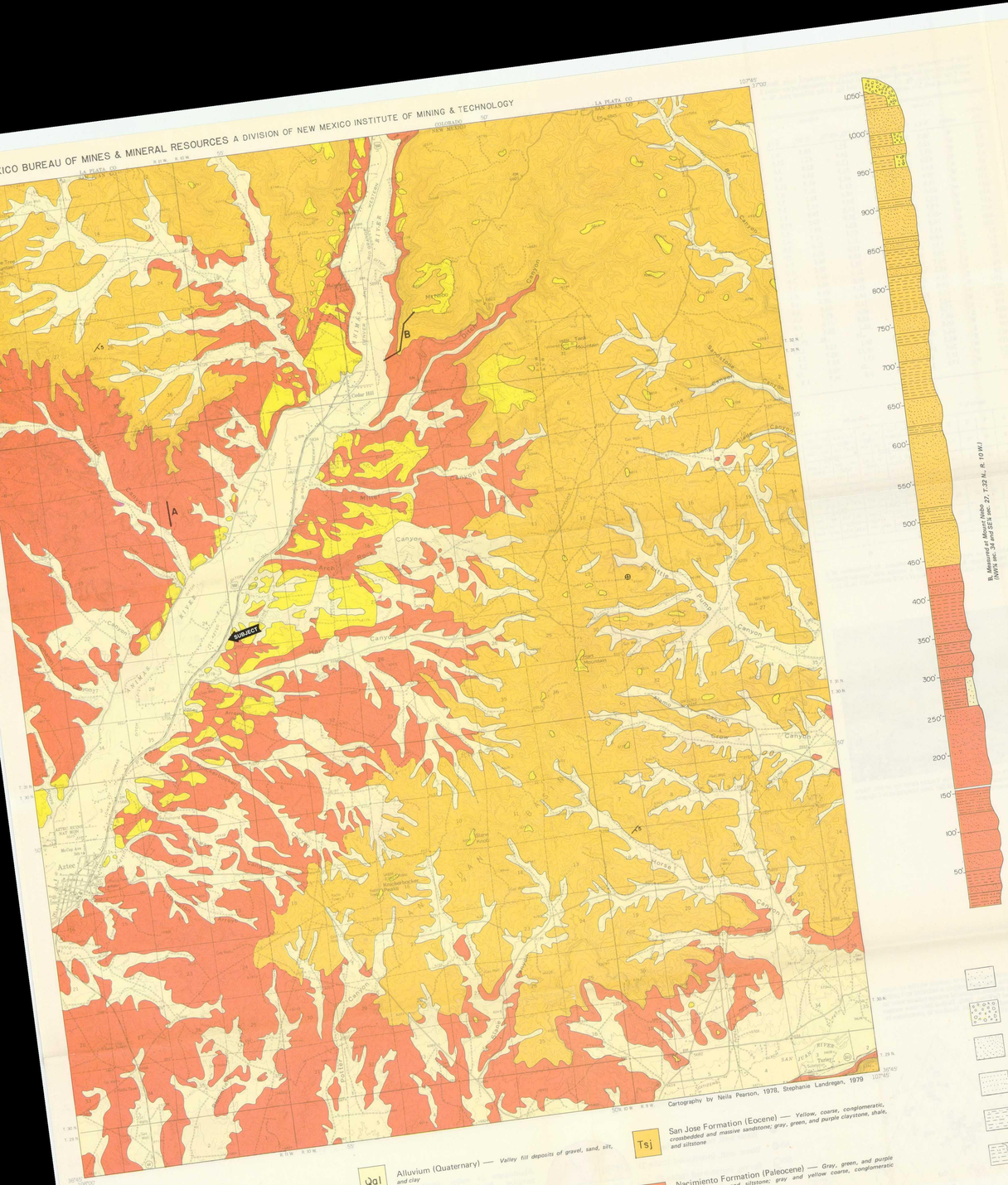

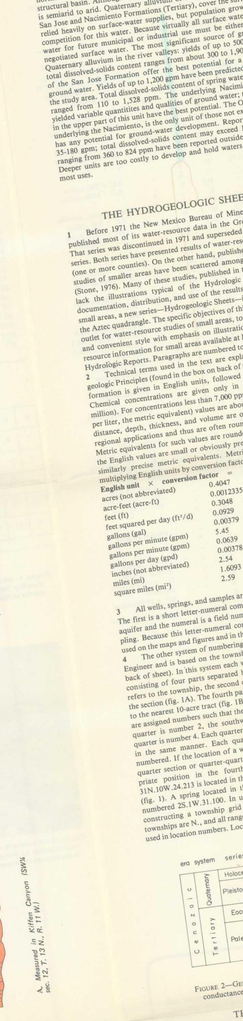

Sand

Gravel

Crossbedded sandstone

Flatbedded to massive sandstone

Claystone, silty claystone, shale, silty shale, or siltstone

Covered; bedrock lithology assumed

FIGURE 4—COMPOSITE STRATIGRAPHIC COLUMN FOR ROCKS AT THE SURFACE IN AZTEC QUADRANGLE.

Qal — Alluvium (Quaternary) — *Valley fill deposits of gravel, sand, silt, and clay*

Qtp — Terrace and pediment deposits (Quaternary) — *Veneers of gravel and sand along valleys and on mesa tops*

Tsj — San Jose Formation (Eocene) — *Yellow, coarse, conglomeratic, crossbedded and massive sandstone; gray, green, and purple claystone, shale, and siltstone*

Tn — Nacimiento Formation (Paleocene) — *Gray, green, and purple claystone, shale, and siltstone; gray and yellow coarse, conglomeratic crossbedded and massive sandstone*

B — Lines of section shown in fig. 4

Strike and dip of beds

Inclined — Horizontal

SCALE 1:62500 — DATUM IS MEAN SEA LEVEL

CONTOUR INTERVAL 40 FEET

TRUE NORTH — MAGNETIC NORTH — APPROXIMATE MEAN DECLINATION 1979

INDEX MAP OF NEW MEXICO showing location of Aztec quadrangle in San Juan County

FIGURE 3— GEOLOGIC MAP OF AZTEC QUADRANGLE.

Abstract

The Aztec 15-minute quadrangle lies about 15 mi northeast of Farmington in northeastern San Juan County, New Mexico, near the center of the San Juan structural basin. Although drained by the Animas and San Juan Rivers, the area is semiarid to arid. Quaternary alluvium or terrace deposits, together with the San Jose and Nacimiento Formations (Tertiary), cover the surface. The area has relied heavily on surface water supplies, but population growth is intensifying competition for this water. Because virtually all surface water is appropriated, Quaternary alluvium in the river valleys; yields of up to 500 gpm are possible; total dissolved-solids content ranges from about 100 to 1,900 ppm. Sandstones of the San Jose Formation offer the best potential for a bedrock source of ground water. Yields from 110 to 1,528 ppm. The underlying Nacimiento Formation has ranged from 110 to 1,200 gpm have been predicted for this unit east of the study area. Total dissolved-solids content of spring waters from the San Jose yielded variable quantities and qualities of ground water; the coarse sandstones in the upper part of this unit have the best potential. The Ojo Alamo Sandstone, underlying the Nacimiento, is the only unit of those not exposed in the area that has any potential for ground-water development. Reported yields range from 35-180 gpm, total dissolved-solids content may exceed 1,000 ppm, but values ranging from 360 to 824 ppm have been reported outside the Aztec quadrangle. Deeper units are too costly to develop and hold waters of inferior quality for most uses.

10 We wish to thank A. J. Budding and Associates, Inc., for use of the department's triaxial apparatus and portable seismic unit. Subsurface data were obtained through A. R. Kendrick, New Mexico Bureau of Mines and Mineral Resources; and Robert Bieberman, New Mexico Oil Conservation Commission, Aztec. Chemical analyses were made under the direction of Lynn Brandvold, New Mexico Bureau of Mines and Mineral Resources. The use of water well records of the with the U.S. Geological Survey, Albuquerque, and El Paso Natural Gas Company, Farmington, is also gratefully acknowledged.

REGIONAL SETTING

11 The topography is dominated by the flat-topped Mesa Mountains, which extend from Colorado into the northern part of the area, and by the extensively dissected terrain between the Animas and San Juan Rivers. Numerous intermittent streams have cut narrow, steep-walled canyons through the sandstones and shales at the surface in the area. The maximum relief is greater than 1,600 ft (480 m), with a low elevation of 5,600 ft (1,707 m) in the river valleys and a high elevation of 7,216 (2,199 m) at Tank Mountain in the northeast. Local relief may exceed 1,000 ft (305 m) where undercutting along rivers has caused steep, high bedrock cliffs. In the southern and western parts of the areas, where shales cover the surface, badland topography has developed.

12 The Aztec quadrangle is drained by two major perennial streams: the Animas and San Juan Rivers. The Animas River rises in the San Juan Mountains of Colorado and flows southwesterly across the quadrangle, draining approximately 140 mi² (360 km²) of the quadrangle. The average annual discharge is 814,200 acre-ft (1,005 hm³) 4 mi (6.4 km) north of Cedar Hill (Cooper and Trauger, 1967). The San Juan River also rises in the San Juan Mountains of Colorado and flows westerly across the southeastern corner of the quadrangle, draining about 100 mi² (260 km²) of the study area. The average annual discharge is 943,300 acre-ft (1,165 hm³) at Archuleta, New Mexico, just outside the quadrangle to the east (Cooper and Trauger, 1967).

13 The climate is arid to semiarid with an average annual precipitation at Aztec Ruins National Monument of 9.33 inches (23.7 cm) for the period 1901 through 1960 (Maker and others, 1971). Almost half falls during intense thunderstorms in which runoff is great. The mean monthly temperature for July is 74° F (23° C) and for January is 29° F (-1.7° C); the mean annual temperature is 51.3° F (10.7° C). Winds are predominantly from the southwest. Annual class A pan evaporation at nearby Farmington averages 67.37 inches (171.12 cm) for the period 1948-1962 (Cooper and Trauger, 1967).

14 Six soil associations have been mapped and described in the quadrangle area (Maker and others, 1971). Soils developed on the Quaternary alluvium include the following associations: the Werlow-Fruitland-Turley, Doak-Shiprock, and Hilly gravelly land. All have slight to high irrigation potential. The soils developed on the Tertiary deposits include the Fruitland-Turley, Doak-Shiprock, Farb, Badland-rock land, and Travessilla-rock land—none generally suited for irrigation.

15 The quadrangle is situated near the center of the San Juan structural basin, a broad, northwest-southeast-trending depression that formed during the Laramide orogeny. The basin is asymmetrical, with steeper dips on the tilting of strata along the northeast margin; it is also deep and contains a thick sequence of sedimentary rocks. The total stratigraphic record exceeds 14,000 ft (4,270 m), as proved in the El Paso Natural Gas Company well near Gobernador (sec. 7, T. 29 N., R. 5 W.).

16 Quaternary alluvium or terrace deposits, together with the San Jose and Nacimiento Formations (Tertiary), cover the surface in the Aztec quadrangle (fig. 2, 3, and 4). The position of the contact between the Nacimiento Formation (Paleocene) and the overlying San Jose Formation (Eocene) has always posed a problem in the northern part of the San Juan Basin. In the south, the San Jose Formation lies on the Nacimiento Formation with angular unconformity (Baltz and West, 1967). In the north, however, the apparent continuous deposition in Paleocene and Eocene time (Reeside, 1924; Simpson, 1948) caused the gradational nature of the contact there. Its location has differed by as much as 5 mi on maps by Reeside (1924) and Dane and Bachman (1965). Fig. 3 shows this contact remapped in detail.

17 Criteria used in mapping the Nacimiento-San Jose contact were similar to those of Reeside (1924, p. 46): the contact was generally placed at the base of the first thick, erosion-resistant, coarse-grained sandstone above which a sandstone lithology dominated and surpassed shale lithology in thickness (fig. 5). In numerous places the contact is easily located by these criteria because a good portion of the Nacimiento Formation is exposed below. From these and other localities, the contact can be traced laterally with relative ease. In other areas, however, the contact is partially covered or uncertain because the San Jose Formation is poorly represented owing to erosion.

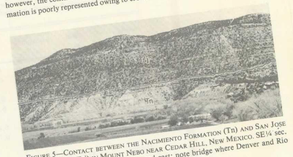

FIGURE 5—CONTACT BETWEEN THE NACIMIENTO FORMATION (Tn) AND SAN JOSE FORMATION (Tsj) IN MOUNT NEBO NEAR CEDAR HILL, NEW MEXICO. SE¼ sec. 22, T. 32 N., R. 10 W.; view toward east; note bridge where Denver and Rio Grande Western Railroad crosses Animas River.

era	system	series	stratigraphic unit	general lithology	approximate maximum thickness (ft)	depth to top of unit (ft)	maximum anticipated well yields (gpm)	water quality	remarks
Cenozoic	Quaternary	Holocene	valley fill	gravel, sand, silt, clay	100	at surface	500	TDS: 308–1,923 ppm	water table fluctuates 10–20 ft seasonally
		Pleistocene	terrace and pediment deposits	gravel, sand	30	at surface	could be high where saturated	not able to sample; probably quite good	not saturated; small quantities of perched water locally
	Tertiary	Eocene	San Jose Fm.	conglomeratic sandstone, mudstone	1,200	surface–30	1,200	TDS (springs): 110–1,528 ppm	specific capacity generally < 2 gpm/ft
		Paleocene	Nacimiento Fm.	mudstone, sandstone	1,000	surface–1,000	100	TDS: 1,004–6,754 ppm SC: 1,601–9,500 µmhos	one well flowed to height of 2 ft above ground surface; no wells known to tap this unit in study area; major aquifer elsewhere
			Ojo Alamo Ss.	conglomeratic sandstone, carbonaceous mudstone	2,000	700 – 3,000 (1,500 avg)	200	not able to sample	

FIGURE 2—GENERALIZED STRATIGRAPHY AND WATER-RESOURCE INFORMATION FOR THE AZTEC QUADRANGLE; TDS = total dissolved solids, SC = specific conductance.

THE AZTEC QUADRANGLE

5 The Aztec 15-minute quadrangle is located about 15 mi (25 km) northeast of Farmington in northeastern San Juan County, New Mexico. The population of about 7,000 people includes the communities of Aztec, Cedar Hill, and Turley. Aztec (population 6,000) is the San Juan County seat.

6 Land use and economy in the Aztec quadrangle are dominated by the petroleum industry and agriculture. Approximately 400 wells have been drilled since the discovery in 1920 of natural gas 1 mi (1.6 km) south of Aztec (Barnes, 1950). In the valleys, approximately 4,000 acres (1,620 ha) are irrigated for farming; the uplands are used for grazing beef cattle.

7 Residents of the area have relied heavily on surface-water supplies derived from the Animas and San Juan Rivers. As the regional population has grown with the increased industrial activity (especially energy-resource development), the competition for this limited surface water has intensified. However, virtually all surface water has been appropriated, and water for future use must be either ground water or negotiated surface water.

8 In response to growing interest in ground-water resources in northwestern New Mexico, the State Engineer declared the San Juan Basin an underground water basin on July 29, 1977. The purpose of declaring such basins is to protect existing surface-water rights from possible impairment by uncontrolled ground-water development. Once a basin is officially declared, its ground water is subject to appropriation, and development is strictly regulated. The detailed rules governing declared basins have been listed by the New Mexico State Engineer's Office (1966), and the ramifications of basin declaration have been suggested by Shomaker and Stone (1976).

9 Ground water has accounted for less than one percent of all water used in San Juan County because: 1) surface water has been readily available, 2) ground water has been considered to be too deep or too saline for use, and 3) little has been compiled on the ground-water potential of the area. In an effort to better define the ground-water resources of northwestern New Mexico, the U.S. Geological Survey, the New Mexico Bureau of Mines, and the Office of the State Engineer are cooperating in a study of the San Juan Basin. Although such a study is necessarily regional in scope, some appreciation of the water-resource situation on a local scale is being provided by detailed studies of selected 15-minute quadrangles. Because the Aztec quadrangle was one of those studied in conjunction with the large basinwide project, this report is intended in part to characterize the water-resource situation in the northern part of the basin—especially that of small communities experiencing water shortages because of reliance on surface-water supplies. The main purpose of this report, however, is to summarize the hydrogeology and ground-water potential of the Aztec quadrangle.

18 The Nacimiento-San Jose contact varies in elevation across the study area—not surprising in view of the stream-channel origin of the San Jose sandstones. The most significant irregularity is the low near the Animas River in T. 32 N., R. 10 W., where the contact drops from an elevation of greater than 6,300 ft to less than 6,200 ft (1920-1990 m).

19 A major change in lithology of the lower part of the San Jose Formation in the much higher sandstone/shale ratio in the southeastern part of the study area. Basal sandstones in the northern part of the area seldom exceed 93 ft (28 m) in thickness; to the southeast more than 320 ft (98 m) of continuous sandstone were measured in the San Jose Formation in SW¼ sec. 19, T. 30 N., R. 8 W. (Brown, 1976, appendix A, measured section 8).

AQUIFERS

Valley fill (Quaternary)

20 The valleys of the Animas and San Juan Rivers and their major tributaries are partially filled with alluvium consisting of gravel, sand, silt, and clay (fig. 3). These materials, deposited by streams in Pleistocene and Recent time, are being eroded by gullying that began regionally about 1880 (Bryan, 1928).

21 In the valley of the Animas River, the alluvium consists predominantly of sand and gravel. This material is outwash from Pleistocene glaciers in the San Juan Mountains to the north (Bandoian, 1969). Most driller's logs report the thickness of the alluvium in the Animas Valley to be 40-100 ft (12-30 m). The average thickness appears to be approximately 60 ft (18 m) and generally occurs in the center of the valley. At the sites of two anomalous reported values for alluvium thickness (170 ft and 308 ft; 52 and 94 m), the depth to bedrock was determined with a small portable seismic unit. Soundings showed the alluvium to be less than 100 ft (30 m) thick in both cases and so compatible with the regional average.

22 Few data exist concerning the thickness of the valley fill of the San Juan River in the study area. The highest value on record is 54 ft (16.5 m) at well A25 (table 1). Rapp (1959) reported a maximum thickness of about 80 ft (25 m) for this aquifer in the Farmington area. This value may also apply to the Aztec quadrangle because well A25 probably only partially penetrates the alluvium. Area drillers admitted that they try to avoid going so deep that they encounter the underlying bedrock because salty waters are often concentrated near this contact.

23 The alluvial deposits of the Animas and San Juan River systems are the most important source of ground water in the Aztec quadrangle and provide moderate supplies of water to numerous shallow wells (table 1). While no yield data are available, a local driller reported that most domestic wells in the Animas

THE HYDROGEOLOGIC SHEET SERIES

Before 1971 the New Mexico Bureau of Mines and Mineral Resources published most of its water-resource data in the Ground-water Report series. That series was discontinued in 1971 and supplanted by the Hydrologic Report series. Both series have presented results of water-resource studies of large areas (one or more counties). On the other hand, published results of water-resource studies of small areas have been scattered among other Bureau publications and lack the illustrations typical of the Hydrologic Reports. To facilitate the documentation, distribution, and use of the results of water-resource studies of the Aztec quadrangle, the Hydrogeologic Sheets—is initiated with this report on a small area series—Hydrogeologic Sheets—is initiated with this report on outlet for water-resource studies of small areas and to make basic water-resource information for small areas available at less cost than is possible for the Hydrologic Reports. Paragraphs are numbered in this section on Hydrogeologic Principles (found in the box on back of this sheet). Most quantitative hydrogeologic terms used in the text are explained in the section. Chemical concentrations are given only in English units (ppm—parts per million). For concentrations less than 7,000 ppm, the ppm and mg/l (milligrams per liter, the metric equivalent) values are about the same. Values for distance, depth, thickness, and volume are often estimated or generalized for regional applications and thus are often rounded to the nearest hundred units. Metric equivalents for such values are small or obviously precise, we have attempted to present the English values and metric equivalents. Metric equivalents were calculated by similarly precise metric conversion factors as follows:

English unit	× multiplying English units by conversion factor	= metric unit
acres (not abbreviated)	0.4047	hectares (ha)
acre-feet (acre-ft)	0.001233	cubic hectometers (hm³)
feet (ft)	0.3048	meters (m)
feet squared per day (ft²/d)	0.0929	meters squared per day (m²/d)
gallons (gal)	3.785	cubic meters (m³)
gallons per minute (gpm)	5.45	cubic meters per day (m³/d)
gallons per minute (gpm)	0.0639	liters per second (l/s)
gallons per day (gpd)	0.003785	cubic meters per day (m³/d)
inches (not abbreviated)	2.54	centimeters (cm)
miles (mi)	1.6093	kilometers (km)
square miles (mi²)	2.59	square kilometers (km²)

3 All wells, springs, and samples are identified in the tables by two numbers. The first is a short letter-numeral combination in which the letter identifies the aquifer and the numeral is a field number assigned during inventorying or sampling. Because this letter-numeral combination is the shorter designation, it is used on the maps and figures and in the text.

4 The other system of numbering used is that used by the New Mexico State Engineer and is based on the township, range, and section land grid (fig. 1 on back of sheet). In this system each well or spring has a unique location number consisting of four parts separated by periods: 31N.10W.24.213. The first part refers to the township, the second designates the range, and the third identifies the section (fig. 1A). The fourth part locates the well or spring within the section to the nearest 10-acre tract (fig. 1B): each section is divided into quarters, which are assigned numbers such that the northwest quarter is number 1, the northeast quarter is number 2, the southwest quarter is number 3, and the southeast quarter is number 4. Each quarter-quarter section is similarly divided and numbered. If the location of a well or spring cannot be determined to quarter-quarter section or quarter-quarter-quarter section, a zero is used in the appropriate position in the fourth part of the number. A well designated 31N.10W.24.213 is located in the NW¼ sec. 24, T. 31 N., R. 10 W. (fig. 1). A spring located in the SW¼NW¼NE¼ sec. 24, T. 31 N., R. 10 W. would be numbered 2S.1W.31.100. In unserveyed areas, locations are approximated by constructing a township grid on the best available map. In this report, all townships are N., and all ranges are W.; therefore, compass designations are not used in location numbers. Location 31N.10W.24.213 will read 31.10.24.213.

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Hydrogeology of Aztec quadrangle, San Juan County, New Mexico

by Daniel R. Brown and William J. Stone

1979