Ground water in the Sandia and northern Manzano Mountains, New Mexico

by FRANK B. TITUS

HYDROLOGIC REPORT 5 New Mexico Bureau of Mines and Mineral Resources 1980

A DIVISION OF

NEW MEXICO INSTITUTE OF MINING AND TECHNOLOGY

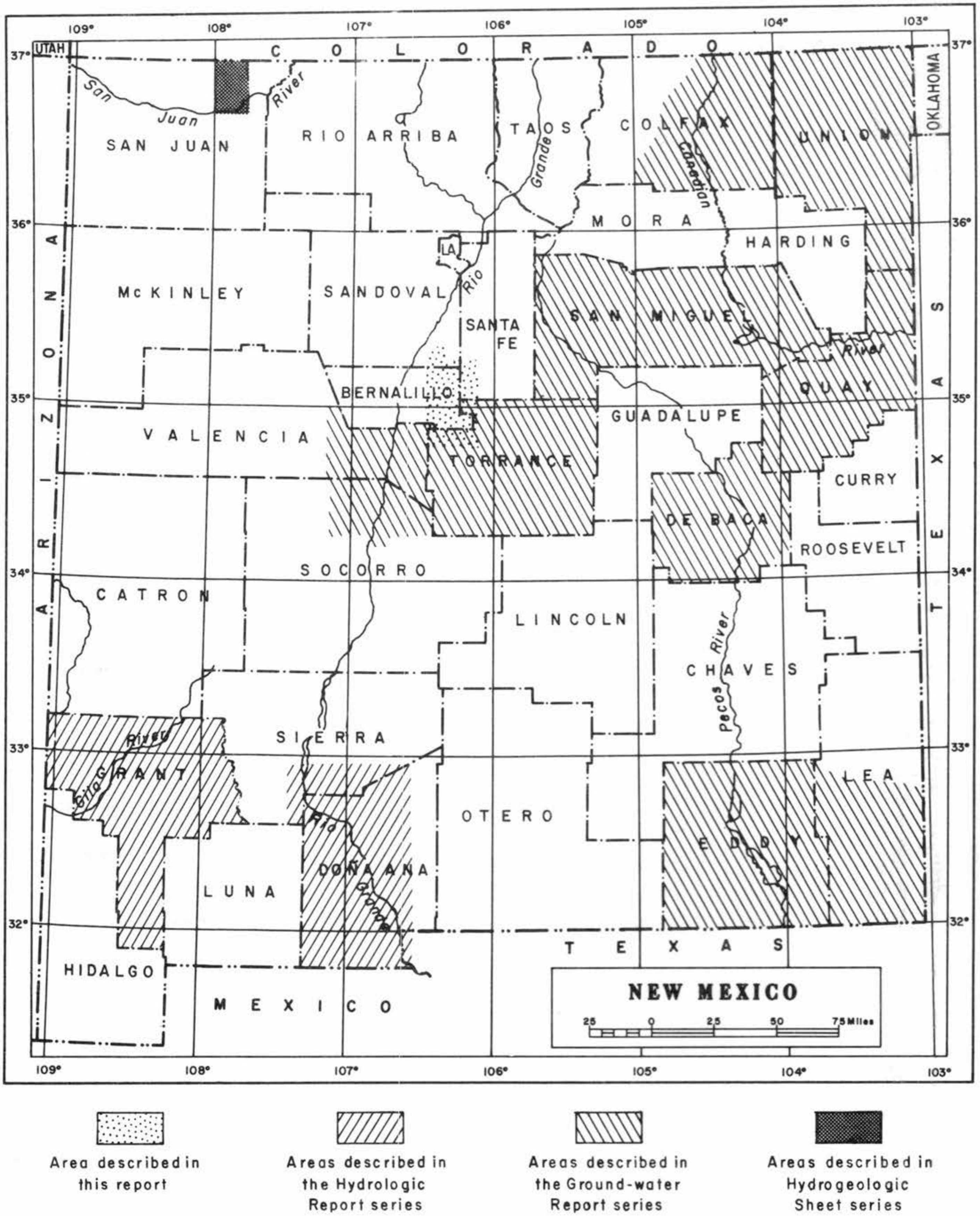

FIGURE 1—AREAS DESCRIBED IN WATER RESOURCES REPORTS PUBLISHED BY THE NEW MEXICO BUREAU OF MINES AND MINERAL RESOURCES IN COOPERATION WITH THE U.S. GEOLOGICAL SURVEY AND THE NEW MEXICO STATE ENGINEER.

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Prepared in cooperation with the
United States Geological Survey and the
Office of the New Mexico State Engineer

SOCORRO 1980

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Abstract

Large supplies of ground water are not available in the Sandia and northern Manzano Mountains east of Albuquerque, New Mexico. In lower Tijeras Canyon maximum water yield from wells was reported to be greater than 50 gallons per minute. Average dissolved-solids concentration is 462 milligrams per liter. In middle Tijeras Canyon well yields are usually below 40 gallons per minute with no water-quality problems. In the Tijeras anticline and syncline area well yields range from less than 1 gallon per minute to 35 gallons per minute. Dissolved-solids concentrations were as high as 1,070 milligrams per liter. Measured well yields in the lower Sandia slopes and Frost Arroyo area are as great as 180 gallons per minute. Water quality in this area generally meets Environmental Protection Agency standards. The Madera Limestone, a major source of water, crops out over higher parts of the Manzano Mountains and over all the eastern dip slope. It also crops out on more than half of the Sandia Mountain dip slope and underlies the valley fill of the Estancia Valley. One in every five wells drilled in the Madera can be considered dry (less than 0.10 gallon per minute). Wells near Tps. 6-8 N., Rs. 7-8 E. will commonly produce more than 1,000 gallons per minute. In the Placitas area nearly all formations have been drilled for water and yields are adequate for domestic use except from the Mancos Shale. Quality is acceptable if the well is finished above the Entrada Sandstone and Todilto Limestone.

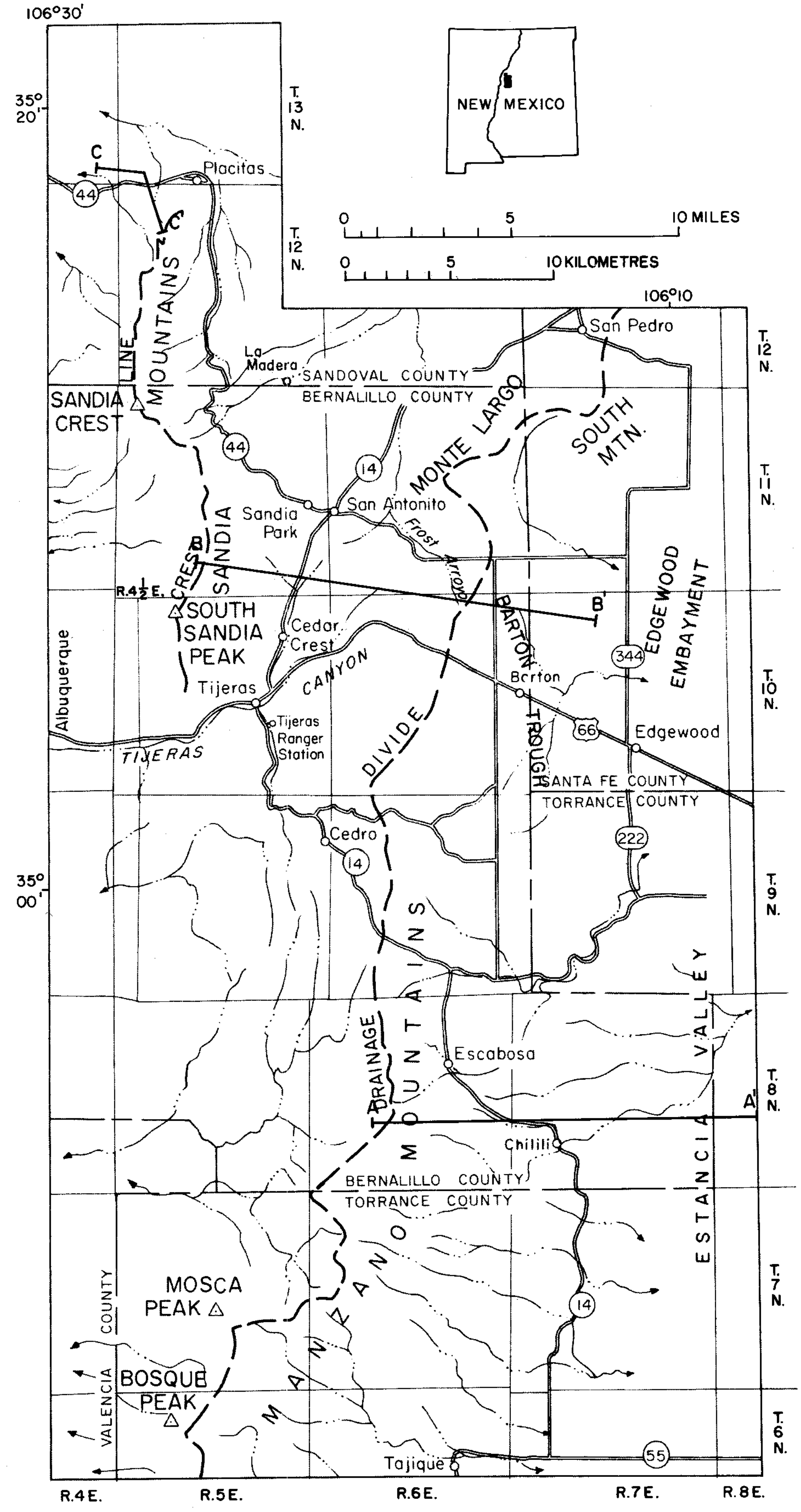


FIGURE 2—Index map showing report area. A-A′ shown in fig. 14; B-B′ shown in fig. 15; C-C′ shown in fig. 19.

Introduction

The Sandia Mountains and northern Manzano Mountains are situated east and southeast, respectively, of Albuquerque in parts of Bernalillo, Torrance, Sandoval, and Santa Fe Counties in central New Mexico (fig. 2). The mountains form the bold escarpment on the east side of the Rio Grande valley. From their crests the slopes incline steeply to gently eastward toward Estancia Valley. The two ranges lie end-to-end in a north-south direction and are separated by Tijeras Canyon. Sandia Crest is the highest point in both ranges with an altitude of 10,678 ft—more than 4,000 ft above the alluvial fans at the foot of the rugged west face. Bosque Peak, with an altitude of 9,610 ft, is the highest point in the Manzanos within the area studied.

The study area includes all of the Sandia Mountains and the northern part of the Manzanos. The study area is about 45 mi long and 20 mi wide. It straddles the ranges from the fan heads at the foot of the west-facing scarps eastward to the gentle alluvial slopes beyond the bedrock outcrops in Estancia Valley.

A few decades ago the population of the mountain area was small and was localized in a few communities or on small ranches. Since World War II, many of the old communities have been deserted and most of the ranches have been subdivided. Increasing numbers of people interested in owning mountain vacation cabins or permanent homes have moved to the mountains and have tended to build on lots of an acre or so.

The former residents needed only a small water supply for domestic purposes—usually not more than could be carried from the well to the kitchen. The old communities were located near known supplies of ground water, frequently springs. The ranchers needed a well with a windmill to supply water for stock, and the same well, when near the ranch house, also served domestic needs. In contrast, the new residents came to the mountains expecting city water conveniences. With few exceptions they were aware that each must construct his own water system—well and pump—but need was seen as the criterion for design, not hydrogeologic availability of ground water.

Purpose and scope

The purpose of this report is to describe the ground-water availability and quality in the aquifers of the Sandia and northern Manzano Mountains. This project has been undertaken cooperatively between the New Mexico Bureau of Mines and Mineral Resources, the Office of the New Mexico State Engineer, and the U.S. Geological Survey (USGS). The study was not designed to give quantitative answers about the ground-water supply. Aquifer tests were not made. Estimate of ground water in storage was not attempted. Nor were predictions made about water-level changes in areas of withdrawal. The study shows the relationship between geology and ground-water availability.

Previous work

A few general references are mentioned here. Reiche (1949) described the geology of the Manzano Mountains, but geologic details of the Sandia Mountains did not begin appearing in publication until the 1961 Guidebook of the New Mexico Geological Society (Northrop, 1961). Kelley (1963) prepared a geologic map of the Sandia Mountains and northern extremes of the Manzano Mountains, and D. A. Myers produced four detailed quadrangle maps in the Manzano Mountains, two co-authored with McKay. For the layman who is interested in the geology of the Sandia Mountains, the description by Kelley (1974) in *Albuquerque, its mountains, valley, water, and volcanoes* is recommended reading.

The hydrologic conditions have not been studied as intensively as has been the geology. Smith (1957) described the general ground-water conditions in the Manzano Mountains as part of a ground-water study in Torrance County. The hydro geologic conditions in the Manzanos and easternmost Sandias were described by Titus (1969).

Data collected and limits of project

This report is based on hydrologic data collected from 1960 to 1964. The data were obtained from existing wells and springs and are based on field observation. When possible, additional information was obtained from the owner, user, driller, or other person who had knowledge of the well or spring. The chemical analyses of water that are reported here were made in the Albuquerque laboratory of the USGS. The water-level contours and water-quality interpretations reflect the conditions during the early 1960's.

The data were compiled and the report prepared by the author in 1973. Before publication details could be worked out between the USGS and the New Mexico Bureau of Mines and Mineral Resources, the author left the state. Because of the need to make the data available and the intense interest in the Sandia-Manzano Mountain area, the report was prepared for publication by the USGS in 1977 and 1978. The author expresses gratitude to the many people who supplied basic information for the interpretations presented here.

Most geologic data were compiled from published maps after considerable field checking and limited checking against aerial photographs. Modifications of the geology from published sources are limited mainly to adding some unmapped faults to the Madera terrain south of Tijeras Canyon and to the Santa Fe terrain in the northwest corner of the map. Two previously unmapped 71/2 -minute quadrangles were geologically mapped for the project by field and photo geologic techniques.

Factors for converting inch-pound units to metric units

In this report figures for measurements are given in inch-pound units only except for chemical analyses, which are given in milligrams per liter (mg/L). The following table contains factors for converting to metric units.

Multiply inch-pound units	by	to obtain metric units
inch	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.60934	kilometer
square mile (sq mi)	2.59	square kilometer
gallon (gal)	0.00378541	cubic meter
acre (acre)	4046.875	square meter
acre-foot (acre-ft)	1233	cubic meter
acre-foot per mile (acre-ft/mi)	766.15	cubic meter per kilometer
gallon per minute (gal/min)	0.06309	liter per second
cubic foot per second (cu ft/s)	0.028317	cubic meter per second

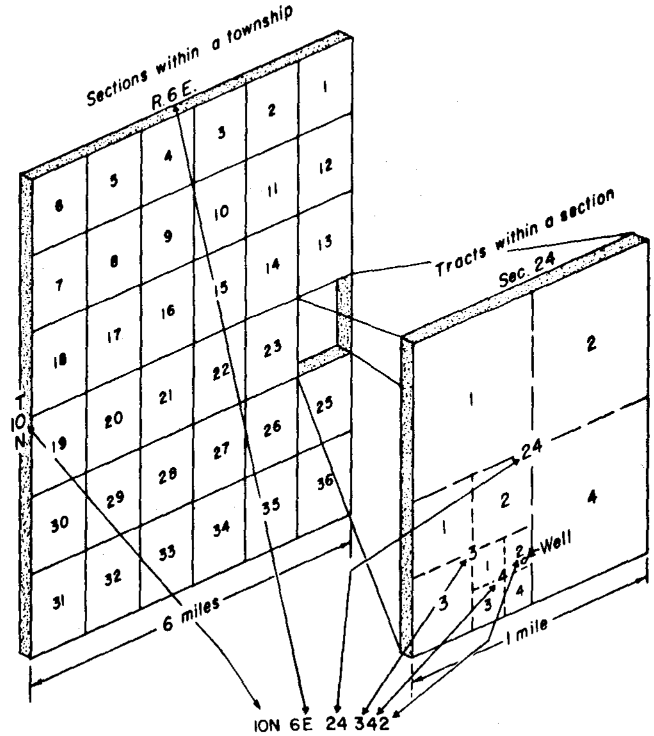


FIGURE 3—SYSTEM OF NUMBERING WELLS AND SPRINGS IN NEW MEXICO.

The fourth segment of the well number consists of three digits that denote the particular 10-acre tract in which the well is located within the section. The section is quartered, and the quarters are numbered in normal reading order. The first digit locates the well within one of these 160-acre quarters. The procedure is then repeated within the 160-acre tract to obtain the second digit, which locates the well in the proper 40-acre tract. The process is repeated once more to determine the third digit, which indicates the 10-acre tract containing the well. Where more than one well occur in a 10-acre tract, the second and subsequent wells are identified by suffixes a, b, c added to the well numbers. In special cases where the location of the well cannot be determined to within a 10-acre tract, a zero is used for the third digit; similarly, if the well cannot be determined to within a 40-acre tract, a zero is also used for the second digit.

Land within the old Spanish land grants has not been subdivided into sections, townships, and ranges by land surveys. Within these areas section lines were projected from adjacent surveyed land and the same numbering system was used. The projected lines are shown by marks only at section corners.

General geology and hydrology of mountain area

The Sandia and northern Manzano Mountains form approximately the northern two-thirds of a great mountain block that has been uplifted and tilted eastward. The uplift is along a major fault system buried west of the west foot of the range (Kelley and Read, 1961, p. 18; Reiche, 1949, p. 1203). The uplift exposed Precambrian rocks in the Sandias that have been dated at more than 1.3 b.y. (billion years), about the same age as similar rocks in the bottom of the Grand Canyon (Fitzsimmons, 1961). The Precambrian rocks form nearly all of the imposing west face of the mountains that appears reddish tan from a distance.

Before uplift and exposure, the Precambrian rocks had been covered by at least 11,000 ft of sedimentary rocks of later geologic periods. Most of the sedimentary rocks have been eroded, but remnants are present on parts of the east slope and at the north end of the Sandias (fig. 4, geologic map, in pocket). One of the older sedimentary formations, the Madera Limestone, crops out and forms the present land surface over most of the eastern area of the mountains. Along the crest of the ridge as viewed from the west, the Madera Limestone forms a stratified cap overlying the unstratified Precambrian rock.

The Sandia Mountains are separated topographically from the northern Manzano Mountains by Tijeras Canyon and are separated structurally by a major northeast-aligned fault system formed by the Tijeras and Gutierrez faults. These two faults come together in a structurally complex area west of the village of Tijeras. Northeast from their junction they are subparallel, bounding a 1.5-mi- to 2.5-mi-wide slice that is downdropped at the southwest end and uplifted at the northeast. In the downdropped wedge the rocks have been folded into the Tijeras anticline (upfold) and the Tijeras syncline (downfold).

Northeast from the axis of the Tijeras syncline to Monte Largo, the entire stratigraphic section, from the Mesaverde Group (Cretaceous) to the crystalline Precambrian rock, crops out. The entire stratigraphic section also crops out at the north end of the Sandias, where complex downfaulting terminates the range.

Southwest and west of Placitas, faulted Paleozoic and Mesozoic strata dip northward and are buried to the north by the Rio Grande valley fill of the Santa Fe Group. In the north-central part of the Sandia Mountains, Precambrian rocks and the Sandia Formation have been faulted up in blocks and exposed by erosion of the Madera Limestone (Pennsylvanian), whereas low on the north backslope of the Sandias patches of the Abo Formation (Permian) still overlie the Madera Limestone.

The Sandia Mountains differ both structurally and topographically from the northern Manzano Mountains. The Sandias, with their higher crest altitude, have relatively steep eastern slopes. They have been intensely faulted, and the strata dip eastward at angles averaging 15-20 degrees. The lower northern Manzano Mountains, in contrast, are capped by strata that dip eastward at angles averaging only 3-4 degrees. Faults near the crest of the Manzanos are aligned generally north-south, parallel to the crest. Lower on the eastern backslope of the Manzanos, the faults tend to be aligned northeast-southwest, approximately parallel to the Tijeras-Gutierrez fault system. The faults have strongly affected the erosional development of drainage off the mountains as exhibited by the valley-and-ridge topography having a prominent northeast-southwest grain.

Over most of the Manzano backslope, valleys follow the fault traces—mainly because erosion can progress more rapidly in the broken rock along faults than across unshattered, resistant limestone ledges. However, the broad valley extending northeastward from sec. 23, T. 8 N., R. 7 E. may have been created directly by faulting that uplifted a block of Madera Limestone to form its east wall. This faulting probably occurred during an early part of the valley-filling stage of the Estancia Valley to the east. Block faulting directly molded present topography of the 6-mi-long north-trending valley containing the community of Barton (sec. 13, T. 10 N., R. 6 E.). This structural valley, here named the *Barton trough,* lies directly across, and intercepts, the eastward drainage off the Manzano Mountains. Barton trough was formed by uplift on the east of a barrier ridge of Madera Limestone.

The *Edgewood embayment,* named here for the small community on its south side (in sec. 27, T. 10 N., R. 7 E.), is a 10-mi-wide semicircular indentation into the lower east slopes of the mountains. The embayment is bounded on the south and west by the curved edge of the Madera outcrops, and on the north by outcrops of the Abo Formation around South Mountain. The valley fill of the Estancia Valley at the head of the embayment extends to the Gutierrez fault. The valley fill is 80 ft thick at well 11N.6E.24.212, 1 mi southwest of the Abo outcrop at the end of South Mountain. East-southeast, toward the open end of the embayment, the formation thickens to an estimated 300 ft and continues to thicken into the axis of the Estancia Valley.

Red beds of the Abo Formation crop out in an apron around much of South Mountain, but these strata dip toward the center of the mountain rather than toward the surrounding lowlands where the Abo lies beneath the valley fill (Kelley, 1963). Whether a bounding fault occurs around the south end of South Mountain is uncertain but estimates of exposed thickness of Abo made solely from Kelley's (1963) map do not require a fault. A bounding fault is postulated at the northeast end of South Mountain. In this area the Glorieta Sandstone crops out; red beds (presumably Abo) have been reported in drill cuttings from well 11N.7E.2.222b.

The approximate locations of subsurface contacts between the Madera Limestone and the Abo Formation and between the Abo and Yeso Formations are shown on the geologic map. The subsurface locations of the Paleozoic formations are based on: drillers' or owners' reports of limestone (Madera) or red beds (Abo) in wells drilled through the valley fill and the locations of gentle, closed topographic depressions a few acres to 10 acres in size resulting from solution of the buried Madera Limestone accompanied by collapse of the overlying alluvium. The most noticeable of the collapse depressions are in NW'/ sec. 3, T. 10 N., R. 7 E., and in NE'/ and SW 1/4 sec. 33, T. 11 N., R. 7 E. The depressions are similar to numerous others in the Estancia Valley described by Titus (1969). Positions of the subsurface contacts shown on fig. 3 are modified somewhat from those shown in Titus (1969, fig. 4).

Rock units and their water-bearing properties

In the following discussion the rock units found in the mountain area are considered individually, starting with the oldest (Precambrian) and progressing to the youngest (Quaternary alluvium mantling the floors of present stream channels). The descriptions of lithology (rock type and character) and stratigraphy (relations of strata to each other) are based on the work of V. C. Kelley (1963) and fieldwork for this and other reports.

Stratigraphic thicknesses are measured at right angles to the bedding planes; therefore, where beds are inclined, the thickness penetrated by drilling a vertical hole will be greater than reported stratigraphic thicknesses. Also where a single rock unit crops out, some of its upper part has usually been removed by erosion. The outcrop thickness will be less than indicated in stratigraphic tables. Beneath an outcropping rock unit all older units present in the local geologic column generally may be found. The alluvial and valley-filling units and the terrace and landslide units rest on old surfaces because some of the intermediate geologic column has been removed by erosion.

Much of the information supporting the detailed aquifer descriptions is included in the appendix at the back of this report (table 1, wells; table 2, springs; and table 3, chemical analyses). A summary of the rock units is contained in fig. 4.

The chemical character of ground water (ions dissolved in the water) is related mainly to the minerals that make up the rock through which the water has moved. In passing through rock the water slowly dissolves minerals; water that has been underground a long time will usually contain more dissolved ions than water that has been in aquifers for only a geologically short time. (Ground water in the mountain area tends to be of the latter type.) The amount of dissolved ions in ground water depends more on solubility of the minerals than on length of time in an aquifer.

The reader is referred for information on drinking-water standards to a publication of the U.S. Environmental Protection Agency (1976) and for an exhaustive review of water-quality criteria to McKee and Wolf (1963).

Precambrian (pe)

Precambrian rocks are the basement rocks on which geologically younger strata were deposited. Prior to burial, the basement rocks were planed off by erosion to a gently rolling land surface. They include sedimentary rocks that were contorted and highly metamorphosed to schist, greenstone, gneiss, and quartzite in very early geologic time and were then intruded by granites. Most Precambrian rocks crop out in the west face of the Sandia and Manzano Mountains and in the higher parts of Monte Largo. Smaller outcrops are also found on the middle and upper east slopes of the Sandias, bounded by faults.

For practical purposes the Precambrian rocks have no intergranular porosity, specific yield, or permeability. *Porosity* is the ratio of the volume of void spaces to the total volume. *Specific yield* is the ratio of the volume of water that will drain from a volume of rock to the volume of that rock; it differs from porosity in that many pore spaces are not interconnected and therefore will not provide water to a well and in that the very narrowest openings (capillary size) will not drain at all, even though they do constitute part of the porosity. *Permeability* is a measure of the ease with which fluid can flow through the interconnected voids.

Faulting and jointing have created locally permeable zones through which small amounts of water can move. A number of small springs and seeps are found on the west face of the mountains, in lower Tijeras Canyon, and usually in the floors of arroyos. Eleven springs (table 2) associated with Precambrian rocks were visited during fieldwork for this report, but E. R. Caprio (1960) describes 22 in the Sandias alone. In the study area spring discharges are usually less than 10 gal/min, although Seven Springs (ION.5E.21.412) in Tijeras Canyon was estimated at 20 gal/min. Discharge, especially from small springs, is variable seasonally; during periods of drought, these springs are commonly dry.

A few wells (table 1) have been drilled into the Precambrian rocks, mostly in the lower part of Tijeras Canyon. The wells are all 90 ft or more in depth; one (10N.4E.36.124) reaches 500 ft. Most produce water from both Precambrian rocks and alluvium. The maximum yield reported, from the deepest well, is 16 gal/min; but simply drilling to greater depth holds little assurance of increasing the yield of wells in this unit. Although there is no record of dry holes being drilled, the prospects of obtaining a useful quantity of water from Precambrian rocks at most locations appear to be small.

Selected ion concentrations from three water samples from Precambrian rocks are plotted on a Piper diagram in fig. 5. The diagram is a way of illustrating percentages of the cations and percentages of the anions for each sample on two small triangles and then projecting the two points for a sample into the field of a parallelogram. The plotted points for a number of samples commonly form a grouping that is distinctive for water

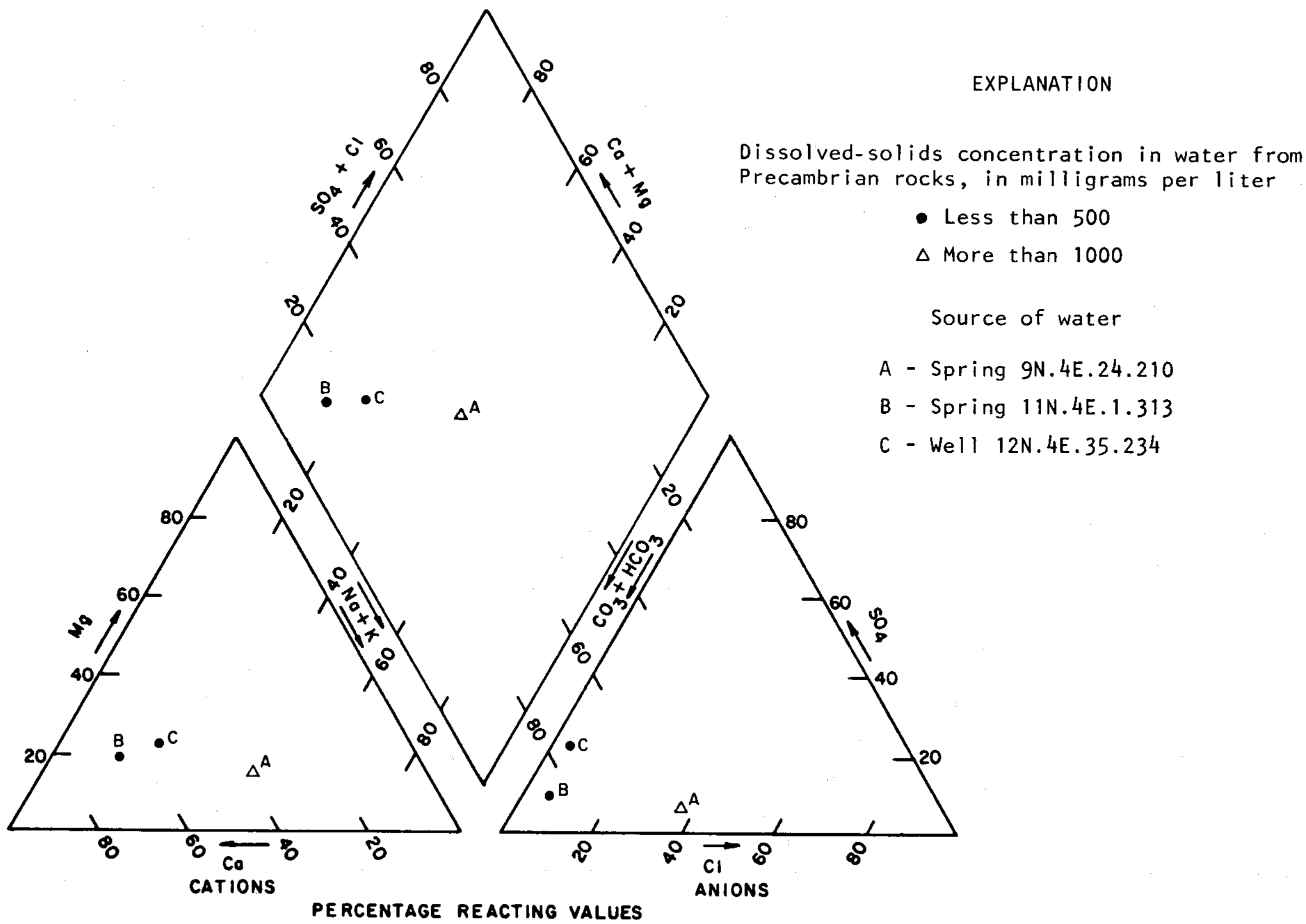


FIGURE 5—Piper diagram showing proportions of major cations and anions in water from Precambrian rocks.

from a single source (Piper, 1953). Water from spring 9N.4E.24.210 (point A, fig. 5) falls somewhat outside the general field for water from Precambrian rocks, if the other two samples are representative of water from Precambrian rocks. Caprio (1960). ran more than 20 chemical analyses on water from Precambrian rocks. His work supports the conclusion reached in this study that water available from Precambrian rocks is likely to be chemically acceptable for domestic use (table 3).

Sandia Formation (Ps)

The Sandia Formation (Early and Middle Pennsylvanian) consists of interbedded black shale, dark-gray limestone, and gray to light-olive-gray and brownish sandstone. Locally the sandstone may be conglomeratic, especially near the base; carbonaceous streaks are found locally. East of Placitas the unit as mapped locally includes up to 90 ft of dark-gray or dusky-yellowish-green limestone and gray to locally red shale of older (Mississippian and Devonian?) strata in its basal part. Total thickness of the unit ranges from 10 to 230 ft (Kelley, 1963; Reiche, 1949). The Sandia Formation and associated rocks were deposited on the erosional surface of the Precambrian, and they crop out wherever the top of the Precambrian is exposed.

Only a few springs discharge from the Sandia Formation, but several yield water from the Sandia and overlying Madera. Most discharges are 20-40 gal/min, but Carlito Spring (10N.5E.15.331) on the north wall of Tijeras Canyon was estimated to discharge more than 250 gal/min from the Sandia and Madera. On the basis of spring discharges, limestone of the Sandia Formation appears to have rather high permeability from fractures and cavernous zones; the sandstones, moderate permeability.

Three water samples from the combined Sandia-Madera were chemically analyzed. These analyses indicate that water in the Sandia is probably similar to that in the overlying Madera. The chemistry of two samples from the Sandia and Madera together are plotted on a Piper diagram (fig. 6).

Madera Limestone (Pm)

The Madera Limestone (Middle and Late Pennsylvanian) is conventionally divided into a lower gray limestone member and an upper arkosic limestone member. The two members are not separated on the geologic map. The lower member consists of massive, cliff-forming beds of cherty gray limestone with minor interbedded gray and black shale and calcareous siltstone. The upper member, in contrast, is more than half siltstone, sandstone, and shale. It consists of alternating light-gray cherty limestone, arkosic calcarenite, red or brown arkosic sandstone, and gray shale. (For stratigraphic details see Myers, 1966, 1969; Myers and McKay, 1970, 1971; Read and others, 1944; Anon-

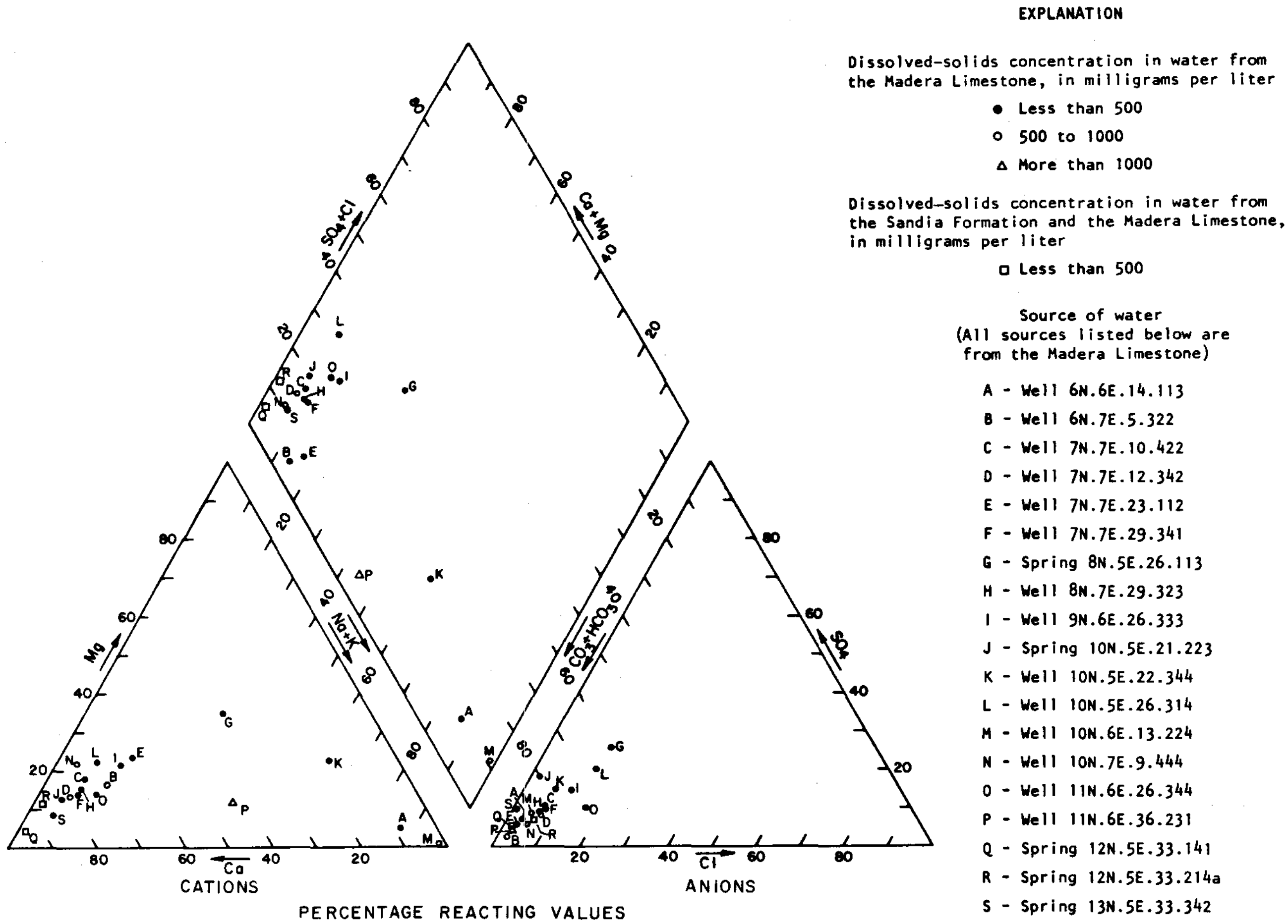


FIGURE 6—PIPER DIAGRAM SHOWING PROPORTIONS OF MAJOR CATIONS AND ANIONS IN WATER FROM THE MADERA LIMESTONE OR THE SANDIA FORMATION AND THE MADERA LIMESTONE.

ymous, 1952, p. 107-180; and Kottlowski, 1961, p. 101.) In outcrops of the lower member the limestones form prominent ledges, whereas the clastic rocks of the upper member form soil-covered slopes. In the Manzano and Sandia Mountains, thicknesses for the Madera of approximately 1,300 ft have been measured in outcrop, while wells in the southeast part of the project area, drilled decades ago for carbon dioxide, show that the formation thickens eastward to about 2,000 ft. In outcrop the lower member is 430-700 ft thick and the upper member 800-900 ft thick.

The Madera crops out and is the principal aquifer over all the Manzano back slope and over more than half the east slope of the Sandia Mountains. It also crops out at the north and south ends of Monte Largo and underlies the valley fill of the Estancia Valley in the southwestern half of the Edgewood embayment. More than 300 wells have been drilled into the formation; water in it discharges to numerous springs throughout this area. Permeability and porosity are provided mainly by solution-enlarged channels in the limestone beds that tend to be localized along fractures and bedding planes. Solution channels in the limestone up to a few inches in diameter can be seen at many places in road-cuts and outcrops (fig. 7). The exposed solution channels are thought to be similar to those encountered at depth in drill holes. Reports by drillers of water coming from "fractured rock," "brittle rock," and "caves" are common.

Some permeability is also provided by fractures or bedding-plane separations in shales, as indicated by several drillers' reports that water production comes from shale intervals. Four of the springs that were visited had ground water discharging from shales interbedded between limestone beds—not from the limestones (springs 8N.7E.30.444 and 13N.5E.14.331). There is little indication that sandstone beds in the Madera will yield significant amounts of water. The permeability of most sandstone and arkose beds seen in outcrop is low; very few drillers report water yields from sandstone. Fracturing is as evident locally in sandstone as in limestone, but fracturing without subsequent enlargement of the openings by solution apparently does not produce significant permeability.

The small solution channels in the Madera Limestone, exposed in outcrops and indicated by wells, were formed after the overlying formations were eroded away. Solution channels that are above the present saturated zone probably developed at times of higher water levels before canyons were cut to their present depth. The absence of large caves and of karst topography in most areas suggests that, since exposure, water levels have not remained for a long time at a single level. The well-known Sandia Cave, a site of human occupancy in late Pleistocene time in the northern part of the Sandia Mountains (Hibben, 1941; Bryan, 1941), was probably formed much earlier and under different structural and topographic conditions than the smaller, more typical solution features found in the limestone.

An anomalous highly permeable zone in the Madera has been described by Titus (1969, p. 27-30) and was recognized and studied independently by J. T. Everheart, geohydrologist in the New Mexico State Engineer Office. Production of more than 1,000 gal/min is not unusual in water wells in the vicinity of Tps. 6 to 8 N., Rs. 7 and 8 E. (part of which is outside the project area). Well 7N.7E.1.233 has reportedly been test pumped at 1,470 gal/min, and wells 7N.7E.11.142 and 7N.7E.13.431 yield 450 and 120 gal/min respectively. The proximity of the high-yield Madera wells to an area of carbon dioxide entrapment in the formation suggests a causative relationship between carbon dioxide and the permeability. Whereas pure water can dissolve only small amounts of calcium carbonate, water containing dissolved carbon dioxide can dissolve much greater amounts. The probable source of the carbon dioxide in this area is leakage from a carbon dioxide gas field. Gas was produced commercially from the field until 1942, when production ceased with considerable amounts still in the structure. Production of carbon dioxide ceased because unacceptable amounts of water were discharging with the gas (Talmadge and Andreas, 1942, p. 305-307). Ground water produced by several wells in this area is highly charged with carbon dioxide, including well 7N.7E.13.431 mentioned above. Several wells downgradient from the abandoned carbon dioxide field contain large amounts of carbon dioxide dissolved in the water. Chemical analysis of water from one such well (6N.7E.5.322) shows a bicarbonate concentration of 1,030 mg/L. The gas evolves as bubbles when the water is brought to the surface and the water reportedly tastes like commercial soda water.

Two wells (10N.7E.4.311 and 10N.7E.16.412) were blowing air when visited. At these locations bedrock is overlain by Estancia Valley fill, and the blowing phenomenon is taken to indicate that they may extend into cavernous Madera Limestone and that the top of the saturated zone is below the top of the cavernous zone. The phenomenon results from barometric pressure changes in the atmosphere that cause air pressure in the dry cavernous zone to equalize with the atmosphere by airflow up or down the well bore. Where the cavernous rock is not isolated from the atmosphere by a low-permeability zone, pressure equalization takes place through natural openings, and the well is less likely to blow or suck air. Presence of "sucking and blowing" wells is not, of course, definite proof that they are bottomed in cavernous limestone. Other unsaturated porous formations that are capped by an impervious layer are known to exhibit this phenomenon.

FIGURE 7—SOLUTION HOLES ON BEDDING PLANE IN MADERA LIMESTONE, west wall of Cedro Canyon (W½ NW¼ sec. 2, T. 9 N., R. 5 E.). Object in center of photograph is a light meter approximately 6 inches long.

The average yield from the Madera for 46 wells is 12 gal/min. The median yield (half producing more, half producing less) is 5 gal/min, indicating that the average is strongly affected by the few wells that produce from 30 to 65 gal/min. (In these calculations the four anomalous wells that reportedly yield more than 100 gal/min were excluded.) Well 10N.7E.25.211 was capable of producing 400 gal/min from the Madera and probably also from the base of the valley fill in the Estancia Valley on the south side of the Edgewood embayment. The well has since caved and been abandoned. For most wells, estimates of yields were reported by owners as either adequate or inadequate for the intended use, usually stock or domestic.

No aquifer-test data are known that would allow calculation of specific yield in the Madera. Visual estimates of specific yield were attempted on a few exposed outcrops on limestone, indicating that specific yield might be of the order of 1 percent—not a reliable indication of conditions in the saturated zone. E. H. Walker (1956), working in a water-bearing limestone terrane in Kentucky, described conditions that in terms of limestone lithologies, solution-channel characteristics, and water-well performance appear to be similar in many respects to the Madera Limestone terrane. Walker was able to calculate specific yield of the aquifer from stream-flow records and water-level decline during drainage to the streams. These data produced an average specific yield for several periods of record of 0.5 percent, with a range of from 0.18 to 0.87 percent (Walker, 1956, p. 46). Based on Walker's determinations, the specific yield in the Madera Limestone is on the order of 1 percent or less.

With a few exceptions the water may be classified chemically as a calcium bicarbonate type. The Piper diagram (fig. 6) shows that these ions strongly predominate over other cations and anions. With a few notable exceptions, the water is hard but is rather low in dissolved solids. Water from only two wells showed concentrations of dissolved solids close to 1,000 mg/L; 6N.7E.5.322 (B, fig. 6) had 927 mg/L and 11N.6E.36.231 (P, fig. 6) had 1,030 mg/L in a sample collected 20 minutes after pumping started; but the concentration, as indicated by specific-conductance measurement, had declined considerably 2 hours later. Bicarbonate is the principal cause of the high dissolved solids in water from these wells; the samples contain 1,030 and 1,110 mg/L bicarbonate, the highest concentrations found in Madera water.

The water sample from spring 8N.5E.26.113 (G, fig. 6) is one of a few that plot outside of the calcium bicarbonate field on the Piper diagram, indicating that the sample contains proportionately more magnesium and sodium plus potassium than is common for Madera water. The spring is in Hell Canyon, far down on the west slope of the Manzano Mountains; the nontypical ratio of cations may result when water in Precambrian rocks joins with that from the Madera and discharges at the spring. Dissolved-solids concentrations in the sample was only 222 mg/L and fluoride concentration was 0.6 mg/L.

Four of the five samples that plot outside the calcium bicarbonate field contain more than 1 mg/L of fluoride. (Only G is below this threshold.) The more fluoride in the sample, the farther the sample plots from the calcium corner of the cation triangle. Other unifying characteristics are not apparent; P contains 1.3 mg/L fluoride, K contains 2.2 mg/L, A contains 3.2 mg/L, and M contains 11 mg/L. H. E. Koester (oral communication) of the USGS has suggested that where an unusual amount of fluoride is present, calcium may unite with it to precipitate as the mineral fluorite, which has very low solubility.

Samples from wells 10N.6E.14.424 and ION.6E.26.132 (not plotted on the Piper diagram for lack of data) contained 3.3 and 11 mg/L of fluoride respectively. Calcium and magnesium were not determined for these samples, but like the samples for which more ions were determined, the sodium plus potassium concentrations are relatively high. At three other wells (10N.6E.27.344, lON.6E.34.221, and 10N.7E.35.231) the water was reported as soft. The significance of the reports was not apparent at the time; samples were not collected. Softness can result from high sodium relative to calcium and magnesium; water from these wells could have significant fluoride.

Abo Formation (Pa)

The Abo Formation is a red-bed sequence of Early Permian age named for Abo Canyon at the south end of the Manzano Mountains. It consists of dark-red to reddish-brown shale, possibly as much as 100 ft thick, separated by lenticular, dark-red to pink, locally light-gray sandstone beds as much as several tens of feet thick and by discontinuous beds of arkose, conglomerate, and pellet limestone. The sandstone beds are fine to very coarse grained, partly conglomeratic, and are moderately to well cemented. The total thickness of the formation reported by Kelley (1963) is 700-900 ft. Somewhat less than half is sandstone; the remainder consists of coarse elastic rock.

The Abo crops out along the southeast side, and in places, along the northwest side of Tijeras Canyon northeastward from the village of Tijeras. Other outcrops on the Sandia backslope extend north from Tijeras Canyon to 4 mi northeast of San Antonito. The Abo forms an apron around much of South Mountain and is found at the surface in discontinuous patches along much of the northern border of the project area.

In the Sandia Mountains the Abo has sufficient permeability to serve as the aquifer for nearly 30 water wells and a few springs. This condition contrasts with that to the southeast in Torrance County where R. E. Smith (1957, p. 29) found the formation to be an uncertain source of stock or domestic water. The better hydrologic conditions in the Sandias are probably the result of rather intense faulting and folding that allows better flow of ground water to wells.

The largest concentration of wells withdrawing water from the Abo is in Tijeras Canyon from 1/2 mi west to 4 mi northeast of the village of Tijeras. Information was collected from 13 wells along the canyon. A few wells that tap the Abo are located on the slope north of Frost Arroyo. Near Placitas two wells probably tap both the Abo and the Madera. In these areas users invariably report well yields to be adequate for domestic purposes. The reported yields from six wells range from about 4 to 40 gal/min. In most areas a penetration of 25-70 ft of Abo beneath the potentiometric surface is sufficient to reach a fractured sandstone bed that will yield enough water for domestic use; in the Placitas area one well penetrated 77 ft and the other penetrated 94 ft of saturated rock.

The Abo lies beneath the Estancia Valley fill in roughly the northeast half of the Edgewood embayment. Six stock wells have been drilled into what is thought to be the Abo. The potentiometric surface seems to be close to the basal contact of the valley fill—perhaps in the valley fill at some places and in the Abo at others. In this area the Abo may be a poor aquifer as a result of less deformation. One dry hole in red beds, thought to be Abo, was drilled immediately east of South Mountain (well 11N.7E.2.222a). A second well drilled 100 yds away produces a reported 0.75 gal/min.

Three water samples from wells in Tijeras Canyon were chemically analyzed, one of which is plotted (E) on the Piper diagram on fig. 8. Dissolved solids were not determined for the samples, but the specific conductances suggested that they would all be near or under 500 mg/L. Potability problems are not indicated with water from this aquifer.

Yeso Formation (Py)

The Yeso (Early Permian) consists of two members which, though not differentiated on the geologic map, are identified individually as aquifer units in the text. The lower unit, the Meseta Blanca Sandstone Member, is an evenly bedded, tan-brown and buff sandstone that is 90-150 ft thick. The upper unit, the San Ysidro Member, is mainly orange-red and pink sandstone with interbedded shale and some gray, cavernous limestone. Locally, discontinuous beds of gypsum or gypsiferous siltstone occur near the top of the unit. Thickness of the San Ysidro Member is 250-400 ft.

The Yeso crops out on the slope of the Sandia Mountains roughly 1 mi west of, and paralleling, NM-14 from a short distance north of Tijeras Canyon to 3 mi northeast of San Antonito. It also crops out in a band across the south end of Monte Largo and on the southeast side of Gutierrez Canyon. A small outcrop area also occurs southwest of Placitas and a few miles northeast of that town. Several scattered springs discharge water from both members.

The Meseta Blanca Sandstone Member is the aquifer for five wells visited, three near Sandia Park and two on the southeast side of Gutierrez Canyon. Yields for the wells near Sandia Park were reported to be 30-40

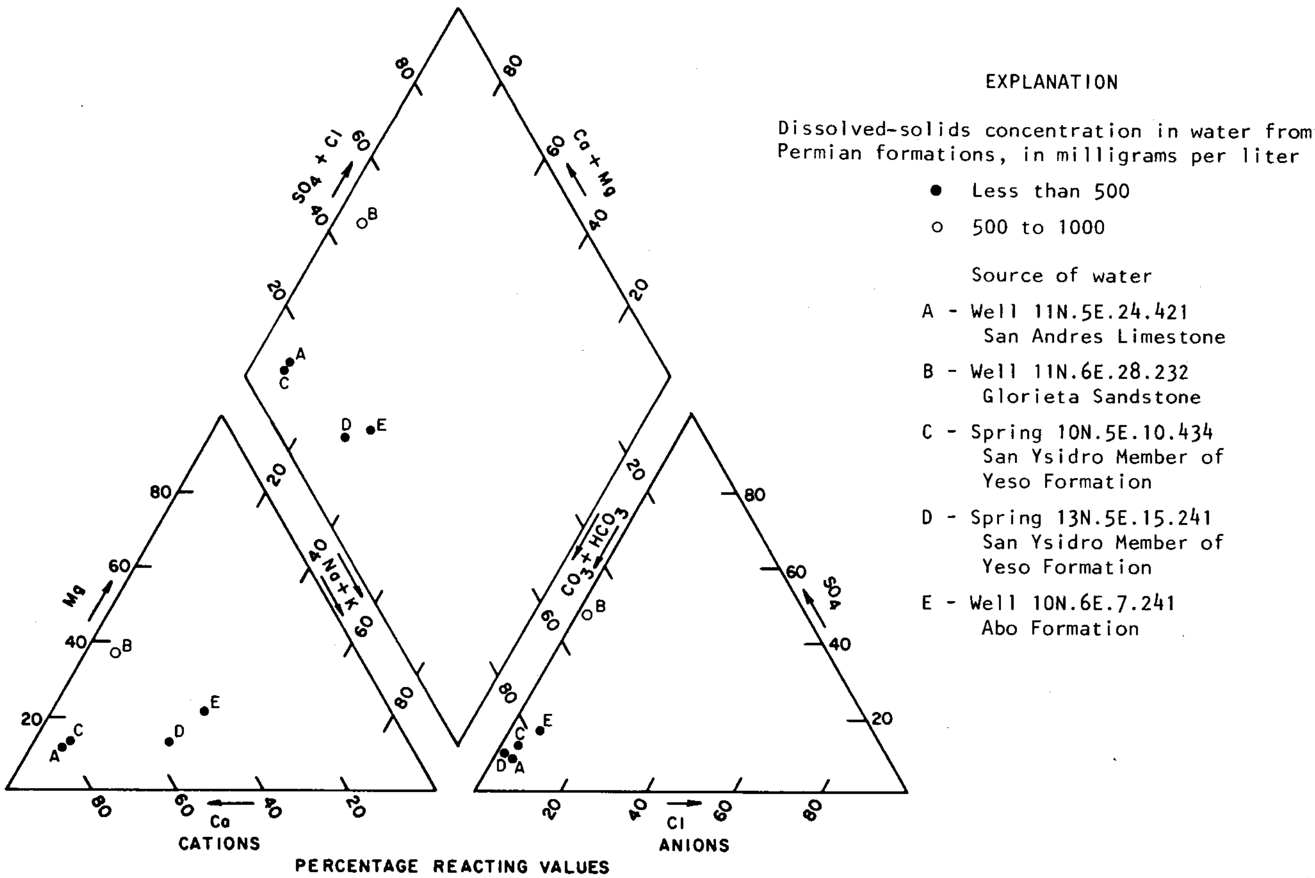


FIGURE 8—PIPER DIAGRAM SHOWING PROPORTIONS OF MAJOR CATIONS AND ANIONS IN WATER FROM PERMIAN FORMATIONS.

gal/min; the wells in Gutierrez Canyon reported yields adequate for domestic use. Penetration of the saturated zone is 25-60 ft.

The San Ysidro Member is the producing aquifer for seven wells visited near Sandia Park and two in Gutierrez Canyon. Red rock or red sandstone was reported as the aquifer in four wells for which such information could be obtained; owners did not mention any limestone or caves. The wells reportedly yielded from 5 to more than 30 gal/min; one (11N.5E.24.144) yielded 84 gal/min. Most wells penetrate from 30 to 60 ft of saturated rock; the high-yielding well mentioned above penetrates 150 ft. Satisfactory yields are readily obtained from sandstones in both members of the Yeso Formation.

Partial chemical analyses were run on four water samples from wells completed in the San Ysidro Member. Analyses of water from two widely separated springs in the San Ysidro Member are plotted on the Piper diagram (C and D, fig. 8). A variation in the calcium-sodium ratio is noted on the Piper diagram, with the higher sodium occurring in the sample from spring 13N.5E.15.241, located 4 mi north of Placitas. Comparison of sodium concentrations in the partial analyses shows that the more typical condition is for sodium to be low; therefore, the conclusion is drawn that spring ION.5E.10.434 discharges water more representative of the aquifer. The water is of the calcium bicarbonate class; dissolved solids are low, and the water has the expected hardness. Gypsum was not present in the upper part of the San Ysidro where samples were collected. Owners reported good water. Evidently gypsiferous strata are not present in the developed area, as would be indicated by high sulfate concentrations.

San Andres Limestone-Glorieta Sandstone, undivided (Psg)

The San Andres Limestone and Glorieta Sandstone of Early Permian age are mapped together on the geologic map and probably act as a single aquifer. (This aquifer possibly could also include the two members of the Yeso Formation.) The Glorieta Sandstone is the lower unit. It is light yellowish gray to white, well sorted and clean, usually tightly cemented, and consists of massive beds in which crossbedding is common. The Glorieta is as much as 150 ft thick. The San Andres Limestone consists of gray, finely crystalline limestone, locally containing numerous solution channels, and buff to tan, medium-grained sandstone and is as much as 190 ft thick. Erosion prior to deposition of the overlying Santa Rosa Sandstone has locally removed both formations.

The Glorieta and San Andres crop out from north of Tijeras to 3 mi northeast of San Antonito, mostly in steeper slopes above the valley. They also crop out in the rolling hills north of NM-44 between San Antonito and Sandia Park and above the Santa Rosa Sandstone north of Frost Arroyo. On the southeast side of the Gutierrez fault southeast of the Tijeras syncline, they are in fault contact with the Mancos Shale or separated from it by a thin slice of Santa Rosa Sandstone. The Glorieta and

San Andres also crop out southwest and northeast of Placitas.

Solution channels and cavernous features are common in the San Andres Limestone and probably formed during Triassic time when the formation was exposed prior to burial by the Santa Rosa Sandstone. The depth at which solution occurred was largely controlled by the depth of the saturated zone. R. E. Smith (1957, p. 35) has described some of the solution features in eastern Torrance County, including cave breccias and, in some places, overlying Triassic material that collapsed into caverns and sinkholes. The hydrologic significance of the solution features is that the limestone beds in the Sandia Mountains could be cavernous at relatively great depths.

The formation is not highly permeable and cavernous everywhere. The limestone itself is massive and quite dense, and where unshattered and in the absence of solution channels is likely to have very low permeability. Spring 10N.5E.10.423 near Cedar Crest yields an estimated 50-75 gal/min from the upper part of the Glorieta Sandstone. Apparently the eastward flow of ground water is impeded by a steeply dipping, massive limestone bed of the San Andres. Porosity and specific yield are highly variable because of differences in fracture and density of solution-channels.

One well (11N.6E.20.443), having a reported yield of 600 gal/min, was drilled through the Santa Rosa Sandstone and penetrates the San Andres Limestone at about 100 ft below land surface. Faulting has been fairly intense in the vicinity of this well. The few other wells thought to pump from the San Andres in the Sandia Mountains are reported to have adequate yields for domestic use. The one spring known to discharge from the unit had a seasonally variable flow estimated at 5 gal/min.

The Glorieta Sandstone aquifer supplies adequate water for one well and 10 gal/min and 12 gal/min for two others. The wells penetrate from 28 to 160 ft of saturated rock. Fractures are probably important in providing permeability in view of the generally well-cemented nature of the unit.

Two water analyses from this pair of formations are plotted on the Piper diagram (A and B, fig. 8). The sample from the San Andres well (11N.5E.24.421) is a calcium bicarbonate type water and probably is typical of most water from these formations. Well 1IN.6E.28.232 is drilled into the Glorieta and is downgradient from the San Ysidro Member of the Yeso Formation. The water sample contains 547 mg/L of dissolved solids, of which 192 mg/L is sulfate. This proportion of sulfate is uncommonly high among the anions, and there is a slightly higher proportion of magnesium than is common among the cations. The high proportion of sulfate and magnesium suggests that the San Ysidro may influence the water quality and that gypsum may occur locally at the top of the San Ysidro in this area.

Chinle Formation (lc)

The Chinle Formation (Late Triassic) is a thick section of reddish-brown, sometimes tan-brown, mudstone (variegated in the lower part) and contains discontinuous, thin sandstone beds. The Chinle is from 1,300 to 2,000 ft thick. In the Sandia Mountains and elsewhere, the Chinle nearly always crops out, mantled by red soil, in valleys that have developed because of the ease with which the soft unit is eroded. Along Arroyo San Antonio (NM-14) the Chinle forms much of the valley floor and the gentle slope to the west. The Chinle also crops out in the similarly gentle slope south of Frost Arroyo and also southwest and northeast of Placitas. Near Cedar Crest, along the Tijeras fault, this unit is in fault contact with the Mancos Shale. Permeability is provided by the sandstone beds and probably by fractures.

Sandstones in the Chinle Formation are aquifers for more than 30 wells, mostly along Arroyo San Antonio and Frost Arroyo. The few reported well yields ranged from 15 to 25 gal/min, and nearly all other wells were reported to have adequate yields for domestic purposes, with some of the wells serving as many as four houses. Most wells penetrate from 20 to 120 ft into the saturated zone, but one 300-ft well (11N.5E.24.441) penetrated more than 250 ft of the saturated zone.

Chemical analyses were made on six samples of ground water from the Chinle, one of which was collected in the Placitas area. Four are shown on the Piper diagram in fig. 9. The six samples, with one exception, contain between 360 and 544 mg/L of dissolved solids. The exception is water from well 11N.6E.28.323 (D, fig. 9), south of Frost Arroyo, that contains 1,070 mg/L dissolved solids. Three of the analyses plotted on the Piper diagram (A, B, and C) are well grouped and fairly close to the calcium and bicarbonate zones of the diagram. However, the fourth sample (D), from the well near Frost Arroyo, shows a predominance of sulfate. The actual concentration of sulfate in the sample was 669 mg/L. This well produces from the Chinle Formation, which is only a short distance downdip and down the hydraulic gradient from steeply dipping strata of the Todilto and Entrada Formations. The Todilto commonly contains gypsum beds; water moving through this formation before reaching the well apparently is the cause of the excessive sulfate in the water. Spring 10N.5E.15.223 discharges from the Chinle at a point where it is in fault contact with the Morrison Formation; the sample from this spring shows an abnormal proportion of sulfate, which probably indicates mixing of some water from the Morrison.

Santa Rosa Sandstone (Tts)

The Santa Rosa Sandstone (Late Triassic) consists of light-gray to reddish-brown, lenticular sandstone and reddish-brown shale. The sandstones tend to be coarse grained and are conglomeratic near the base where pebbles of limestone and quartz are present. The unit is 70-400 ft thick and is the lower part of a thick red-bed sequence that includes the overlying Chinle Formation.

The Santa Rosa crops out on the west side of Arroyo San Antonio valley (NM-14 north of Tijeras Canyon), generally forming the first steep slopes above the valley. It forms the lower slope above Frost Arroyo on the north side of that valley. The Santa Rosa also crops out southwest and northeast of Placitas.

Several wells produce water from the Santa Rosa in Arroyo San Antonio west of NM-14 between Tijeras

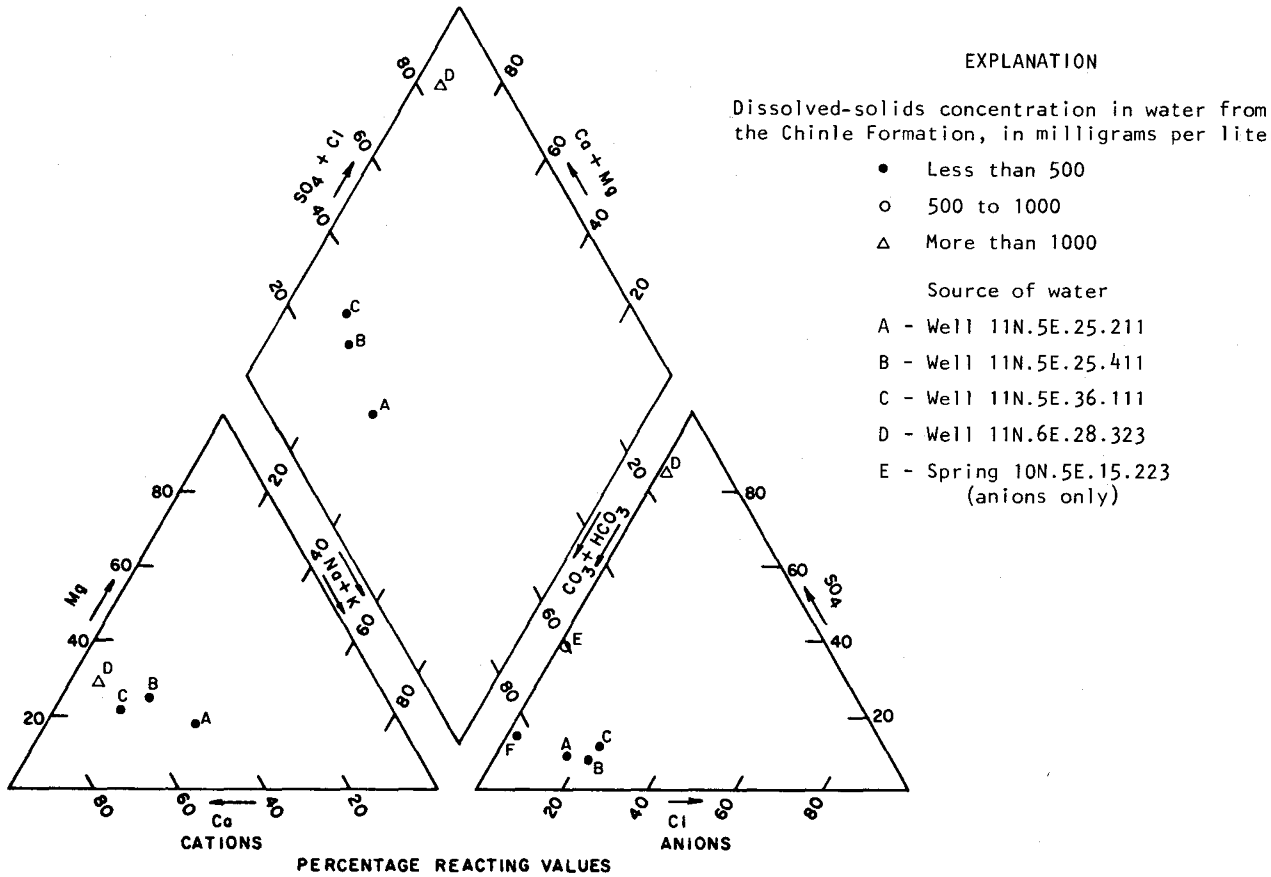


FIGURE 9—PIPER DIAGRAM SHOWING PROPORTIONS OF MAJOR CATIONS AND ANIONS IN WATER FROM THE CHINLE FORMATION.

and San Antonito and in the vicinity of Frost Arroyo east of San Antonito. These wells are the only ones known to have been completed in the Santa Rosa within the report area, and most penetrate 30-110 ft of saturated thickness. Yields are generally adequate for domestic use. Chemical analyses were not made for water samples from the Santa Rosa Sandstone.

Todilto Limestone-Entrada Sandstone, undivided (Jte)

The Todilto Limestone and Entrada Sandstone (both Middle Jurassic) are undifferentiated on the geologic map. The Entrada Sandstone, the lower unit, is buff to tan-brown, locally greenish-yellow sandstone from 100 to 145 ft thick. The Todilto Limestone, which overlies the Entrada, consists of a basal laminated limestone, black and fetid, from less than 1 to 85 ft thick; it also has gypsum, with laminae of limestone, 25-230 ft thick. The two formations crop out in a narrow band against the Chinle Formation around the northwest and northeast parts of the Tijeras anticline and syncline, southwest of Placitas.

Down the hydraulic gradient from this formation, ground water is likely to contain high concentrations of sulfate. An example was previously cited in the section on the Chinle. Well 11N.6E.29.214 possibly is drilled into the unit, but this determination was made from a geologic map after fieldwork was completed and has not been verified.

Morrison Formation (Jm)

The Morrison Formation (Late Jurassic) is a multicolored mudstone, sandstone, and conglomerate and contains some limestone. The coarse-grained elastic rock and the limestone beds are medium to thin bedded and tend to be lenticular; the sandstone is usually tightly cemented. In the Sandia Mountains the unit is 480-750 ft thick. The Morrison and the overlying Dakota Sandstone tend to crop out in ridges that separate valleys cut in the Chinle on one side and the Mancos Shale on the other. Such ridges crop out around the north end of the Tijeras anticline and syncline immediately east of NM-14 and south of Frost Arroyo. The Morrison also crops out, partly as a ridge, southwest of Placitas.

A few wells south of San Antonito and at least one well west of Placitas are completed in the Morrison. Permeability is presumed to be from fractured sandstones, but data are inadequate to predict aquifer conditions. Well 11N.5E.25.232, which was not complete when visited, was dry an estimated 170 ft below the top of the saturated zone. Initially, well 10N.5E.2.222b, near a fault zone, reportedly produced 15 gal/min. The well is estimated to have penetrated less than 10 ft of saturated rock; the yield was reported to be decreasing less than a year later. The only well (13N.5E.32.323) known to be producing from the Morrison in the Placitas area yields a reported 55 gal/min and is completed about 55 ft beneath the potentiometric surface.

Water produced from a well completed in the Morrison near Placitas is undesirable chemically because of a sulfate concentration of 1,500 mg/L. This sample is plotted on the Piper diagram (A, fig. 10). The sulfate probably comes from gypsum beds in the Todilto Limestone upgradient from the well; water having a high-sulfate concentration also occurs in the Mancos Shale above the Dakota Sandstone. As the Morrison and the Dakota are underlain and overlain by formations that contain gypsum, ground water in these formations commonly is high in sulfate.

Mancos Shale-Dakota Sandstone, undivided (Kmd)

The Dakota Sandstone (Kd), underlying the Mancos Shale (Km), is mapped with the Mancos; both are Cretaceous age. The Dakota, consisting of light-gray to buff sandstone with some black shale, is 5-250 ft thick and crops out with the Morrison in prominent ridges. The sandstone could be permeable owing to fracturing. The Dakota and Morrison may compose a single hydrologic unit with similar permeability and chemical quality.

Poor-quality water from well 12N.5E.6.224 west of Placitas and spring 10N.5E.11.333 southwest of Cedar Crest probably comes from the Dakota Sandstone. Chemical analyses were not made on water from the Dakota Sandstone.

The Mancos Shale consists of black shale with interbedded light-gray and yellowish-gray, rusty-weathering sandstone and siltstone beds. It contains some thin coal beds in the upper part and near the base. The formation is 1,500-1,800 ft thick and crops out around the Tijeras anticline and syncline and west and northwest of Placitas. Because easily eroded, the Mancos is usually a valley-forming unit.

The silty sandstones yield a few gallons per minute of water to wells. More than 15 wells have been drilled into the formation, mainly for domestic water. Most wells penetrate 35-75 ft beneath the potentiometric surface; a few go much deeper. Well 10N.5E.2.222a penetrates about 225 ft of saturated sediment but reportedly produces only a quarter of a gallon per minute. Six dry holes, the deepest to 900 ft (10N.5E.2.334), were drilled in the Mancos within a small area about 1 mi north of Cedar Crest.

Chemically, ground water from the Mancos Shale is usually undesirable for domestic purposes. Two complete chemical analyses of water samples from the Mancos are plotted on the Piper diagram (B and C, fig. 10). The sample from well 10N.5E.11.211 (B) contains 2,520 mg/L dissolved solids of which 1,460 mg/L are sulfate. This water is reported to cause rust stain, indicating iron in solution; no mention was made of a sulfide odor, nor was any noticed when collecting the sample. In those areas where sulfide odors were noticed, sulfur is probably precipitated in the aquifer in the reduced state as the mineral pyrite (FeS_2) with a minor amount dissolved as hydrogen sulfide (H_2S). If pyrite is precipitated in the aquifer, this accounts for some water samples turning black. As the water equilibrates with gases in the air, the pyrite oxidizes and turns black. Pyrite is a relatively rare

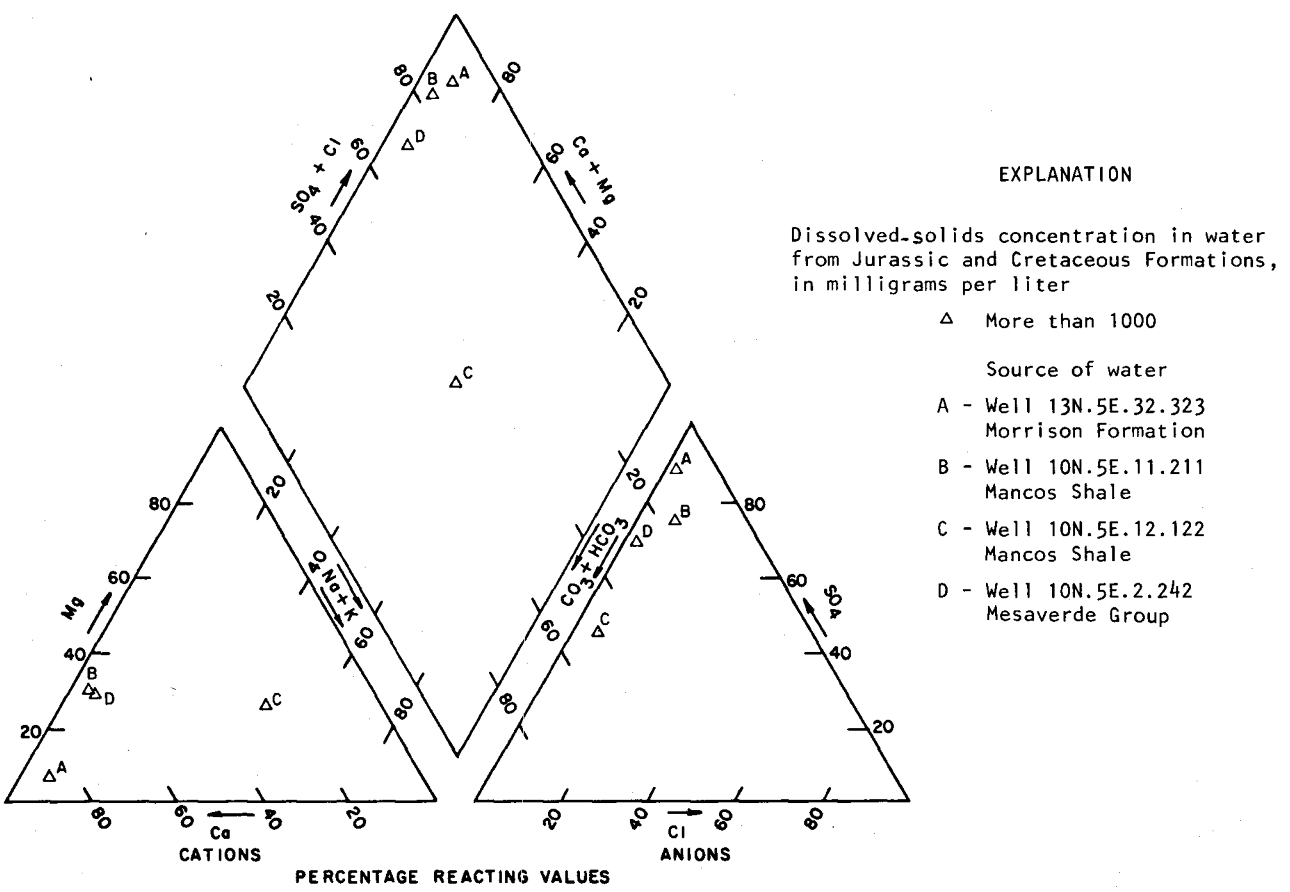


FIGURE 10—PIPER DIAGRAM SHOWING PROPORTIONS OF MAJOR CATIONS AND ANIONS IN WATER FROM JURASSIC AND CRETACEOUS FORMATIONS.

form of sulfur compound in an aquifer; the more common case is for the sulfur to occur as the oxidized ion sulfate (SO4), which remains dissolved in the water.

Some well owners in the valley of Arroyo San Antonio and in Gutierrez Canyon report their water is soft and not chemically objectionable. This better quality water may be due to Mancos water mixing with water from overlying alluvium (for example, at wells 10N.5E. 11.213, ION.5E.11.231) or to ground water from other formations flowing into the Mancos across nearby faults (for example, at well 10N.5E.15.432). Wells in Gutierrez Canyon pump water from the Mancos that is locally recharged to the aquifer. Reports by owners and the water analysis from well 10N.6E.6.324 show that, except for the sulfide-gas odor, the water is not necessarily objectionable.

Mesaverde Group, undivided (Kmv)

The Mesaverde Group (Late Cretaceous) consists of grayish to tan sandstone, dark-brown to black shale, carbonaceous shale, and numerous coal lenses as much as 4 ft in thickness. The Mesaverde crops out over an area of about 4 sq mi on the Tijeras anticline and Tijeras syncline. Erosion has removed all but the lower few hundred feet on the anticline, and all but about 1,500 ft along the synclinal axis. The entire thickness is about 2,900 ft and is found in outcrops west and north of Placitas that dip steeply northward beneath younger strata.

Wells on the Tijeras anticline and along Arroyo San Antonio are capable of producing from 1/2 to 35 gal/min from the Mesaverde. These wells penetrate 35-150 ft of the saturated zone. Other wells west of Placitas penetrate from about 20 to 130 ft of saturated strata and produce up to 7 gal/min.

The quality of water produced commonly is poor, being high in dissolved solids and sulfate. The chemical analysis of water from well 10N.5E.11.431 shows 875 mg/L dissolved solids, of which 299 mg/L is sulfate. Four chemical analyses were made, one of which is plotted (D) on fig. 10.

Galisteo Formation (Tg)

The Galisteo Formation (early Tertiary) consists of gray, buff, and reddish-brown sandstone and conglomeratic sandstone and gray to reddish-brown and purple mudstone. It is 2,300-3,000 ft thick outside the project area east of Placitas. The lower part is exposed west and north of Placitas, where it dips steeply northward and is buried by sediment of the Santa Fe Group in the Rio Grande trough. The Galisteo is not known to have been drilled for water in the project area.

Santa Fe Group, undivided (QTs)

The Santa Fe Group (Miocene to Pleistocene) is one of the valley-filling deposits in the Rio Grande trough. It consists of alluvial silt, sand, and gravel that is uncemented to poorly cemented. Caliche (zones of cemented calcium carbonate) developed under old, buried land surfaces may occur at various depths. The Santa Fe Group is a few hundred feet thick north of Placitas and thickens westward along the Sandia and Manzano Mountain fronts, attaining more than 1,000 ft at the Rio Grande.

Potential ground-water production from wells in the Santa Fe Group is very large where adequate saturated thickness occurs, especially where gravel beds are encountered by a well. When fieldwork was done for this project only a few domestic wells had been drilled into the Santa Fe Group near the Placitas area, of which three were visited. These reportedly produced from 12 to 20 gal/min, with 45-100 ft of saturated thickness.

The thickness of saturated sediments in the Santa Fe is largely unknown, because data concerning the depth of the Santa Fe contact with underlying rocks are scarce. The bounding fault between the Santa Fe on the west and the Mancos Shale on the east is exposed in a roadcut about 3 mi west of Placitas (SE'/ NW'/ sec. 1, T. 12 N., R. 4 E.) where the fault dips westward at an angle somewhat less than 45 degrees. Wells drilled into the Santa Fe a few hundred feet west of the fault (13N.4E.36.334) should pass through the fault and into Mancos Shale at depths of a few hundred feet.

The chemical quality of the ground water is probably satisfactory for domestic use. The only water sample collected (13N.4E.36.334) from the Santa Fe Group contains 258 mg/L dissolved solids. This sample is plotted on the Piper diagram (E, fig. 11). In the Placitas area ground water near the base of the Santa Fe is in contact with formations containing water high in sulfate.

Readers interested in ground water in the Santa Fe Group in the vicinity of Albuquerque are referred to Bjorklund and Maxwell (1961); those interested in ground water west of the Manzano Mountains are referred to Titus (1963).

Estancia Valley fill (Qe)

The Estancia Valley fill (Quaternary) consists of alluvial silt, sand, and gravel that is uncemented to poorly cemented. Like the Santa Fe Group west of the mountains, these sediments can contain caliche zones at various depths. The Estancia Valley fill crops out everywhere along the eastern margin of the mountain area but is most extensive in the Edgewood embayment. The fill extends into the lower reaches of major valleys and downfaulted blocks. On the geologic map the valley fill is shown to be in contact with Quaternary alluvium but contact positions are based arbitrarily on valley widths. The Quaternary alluvium in the tributary valleys is modern sediment, younger than most of the valley fill, and is generally in transport toward the Estancia Valley. The marked stratigraphic differences are reason enough to distinguish the two units.

The thickness of the valley fill ranges from a feather edge overlapping older rocks to more than 250 ft in the eastern part of the Edgewood embayment and to about 200 ft at the southeast corner of the project area. The fill is more than 80 ft thick southwest of South Mountain, 50 to possibly 90 ft thick in the Barton trough, and usually 20-60 ft thick in parts of the lower valleys off the Manzano Mountains. The unit thickens east of the project area to more than 400 ft along the axis of the Estancia Valley.

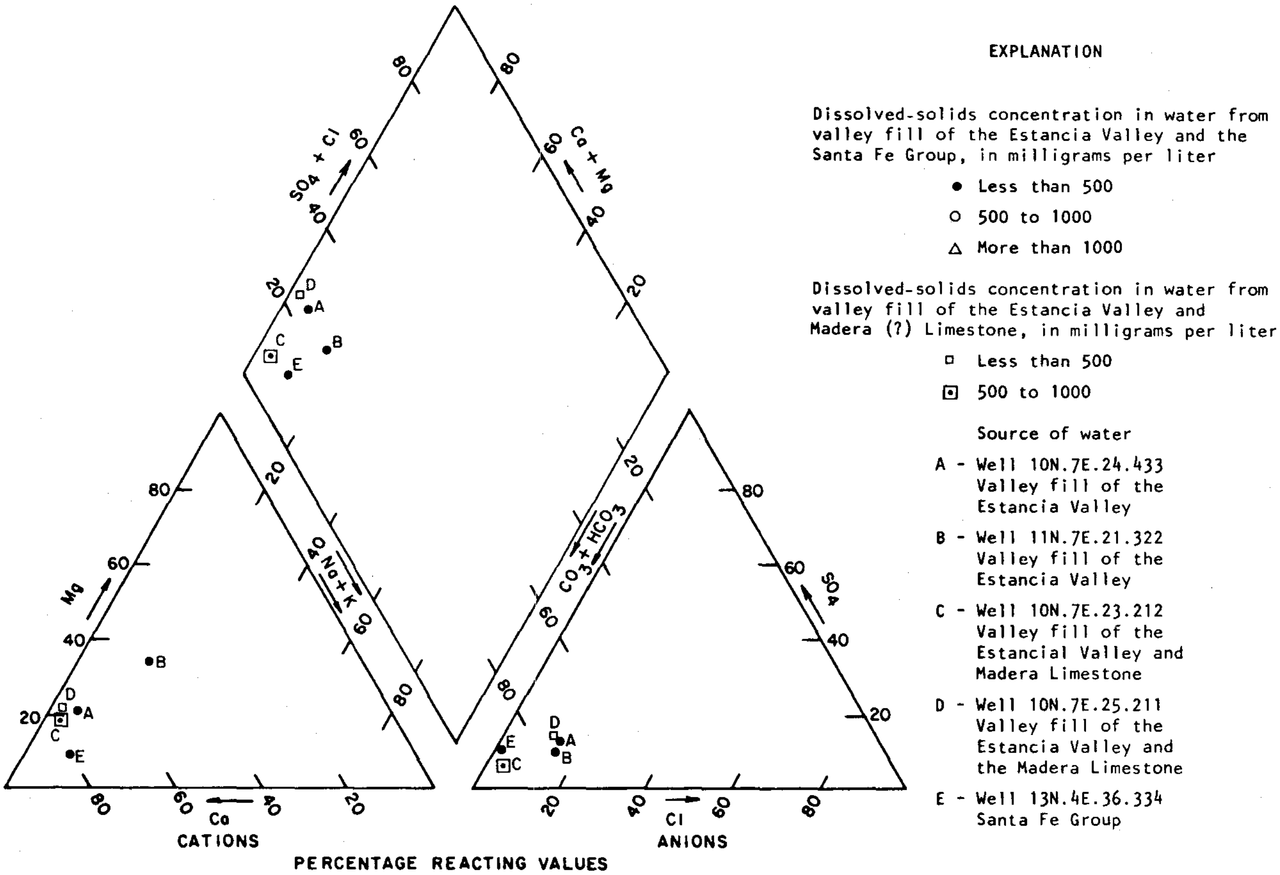


FIGURE 11—PIPER DIAGRAM SHOWING PROPORTIONS OF MAJOR CATIONS AND ANIONS IN WATER FROM THE VALLEY FILL OF THE ESTANCIA VALLEY AND THE SANTA FE GROUP AND FROM THE VALLEY FILL OF THE ESTANCIA VALLEY AND THE MADERA LIMESTONE.

The valley fill has been penetrated by numerous water wells to obtain domestic, stock, and irrigation supplies. The irrigation wells, found only in the southeast part of the Edgewood embayment, are thought to have been drilled through the valley fill and into the underlying Madera Limestone. The permeability required for yields up to 400 gal/min (10N.7E.25.211) could be provided by solution channels in the Madera. The valley fill may provide aquifer storage, draining into the Madera as the wells are pumped. This multiple-aquifer system exists in the Estancia Valley for several miles south and southeast of the project area, where yields of more than 1,000 gal/min are not unusual (Titus, 1969). Yields of several hundred gallons per minute from the valley fill north of Moriarty were recorded by R. E. Smith (1957). Where only the basal part is saturated, small yields for domestic and stock uses usually can be obtained.

In the valley fill the potentiometric surface is in the lowermost part; in many places the potentiometric surface is beneath the base of the unit. The saturated thickness is probably less than 60 ft.

Chemically, water from the valley fill is of the calcium bicarbonate type. Four analyses were made; all are plotted (A through D) on fig. 11. Two of these are from wells producing from both the valley fill and the underlying Madera. Three samples contained from 301 to 368 mg/L dissolved solids, and one well (10N.7E.23.212) contained 548 mg/L.

Terrace alluvium (Qt)

Terrace alluvium (Quaternary) consists of sand, gravel, and soil material deposited on sloping terraces before streams began cutting down to their present positions. In the Sandia Mountains the terrace deposits mantle sloping bedrock surfaces standing above present incised valleys. In the Estancia Valley the terraces probably represent the highest level of accumulation of the valley fill before the present cycle of valley cutting began. The unit is above the potentiometric surface in the project area.

Landslide deposits (Q1)

Landslide deposits (Quaternary) consist of coarse, chaotic debris and large blocks deposited by extensive landslides on the eastern dip slope of the Sandia Mountains. Cole Spring (11N.5E.34.243) emerges from the lower part of a landslide block that has carried Madera Limestone downslope over the Abo Formation.

Alluvium (Qal)

Alluvium (Quaternary) consists of unconsolidated silt, sand, and gravel covering the floors of mountain valleys. Information from drillers and well owners indicates that in the lower part of Tijeras Canyon alluvium is 100 ft or more thick; along Arroyo San Antonio, as much as 65 ft thick; and in the upper end of Frost Arroyo, as much as 90 ft thick. Information from the area east and northeast of San Antonito is inconclusive, but here the unit may be 30-40 ft thick.

In the Placitas area, alluvium 30-40 ft thick and up to a maximum of about 65 ft fills the lower parts of former broad, open valleys cut in older sedimentary rocks. After being deposited the alluvium has nearly been cut through in many places by narrow deep arroyos.

Many springs and seeps issue from the alluvium on valley floors, but these points of ground-water discharge often represent discharge from the underlying bedrock rather than discharge of underflow in the alluvium itself. Because the alluvium is generally coarse grained, reasonably well sorted, and unconsolidated, it is much more permeable than the underlying bedrock. In most places where the alluvium is thick, only the lower part of the unit is saturated; in many places, such as low on the backslope of the Manzanos, the base of the unit is above the potentiometric surface.

Many wells have been drilled into and through the alluvium; most, although not all, hand-dug wells in the mountain area are completed in alluvium. Yields from these wells range between wide limits, depending on saturated thickness and other factors, but the maximum potential yield seems to be about 50 gal/min. In some areas the yield can be expected to fluctuate seasonally as water levels vary in response to changes in precipitation. Along Arroyo San Antonio seasonal water-level fluctuations as great as 12 ft have been reported (well 10N. 5E.11.342).

Chemically, ground water in the alluvium reflects to some degree the water chemistry of nearby bedrock aquifers that discharge into the alluvium; direct recharge into alluvium from periodic storm runoff is also a factor. The chemistry of local subsurface flow into the alluvium is improved by the degree of mixing, depending upon the relative volumes of the underflow and the discharge from local aquifers. Chemical analyses were made on water samples from 25 wells and springs that produce water from the alluvium or from a multiple source consisting of the alluvium and another aquifer. Four of the analyses are plotted on the Piper diagram in fig. 12. The samples on the diagram are from water in the alluvium and have dissolved-solids concentrations less than 500 mg/L, except for the sample from well 9N.4E.35.100 which had 892 mg/L, and large concentrations of calcium and bicarbonate ions. Specific-conductance measurements on other samples also indicate low dissolved solids. Two samples contained excessive nitrate (wells 10N.41/2E.25.234, 10N.5E.30.324).

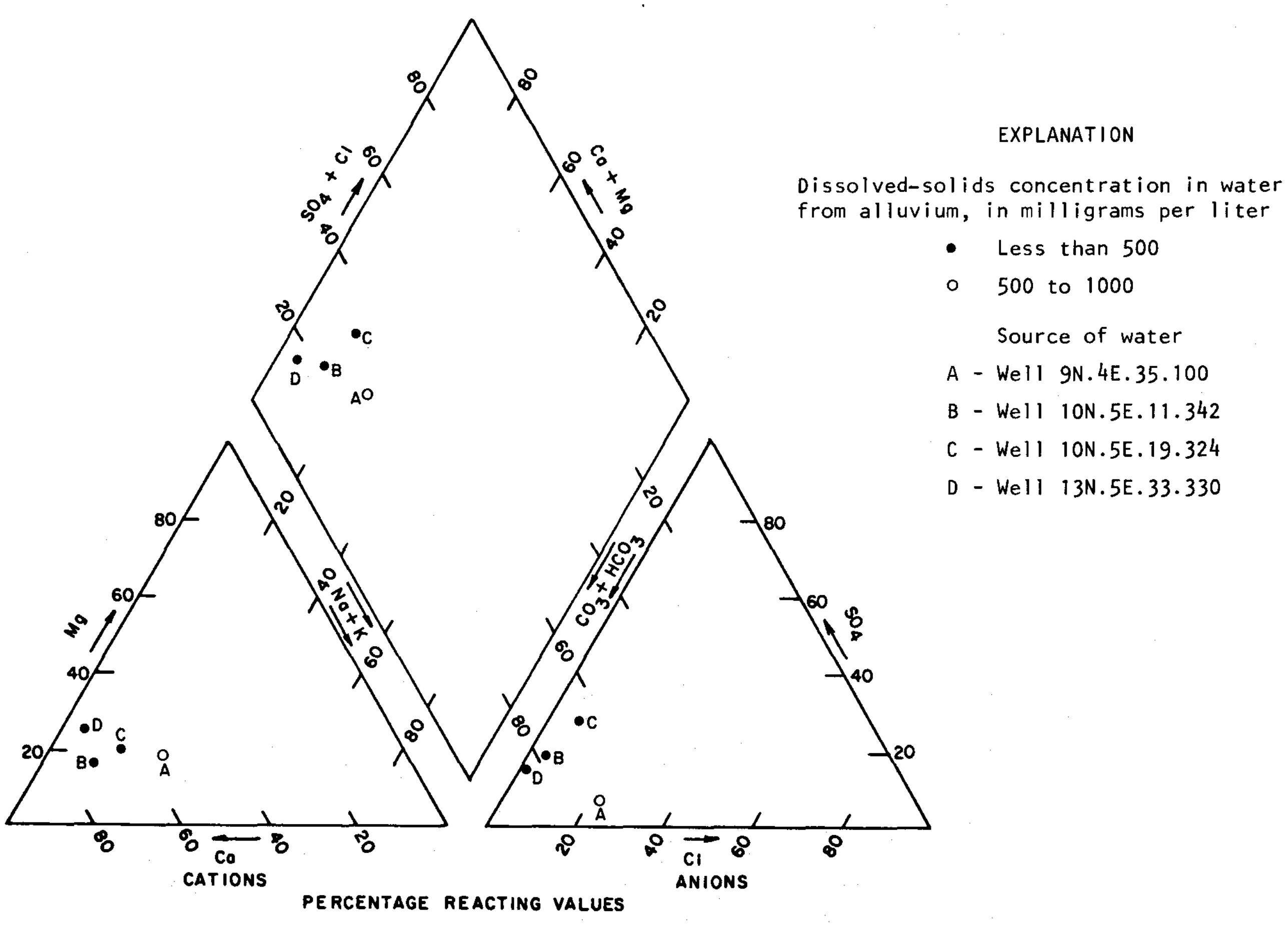


FIGURE 12—PIPER DIAGRAM SHOWING PROPORTIONS OF MAJOR CATIONS AND ANIONS IN WATER FROM ALLUVIUM.

Recharge and runoff

Recharge depends primarily on precipitation and is greatest at higher altitudes where precipitation is greater. Fig. 13 illustrates the increase in precipitation with altitude. A large part of the annual precipitation comes from intense, short-lived summer thunderstorms.

Once water has infiltrated, the quantity not used to wet the rock or soil drains slowly downward. If not extracted by plant roots or evaporated while near the land surface, the water ultimately drains to where all connected pores and cracks are saturated with water and the pressure is equal to or greater than atmospheric. This *zone of saturation* contains the *ground-water reservoir* (if porosity, permeability, and other conditions are such that man can exploit the ground water). The upper surface of the zone of saturation, where that surface is not confined and is at atmospheric pressure, is the *water table.*

The concept of a water table must be modified when considering semiconfined or confined aquifers. Water in confined aquifers is under pressure between two relatively impermeable layers of material. A well drilled into a confined aquifer is an artesian well or a flowing artesian well (Lohman, 1972, p. 7) if the water rises above the land surface. Artesian pressure is maintained because of water in the recharge area standing above the general level of the aquifer. Semiconfined aquifers have confining beds that do not form a perfect seal, with leakage into or out of the aquifer, depending upon the pressure head in the aquifer relative to the head in overlying and underlying beds. More than one potentiometric surface can exist at a geographic location if wells produce from different aquifers, a combination of aquifers, or from differing depths or zones in the same aquifer. A potentiometric surface is a surface that represents the static head. It is defined by the levels to which water will rise in tightly cased wells.

In a stream channel above the zone of saturation, runoff is lost by infiltration through the channel bed. Keppel (1960, p. 39) has reported losses into alluvial channels in Arizona grasslands of 4.3 acre-ft/mi of channel per hour of flow duration during heavy runoff. These values indicate the order of magnitude of channel loss that can occur. For the smaller runoff events in the Sandia and Manzano Mountains the infiltration rates are probably much lower. Because very little runoff leaves the mountain area and because growth of plants that transpire a large volume of water is limited, recharge occurs from summer precipitation infiltrating through channel beds and winter precipitation percolating through the soil cover to the saturated zone.

Ground water is flowing outward from the mountain area around its entire perimeter. Even though in absolute terms an immense volume of ground water is in the system, an outside source is not known to supply water. All of the water in the flow system has originated as recharge within the area.

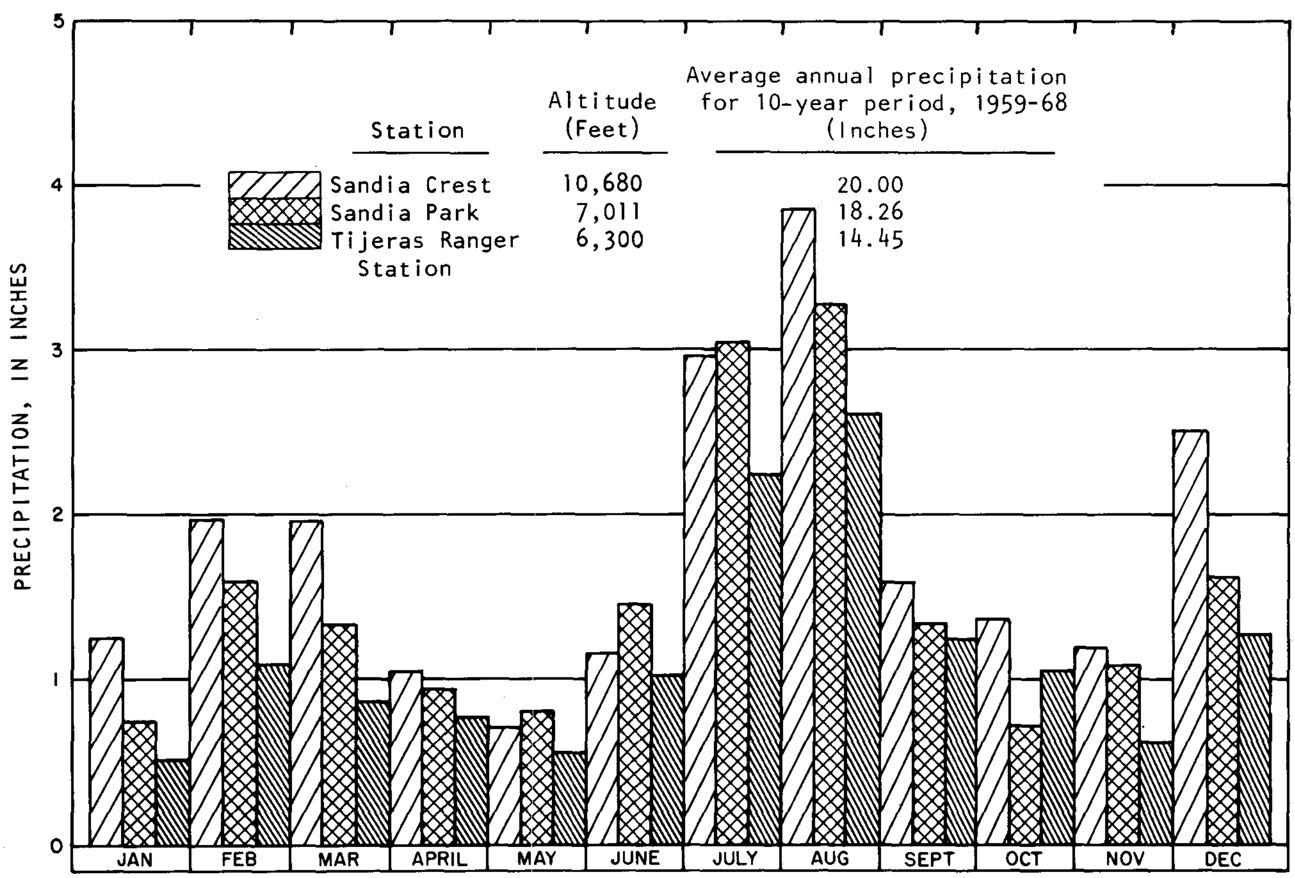


FIGURE 13—GRAPH SHOWING AVERAGE MONTHLY PRECIPITATION AT DIFFERENT ALTITUDES IN THE SANDIA MOUNTAINS FOR THE 10-YEAR PERIOD 1959-68.

Potentiometric surface—hydrologic and geologic implications

The form or shape of the potentiometric surface generally follows the form of the land surface, being highest in the mountainous upland areas and generally following the downward slope of the land surface.

The altitude, slope, and curvature of the potentiometric surface is shown by contours in fig. 4. In localities where the potentiometric-surface contours are closely spaced, a steep hydraulic gradient is indicated. The potentiometric surface of the west face of both the Sandia and the northern Manzano Mountains and the higher east slopes of the Sandias as well as part of the lower Sandia east slope between Placitas and La Madera was not contoured because of lack of data.

Manzano Mountains

A diagrammatic section (fig. 14) down the east slope of the Manzano Mountains illustrates the sloping potentiometric surface following the regional eastward dip of the Madera Limestone as well as the slope of the land surface. If water-level data points were closely enough spaced, they would probably show that some local topographic irregularities were reflected in very subdued form on the potentiometric surface.

Inasmuch as ground water always moves whenever a hydraulic gradient exists, lines showing direction of flow could be drawn perpendicular to the contours. (This would ignore the possibility that anisotropy—greater permeability in one direction than in others—could cause flowlines to be somewhat non perpendicular to the contours; data on anisotropy are not available). In this geologically and hydrologically simple area, ground water in the Madera Limestone is flowing east ward from the Manzano Mountains toward the Estancia Valley.

Sandia Mountains and Tijeras Canyon

The shape of the potentiometric surface of the Sandia Mountains is similar to that of the Manzanos, except that the steeper eastern dip slope imposes a higher gradient. Fig. 15 is a diagrammatic section from the crest of the Sandias to the Edgewood embayment on which the potentiometric surface is also shown. (The position of the potentiometric surface at the higher altitudes has been estimated.) The way the potentiometric surface tends to follow land surface is well shown on this section. Ground-water flow paths along this section are in most places not parallel to the section, but diverge markedly from it (fig. 16).

The potentiometric surface in the Sandia Mountains (fig. 16) shows that ground water moves toward the major valleys serving as line drains in transporting water out of the area. The ground-water flow pattern in the upper Tijeras Canyon-San Antonito-Frost Arroyo area has been constructed from the potentiometric-surface contours on fig. 4. Tijeras Canyon with its tributaries, Cedro Canyon, Arroyo San Antonio, and Gutierrez Canyon, is one of the two principal ground-water drain systems in this part of the mountain area. The other drain system is the lower end of Frost Arroyo and its master stream San Pedro Creek, draining northward between Sandia Mountain and Monte Largo. Ultimately this second system turns west beyond the north boundary of the project area and discharges, as does Tijeras Canyon, into the Rio Grande trough.

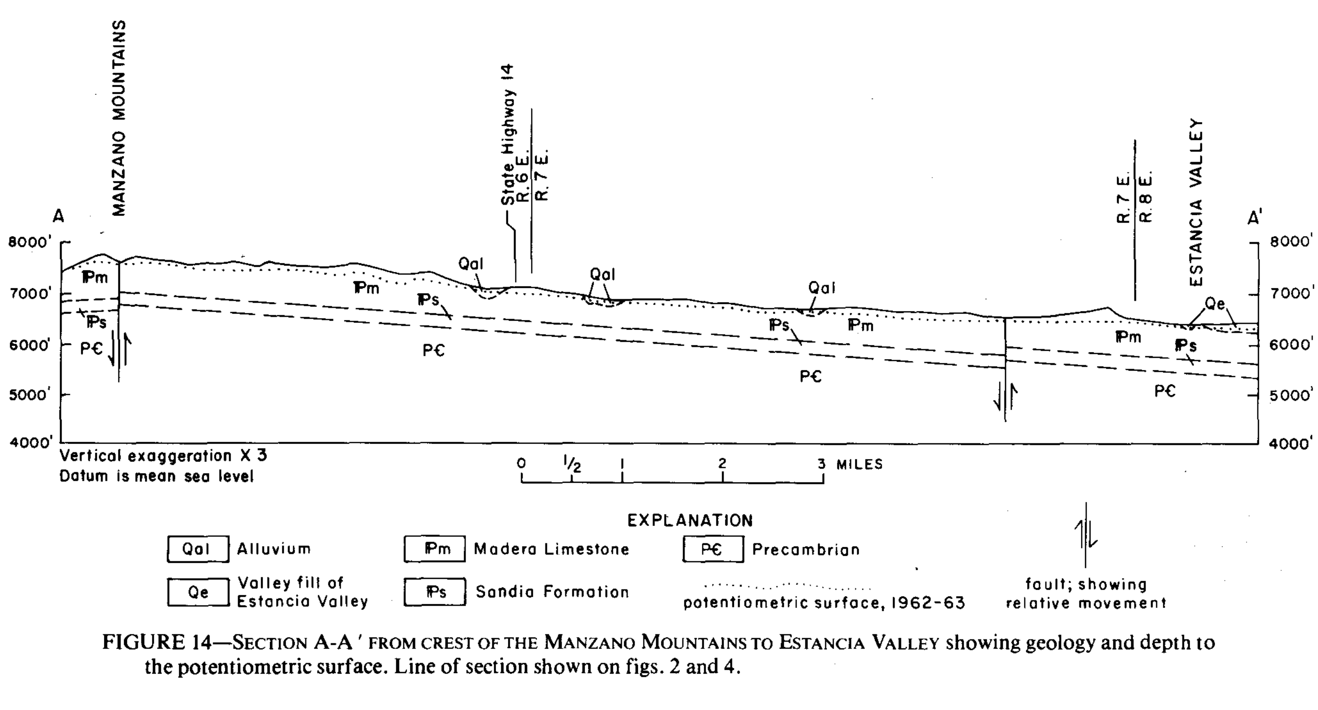


FIGURE 14—SECTION A-A′ FROM CREST OF THE MANZANO MOUNTAINS TO ESTANCIA VALLEY showing geology and depth to the potentiometric surface. Line of section shown on figs. 2 and 4.

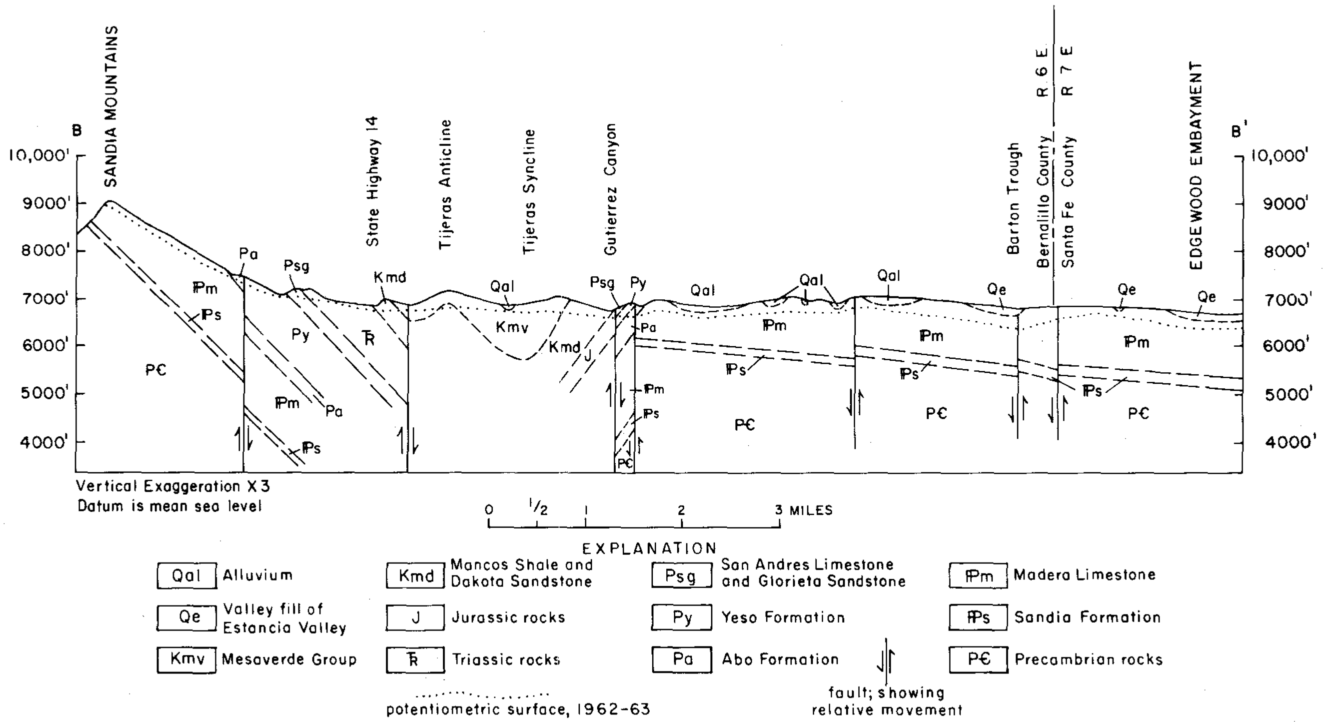


FIGURE 15—SECTION B-B' FROM CREST OF THE SANDIA MOUNTAINS TO THE EDGEWOOD EMBAYMENT showing geology and depth to the potentiometric surface. Line of section shown on figs. 2 and 4.

In some cases the direction of ground-water flow at depth can be quite different than at the top of the saturated zone. This principle has been explicitly described by such authors as Toth (1963) and Freeze and Witherspoon (1966, 1967, 1968). A good example of the phenomenon is the small ground-water divide lying immediately east of Arroyo San Antonio shown on fig. 16. The divide interpretation was made because of the water level measured in well 10N.5E.11.433 and a reported water level in a nearby well. The divide also seems likely because of the narrow topographic ridge of Mesa Verde sandstone beneath which the divide occurs. The regional flow pattern, in contrast to the local pattern of the ridge, is southeastward from the Sandia Mountains toward Arroyo San Antonio; ground water at moderate depths and greater is inferred to pass under the groundwater ridge along flow lines that swing from southeast to south before turning to follow Tijeras Canyon.

Ground-water divide near Frost Arroyo

A major ground-water drainage divide, one sufficiently large that deep flow beneath it is not anticipated, is shown in the eastern part of fig. 16. This is the master divide between the Rio Grande drainage on the west and the Estancia Valley drainage on the east. Farther south this master divide is coincident with the crest of the Manzano Mountains. Its position in fig. 16, however, implies that all ground water in the Sandia Mountains ultimately moves toward the Rio Grande trough. Nearly everywhere the ground-water divide lies beneath and follows a prominent topographic ridge. An exception is in the vicinity of Frost Arroyo (secs. 27 and 28, T. 11 N., R. 6 E.; fig. 15) where the ground-water divide is about 3 mi west of the upper end of Frost Arroyo.

Water levels in wells (within 1/4 mi of each other) near Frost Arroyo differed in altitude by as much as 200 ft (fig. 17). The aquifers that the wells are completed in may account for the unpredictable water levels found in this area.

The aquifer southeast of the Gutierrez fault, passing diagonally through the area, is the Madera Limestone. Wells in it are commonly drilled to depths where fractures are penetrated that will yield adequate amounts of water. The water level in the wells depends on pressure in those fractures. If fracture permeability is not encountered, the well receives no water, a fact exemplified by two holes that were measured and found to be dry at depths below the top of the saturated zone: (well 11N.6E.33.222, dry at depth of 232 ft, bottom altitude 6,566 ft; well 11N.6E.34.244, dry at depth of 435 ft, bottom altitude 6,505 ft).

The aquifer system northwest of the Gutierrez fault consists of nearly the entire sedimentary sequence of rocks, from Pennsylvanian to Cretaceous age, which form the Tijeras anticline and syncline and the Monte Largo uplifted block.

Water-level altitudes (fig. 18) for wells in the area of erratic water levels are plotted against the altitude of the bottom of the hole (assumed to be near the level in the aquifer where water enters the hole). The distribution of points is linear, with reasonably small scatter. Part of the scatter may be due to errors introduced by the above assumption. The diagram shows that hydraulic potential, indicated by the altitude of the water level, decreases with increase in well depth. This relationship indicates that the vertical hydraulic gradient tends to drive water downward.

If, on the diagram in fig. 18, there were a linear distribution of points having a slope of 45 degrees, the

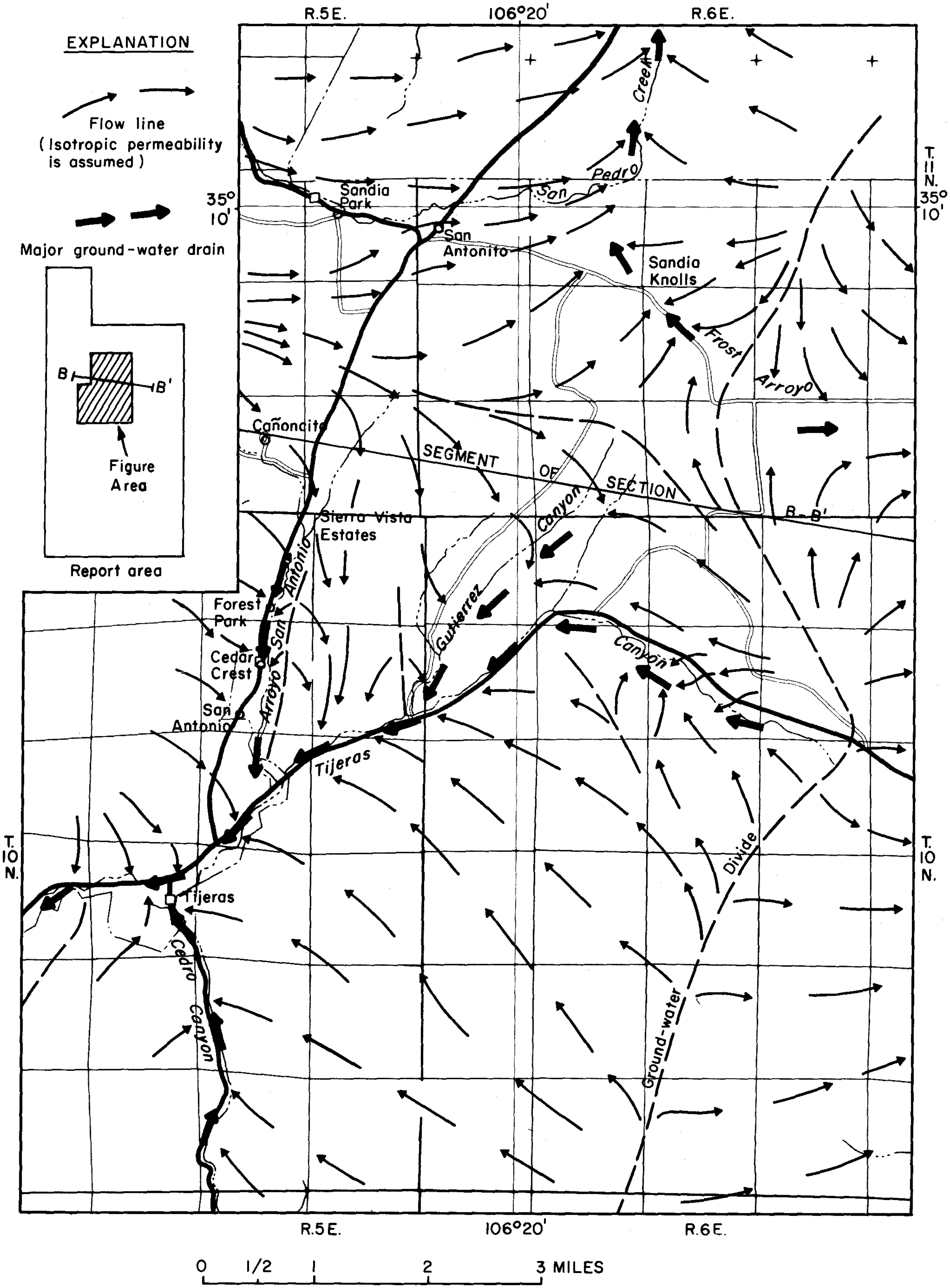


FIGURE 16—Ground-water flowlines at the potentiometric surface in the San Antonito and upper Tijeras Canyon area.

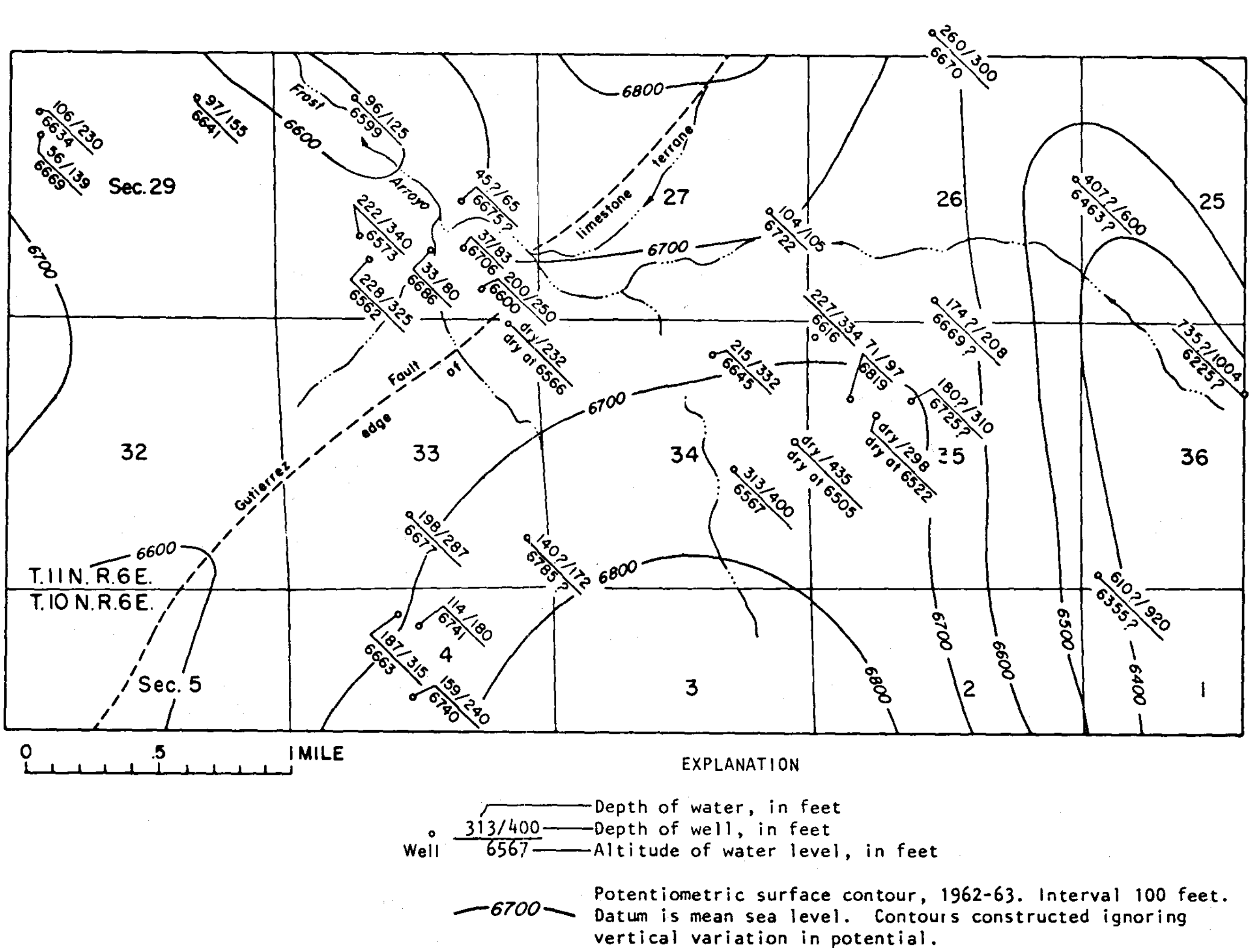


FIGURE 17—Well locations, depth to water, water-level altitudes, and depth of well near Frost Arroyo.

ground water would be perched (supported locally by impermeable layers above the true zone of saturation). The slope, however, is less than 45 degrees and shows that for each 100-ft increase in depth in the aquifer the potential drops roughly 65 ft. One well (11N.6E.35. 132a), a 97-ft hole, has water standing 71 ft below land surface at an altitude of 6,819 ft. This water level is nearly 80 ft higher than others in the immediate vicinity, suggesting that water in the well comes from local recharge. The fact that the well plots very near the line through the other points on fig. 18 tends to indicate that the water is in hydraulic continuity with deeper water.

One inference drawn from figs. 17 and 18 is that the aquifer is anisotropic, with horizontal permeability strongly predominating over vertical. The downward vertical component of gradient is greater than the horizontal (fig. 18), but because the channels available for flow are mostly horizontal (fig. 17) the water moves mostly in the horizontal direction even though the horizontal component of gradient is very small.

Barton trough

The potentiometric surface in the Barton trough is at low altitudes and is marked on the east and west by steep hydraulic gradients into the trough (fig. 4). The

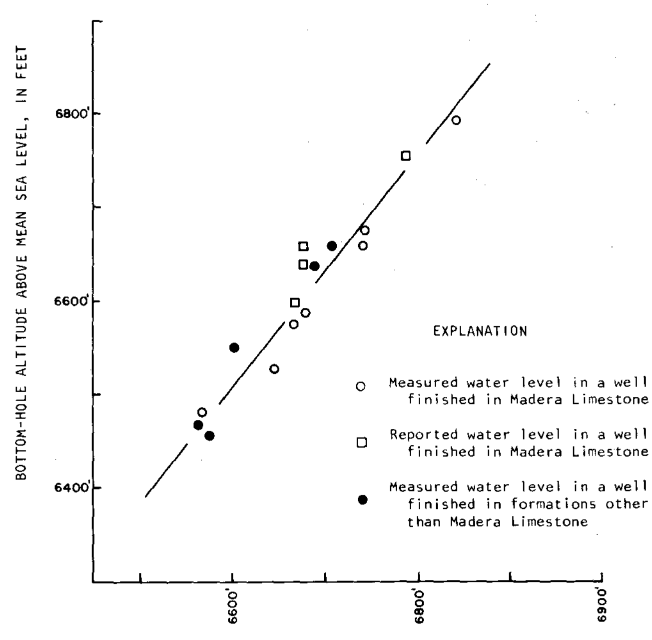


FIGURE 18—Water-level altitude versus bottom-hole altitude for wells near Frost Arroyo.

steep-sided, elongate low on the potentiometric surface in the Barton trough may allow ground water in underlying Precambrian rocks to flow upward toward the low on the potentiometric surface. However, in most of the Barton trough, water-level and well data are not adequate to explore the vertical distribution of potential.

The Barton trough severely modifies the general eastward flow of ground water toward the Edgewood embayment. Whether or not ground water rises into the trough from the Precambrian, ground water unquestionably drains to the Barton trough from the Madera aquifer in the uplands that surround the trough. Probably all ground water that flows into the trough leaves through the narrow gap in its southeast side (NE corner sec. 20, T. 10 N., R. 7 E.; fig. 4).

The uplifted east wall of the trough blocks groundwater flow except at the gap for the following reasons:

1) The amount of fault displacement that accompanied uplift of the east wall is not known, but 1.5 mi north of the gap the crest of the ridge is 250 ft above the floor of the valley. This, when added to the 100 ft or more of valley fill in the Barton trough, indicates about 350 ft of uplift (fig. 15). This fault displacement is enough to elevate most of what is known to be the highly cavernous, therefore permeable, part of the Madera above the level of the potentiometric surface in the Barton trough.

2) Using the valley floor as a datum, the uplift is enough to thin the saturated zone in the combined Sandia-Madera by nearly 25 percent. Even with no change in permeability, a 25-percent thinning of the saturated zone would restrict the eastward flow of ground water by 25 percent.

3) In well 11N.7E.31.434 the water level is at an altitude of nearly 6,700 ft, indicating that a contour at this altitude occurs in the ridge. The potentiometric surface in the east ridge is higher there than in the trough, making eastward flow of ground water through the trough impossible. Given these circumstances, eastward ground-water flow is blocked by the ridge and diverted through the gap to the south.

The rate of ground-water flow through the gap into the Estancia Valley must be large in comparison with rates anywhere else on the east slopes because of the concentration of flow in the small gap area. To accommodate this flow, under the very low hydraulic gradient that is indicated by the spacing of the potentiometric contours, requires a very high value for permeability through the gap. The water level measured in a Madera well directly in the gap (ION.7E.20.112) is 349 ft below land surface. The valley fill of the Barton trough might be more than 90 ft thick, but the saturated zone is well into the Madera Limestone. The high permeability probably results from shattering of the Madera by faulting, enhanced considerably by cavernous channels dissolved in the limestone. On the strength of the hydrologic argument, two faults are shown crossing through the gap and extending into the Edgewood embayment.

Edgewood embayment

The configuration of the potentiometric surface in the Edgewood embayment is peculiar with its irregularly shaped ground-water trough reaching nearly to the gap east of Barton. The trough (defined on fig. 4 by the 6,300-ft contour) must be transmitting all of the water supplied through the gap as well as the water flowing to it from the sides, and yet the gradient along its axis is about 28 ft/mi. As in the Barton trough gap area, the high permeability indicated by the trough is due to characteristics of the limestone; possibly an unrecognized gravel-filled channel at the base of the valley fill may be contributing to the high permeability. In the irrigation well just south of the trough (ION.7E.23.212) the potentiometric surface is thought to be in the valley fill just above the top of the Madera. In a well just north of the trough (10N.7E.16.412) the potentiometric surface is probably in the Madera because, when visited, the well was blowing air probably from cavernous limestone above the saturated zone.

The faulted, probably cavernous zone that passes through the gap is therefore projected northeastward along the axis of the trough. A note of caution—the equipotential lines are located by interpolating from water levels in wells that in some places are more than 2 mi apart, resulting in a trough that appears to have a broad floor. If fault controlled, however, the permeable zone may be rather narrow. Though the permeable zone is probably in the uppermost part of the saturated rock, possibly a highly permeable zone lies at depth in the limestone.

The northwestward arm of the trough and a suggestion of a southeastward arm that are shown by the 6,300-ft contour (fig. 4) may be stratigraphically controlled. The geologic contact between the Madera and the overlying Abo (buried beneath the valley fill of the Estancia Valley) is shown on fig. 4 to roughly parallel these arms but to lie northeast of them about 2 mi. By inference the alignment of the arms is also paralleled by the limestone bedding. The general position of the buried geologic contact also coincides with a marked change in pattern of the contours on the potentiometric surface. South of the position of the contact, in the area underlain by Madera Limestone, the contours are sharply curved around the arms of the trough; whereas north of the contact, where the valley fill of the Estancia Valley is underlain by Abo, the contours are parallel and evenly spaced, marking the smooth slope of the potentiometric surface away from South Mountain.

Placitas area

Ground-water flow patterns implied by the potentiometric surface in the vicinity of Placitas at the north end of the Sandia Mountains are relatively simple. However, because of steeply dipping strata—part of which contains geologic sources of poor-quality water—residents are confronted with seemingly erratic distribution of potable ground water. Water levels under the north-sloping terrain west of Placitas at most places are 100 ft or less below land surface, and the potentiometric surface closely parallels the land surface (fig. 19). The relatively steep hydraulic gradient is required to drive ground water across the bedding of the strata, which dip in the direction of ground-water flow but at a steeper angle than the potentiometric surface. (In strata containing interbedded sandstone and shale beds, the permeability across the bedding will be lower than that parallel to the sandstone beds.)

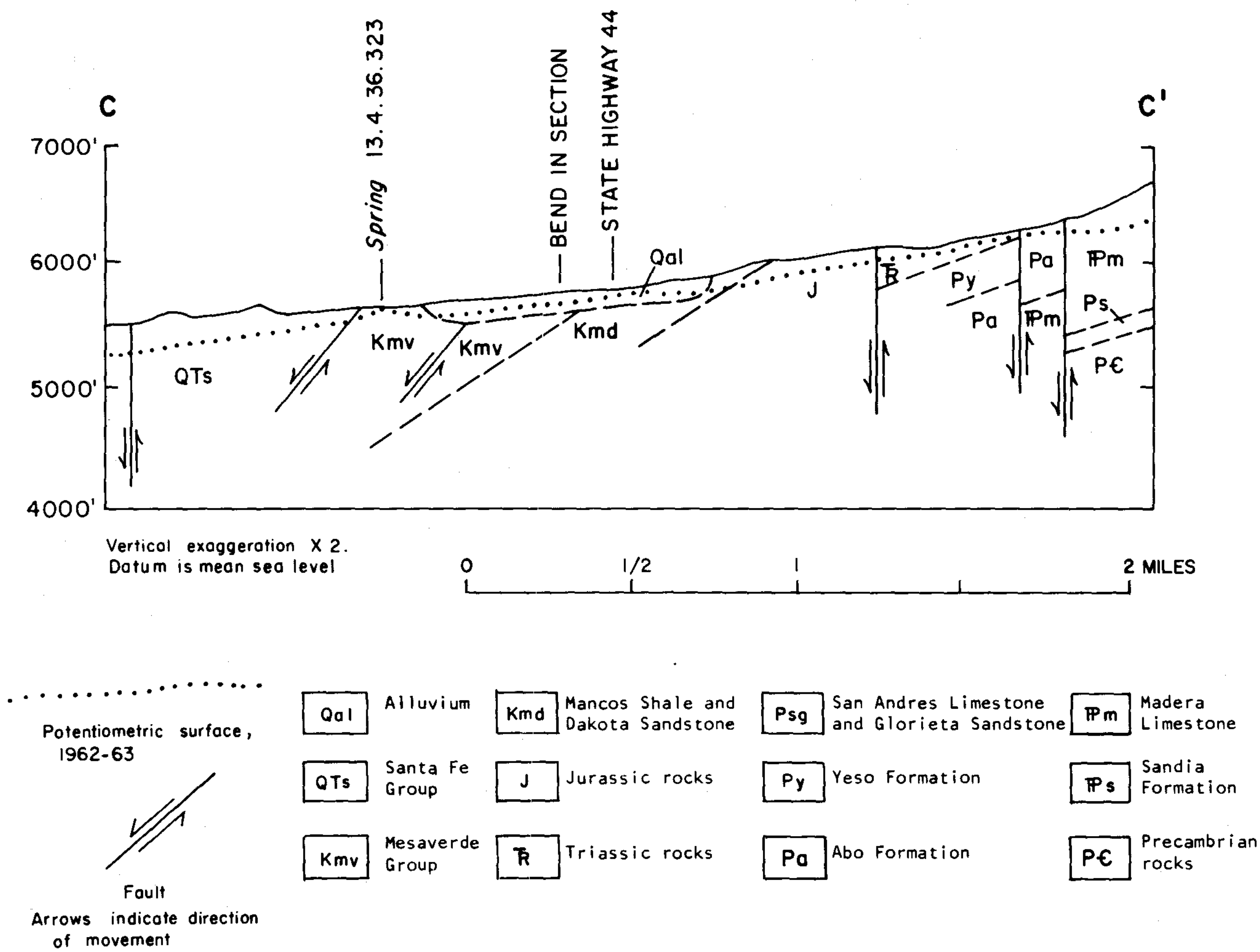


FIGURE 19—SECTION C-C' NEAR PLACITAS showing geology and depth to the potentiometric surface. Line of section shown on figs. 2 and 4.

The drainage area for ground water west of Placitas is small; therefore, the amount of recharge that must flow through the steeply dipping strata is small in comparison with other parts of the Sandia and Manzano Mountains region.

From the terrane of steeply dipping older rocks, flow continues westward or northward into the alluvium of the Santa Fe Group. The equipotential lines in the Santa Fe Group were constructed for fig. 4 from scant well data and therefore will require minor modification as more information is collected. The lines are reasonable in that they fit data published by Bjorklund and Maxwell (1961) for the Albuquerque area and fit the points where springs discharge from the aquifer.

The fault shown on the geologic map between secs. 20 and 21, T. 13 N., R. 5 E. is inferred from hydrologic evidence and from an obvious change in topographic relief along this line. The Santa Fe, east of the fault, crops out as an upland terrace with steep, highly dissected slopes. The fault displacement indicated by the topographic relief is about 200 ft, which is probably a significant fraction of the aquifer thickness. Spring 13N.5E.28.322, which may indicate another fault or an igneous dike in the Santa Fe, discharges as much as 100 gal/min from the Santa Fe. This spring water then flows as surface water for about 1 mi to the fault described above, where it again infiltrates into the aquifer. Through this reach, the surface flow is interpreted to indicate lower permeability and a thinner aquifer that resulted from uplift of the eastern block—reason for inflecting the equipotential lines where they cross the fault.

Ground-water availability and quality by area

In the discussions of specific areas that follow, information about ground-water occurrence, availability, and quality are summarized. In some cases additional information is presented, for example on dry holes in the Madera Limestone. Each area comprises a terrane in which a particular formation or sequence of formations crops out. The limits of each area treated in the following pages are shown on fig. 20. The geologic significance of the areas can be seen on the geologic map. The precipitous Precambrian terrane on the west faces of the mountains, the upland areas of Monte Largo and South Mountain, and the mountainous terrane southeast to northeast of Placitas are not considered here.

Lower Tijeras Canyon (Precambrian)

This area is that part of Tijeras Canyon cut in Precambrian rock. Its upper end is the narrow section of the canyon 1 mi west of the village of Tijeras; its lower end, the mouth of the canyon. Alluvium underlies the floor and the lower side slopes of the canyon to maximum depths that exceed 100 ft. Where major tributary canyons enter, the alluvium can be as much as 100 ft thick '/2 mi away from the axis of Tijeras Canyon.

Both the alluvium and Precambrian rocks serve as aquifers. Although the more productive wells derive at least part of their water from the alluvium, the Precambrian rocks have sufficient fracture permeability, where tested, to provide some water. Wells have been drilled along the canyon floor and into the alluvial-fan material of tributary valleys and are mostly 25-150 ft deep. One well high on the south side of the canyon (ION.4E.36.124) was drilled to 500 ft in Precambrian rock. The driller reported no additional water was obtained below 240 ft. Water levels in wells range from a few feet for those near the stream in Tijeras Canyon to about 70 ft in the 500-ft well. Yields from the wells were all reported to be adequate; the maximum yield reportedly exceeds 50 gal/min. The deep well produces about 15 gal/min.

Water from the deep well (10N.4E.36.124) differs chemically from all other water in the canyon. It contains 1,140 mg/L dissolved solids of which 280 mg/L are sulfate and 3.5 mg/L are fluoride. Most of the water produced by this well is from Precambrian rocks; about 30 ft of saturated alluvium overlies the Precambrian rocks.

For other water sampled in this area the average dissolved-solids concentration (five samples) is 462 mg/L with average sulfate (seven samples) and fluoride (two samples) concentrations of 110 mg/L and 0.2 mg/L respectively. Concentrations used in computing these averages are from water samples taken from wells and springs in Precambrian rocks, alluvium, or both aquifers.

The chemical quality of ground water is good, except for one critical constituent—nitrate. Seven of the 21 samples analyzed for nitrate contained between 45 and 108 mg/L of the ion, 14 contained 0.0-4.4 mg/L. Water from the deep well contained no measurable nitrate. Nitrate concentrations in water from 18 wells and springs are above 5 mg/L, considered normal or background for the mountain region.

Middle Tijeras Canyon (Abo and Yeso)

This area extends from the narrow section of the Tijeras Canyon west of the village of Tijeras northeastward for about 6 mi (fig. 20). The northeastern limit is in a tributary canyon about a mile beyond where the main canyon (and the highway) turns east. Along most of this reach, the area is bounded on the northwest by the Gutierrez fault. Along the Gutierrez fault, where adjacent to the Tijeras syncline, a narrow outcrop band of the Glorieta Sandstone and San Andres Limestone and a very thin section of the lowermost part of the Santa Rosa Sandstone (not shown on the geologic map) are included in the terrane. Thus, in addition to the floor and sloping sides of Tijeras Canyon, the areas include the ridge between Tijeras and Gutierrez Canyons and the southeast side of Gutierrez Canyon.

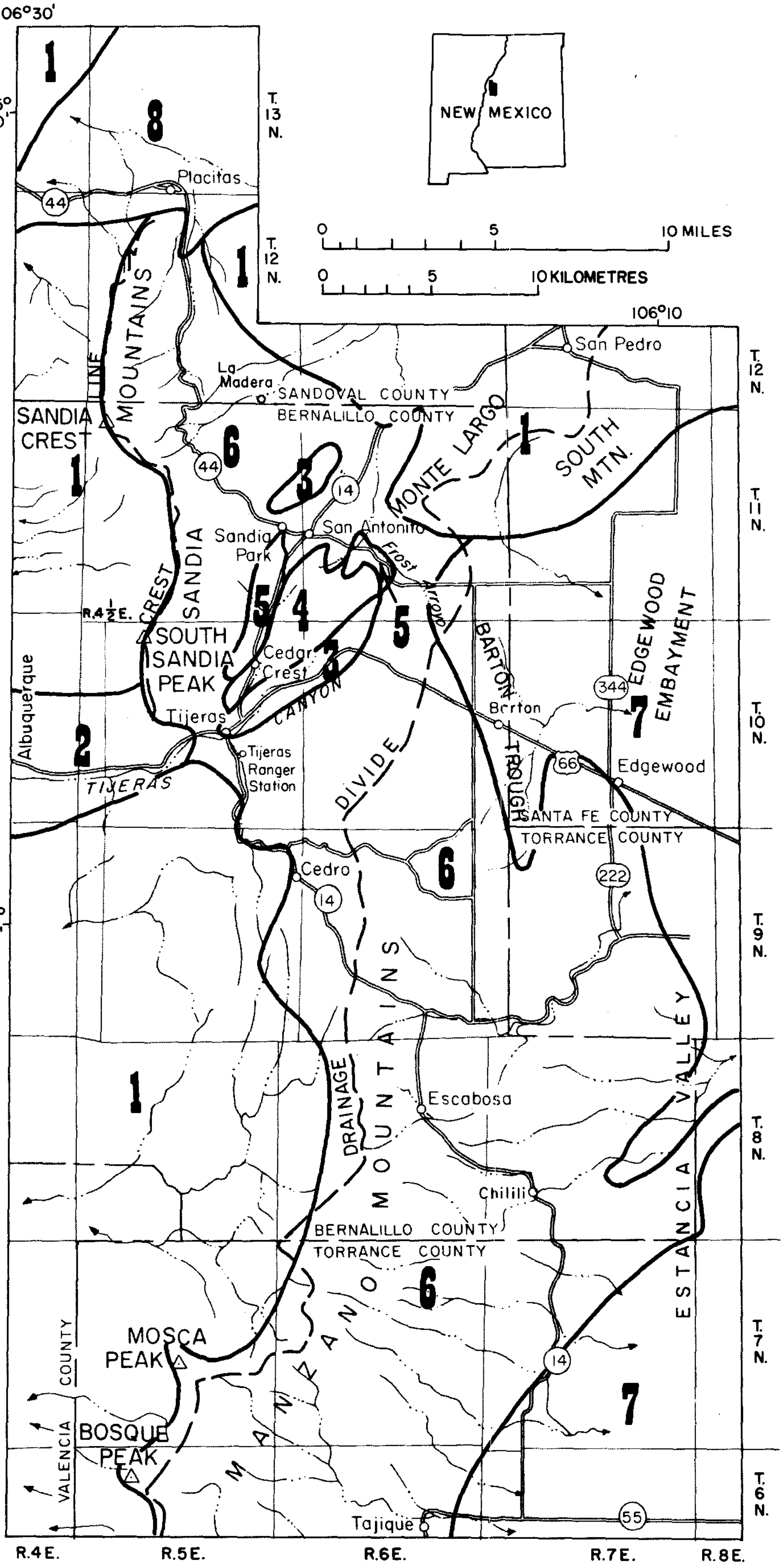
The sandstone beds in the Abo and Yeso Formations yield ground water to wells in most parts of the area. Well depths in the Abo range from about 70 to 240 ft, and water levels range from 30 to 145 ft. The deeper water levels are found higher on the slopes above the floor of the canyon. Wells in the Yeso between Tijeras and Gutierrez Canyons are deeper, as much as 310 ft, and water levels may be as much as 250 ft below land surface.

Generally, well yields reported are adequate for domestic use. In the part of the canyon that lies within about 1 mi of the village of Tijeras, yields of 18-40 gal/min were reported. The closely spaced faults here indicate that former geologic stresses probably fractured the sandstone beds to a greater degree than elsewhere.

The few chemical analyses of water from the area indicate no potability problem, but water users should be concerned with the possibility of unusual nitrate concentration in ground water. No unusual nitrate concentrations were apparent in samples that were analyzed for this study. Wells very near faults that separate this terrane from the Mancos and Mesa Verde terrane could, with long-term pumping, create cones of depression that induce ground-water flow across the fault to the wells, thereby drawing in water high in sulfate.

Tijeras anticline and syncline (Jurassic, Mancos, and Mesa Verde)

The area is bounded on the southeast by the Gutierrez fault, on the west by the Tijeras fault and the contact between Triassic and Jurassic rocks south of San Antonito. The north end of the area is bounded by Frost Arroyo. The lower reaches of Arroyo San Antonio, followed by NM-14, are included in the area (fig. 20). The 2-mi-wide block between the Tijeras and Gutierrez faults has been compressed into two large folds, an anticline well exposed north of Tijeras Canyon and a syncline. Other smaller anticlines and synclines are found in



EXPLANATION

1
Not treated because of rough terrain, scarcity of water, or lack of data

2
Lower Tijeras Canyon, terrane of Precambrian rock

3
Middle Tijeras Canyon, terrane of Abo and Yeso Formations

4
Tijeras anticline and syncline, Jurassic rock and Mancos, Mesaverde terrane

5
Lower Sandia slopes and Frost Arroyo to Highway 14; Permian and Triassic terrane

6
Madera Limestone terrane

7
Edgewood Embayment terrane of valley fill of the Estancia Valley

8
Placitas area

FIGURE 20—AREAS HAVING SIMILAR GROUND-WATER CONDITIONS.

the northwest part of the area. Jurassic rocks crop out around the north end of the folded area; the Mancos Formation and Mesa Verde Group (both Cretaceous) crop out extensively in the central part of the area.

A distinctive characteristic of the rocks forming and underlying this area is that they all contain water that is objectionable for domestic purposes. Typically the water contains excessive sulfate and dissolved solids; in many places the iron stains plumbing fixtures, and the sulfide evolves as foul-smelling hydrogen sulfide gas.

However, ground water is not difficult to obtain from sandstone strata. Even the Mancos, predominantly a shale formation, contains thin interbedded sandstones. Well depths range from about 50 ft to more than 400 ft, with most being between 150 and 200 ft. Most of the deeper wells are located on the uplands where the top of the saturated zone lies at greater depth. (section B-B', fig. 16.) Water levels range from about 35 ft to about 350 ft, with shallower water levels at lower land-surface altitudes. Yields from wells can be as great as 35 gal/min, but most are less than 10 gal/min and some wells reportedly yield only a fraction of a gallon per minute.

In the lower reaches of the Arroyo San Antonio valley, the position of a drill hole relative to the Tijeras fault is critical if water is not obtained from the alluvium and drilling continues into bedrock. At one site west of NM-14 at Forest Park, six dry holes were drilled in the Mancos Shale while attempting to develop a water supply. The deepest of these (well ION.5E.2. 344) was reportedly drilled to 900 ft. By moving the well location a few hundred feet west across the Tijeras fault into outcrops of the Chinle, a well (10N.5E.2.341) was successfully completed. Permeable sandstones are more prevalent in the Chinle than in the Mancos, and the quality of Chinle water is good while that of Mancos water is poor.

The ground-water flow patterns in the western part of the area (fig. 16) are southeastward from the terrane of Chinle and older rocks into the Cretaceous rocks. Ground water, which in the Chinle is potable, acquires the chemical characteristics of Mancos water in only a few hundred feet of flow in that formation. The analysis for water from well 10N.5E.11.211, which is only about 800 ft southeast of the Tijeras fault, shows that the water contains more than 2,500 mg/L dissolved solids of which 1,460 mg/L are sulfate. On entering the Mancos the water probably contained 350-400 mg/L dissolved solids and 25-30 mg/L sulfate.

Most of the discharge from the Cretaceous terrane is into the Tijeras Canyon "ground-water drain"; yet there are no chemical data or reports of poor water from well owners in this area to indicate natural degradation of the shallow ground water. The implication is that much of the water discharges at depth and is below the wells. In contrast to this, chemical analyses show that two wells on the south side of Frost Arroyo in the Chinle supply water affected by having moved through gypsum-bearing Jurassic rocks.

The Mancos and Mesa Verde undoubtedly discharge some ground water to the alluvium of Arroyo San Antonio. The discharge might noticeably affect the quality of water in the alluvium, especially in the lower reaches of the valley where the Cretaceous formations occur on both sides of the channel. The effect, however, seems to be minor, as the highest concentration of sulfate in the two samples of alluvial water in the area was 110 mg/L. The volume of underflow contributed by discharge from the Chinle and local recharge from runoff is evidently large relative to the amount of discharge from the Cretaceous formations. Hence, dilution is sufficient to make the water palatable. If ground water were pumped only from the basal part of the alluvium in the lower reaches of the channel, increased chemical concentration might be noticeable.

About 1 mi south of San Antonito, east of NM-14, wells have been drilled from the sides and top of the ridge through the Morrison, Todilto, and Entrada Formations into the underlying Chinle Formation. These intercept ground water moving eastward as it moves down dip in the Chinle toward the axis of a small syncline. In one of these wells (11N.5E.25.232) water was not obtainable from sandstones in the Morrison during drilling even at a depth estimated to be 170 ft beneath the potentiometric surface. The contact between the Chinle and Entrada Formations is immediately east of NM-14 (section B-B ', fig. 15). The contact dips at an angle of 25 degrees beneath the ridge at a location 0.9 mi south of San Antonito; but 1.4 mi farther south near the south end of the ridge, the dip has steepened to more than 50 degrees. Steeper dips mean that along any line parallel to the outcrop the Chinle will be at progressively greater depths from north to south.

Discontinuous lenses of white gypsum are present in the Todilto Limestone immediately east of NM-14, though they are usually hidden by soil cover. This gypsum is a potential source of contamination for ground-water down dip beneath the ridge. If drilling through overlying strata into the Chinle is planned for a domestic water supply, water from the younger formations should be sealed off to pump only from the Chinle.

The developers of Sierra Vista Estates tried to obtain water from the Mesa Verde Group near the axis (well ION.5E.1.122) and on the west flank (well 10N.5E.2. 242) of the Tijeras anticline. Well ION.5E.2.242 was capable of producing 35 gal/min, but the water was high in sulfate, and use of the well was discontinued. Subsequently, other wells were drilled west of NM-14 in the Chinle terrane to obtain a potable water supply; presumably that water is being imported into the area of the Tijeras anticline.

Wells drilled into the Mancos Shale in the bowl-shaped reentrant off Tijeras Canyon at the south end of the Tijeras anticline produce water that is undesirably high in sulfate and dissolved solids (well ION.5E.2.242). Here much of the water also contains enough dissolved hydrogen sulfide to have an objectionable odor; minute pyrite crystals pumped out with the water will often oxidize and turn the water black after standing in a container.

In Gutierrez Canyon several domestic wells (10N.6E. 6.324) in the Mancos Shale produce water low in dissolved solids and sulfate, although some of this water reportedly also will turn black upon exposure to air. The formation here is dipping northwestward toward the axis of the Tijeras syncline. Sandstone beds that at depth are aquifers crop out in and somewhat above the channel of the Canyon. The lower content of dissolved ions in water from this area probably results from mixing of local recharge to the outcropping sandstones and existing water in the formation. This better quality Mancos water probably does not extend far down dip. If the cumulative pumping effect of the several wells in the area is to remove more water annually than is recharged, the quality probably will deteriorate with time as water from down dip is drawn toward the wells.

Residents of this area will find no improvement in water quality with depth except possibly in the Chinle along the previously described northwestern border where the Chinle dips beneath the ridge. Nor is there better quality water laterally except beyond the faults that bound this terrane. Those who live in Gutierrez Canyon might increase the local recharge and water quality by constructing impoundments for local runoff over the edges of the outcropping sandstone beds. For those who live outside of Gutierrez Canyon the only alternatives are demineralization of the local water or water importation.

Lower Sandia slopes and Frost Arroyo (Permian and Triassic)

The Permian and Triassic terrane consists of outcrop areas of the Abo, Yeso, Glorieta, and San Andres Formations (all Permian) and the Santa Rosa and Chinle Formations (both Triassic) occurring in a discontinuous irregular band around the west to northwest to northeast margins of the folded Cretaceous terrane. Geographically the area is situated generally west of NM-14 from south of Cedar Crest to about Sandia Park and east of the village of San Antonito along NM-44 and includes the Permian and Triassic outcrops on both sides of Frost Arroyo.

These formations either consist predominantly of sandstone or contain sandstone strata interbedded with sometimes thick shale sections. The sandstone strata are the principal water-yielding units. In contrast, the water-yielding unit of the San Andres Limestone is a fractured and sometimes cavernous limestone. Typically the ground water is potable. The occasional local exception is caused usually by subsurface flow from one of the Jurassic or Cretaceous formations into a Permian or Triassic Formation. The water then becomes similar in water quality to that in the Tijeras anticline and syncline area.

The older formations of this sequence (particularly the Abo) that crop out higher on the Sandia dip slope tend to be more severely faulted than the others. Closely spaced faults cut most formations in and southwest of the vicinity of Sandia Park and San Antonito:, very intense faulting is found in the southernmost extremity of the area and at the lower end of Frost Arroyo (east side sec. 20, T. 11 N., R. 6 E.). In these areas fracturing associated with the faulting has been especially intense. Fracturing has probably affected all the sandstones and limestones in the terrane and is probably a necessary condition for high permeability.

On the east slope of the Sandia Mountains is a line of springs extending north from Tijeras Canyon to the vicinity of Sandia Park. These springs discharge ground water from the formations that extend upslope from the springs. Along the northern part of the line of springs the discharging formation is the Abo; farther south several younger formations contribute to the springs. Nearly all the springs are in valleys and most occur where faults have offset sandstone or limestone strata to place them against less permeable parts of the formations across the faults. The springs may indicate the lower permeability of the downslope formation.

A few wells are located as far upslope as the springs, but most are at lower altitudes where the top of the saturated zone is well below land surface. The potentiometric surface slopes eastward at an angle equal to or somewhat greater than the land surface (section B-B ' , fig. 15). A few miles to the south of San Antonito, where Arroyo San Antonio is in a canyon, the canyon bottom reaches the potentiometric surface. Although the potentiometric surface slopes fairly evenly eastward, the water levels in the wells are controlled by the topographic setting at the well location.

Most wells in the area along NM-14 and in the vicinity of Frost Arroyo are 100-200 ft deep, but depths range from a few tens of feet to about 350 ft. Water levels are mostly 40-100 ft below land surface with a maximum range of slightly more than 180 ft near San Antonito to nearly 230 ft near Frost Arroyo. Data were collected in the Permian and Triassic terrane for approximately 75 wells, including most of the wells drilled prior to the fieldwork for this report (1960-64). Many additional wells have been drilled since then. Nearly all the wells produce 1-5 gal/min, adequate for domestic use. Two exceptional producers are well 11N.5E.24.144 from which 84 gal/min was measured and well 11N.6E. 20.443 reported to be capable of initially producing 600 gal/min.

In the southern part of the terrane, near and southwest from the community of San Antonito much of the water that is used comes from springs that discharge from various formations. Only a few wells have been drilled in this area. Spring 10N.5E.15.223 discharges into an arroyo where very steeply dipping Morrison Formation on the east is in fault contact with the Chinle on the west. The water is sufficiently high in dissolved solids and sulfate concentration to suggest that part of the yield is from Jurassic rocks; however, most is probably from the Chinle. Iron concentrations are relatively low, although the rocks at the spring are considerably iron stained. Precipitation of the iron appears to be aided by algae or bacteria.

In this hydrologic setting, where the rock is saturated at shallow depths, possible contamination of ground water by sewage effluent should be suspected. In some places only a thin layer of filtering sediment may separate sewage discharge from the saturated zone. Contamination is not apparent from the data.

Northward from Forest Park to San Antonito the Chinle Formation crops out along the relatively gentle slopes west of the highway; sandstones of the Santa Rosa form the first steep slopes above the valley. The Santa Rosa dips eastward beneath the Chinle. Sandstone beds in these two formations, particularly those in the Chinle, are by far the most widely used aquifers in the Permian and Triassic terrane. The Chinle sandstones are relatively thin and discontinuous, but enough of them are interbedded in the predominantly shale formation that they are usually penetrated by wells. The few wells in the Permian and Triassic terrane that are reported to yield barely adequate water supplies are in the Chinle Formation. Drilling deeper would probably increase yield. Where wells could be reasonably drilled to the Santa Rosa, the probability of obtaining adequate water for domestic use is very high.

Well 10N.5E.2.144 is completed in the Santa Rosa Sandstone a short distance beneath the overlapping Chinle; reports indicate artesian flow. The geologic conditions are such that artesian flow is not surprising, but cannot be expected at most places in this terrane.

While the chemical quality of ground water in the Chinle and Santa Rosa can generally be expected to be good, drilling into the Triassic formations very near a fault contact with the Mancos or Mesa Verde sedimentary rocks could draw water of poorer quality from these formations. The probability of drawing water from the Mancos and Mesa Verde is not great because the natural hydraulic gradient is eastward, and the usual domestic well will not lower the water table enough to reverse the direction of flow very far from the well.

In the Sandia Park-San Antonito vicinity all the Permian and Triassic formations crop out and serve as aquifers for the many wells clustered around and between the communities. Water is also pumped from alluvium in the small valley and the broad alluvial deposit downslope from San Antonito. Because of the topographic relief, some of the deeper wells in the Permian and Triassic terrane are located here.

The owners of well 11N.6E.20.443, on the southwest side of Frost Arroyo, reported a yield of 600 gal/min unusual for this area. When visited in 1965 the well was equipped to pump an estimated 180 gal/ min. The upper part of this 110-ft hole is in the Santa Rosa Sandstone, which crops out around the well; from an abbreviated driller's log, apparently the lower part is in the San Andres Limestone. The area is cut by several closely spaced small faults that intersect the major Tijeras fault.

The San Andres Limestone is known to be cavernous in places; at this site, permeability may also be provided by fracturing that accompanied the local faulting. The sandstone of the Santa Rosa and the alluvium could provide storage for a highly permeable limestone. The possible high permeability and storage characteristics could then create conditions where large yields from wells could be expected.

Madera Limestone

The Madera Limestone crops out over higher parts of the Manzano Mountains and over all the eastern dip slope. It also crops out over more than half of the Sandia Mountain dip slope and underlies the valley fill of the Estancia Valley in about half the Edgewood embayment.

The overall drilling experience for the Madera terrane has been that about one well in five can be expected to be a dry hole. Also many of the wells that are producible yield such small quantities of water that depending on them as a water supply for a home with modern conveniences is impractical. Wells yielding more than 150 gallons of water per day (about 0.10 gal/min) were considered to be producible; conversely, a well yielding less than this was considered to be a dry hole, as were wells so described by owners or drillers.

Fig. 21 shows the distribution of dry holes and producible wells drilled in the limestone terrane. At a few locations two dry holes have been drilled very close together, and in this case only one location is given on the map. In constructing this figure several dry holes that are not listed in table 1 were used. These holes could not be located in the field because they had either been covered over or filled in after being abandoned; however, their description by owners or drillers and their locations on the map are thought to be reliable. Holes drilled that did not reach the saturated zone are not shown, although these are listed and identified in table 1. The average depth of all dry holes that reached the potentiometric surface exceeds the average depth of drilled producible wells by about 140 ft. (Shallow, hand-dug wells were excluded from this calculation; had they been included among the producible wells, the difference would have been much greater.)

Drilling success has been notably poor in the Madera Limestone in Tps. 10-11 N., R. 6 E., and nearby to the east (fig. 21). In this rectangular area having dimensions of approximately 8 mi by 6 mi, out of every five wells drilled, two are dry holes. The southeast boundary of the rectangle is reasonably well defined by existing wells, but the southwest limit is established simply for lack of wells drilled beyond it in that direction.

The search for water has been carried to great depth. A 1,000-ft hole (10N.6E.10.344) and five shallower holes were drilled in an attempt to obtain a water supply at the restaurant and service station complex on NM-66 at the drainage divide. Water levels in the holes indicate that the potentiometric surface here is little more than 50 ft below the surface. Some of these holes do not precisely fit the dry-hole criterion, as they were reported to be capable of yielding a few hundred gallons per day; others in the group do.

The other areas in which dry holes are closely spaced are all small. In the west-central part of T. 7 N., R. 7 E., straddling NM-14, six dry holes were drilled within an area of about 2 sq mi. Just north of the village of Tajique in T. 6 N., R. 6 E. three dry holes have been drilled; and a few dry holes interspersed with numerous producible wells were drilled in the southwestern part of T. 9 N., R. 6 E. Outside the areas mentioned, dry holes in the Manzano Mountains are widely and irregularly spaced.

In the Sandia Mountains a few attempts have been made to obtain water from the Madera Limestone; most have resulted in dry holes. A hole 380 ft deep drilled at Sandia Peak Ski Area (11N.5E.4.322) was dry. Slightly more than 1 mi north of the community of La Madera, three dry holes were drilled (12N.5E.25.311, and 12N.5E.26.423 and 432), the deepest of which is 680 ft. Two other wells nearby reportedly yield up to 5 gal/min.

In the higher parts of the Sandia Mountains, springs often are located at, or immediately upslope from, major north-aligned faults. They also are found where canyon erosion has cut down to the Sandia Formation. The occurrence of springs at faults in some places indicates low permeability across the fault plane itself and elsewhere indicates decreased formational thickness in the

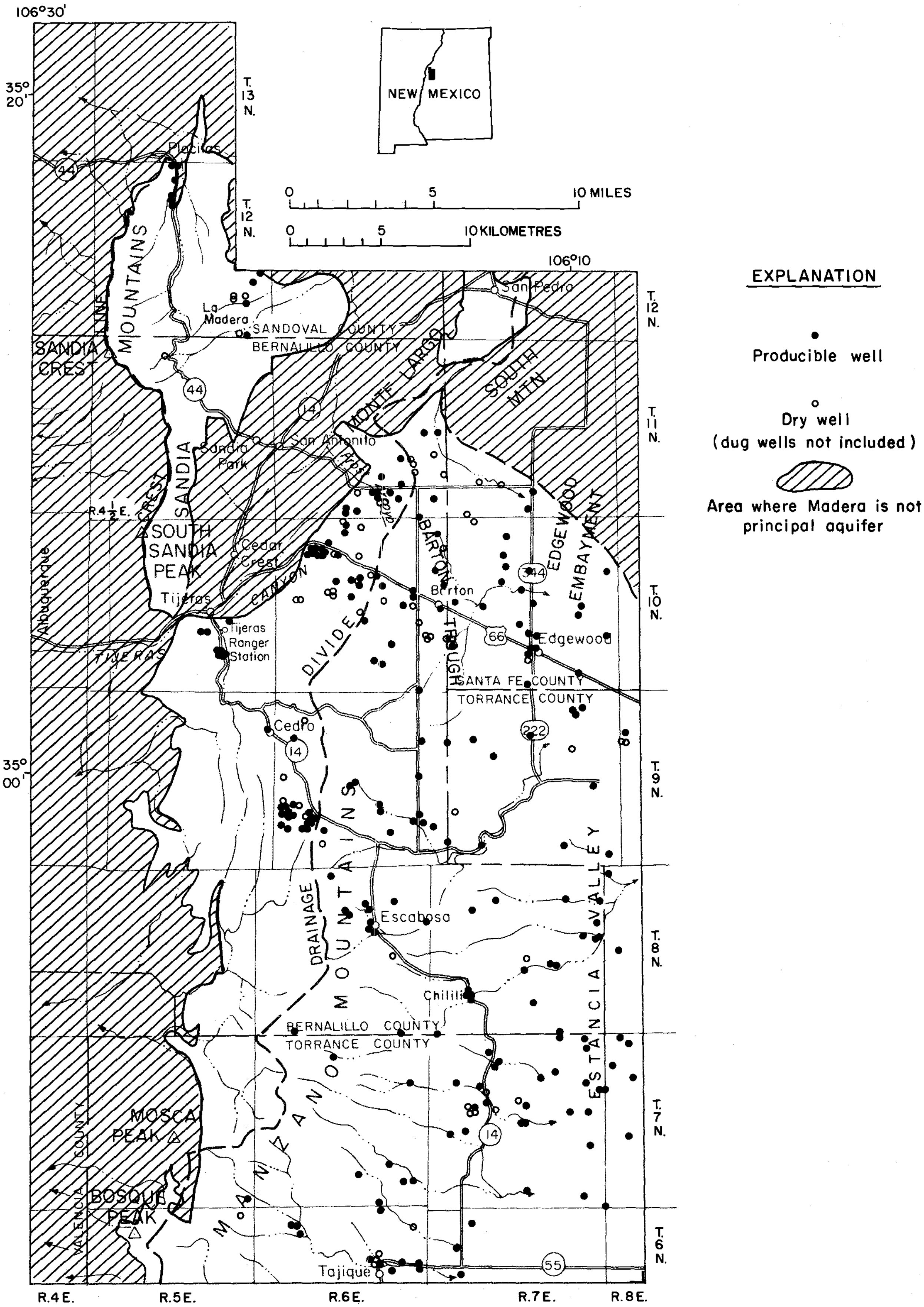


FIGURE 21—Distribution of producible wells and dry holes in the Madera Limestone.

aquifer downslope from the fault in the upfaulted block to the east.

The lack of permeability in the upper few hundred feet of Madera Limestone where dry holes have been drilled may be caused by insufficient solution channels through the formation owing to less intense fracturing of the limestone. The low permeability may also be related to a lack of thin shale beds—commonly the solution channels along bedding planes in the formation are concentrated in the base of a limestone layer immediately above a shale layer.

The depth to which a well should be drilled in the Madera before concluding that it is dry depends on several factors. The first and overriding factor is that the hole must reach the top of the saturated zone (eight wells listed in table 1 do not). The second factor is that the well must be drilled through a reasonably saturated thickness. Three out of four producible wells in the formation penetrate 100 ft or less beneath the potentiometric surface. The maximum penetration among producible wells is about 390 ft, but all other wells penetrate less than 285 ft. (The unique 1,100-ft artesian wells at the Ideal Cement plant at Tijeras [10N.5E.22. 344 and 433] are ignored here.) The third factor is the depth interval in which solution of the limestone has caused increased permeability.

The chemistry of water in the Madera is covered in the description of that aquifer; in general, the water is potable. Fluoride in excessive concentrations is found in water from the Barton trough, in one sample from near the village of Tijeras, from a well near Tajique, and may also occur near the community of Edgewood. Nitrate occurs locally in concentrations that may suggest pollution. Carbon dioxide gas evolves from the water from some wells in the southeastern part of the terrane; an unidentified gas was reported from a few wells in the Barton trough.

Edgewood embayment (Estancia Valley fill)

In most places the top of the saturated zone is near the base of the valley fill or in the underlying Madera or Abo Formations. Around the southern part of South Mountain, the saturated zone may be locally higher in the valley fill; hand-dug wells in the valley fill are used to obtain water.

Chemically the water is generally satisfactory for domestic use. One report (well ION.7E.8.242 in the southwestern part of the area) states that water may "make people sick." Also, reported soft water near Edgewood suggests the need for checking fluoride concentrations there.

Placitas area

The Placitas area as here defined includes all of the terrane of north-dipping strata lying north of the Sandia Mountains. The terrane is separated structurally from the Sandias by a major fault. On the downdropped Placitas block, strata from the Madera, up through and including the Galisteo Formation crops out. On the north the valley-filling alluvium of the Santa Fe Group overlaps the Galisteo Formation. The block is cut by several faults, especially near the mountains. One major north-aligned fault, downthrown on the west, cuts through the middle of the terrane laterally, offsetting formational contacts in the northern part of the terrane by more than 1 mi. At its west end the block is in fault contact with the Santa Fe Group.

The structural and stratigraphic relationships of the Placitas area are illustrated by the diagrammatic section in fig. 19. Alluvial deposits 30-65 ft thick overlie the dipping bedrock in the bottoms of two flat-floored bedrock valleys. Subsequent arroyo cutting has incised steep-walled channels nearly through the alluvium in lower reaches of the valleys, but the arroyo depths decrease upvalley. The village of Placitas is at the head of the larger bedrock valley extending downslope to the west-northwest. The other bedrock valley, in the western part of the terrane, slopes first northward then turns westward to open onto the Santa Fe sediments west of the bounding fault. A deposit of terrace gravel mantles a sloping divide area between the two drainages.

Nearly all formations in the area have been drilled for water or yield water to springs. Most formations, except the Mancos Shale, supply adequate well yields for stock and domestic use. Well depths are as much as 300 ft, the deepest being in the Madera Limestone. Most wells are 150 ft deep or less. Water levels in most places are a few tens of feet below land surface.

The potentiometric surface slopes northward with the land surface; where alluvium mantles the floors of bedrock valleys, the potentiometric surface is in the basal part of the alluvium (fig. 19). In the lower reaches of the bedrock valleys, springs and seeps in the arroyos, particularly the eastern one nearer Placitas, discharge ground water, establishing the maximum height to which the potentiometric surface (water table, in this case) can rise.

Water discharges from the Sandia Formation at Tunnel Spring (12N.5E.5.334) and from the Madera and Abo Formations on both sides of the ridge east of the village of Placitas. Under most of the terrane, however, ground water is driven northward by the hydraulic gradient. In moving downgradient the ground water passes across the alternating beds of sandstone and shale that dip more steeply than does the land or the potentiometric surface.

Flowing in sequence through the Madera, Abo, Yeso, Glorieta, San Andres, Santa Rosa, and Chinle Formations, the ground water maintains a chemical quality satisfactory for domestic supplies. Upon entering the Entrada and Todilto Formations, however, the ground water begins to dissolve gypsum and to increase in dissolved solids, particularly in sulfate. Potability is questionable throughout the rest of the flow paths in the terrane. A water sample from the Morrison Formation less than 1 mi west of Placitas (well 13N.5E.32.323) contained 2,340 mg/L dissolved solids and 1,500 mg/L sulfate; a sample probably typical of the Mesa Verde Group (well 13N.4E.36.234) contained 1,680 mg/L sulfate.

The quality of water in the alluvium is generally acceptable for domestic use, probably because of the amount of recharge received from precipitation and runoff. At spring 13N.5E.32.332, however, the effect of discharge from Morrison bedrock is indicated because water from the spring has a total dissolved-solids content of about 880 mg/L. Most water in the alluvium has less than 450 mg/L total dissolved solids. Water from the Morrison near the spring has 2,340 mg/L total dissolved solids.

The thickness of saturated alluvium is only a foot to a few feet in many places—not enough to yield much water to a well. Many times a well is drilled through the alluvium into the underlying formation to penetrate additional aquifer thickness. Nearly everywhere, however, the underlying bedrock consists of the Mancos or Mesa Verde containing water high in undesirable constituents. In some places water from the two units is usable owing to mixing. In most places, by the time a yield that is considered to be adequate is obtained, the water from the Cretaceous formations predominates and the mixture is objectionable.

Special hydrologic problems

This section describes both natural and induced hydrologic conditions affecting the ground-water resources in the area. Some of the conditions already prevail in the region; others may be expected to develop as an increasing population subjects parts of the region to increased hydrologic stress.

Fluoride in drinking water

The significance of fluoride concentrations found in ground water in parts of the mountain region may be evaluated by the following quotation from the U.S. Environmental Protection Agency (1976, p. 66):

> "Excessive fluoride in drinking water supplies produces objectionable dental fluorosis which increases with increasing fluoride concentration above the recommended upper control limits. In the United States, this is the only harmful effect observed to result from fluoride found in drinking water. . . . Other expected effects from excessively high intake levels are: (a) bone changes when water containing 8-20 mg fluoride per liter (8-20 mg/L) is consumed over a long period of time . . . ; (b) crippling fluorosis when 20 or more mg of fluoride from all sources is consumed per day for 20 or more years . . . ; (c) death when 2,250-4,500 mg of fluoride (5,000-10,000 mg sodium fluoride) is consumed in a single dose. . . ."

The following table (USEPA, 1976, p. 67) lists the recommended limits of fluoride relative to the average air temperatures of an area.

Annual average of maximum daily air temperatures (°C)	Recommended control limits—fluoride concentrations in mg/L			Approval limit mg/L
	Lower	Optimum	Upper	
12.0 and below	1.1	1.2	1.3	2.4
12.1-14.6	1.0	1.1	1.2	2.2
14.7-17.6	0.9	1.0	1.1	2.0
17.7-21.4	0.8	0.9	1.0	1.8
21.5-26.2	0.7	0.8	0.9	1.6
26.3-32.5	0.6	0.7	0.8	1.4

The amount of fluoride measured by chemical analysis in the waters from the mountain area ranged from a low of 0.0 mg/L to a high of 14 mg/L, with concentrations and numbers of well and spring sources as follows:

0.0- 0.5 mg/L	29	wells and springs
0.6- 1.0	7	
1.1- 1.5	4	
1.6- 2.0	1	
2.1- 2.5	1	
2.6- 3.0	0	
3.1- 3.5	3	
3.6- 4.0	1	
4.1-14	2	
	48	total wells and springs analyzed for fluoride

The locations of sample points where more than 1.0 mg/L fluoride was found in the water are shown on fig. 22.

All samples having fluoride concentrations greater than 1.0 mg/L were either from Precambrian rocks or the Madera Limestone, except that 1.4 mg/L was measured in water from spring 13N.5E.15.241 issuing from the Yeso Formation on or very near a major fault. Two of the samples exceeding 1.0 mg/L (but not among the higher concentrations) were from wells penetrating deeper than 1,000 ft into the Madera Limestone. These wells were 10N.5E.22.344 at the Ideal Cement Co. plant and 11N.6E.36.231 at the north end of the Barton trough.

The highest concentrations of fluoride are found in water samples collected from the Madera Limestone in the vicinity of the Barton trough. The analysis of water from well 10N.6E.13.224 showed 11 mg/L, but the chemistry of the water differed so strikingly from other Madera water that resampling was required for a second analysis. The second analysis verified the chemical conditions indicated initially, except that fluoride in this sample was 14 mg/L. Another well (10N.6E.26.132) in the same structural area produced water containing 11 mg/L fluoride.

The chemical analyses show that water high in fluoride is very soft in comparison with other samples from the region. The softness may result from calcium uniting with the fluoride to precipitate as the mineral fluorite; hence, softness may be an indicator of anomalous fluoride.

Outside the Barton trough the Madera Limestone may yield water with anomalous fluoride in three loca-

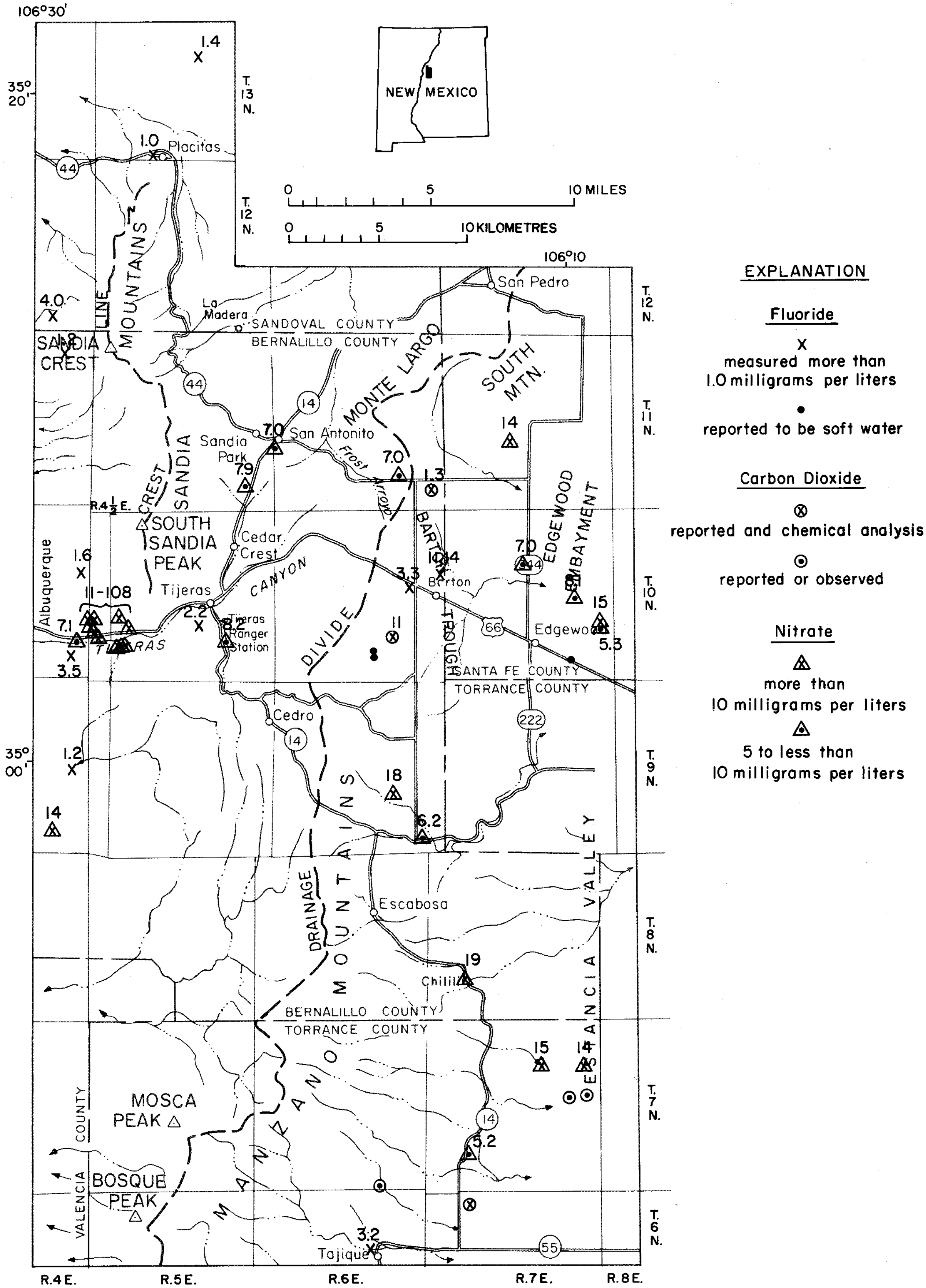


FIGURE 22—DISTRIBUTION OF WELLS AND SPRINGS THAT YIELD WATER CONTAINING APPRECIABLE CONCENTRATIONS OF FLUORIDE, CARBON DIOXIDE, AND NITRATE.

tions. About 13/4 mi southeast of Edgewood on US-66 a well owner reported that his water (well 10N.7E.35.231) was noticeably softer than that from nearby wells. This location is in the general direction of ground-water flow from the Barton trough. Whether fluoride from a source in the trough could remain in solution for a 4-mi flow through a limestone aquifer, with its surplus of calcium, is questionable. Chemical data to provide the answers are not available in the intervening distance. A second location is near the village of Tijeras, where one of the 1,100-ft wells of the Ideal Cement Co. in the Madera produces water containing 2.2 mg/IL of fluoride. The third location is at the village of Tajique, where a village well (6N.6E.14.113) no longer in use produced water in 1951 containing 3.2 mg/L of fluoride. Another well now used as a community supply by the village has been reported by the New Mexico Department of Public Health (1967) to yield water containing 0.25 mg/L of fluoride.

Nitrates and contamination by sewage

Excessive nitrate in drinking water can cause methemoglobinemia in infants, a condition in which the blood is insufficiently oxygenated, indicated by a bluish skin coloration. The condition is serious and occasionally fatal. Nitrate poisoning appears to be confined to infants during their first few months of life; adults drinking the same water are not affected but breast-fed infants of mothers drinking such water may be poisoned (U.S. Public Health Service, 1962, p. 47-48). The U.S. Environmental Protection Agency (1976) recommends the limit that should not be exceeded as 10 mg/L nitrate as nitrogen (about 45 mg/L of the nitrate ion).

Nitrates are the end product of aerobic stabilization of organic nitrogen, and as such they occur in polluted waters that have undergone self-purification or aerobic treatment process (California State Water Pollution Control Board, 1952, p. 300). Nitrates in water at and near the land surface are taken up as fertilizer by biological activity, but at depth they tend to persist in solution and travel with the ground water. However, George and Hastings (1951) in a study in Texas reported that high nitrate concentrations were generally found in wells 200 ft deep or less. The study also found that nitrate concentrations were higher in up dip areas and generally lower in down dip areas. Durum (in Berry, 1952) found that water from wells in parts of Kansas less than 200 ft deep generally contained higher nitrate concentrations than water from deeper wells.

Some sources for nitrate in ground water other than sewage effluent include leaching of nitrate fertilizer from the soil zone and decomposition of animal excrement. Small amounts are derived from nitrogen taken into solution directly from the air and from decomposition of organic matter in soils. Feth (1966) reviewed reports concerned with the occurrence of nitrates. He found the literature reported many possible geologic sources of nitrates. Some of these geologic sources include nitrate deposits (cave, caliche, playa) sheltered from leaching, organic-rich shale, and carbonate rocks.

The amount of nitrate in water samples from the mountain region ranged from 0.0 to 108 mg/L. The concentrations and numbers of well and spring sources in which nitrates are found are shown in the following tabulations:

0.0- 1.0 mg/L	32	wells and springs
1.1- 2.0	7	
2.1- 3.0	8	
3.1- 4.0	3	
4.1- 5.0	1	
5.1- 6.0	2	
6.1- 7.0	6	
7.1- 8.0	2	
8.1- 9.0	3	
9.1- 10.0	0	
10 -108	22	
	86	total analyzed for nitrate

These data suggest that the upper limit of background concentrations for this ion in the region, that is, the concentration that can be expected to result from nitrogen dissolved from the air and nitrate dissolved by water passing through soils, is about 5 mg/L. The locations of sample sites that produced water containing more than 5 mg/L are shown on fig. 22.

Nitrate concentrations greater than about 10 mg/L may indicate pollution. Behnke and Haskell (1968) report nitrate concentrations exceeded 35 mg/L beneath a subdivision at Fresno, California using individual septic-tank disposal; beneath a nearby sewage disposal plant the nitrate concentration exceeded 50 mg/L. Nightingale (1970) showed that beneath the entire Fresno area nitrate concentrations increased by 46 percent between the 1950-55 period and the 1962-67 period, as more septic tanks were installed. However, as subdivisions were converted to community sewer systems in the latter 5-year period, the rate of increase of nitrate concentration lessened.

Sewage effluent discharging from a septic tank or sewage line into the soil zone and percolating downward toward the zone of saturation carries particulate matter with bacteria and virus organisms. During percolation through the unsaturated zone and during flow through the aquifer, the particulate matter will be more or less filtered out depending on the size of pore spaces and distance through which the water moves. Flow through open fractures or through solution channels may transmit suspended material for thousands of feet. In contrast, at the Santee project near San Diego, California, coarse gravel was found to effectively filter out both bacteria and viruses in less than 200 ft. In another study made near Richmond, California, the maximum distance required in a sandstone for total filtration was less than 100 ft (McGauhey, 1968, p. 11). The effluent from a septic tank might easily contaminate a person's own well or the well of a near neighbor down gradient, but one disposal system is not likely to contaminate large areas. The situation is obviously different in localities where there are many, closely spaced disposal systems and wells.

Chemical analyses from the lower reach of Tijeras Canyon show that nitrate concentrations in ground water in this area reach a maximum of at least 108 mg/L; even higher concentrations are reported. This area is the only one in the region where concentrations exceed the Environmental Protection Agency recommendations. Here the nitrate concentrations reach unhealthful amounts without considering the biological pollution that might be implied. Two of the wells (10N.4E.25.431 and 10N.5E.30.324) having the lower concentrations were very near the channel of Tijeras Arroyo. The third well (10N.5E.30.334) is in a south tributary to the canyon and is topographically higher than all other wells and dwellings in the tributary canyon.

Possible effects of water and sewer systems

Before man moved to the mountains in large numbers an equilibrium existed among the factors of recharge, ground-water flow, and discharge. The system was in steady state with each part balanced against the others. Whatever local or regional changes occurred in the level of the potentiometric surface were mainly the result of natural fluctuations of rain and snowfall. The arrival of a relatively large human population is thought not to have changed the steady state of the system as applicable to the general configuration of the potentiometric surface. While water has been pumped out of the aquifers, nearly all of it has been returned to the system through nearby individual sewage facilities and net depletion is attributed to evaporation or to transpiration by the few irrigated plants but depletion by man is probably insignificant. Increased population is probably adversely affecting the quality of the water.

In some localities the capacity of the aquifers and the unsaturated zone to filter particulate material, including micro-organisms, probably will not be exceeded even for fairly closely spaced wells and disposal facilities. The Permian and Triassic terrane, with its thick shale layers and clay soils may be in this category.

If man is responsible for the nitrate problem in the lower reach of Tijeras Canyon, such problems will become more intense and more common; actions will have to be taken to solve them. Some alternative actions that will permit the population to remain are: collect and treat, or export the sewage through a centralized sewage system; provide uncontaminated water through a centralized water system; recycle the available water using centralized systems; or require purification of all water that is produced by each individual well. The intention here is to mention briefly some of the effects accompanying centralized systems.

Construction of a sewer collection and treatment system would immediately stop the injection of micro-organisms and chemically degraded water at each domestic site, thereby halting the increase in both biological and chemical degradation of the aquifers. Stopping the contamination by not returning the effluent water to the aquifer system near where it was removed would result in lowering the water levels in wells as pumping from the aquifers continued. In time the construction of any sewer system would create additional reason for a parallel water-delivery system.

If an extensive water-distribution system is contemplated, the system may need to be planned around a water-importation scheme because of the small yields characterizing the mountain aquifers. The hydrology of these aquifers will nowhere allow the construction of the 1,000 gal/min wells that are economical. If water were imported, distributed to consumers, and then disposed of through the present individual septic tanks, the inevitable result would be a rise in the water levels in wells in the affected area. Of course this recharged water would contain all the biological and chemical load that the present septic tanks discharge to the aquifers. In some parts of the region, for example the Permian and Triassic terrane where the population density is high and the top of the saturated zone shallow, the increased recharge may locally raise the top of the saturated zone to land surface. This would thus cause the discharge of possible contaminated water through newly created seeps and springs. Only the parallel construction of a sewer system would prevent this undesirable effect.

The region seems well suited to construction of a combination water-distribution and sewage-treatment system with advanced purification and recycling of the water. Particularly relevant is the very low consumption of water in the region. Once the combined system is in operation, the amount of water needed to be continually added to the recycling system would be small. In fact it might be so small that the water could be pumped from some of the mountain aquifers, thereby eliminating the need for water importation. In view of both the great expense of installing pipes and pumping water from outside the area, not to mention the legal problems of obtaining water rights and permission to export water from either the Rio Grande or the Estancia Underground Water Basins, this alternative becomes important.

Summary

Large supplies of ground water are not available in the Sandia and northern Manzano Mountains. The mountainous area contains several contrasting geologic terrains in which ground water is found. In some of these terrains, developing adequate quantities of ground water is difficult; in others, the poor chemical quality of the available ground water makes its use objectionable.

The terrane of Precambrian rocks contains small supplies of good-quality water (nitrate is a problem in certain localities). Water is yielded to wells in this terrane from aquifers in both the alluvium and Precambrian rocks. Depths of wells range mostly from 25 to 1150 ft.

Ground water of satisfactory quality seems reliably obtainable from sandstone beds in the Abo and Yeso Formations of Permian age. Well depths in this terrane range from about 70 to more than 300 ft.

Rocks of Jurassic age and Mancos Shale arid Mesa Verde Group of Cretaceous age form a geologic terrane containing water that, to a greater or lesser degree, is objectionable for domestic purposes. The ground water, however, is not difficult to obtain, except possibly locally. Most well depths range between 150 and 200 ft. In certain localities dry holes as deep as 900 ft have been drilled.

The Permian and Triassic terrane consists of outcrop areas of the Abo and Yeso Formations, the Glorieta Sandstone, the San Andres Limestone of Permian age, and the Santa Rosa Sandstone and Chinle Shale of Triassic age. Wells drilled in this terrane yield adequate (a few, barely adequate) amounts of water for domestic use; reported yields range to as much as 40 gal/min. Well depths range from a few tens of feet to about 350 ft. Many springs are present; some are used for domestic purposes. In general, ground water is potable.

The Madera Limestone of Pennsylvanian age crops out over higher parts of the mountains and over much of their eastern dip slope. The overall experience in obtaining ground water in Madera terrane has been that about two wells in five can be considered as dry holes. In some areas the search for water has resulted in dry holes more than 1,000 ft deep. The chemical quality of the water yielded from wells tapping the Madera Limestone is potable.

East of the Sandia Mountains, alluvial silt, sand, and gravel, called the valley fill of the Estancia Valley, overlie either the Madera Limestone or the Abo Formation. Where Madera Limestone is the underlying unit, ground-water supplies are reliably obtained from wells ranging in depth from 200 to 500 ft. Water is less reliably obtained from wells in areas where the Abo Formation underlies the fill. Chemically, the water from both formations is generally satisfactory for domestic use.

The terrane of north-dipping strata lying north of the Sandia Mountains is highly faulted and contains rock outcrops ranging in age from Pennsylvanian to Quaternary. Most formations (the Mancos Shale excepted) yield adequate supplies of water for stock and domestic use. Well depths are as much as 300 ft; most wells are less than 150 ft deep. The chemical quality of most ground water in this terrane is satisfactory for domestic use. However, Jurassic formations, in places, contain gypsum that renders the water from these formations undesirable. The Mancos Shale and formations of the Mesa Verde Group also contain water of poor chemical quality.

The principal use of ground water in the mountain area is for domestic purposes. Most of what is pumped is usually disposed of through a septic tank or cesspool. The raw sewage effluent contains constituents that are partly converted to nitrates, sulfates, carbonates, and phosphates. In addition to the chemical constituents, some particulate matter, largely organic, is discharged with the effluent. This particulate matter can include disease-causing organisms; it always includes *E. coil*, which in itself is not harmful, but is an indicator of the possible presence of fecal contamination. The effluent from a septic tank might easily, in certain terrains, percolate to the water table. The effluent might contaminate the individual's own well or the well of a near neighbor down gradient. One disposal system is not likely to contaminate large areas; however, many closely spaced disposal systems and wells are a potential hazard of widespread contamination.

The relatively large population (in 1967) in the Sandia and northern Manzano Mountains has not significantly changed the steady state of the ground-water system. The important hydrologic change that may be created by the increased population pertains to the degradation of the quality of the water. In some localities the capacity of the aquifer and the unsaturated zone to filter particulate material probably will not be exceeded even for fairly closely spaced wells and sewage-disposal facilities. In some other localities the time for concern may be reached sooner. In the lower reach of Tijeras Canyon the ground water contains excessive concentrations of nitrate. As such situations become more intense and more common, actions will have to be taken to solve them. Actions that would permit a large population density in the mountainous area are: a) collect and treat, or export, the sewage through a centralized sewage system, b) provide water to residents through a centralized system, or c) a combination water-distribution and sewage-treatment recycle system.

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TABLE 1—Records of selected wells in the Sandia and northern Manzano Mountains and vicinity.

EXPLANATION:

Location: See explanation of well-numbering system in text.

Owner or name: Owner, or name of well, at time of visit.

Chem. anal.: X indicates chemical analysis in Table 3.

Well depth: M, measured; E, estimated; otherwise reported.

Casing diameter: If uncased, diameter of hole.

Water level: R, reported; otherwise measured; E, estimated; P, pumping or recovering from prior pumping when measured, see Remarks.

Geologic unit: Qal, alluvium; Qe, Valley fill of the Estancia Valley; QTs, Santa Fe Group; Kmv, Mesaverde Group; Km, Mancos Shale; Kd, Dakota Sandstone; Jm, Morrison Formation; Jte, Todilto Limestone and Entrada Sandstone; TRc, Chinle Formation; TRs, Santa Rosa Sandstone; Ps, San Andres Limestone; Pg, Glorieta Sandstone; Pys, San Ysidro Member of Yeso Formation; Pym, Meseta Blanca Sandstone Member of Yeso Formation; Pa, Abo Formation; IPm, Madera Limestone; IPs, Sandia Formation; pЄ, Precambrian rocks.

Yield: Gallons per minute; E, estimated; M, measured; otherwise reported. Also reports of adequate, A; or inadequate, I; for use indicated; N, none, if dry hole or abandoned.

Pump/power: C, cylinder; S, submersible; J, jet; T, turbine; Ce, centrifugal; B, bucket; W, windmill; E, electric; I, internal combustion engine; H, hand; N, none.

Use: D, domestic; S, stock; Ps, public supply; Ir, irrigation; Com., commercial; O, observation well; N, none.

Remarks: "Dry hole", less than 0.10 gallon per minute yield or well reported as dry hole. "Potability problem", one or more of the constituents iron, sulfate, chloride, fluoride, and nitrate do not meet U.S. Environmental Protection Agency drinking water standards; see Table 3 and text.

Location (well no.)	Owner or name	Chem. anal.	Year completed	Casing diam. (inches)	Well depth (feet)	Water level Depth (feet)	Water level Date	Geologic unit (aquifer)	Yield	Pump/ power	Use	Remarks
6. 5. 1.210	Inlow Youth Camp	-	-	-	600	-	-	IPm	N	N	N	Reported dry hole.
6. 6. 1.410	Romelo Barela	-	1929?	-	300	-	-	IPm	N	N	N	Do.
2.122	-	-	-	5	316	169.6 256.5	11- 7-63 12- 8-49	IPm	-	C/W	D,S	Not in use when visited.
5.321	Jane Clack	-	1960	-	135	-	-	IPm	A	-/E	D	-
5.322	do.	-	1960	-	175	2 R	1960	IPm	A	-/E	D	-
5.433	Max Flatow	-	1947?	-	100	-	-	IPm	A	-/I	D	Top of producing zone 60 feet.
10.400	Pete Lucero	-	1933	-	200	-	-	IPm	N	N	N	Dry hole.
11.324	Juan Chavez, Jr.	-	1961	-	150	-	-	IPm	N	N	N	Do.
11.333	Village of Tajique	-	1948	-	200	-	-	IPm	1(-)	N	N	Former community supply.
11.334	Frank Dow	-	1961?	-	200	-	-	IPm	N	N	N	Dry hole.
11.341	do.	-	1963	-	200	-	-	IPm	N	N	N	Do.
11.344	Village of Tajique	-	1945	-	200	57 R	1964	IPm	5	S/E	Ps	Pumps about 1,600 gal/day.
12.334	-	-	-	6	-	29.4	10-26-64	IPm	-	N	N	-
13.220	Cecil D'Spain	-	1930	-	240	175.1	12- 9-49	IPm	-	-	-	Top of producing zone 238 feet; Well 6.6.13.210 in Smith (1957).
6. 6.13.221	Cecil D'Spain	-	1958?	6	-	-	-	IPm	Adeq	S/E	D	-
14.113	Village of Tajique	X	1948	-	200	59.4	12- 7-49	IPm	Inad	-/E	Ps	Former community supply; 6.6.14.111 in Smith (1947); potability problem.
15.224	George Formwalt	-	-	-	39M	37.2	12- 7-49	IPm	-	-	-	Dug well.
6. 7. 5.322	C. E. Leasure	X	-	-	325	-	-	IPm	A	C/E	S	Top of producing zone 283 feet; water reportedly tastes bad (contains CO_2).

7.244	Mrs. Simmons	-	1917	8	250	142.0 143.4	10-26-64 12- 9-49	IPm	A	C/W	D,S	-
9.424	-	-	-	-	72M	64.0	6- 9-50	Qe	-	N	N	Unused when visited in 1964.
11.222	-	-	-	-	-	137.8 138.6	2- 4-55 12-15-49	Qe	-	N	N	Caved and abandoned in 1964.
17.131	-	-	-	6	-	110+	10-26-64	IPm	-	C/W	N	Dry at 110 feet.
7. 5.36.424	Inlow Youth Camp	-	-	-	100	-	-	IPm	A	-/E	Ps	-
7. 6. 4.414	La Jara Estates ?	-	1962?	6	-	10.0	10- 2-63	IPm	A	C/W	S	Pumps into pond.
12.324	R. H. Lavendar	-	1944	-	140	90.4	11-13-63	IPm	2	C/W	D	Water level reported 65 feet in 1944.
26.412	-	X	1938?	12	-	46.1 54.0	11- 7-63 12- 8-49	IPm	-	C/W	S	Well 7.6.26.411 in Smith (1957).
27.434	Glover	-	1934	6	170	140.9 148.7	11-14-63 12- 8-49	IPm	A	C/W	D,S	Well 7.6.27.341 in Smith (1957).
35.343	-	-	-	5	-	150.1p	11- 7-63	IPm	A	C/W	S	Pumped recently; gas evolving from water.
36.121	-	-	-	4	-	24.6	11- 7-63	IPm	-	C/W	S	-
36.211	-	-	-	-	70M	44.9 47.3	11- 7-63 12- 8-48	IPm	-	C/W	S	Well 7.6.36.122 in Smith (1957.
7. 7. 1.122	A. H. Sutherland	-	1957?	-	208	140 R	1961	IPm	-	C/E	D,S	-
1.233	do.	-	1953	10	300	174.7	10-30-63	IPm	1,470	T/E	Ir	-
2.211	do.	-	1957	6	200	126.2	10-30-63	IPm	A	C/W	S	-
4.313	C. Lucero	-	-	-	-	160.3	11- 7-49	IPm	-	C/W	D,S	-
4.343	D. F. Brinkley	-	1943	-	100	80 R	1963	IPm	A	S/E	D,S	-
5.444	P. Barela	-	1935	-	60	53.7	11-14-63	IPm	A	C/W	D,S	Dug well; 30 feet of alluvium over IPm.
7.331	A. Schubert	-	1860?	-	20	13.0	11-13-63	Qal?	A	C/W	S	Dug well; reported used to flow.
7.424	L. Aceves	-	1959	6	120	60 R	11-13-63	IPm	A	C/W	D,S	Top of producing zone 80 feet; 62 feet dug well in Qal nearby.
8.432	J. Aguilar	-	-	5½	80	32.6	11-14-63	IPm	A	C/W	S	-
9.112	D. F. Brinkley	-	1900	-	100	80 R	1963	IPm,Qal?	A	C/W	S	Orginally dug 30 feet in Qal?; later drilled deeper.
10.422	T. Griffing	X	-	-	110M	103.2	5-12-50	IPm	-	C/W	S	-
11.142	do.	-	-	-	300	110.8	10-30-63	IPm	450	T/I	Ir	-
7. 7.12.342	DeHart Estate	X	1936	6	65	40.7	5- 8-45	IPm	-	N	N	Former observation well; destroyed in 1945.
12.444	C. B. Rowland	-	1933	7	1,359	46.0	8-11-64	IPm	-	N	O	Top of producing zone 64 feet; CO_2 test hole; reportedly produced water.
13.431	-	-	1963	-	-	111.8	10-31-63	IPm	120	S/E	D?	Water reportedly contains CO_2.
14.442	D. F. Brinkley	-	-	6	200	-	-	IPm	-	C/W	S	Water contains CO_2.
15.133	-	-	-	-	300	-	-	IPm	N	N	N	Dry hole.
15.144	E. Garvin	-	-	-	290	-	-	IPm	A	T/I	D,S	Maintains 1-acre pond.
16.314	-	-	-	-	300	-	-	IPm	N	N	N	Dry hole.
17.222	-	-	-	-	496	-	-	IPm	N	N	N	Do.
17.244	D. Corbin	-	-	-	310	-	-	IPm	A?	-/E	D	-
17.320	Felipe Chavez	-	1940	-	90	-	-	IPm	N	N	N	Dry hole.
17.340	do.	-	1940	-	200	-	-	IPm	N	N	N	Two dry holes 100± yards apart.
17.411	W. Metzgar	-	1934	-	68	48 R	1945	IPm	A	C/W	D,S	Base of Qe 20± feet.
19.412	Goodner Estate	-	-	-	-	165 R	1940	IPm	A	C/W	S	-
20.134	do.	-	-	-	180	-	-	IPm	A	C/W	D	-
22.121	D. F. Brinkley	-	-	-	168	72.6	10-31-63	IPm	-	N	N	-
23.112	do.	X	-	-	200	119.9	5-11-50	IPm	A	C/W	S	-

TABLE 1 (continued)

Location (well no.)	Owner or name	Chem. anal.	Year com-pleted	Casing diam. (inches)	Well depth (feet)	Water level Depth (feet)	Water level Date	Geologic unit (aquifer)	Yield	Pump/ power	Use	Remarks
24.434	-	-	-	-	-	136.8	10-27-64	IPm	-	C/W	S	Windmill disconnected when visited.
29.341	R. Garland	X	1930?	5	245M	229.8	11-14-63	IPm	-	C/W	S	Well 7.7.29.343 in Smith (1957).
						236.6	2- 3-50					
34.144	-	-	-	-	93M	66.7	5-11-50	IPm	-	C/W	S	-
36.323	J. B. Milbourn	-	1946	-	285	139	10-26-64	IPm,Qe?	I	S/E	D	Deepened from 130 (in Qe?) in 1963, no improvement in yield.
36.324	do.	-	-	-	110	-	-	Qe	-	C/W	S	Reported small but reliable yield.
7. 8. 6.212	E. Hunt	-	-	-	-	150.2	3- 5-64	IPm	-	T/I	Ir,O	-
6.224	J. H. Hunt	-	-	-	97	80.0	2-23-50	IPm?	-	C/W	D,S	-
7.121	C. T. Norman	-	-	12	200	77.2	2-10-50	IPm	-	-	N	Destroyed about 1951.
7.333	-	-	-	8	-	40.1	10-30-63	IPm?	-	C/W	S	-
8.311	-	-	-	6	-	122.7	10-27-64	IPm	-	N	N	-
						109.2	5-19-48					
19.422	B. Grimes	-	1948	12	400	131.1	2-16-49	IPm	-	-	N	Plugged about 1951.
31.333	-	-	-	-	131M	116.8	5- 9-50	IPm,Qe?	-	C/W	S	-
8. 6. 4.213	Glenn Mackie	-	1958	6	278	144 R	-	IPm	A	C/W	D,S	Top of producing zone 275 feet; uncased.
10.241	Ross	-	-	4	350	264.2P	9-26-63	IPm	A	C/E	D	Pumped shortly before measured.
10.244	Grace Simpson	-	1963	11	256	189.1	9-26-63	IPm	-	N	D	New, unequipped when visited.
10.311	Frank Norris	-	-	-	311	-	-	IPm	-	C/W	D,S	-
10.314	do.	-	-	-	314	-	-	IPm	-	C/W	S	Yield reported good.
11.223	-	-	-	6	-	109.3	9-26-63	IPm	-	C/W	S	Windmill disconnected when visited.
8. 6.12.444	T. J. Loyd	-	-	24	40	22.2	12-16-49	IPm	-	N	N	Dug well; 8.6.12.444 in Smith (1957).
12.444a	do.	-	1934	8	160	40 R	-	IPm	-	C/W	D,S	In 1949 would pump dry in 2 hours.
14.131	-	-	-	-	180	-	-	IPm	-	-	-	-
14.311	Community of Escabosa	-	-	48	31.5M	22.9	9-26-63	IPm	A	B/H	D,S	Dug well; used by few families.
15.222	-	-	-	-	54	-	-	IPm	-	-	D	-
15.224	Aragon	-	-	-	57	26.4	1-17-50	IPm	A	C/W	D	Well 8.6.15.221 in Smith (1957).
15.224a	-	-	-	-	30	-	-	IPm	-	-	D	Dug well.
23.200	-	-	-	-	200	-	-	IPm	N	N	N	Dry hole.
32.342	-	X	-	8	-	18.7	10- 2-63	IPm	-	C/W	S	-
35.444	-	-	1962	-	-	4 E	10- 2-63	Qal,IPm?	-	C/H	D	Several cabins with shallow wells and out-houses in vicinity.
						25.7	12-15-49					
36.333	-	-	1948	6	65	23.4	10- 2-63	IPm	A	C/W	D,S	Well 8.6.36.313 in Smith (1957).
8. 7. 8.342	-	-	1945	5	195	135.0P	1-18-50	IPm	-	C/I	S	Pumping when measured; well 8.7.8.341 in Smith (1957).
						75.2	1-18-50					
9.123	-	-	-	-	-	49.8	9-27-63	IPm	-	C/W	S	Windmill disconnected; well 8.7.9.142 in Smith (1957).

11.214	-	-	-	6	106	93.6	12-15-49	IPm	-	C/W	S	Well 8.7.2.443 in Smith (1957); not in use Oct. 1963.
12.224	Ross Thompson	-	-	-	217	-	-	IPm	6(-)	C/I	S	-
13.221	do.	-	-	-	100	86.R	-	IPm	6	C/-	S	-
13.321	-	-	-	5	220	87.5P	10- 3-63	IPm	A	C/W	S	Pumped shortly before measured.
13.423	W. C. Riggs	-	-	-	290	-	-	IPm	4	C/W	S	Driller reports soft material; fault zone.
13.423a	do.	-	-	-	295	45R	1958(?)	IPm	4	-/E	D	Top of producing zone 287 feet; driller reports hard rock.
22.143	Candelario Griego	-	1935?	-	500+	-	-	IPm	N	N	N	Dry hole; reportedly used as latrine for many years.
22.332	Francisco Gutierrez	-	1929	-	150	46.5	12-16-49	IPm	A	C/W	D,S	Uncased; not in use 1963; well 8.7.22.320 in Smith (1957).
23.312	do.	-	-	8	86M	77.0	10- 3-63	IPm	-	C/W	S	-
23.324	Augustin	-	-	-	100?M	76.6	12-16-49	IPm	-	C/W	D,S	Well 8.7.23.144 in Smith (1957).
27.433	-	-	-	-	200M	153.6	12-16-49	IPm	-	-	-	-
29.312	-	-	-	-	350	-	-	IPm	A	C/W	D	-
29.314	Ben Mora	-	-	6	180	36.3 41.7	9-26-63 12-16-49	IPm	A	C/W	D	-
8. 7.29.323	E. A. Dow	X	1948	6	86	36.8	9-27-63	IPm	-	C/W	N	Well 8.7.29.322 in Smith (1957).
29.341	Community of Chilili	-	1953	-	150	-	-	IPm	A	-/E	Ps	-
31.334	-	-	-	-	-	-	-	IPm	1-5E	C/W	S	-
35.433	Homer Voss	-	1932?	-	150?	126.9	5-12-50	IPm	-	C/W	D,S	Well 8.7.35.344 in Smith (1957).
8. 8. 6.114	-	-	-	6	136	-	-	IPm	N	N	N	Filled with rocks.
18.413	-	-	-	-	-	189.5P	10-27-64	IPm	-	C/W	S	Pumped shortly before measured.
19.121	-	-	-	-	214M	140.2	2-24-50	IPm	-	C/W	-	Well 8.8.19.112 in Smith (1957).
19.211	-	-	-	-	-	93.3	10-27-64	IPm	-	C/W	S	-
9. 4.35.100	Military Reservation	X	-	2	21R	21 R	1944?	Qal	-	-	-	Potability problem.
9. 5.12.232	-	-	1960	-	98	-	-	IPm	A	-	D	Top of producing zone 80 feet.
12.422	Augustin Griego	-	1900	50	35	18.4	11-25-60	IPm	A	B/H	D,S	Dug well.
9. 6. 2.123	Haddon	-	-	96	35	25 R	-	IPm	A	-	S	Do.
3.242	-	-	-	48	-	23.7	11- 8-62	IPm	-	N	N	Do.
5.333	-	-	-	-	-	23.7	-	IPm	N	N	N	Dry hole.
6.144	-	-	-	60	30±M	Dry 9.9	7-15-55 11- 8-62	IPm,Qal?	N	N	N	Dug well.
7.411	Thunderbird Mtn. Estates	-	1960	5	120M	68.4	11-22-60	IPm	-	S/E	D	-
9.222	-	-	-	48	38M	28.9 34.4 29.6	2- 1-50 7-15-55 11- 8-62	IPm	-	N	N	Dug well; well 9.6.9.224 in Smith (1957).
10.112	H. E. Harling	-	1965	6	180	-	-	IPm	4-6	C/W	D	-
12.332	Everett Loyd	X	1959	6	186	159±	11-14-62	IPm	5-7E	C/W	S	-
13.333	G. B. Loyd	-	-	8	270M	154.2	1-23-50	IPm	N	N	N	Caved at 130 feet, abandoned prior to 1963; well 9.6.23.222 in Smith (1957).
18.343	Campfire Girls	-	1961	-	530	-	-	IPm	N	N	N	Dry hole.
19.341	-	-	1960?	-	400+	-	-	IPm	N	N	N	Do.

TABLE 1 (continued)

Location (well no.)	Owner or name	Chem. anal.	Year com-pleted	Casing diam. (inches)	Well depth (feet)	Water level Depth (feet)	Water level Date	Geologic unit (aquifer)	Yield	Pump/ power	Use	Remarks
19.343	-	-	-	4	138	122.7	12- 5-60	IPm	-	N	N	-
19.343a	-	-	1959?	-	-	-	-	IPm	-	S/E	D	-
19.432	Harbert	-	1960?	6	136M	114.6	12- 5-60	IPm	-	S/E	D	-
21.213	A.S. Anaya	-	1947	6	296	177.0	1-23-50	IPm	A	J/E	D	Top of producing zone 120 feet; drilled into cavern at bottom; well 9.6.21.230 in Smith (1957).
						66±	11-25-60					
21.221	Arthur French	-	-	-	240	-	-	-	-	-	D	-
21.311	Rhed Garrett	-	-	-	58	56 R	11-25-60	IPm	-	-	S	Dug well.
21.422	do.	-	-	-	62	40 R	-	IPm	1-10	C/E	S	Do.
22.434	Jan Eisengard	-	1930±	5	200+	77.0	11-25-60	IPm	-	C/E	D,S	-
23.343	-	X	-	-	73M	56.2 P	11-25-60	IPm	1E	C/W	S	Dug well; pumping slowly when measured.
9. 6.25.113	C. W. Johnson	-	-	6	120	63.2	11-25-60	IPm	-	C/N	N	-
25.134	-	-	-	5	-	87.2	11-25-60	IPm	-	N	N	-
25.334	-	-	1920?	-	25	10.9	1-17-50	IPm	A	C/W	S	Dug well; seeps in arroyo nearby.
						8.2	12-21-60					
25.414	Mrs. Alley	-	1939	-	180	143.0	2-26-63	IPm	A	C/E	D,S	-
26.244	Mrs. Romero	X	-	-	103	-	-	IPm	3E	C/W	S	-
26.333	R. N. Hise	X	-	4	160	50 R	1959	IPm	A	C/E	D	-
27.221	-	-	-	-	-	65+	11-25-60	IPm	-	C/W	S	-
29.112	Cowan	-	1959?	-	190	-	-	IPm	10	-	D	Another hole 30 feet away, similar depth, dry.
29.123	A. A. Arrington	-	1959	4	115	66 R	1959	IPm	22	S/E	D	-
29.141	E. J. Slemmer	-	1959	6	345	235.4	12-22-60	IPm	2	S/E	D	Uncased hole.
29.142	Earl Hovenden	X	1957	-	315	245.3	10- 7-60	IPm	6-7	J/E	Com. D	Top of producing zone 280 feet; uncased hole; cafe and gas station.
29.143	Lincoln	-	1959?	-	300	210 R	-	IPm	-	-	D	-
29.312	Byrne	-	1953	-	226	-	-	IPm	5	-/E	D	-
29.313	R. L. Carmichael	-	1952	6	285	-	-	IPm	A	C/E	D	Reported sometimes turbid after rain.
29.314	Keith	-	1952	-	227	-	-	IPm	-	C/E	D,S	-
29.441	Elks Club	-	1959	-	199	140 R	-	IPm	A	C/W	Ps	-
30.122	William Jones	-	-	5	210	127.9	12- 5-60	IPm	5(-)	S/E	D	-
30.213	E. D. Sweenhart	-	1960	-	200	130 R	1960	IPm	20	S/E	D	Reported pumped dry by 1963; drilled new well.
30.321	-	-	-	4	-	86.3	12- 5-60	IPm	-	S/E	D?	-
32.223	Donald Belmore	-	1963	8	435	212.2	9-25-63	IPm	N	N	N	Dry hole.
34.142	Manuel Gutierrez	-	1900?	-	53M	43.2	1-17-50	IPm	-	C/W	S	Dug well.
34.242	-	-	-	-	42	40 R	1960	IPm	-	B/H	D	Do.
9. 7. 2.342	Vigil Brothers	-	1913	6	172	125.6P	5- 3-50	IPm	A	C/W	D,S	Pumping when measured; pumped continually.
2.421	-	-	-	6	76M	61.5	10- 4-63	IPm	-	N	D	-
2.431	Andres Martinez	-	-	-	140	-	-	IPm	A	C/W	D	-
7.331	G. B. Loyd	-	1926	8	428	393 R	1962	IPm	A	C/W	D,S	Uncased; reported lime-stone top to bottom; produces from 3-inch "vein" at bottom.
7.424	do.	-	-	-	86M	72.5	11-14-62	IPm	I	C/W	S	Drilled in fault gouge?; windmill pumps dry in 3 hours.

9.244	Pete Muller	-	1958	-	215	-	-	IPm	A	C/E	D	Reported easy to get water this vicinity.
15.132	Muller	-	1916?	48	48	19.4 47.1	10- 4-63 5- 3-50	IPm,Qal	-	C/H	D	Dug well; well 9.7.15.113 in Smith (1957); drilled well 50 feet away, 191 feet deep.
17.232	G. B. Loyd	-	1960	4½	465	77.4	11-14-62	IPm	A	C/I?	S	Not in use when visited.
9. 7.24.113	C. W. Dunn	-	-	-	200	140 R 164.0P	1950 10-27-64	IPm	A	C/W	D,S	Pumping slowly when measure; uncased.
30.100?	W. E. Meahl	-	1961	-	400	-	-	IPm	N	N	N	Dry hole.
31.131	Manzano Springs Estates	-	1959	-	115	-	-	IPm	40	-/E	Ps	Top of producing zone 82 feet.
32.132	Paul Dannevic	-	-	-	-	25.2	10-16-63	IPm	-	C/E	D,S	-
35.113	-	-	-	-	88M	71.6	4- 3-50	IPm	-	-	-	Not in use when visited in 1950.
36.414	-	-	-	-	132	102.6	2- 3-50	IPm	-	-	D,S	Uncased below surface pipe.
9. 8. 7.143	C. T. Butler	-	-	-	90+	-	-	IPm	-	-	D,S	-
7.314	do.	-	-	-	100	64.7	10-27-64	IPm	-	-	N	Dry hole.
7.314a	do.	-	-	-	100	Dry	10-27-64	IPm	-	-	N	Do.
10. 4.13.212	U.S. Forest Service?	-	-	8	41M	Dry	12-29-61	Qal	N	N	N	Hole doesn't reach saturated zone.
25.314	Paradise Supper Club	-	1955	-	few	-	-	Qal	50+E	N	Fish-ponds	Dug infiltration gallery; horizontal perforated pipe buried in alluvium of stream channel.
25.414	R. Garcia	-	-	-	-	34.9	10-21-60	Qal	-	N	N	25 feet from used domestic well.
25.431	Alfredo Garcia	X	-	-	-	1	6- 5-62	Qal	A	J/E	D	Dug well in arroyo channel. Supplies three families.
25.433	-	-	1951	-	98	75 R	1960	Qal	A	-/E	D	Supplies two families.
36.124	C. H. Carder	X	1960	8	500	70.9	10-21-60	Qal,pC	16	S/E	D,S	Base of alluvium 100± feet deepest water-yielding fractures in granite 240± feet; potability problem.
10.4½.24.344	F. C. Fach (#2)	X	1952	8	100	55.5	10-21-60	Qal	10E	J/E	Ps	50 feet downslope from bull-dozed water catchment and infiltration pit.
24.344a	do. (#3)	X	1962	6	110	48 R	1962	Qal,pC	7	S/E	Ps	120 feet NW of 10.4½.24.344; base Qal reported 65 feet.
25.124	do. (#1)	X	1946	8	100	45.8 P	10-21-60	pC	A	J/E	Ps	Pumped recently; base of Qal reported 26± feet; potability problem.
25.142	do. (#4)	X	1962	6	91	64.2	9-13-62	Qal,pC?	15M	S/E	Ps	Base of Qal reported 80 feet; potability problem.
25.144	G. J. Torres	-	1950	-	80	-	-	Qal	A	-/E	D	-
25.234	Antonio Salazar	X	1956	-	80	50 R	-	Qal	A	-/E	D	Potability problem.
25.244	Henry Garcia	-	1961	6	63	40 R	2-15-61	Qal	50	S/E	D	-
10. 5. 1.122	Sierra Vista Estates	-	1961	6½	500+M	351.1	7-26-62	Kmv	½	N	N	Drilled for Ps, inadequate.
2.144	do.	-	-	-	125	-	-	TRs	23	S/E	Ps	Reported initially had artesian flow; water exported to Mesaverde terraine. (Data from State Engineer Office).
2.222	A. H. Moss	-	1956	6	45	41.7	7-26-62	Km	¼	N	N	Inadequate for domestic

TABLE 1 (continued)

Location (well no.)	Owner or name	Chem. anal.	Year com-pleted	Casing diam. (inches)	Well depth (feet)	Water level Depth (feet)	Water level Date	Geologic unit (aquifer)	Yield	Pump/ power	Use	Remarks
10. 5. 2.222a	A. H. Moss	-	1962	-	260	34.1	7-26-62	Km	¼	N	N	Inadequate for domestic supply; 8 feet from well 10.5.2.222.
2.222b	do.	-	-	-	70	-	-	Jm	15	S/E	D	Yield reported decreasing.
2.223	O. L. Howard	-	1962	-	100	-	-	TRc?	25	S/E	D	Top of producing zone 70 feet.
2.232	Rhoads	-	1950	-	160	-	-	TRc	A	J/E	D	Top of producing zone 160 feet; reported flowed for 2½ years after drilled.
2.242	Sierra Vista Estates	X	1961	7	186	147.4	7-12-62	Kmv	35	S/E	Ps	Top of producing zone 161 feet; potability problem.
2.341	Flatow, Moore, Bryan, Fairburn	-	1954	-	132	18 R	1955	TRc	-	C/I	Ps	Use 6,000± gal/day.
2.344	do.	-	1954	-	900	-	-	Km	N	N	N	Dry hole; deepest of 6 dry holes in Km in vicinity.
2.413	Unger	-	1960	6	180	143.4	7-20-62	TRc TRs?	-	C/W	D	Barely adequate.
2.433	R. J. Smith	X	1928	-	42	-	-	Qal	A	T/E	Ps, Com.	Dug well; supplies restaurant, 2 to 3 houses.
2.434	do.	-	1928	72	35E	17.5	8- 2-62	Qal	A	Ce/E	Ps, Com.	Dug well. Supplements well 10.5.2.433; reported better producer.
10.223	-	-	1960?	6	115M	86.9	7-24-62	Pg?	-	N	N	Domestic well not in use 1962.
10.241	-	-	1960?	6	110+	110+	7-24-62	Ps?	-	N	N	Dry at 110 feet, couldn't measure deeper.
10.242	C. C. Tolbert	-	1939	5	56+	39.5	7-26-62	Ps	A	S/E	D	-
10.424	C. H. Maak	-	1954	6	160	47.9	8-3-62	TRs	A	J/E	D	Top of producing zone 100 feet.
11.124	H. C. Black	-	-	6	-	-	-	Km	A	S/E	D	Supplies 2 houses; water reported hard, iron stains.
11.131	Bill Huff	-	-	-	75-90	-	-	Qal	A	-	D	-
11.132	Urquhart	-	1953	6	65	2.2	7-26-62	Qal,TRc?	A	J/E	D	Supplies 2 houses.
11.211	Robert O'Connell	X	1956	-	156	116 R	1956	Km	A	S/E	D	Potability problem, reported hard, iron stains.
11.213	Wiebe	-	1940	-	70	35 R	-	Km	I	J/E	Com.	Restaurant; not quite adequate; water reported hard.
11.231	do.	X	-	-	90	40.1	7-24-62	Km	A	J/E	D	-
11.233	V. A. Anderson	-	-	-	25	19.9	8- 2-62	Qal	A	C/W	S	Dug well.
11.234	do.	-	1954	4	38	28.7	8- 2-62	Qal	A	J/E	D	Supplies 2 houses.
11.313	C. Boggus	-	1952	48	20	5 E	8- 3-62	Qal,TRc?	A	-/E	D,S	Dug well; supplies several families.
11.323	W. E. Schaub	-	1962	8	100	33.9	8- 3-62	Km	-	S/E	Com.	Laundromat.
11.342	Ralph Bruner	X	1952	6	55	28 R	1952	Qal	30	-	D	Water level reportedly fluctuates 12 feet annually.
10. 5.11.413	P. R. Jasler	-	-	-	30	-	-	Qal	-	C/W	-	Dug well; reported dry each July, water level rises in winter.
11.413a	do.	-	1955	-	80	-	-	Qal	A	J/E	D	15± feet from well 10.5.11.413.

11.424	-	-	-	-	30	27.9	2-19-63	Qal	-	N	S?	Dug well.
11.431	Paul Souder	X	1950?	-	125	90 R	1959	Kmv	A	J/E	D	Potability problem.
11.433	-	-	-	48	21M	18.4	2-15-61	Qal	-	C/W	S	Dug well; near 20-feet deep arroyo.
11.444	-	-	-	-	25	23 R	-	Qal	-	-	D	Dug well.
12.121	H. T. Rice	-	1960	4	320	176.7	2-15-61	Km	- -	S/E	D	Planned for 2 or more houses; sulfide odor.
12.122	D. M. Bush	X	1962	6	140	96.4	6- 5-62	Km	5+	S/E	D	Top of producing zone 118 feet; sulfide odor; potability problem.
12.233	-	-	1962	-	400	-	-	Km	A	S/E	D	Top of producing zone 120 feet; sulfide odor.
12.412	Alan Gruer	-	1958	-	156	82.8	2-15-61	Km	A	S/E	D	On or near fault between Km and Ps; water murky.
12.444	Adamek	-	-	-	120	-	-	Pa	-	S/E	D	-
12.444a	Humphry	-	1961	4	120	75.6	5-15-62	Pa	A	S/E	D	-
14.324	Paul Switzer	X	1956	-	170	144.4	8- 3-62	Pa	A	S/E	D,S	-
14.334	Arthur Wilson	-	1957	-	150	-	-	Pa	A	J/E	D	-
15.223	Charles Hobby	-	1960?	6	118	12 R	1962	TRs	-	N	Ps	Main producing zone at bottom; emergency supply, trailer court.
15.432	V. A. Knott	-	1960	6	200	152.2	6-12-62	Km	-	N	Ps?	Community undeveloped when visited; near fault between Km and Pa.
15.433	W. Meahl	-	1962	8	232	89.8	6-12-62	Pa	3-4	N	N	Top of producing zone 108 feet.
15.433a	do.	-	1962	5½	250	95.0	6-12-62	Pa	6-8	-/E	D	Top of producing zone 218 feet; 50± feet from well 10.5.15.433.
19.321	G. R. Troyer	-	1960	-	105	-	-	Qal	7	J/E	D	Top of producing zone 95 feet.
19.324	F. S. Leib	X	1960	6	146	49.8	6-13-62	Qal	13	T/E	D	-
19.341	C. W. Dickenson	-	1954	-	102	-	-	Qal	A	-/E	D	Top of producing zone 65 feet.
22.141	Fidos Bar	-	1961	-	72	32 R	1961	Pa?	25	S/E	Com.	-
22.212	E. O. Trumper	-	1961	6	117M	86.2	6-12-62	Pa	-	N	Ps	Community undeveloped when visited.
22.344	Ideal Cement Co. #1	X	1957	-	1,100	Artesian	1957	IPm	35	T/E	Com.	Top of producing zone 450 feet; flowed until frequent pumping started; potability problem.
10. 5.22.433	Ideal Cement Co. #2	-	1957	-	1,100	Artesian	1963	IPm	65	T/E	Com.	Top of producing zone 500 feet; would flow in 1963 when not pumped or sealed.
22.424	Chuck Schilling	-	1959	-	79	60 R	1959	Pa?	40	-	D	-
22.424a	R. L. Miller	-	1946	8	63	39.0	3-12-63	Qal	A	J/E	D	-
23.121	Dugan Guest	-	1959	-	75	30.4	2-15-61	Pa	-	S/E	D	-
23.222	P. T. Bolling	X	1962	-	180	-	-	Pa	18	S/E	D	-
23.224	J. N. Yearout	-	1953	-	131	-	-	Pa?	A	-/E	D	Use includes swimming pool.
23.322	Max Martinez	-	1961	6	97	-	-	IPm	A	S/E	D	Top of producing zone 80 feet.
26.311	-	-	1956	-	125	-	-	IPm	A	-	D	Top of producing zone 75 feet.

TABLE 1 (continued)

Location (well no.)	Owner or name	Chem. anal.	Year completed	Casing diam. (inches)	Well depth (feet)	Water level Depth (feet)	Water level Date	Geologic unit (aquifer)	Yield	Pump/ power	Use	Remarks
26.311a	Milton Nance	-	1949	-	119	99.2	3-12-63	IPm	A	S/E	D,S	-
26.313	Robert Daugherty	-	1952	-	146	-	-	IPm	A	S/E	D	Deepened from 90 feet in 1956.
26.313a	David Judd	-	1956	-	300	-	-	IPm	-	-	D	-
26.314	J. L. Pollack	X	1951	8	96	30.8	3-12-63	IPm	A	J/E	D	-
30.124	P. W. Smith	-	1947	-	65	30 R	-	Qal	-	-	-	-
30.124a	do.	-	1955	-	105	-	-	Qal	A	S/E	D	-
30.213	Norris	X	-	6	-	66.8	6-13-62	Qal	A	T/E	D	-
30.224	Garcia	-	1948	-	56	39.1	6-13-62	Qal	A	T/E	D	Will pump dry in about 2 hours.
30.324	Bill Dickson	X	1935	-	26	18? R	-	Qal	3	-/E	D	Original depth 56 feet; base of Qal 26(?) feet.
30.334	Vincent Moore	X	1952	-	120	57.9 P	6-21-62	p€	A	J/E	D	Pumped recently; top of producing zone 118 feet.
30.334a	do.	-	1943	-	120	-	-	Qal,p€	A	C/E	D	Rarely pumped; rept. evolves gas.
30.341	G. M. Scranton	X	1960?	-	-	-	-	Qal?	-	-/E	D	-
30.342	Orville Fletcher	X	1952	5½	103	-	-	Qal	A	C/E	D,S	Potability problem.
10. 6. 1.421	-	-	-	6	537	490 R	-	IPm	A	C/E	D,S	Reported can be pumped constantly; near major fault?
2.444	Allen Wakefield	-	1960	-	340	-	-	IPm	N	N	N	Hole probably doesn't reach saturated zone.
3.113	-	-	1941	-	300+	-	-	IPm	N	N	N	Dry hole.
4.122	Kellum	-	1960	6½	315	186.9	4-14-62	IPm	N	N	N	Do.
4.124	Neal Carpenter	-	1963	6	180	113.8	9-12-63	IPm	4	S/E	D	Top of producing zone 147 feet.
4.144	Joe Serna	-	1930	6	240	159.3	6-13-62	IPm	A	C/W	D	-
4.322	-	-	-	60	-	80 R	1961	IPm	-	N	N	Dug well.
10. 6. 5.121	J. B. Hobart	X	1960	4½	310	-	-	Pys	A	S/E	D	Top of producing zone 280 feet.
5.343	W. A. Christy	-	-	-	100	30-40 R	-	IPm	A	C/E	D	-
5.344	do.	-	1962	6	131M	106.8	6-13-62	IPm	-	J/E	D	-
5.442	John Keulen	-	1959	-	467	-	-	IPm	1-2	-	D	Top of producing zone 401 feet.
5.443	R. B. Johns	-	1958	-	188	108.5	2-16-61	IPm	-	N	N	Uncased below surface pipe.
5.443a	do.	-	1959	-	317	-	-	IPm	9	S/E	D	Uncased; 50± feet from well 10.6.5.443.
6.132	-	-	-	100±	110M	41.3	7-20-62	Kmv	N	N	N	Dug hole; probably prospect pit.
6.324	R. M. Workhoven	X	1962	-	162	120 R	1962	Km	8	-/E	D	Sulfide odor from water.
6.324a	M. L. Pruit	-	1962	-	175	84 R	1962	Km	6-8	S/E	D	Sulfide odor.
6.413	-	-	1937?	5	200+M	158.8	10- 5-60	TRs	-	C/N	D	Not in use in 1960.
6.414	Al Green	-	1962	-	300	230 R	1962	Pys	25+	S/E	D	Top of producing zone 270 feet.
6.433	Higginbotham	-	1959	6	252	-	-	Pym?	A	S/E	D	-
7.124	P. Young	-	1957	-	178	143 R	-	Pym	A	J/E	D	-
7.241	P. White	X	1951	4	148	79.6	5-10-62	Pa	A	S/E	Ps	Trailer park, restaurant.

7.314	Fred Sparks	-	-	6	127	71.6	5-15-62	Qal?	A	J/E	Com.	Restaurant, service station.
8.114	Williamson Real Estate	-	1960	4	350	290 R	1960	IPm	30	S/E	Ps	Top of producing zone 319 feet.
8.121	-	-	-	4	-	120+	5-10-62	IPm	-	C/E	D	-
8.122	Williamson	-	1954	-	272	162 R	1954	IPm	-	C/E	D	Top of producing zone 196 feet.
8.212	E. O. Cleaver	-	1959	-	300	-	-	IPm	A	S/E	D	-
8.212a	Corbin	-	1962	6	360	232.8	5-22-62	IPm	3	S/E	D	-
9.113	R. H. Foster	-	-	8	390	105.4	6-13-62	IPm	1/6	N	N	Report inadequate, domestic use.
9.114	do.	-	-	6	168	-	-	IPm	A	C/E	D	Top of producing zone 165 feet; owner reported "swamp gas" smell from producing zone.
9.212	-	-	-	-	65	Dry	6-13-62	IPm	-	-	-	Dug well.
9.242	-	-	1940?	-	360	-	-	IPm	N	N	N	Dry hole.
10.331	Community of Sedillo	-	-	72	29M	9.2	2-14-61	IPm	A	B/H	Ps	Dug well; used by few families.
10.341	Frank Padilla	-	1951	-	53	33 R	1951	IPm	A	J/E	D	Dug well.
10.344	W. Eisenhut	-	1955	-	1,000	52.7	2-13-61	IPm	0.1	N	N	Deepest of 6 holes drilled in radius of few hundred feet; most produced very few hundred gallons per day.
10. 6.10.433	Brickner	-	1950	8	400	-	-	IPm	-	N	N	Filled and destroyed.
12.432	Chester Hill	-	1963	-	725	458 R	10- 4-63	IPm	7	-	S	Top of producing zone 710 feet.
13.224	T. O. Harrell	X	1945?	-	485	410 R	-	IPm	5	C/E	D	Top of producing zone 485 feet; potability problem.
14.422	F. H. Lester	-	1960	8	325	113.8	2-14-61	IPm	1(+)	N	-	Produces from 120 to 210 feet; base of Qe 90 feet.
14.424	do.	X	1950	6	260	-	-	IPm	A	C/E	D,S	Producing zone 140 to 240 feet; base of Qe 80 feet?; potability problem.
14.444	-	-	1961	-	350?	-	-	IPm	N	N	N	Dry hole; base of Qe 40 feet.
15.111	Salvadore Jaramillo	-	1943	-	250	215.6	2-14-61	IPm	A	C/W	D,S	-
15.241	Continental Realty	-	1961	4½	210	50 R	1961	IPm	1/3	N	N	Plugged at 37 feet 1962.
16.111	Mrs. Pablo Garcia	-	1961	10	361M	338.5	5-22-62	IPm	50	N	N	Drilled as domestic well.
16.221	Jaramillo	-	1960	-	235	200 R	-	IPm	-	N	N	-
16.222	-	-	-	-	300	-	-	IPm	N	N	N	Dry hole.
16.222a	-	-	1959?	-	155	-	-	IPm	A	J/E	D	-
16.311	-	-	1961	-	220	-	-	IPm	N	N	N	Dry hole.
16.313	-	-	1961	-	200	-	-	IPm	N	N	N	Do.
16.432	-	X	-	-	-	-	-	IPm	-	C/W	S	-
17.424	-	-	1961	-	475	-	-	IPm	N	N	N	Dry hole.
18.441	-	-	1961?	-	-	-	-	IPm	N	N	N	Do.
18.442	-	-	1962	-	400M	380.0	11- 7-62	IPm	N	N	N	Do.
21.241	-	-	-	60	42M	16.3	5- 7-62	IPm	-	J/E	D	Dug well; reported one of oldest in area.
22.131	Presbyterian Church	-	1961	-	300	222.2	9-13-62	IPm	N	N	N	Dry hole.
22.312	do.	-	1962	6	420	262.0	9-13-62	IPm	-	N	-	Driller reported water has bitter taste.

TABLE I (continued)

Location (well no.)	Owner or name	Chem. anal.	Year com- pleted	Casing diam. (inches)	Well depth (feet)	Water level Depth (feet)	Water level Date	Geologic unit (aquifer)	Yield	Pump/ power	Use	Remarks
24.221	Dugan Guest	-	-	4½	500	388.1	6-25-62	IPm	-	C/E	D	-
24.313	Mike Long	-	1960	-	500	132.6	11- 9-62	IPm	N	N	N	Dry hole.
25.122	Vester Harker	-	1958	6	305	-	-	IPm	N	N	N	Dry hole; 3 holes in 100-feet radius.
25.122a	do.	-	1958	-	420	-	-	IPm	N	N	N	Dry hole.
25.122b	do.	-	1960	-	553	-	-	IPm	N	N	N	Dry hole; reported "sulfur" odor when completed.
26.132	K. D. Stout	X	-	-	329	142.4	3-15-50	IPm	A	C/E	D,S	Gas evolves from water; potability problem.
27.344	Bob Brannan	-	1958	7	425	142.2	11- 9-62	IPm	A	S/E	D,S	Water reported soft.
30.424	-	-	-	60	42M	38.0	11- 7-62	IPm	-	N	N	Dug well.
10. 6.34.221	E. A. Brown	-	1962	-	260	100 R	1962	IPm	30	S/E	D	Water reported to be like well 10.6.27.344 (soft?).
26.333	Leonardo Griego	-	-	-	-	-	-	IPm	-	-	S	-
10. 7. 4.311	Howard Hill	-	-	6½	-	339.0	6-27-62	IPm	-	C/W	S	Blowing air when visited.
6.222	do.	-	-	-	500	-	-	IPm	N	N	N	Dry hole.
6.322	-	-	1934	11	2,750	150 R	-	IPm	N	N	N	Oil test hole; driller reported 80 gal/min-local residents skeptical.
8.242	Joe Hill	-	1920?	-	385	-	-	IPm	8	-	D	Reported makes people sick (high CO_2?).
9.331	-	-	-	-	297M	289.0	2-27-62	IPm	-	N	N	-
9.444	Howard Hill	X	1957	6	340	300 R	-	IPm	3E	C/E	D,S	-
11.111	-	-	1942	-	203	148.4	4-27-50	Qe	-	C/W	N	-
12.434	Mrs. Cecil Blackwell	-	1920	-	267	227.2	4-27-50	Qe	-	C/W	D,S	-
15.333	Hughes	-	1920?	-	280	-	-	IPm	-	C/E	D,S	-
16.412	Howard Hill	-	-	6½	300	216.2 229.8	5- 4-50 6-27-62	IPm	A	C/W	S	Blowing air when visited in 1962.
17.242	Joe Hill	-	1962	6	440	261.6P	6-27-62	IPm	8	C/W	S	Pumped recently; top of producing zone 320 feet.
18.343	Don Hill	-	-	-	400	345 R	-	IPm	15	S/E	D,S	May be in fault zone.
20.112	-	-	-	-	-	349.1	6-25-62	IPm	A	C/E	D	-
21.414	-	-	1963	8	460	333.7	10- 4-63	IPm	-	S/E	D	-
23.212	D. Huston	X	-	12	200	151.3 138.3	3- 5-64 8-25-48	Qe+ IPm?	-	T/I	Ir,O	-
23.234	Ray Bassett	-	1948	16	206	154.6 143.1	2- 9-62 8-25-48	Qe+ IPm	-	T/-	Ir,O	-
24.433	W. L. Williams	X	-	-	148M	127 R	1950?	Qe	-	C/E	D	-
25.122	do.	-	1919?	-	143	131.0	4-25-50	Qe	-	N	N	-
25.211	do.	X	1947	16	324	129.0 123 R	10-30-64 1950	Qe+ IPm?	N	N	N	Irrig. well, abandoned prior to 1964; reported former yield 400 gal/min main producing zone 145 feet.
27.112	Howard Calkins	-	1962	-	335	-	-	IPm	-	-	Ps	Top of producing zone 312 feet; supplies Edgewood.

27.311	Ray Bassett	-	-	-	-	-	-	IPm	-	C/E	Ps	Supplies Edgewood.
27.311a	do.	-	-	-	-	-	-	IPm	-	C/E	Ps	Supplies Edgewood; 100 feet from well 10.7.27.311.
10. 7.28.222	W. O. Bassett	-	1930?	-	312	290 R	-	IPm	A	C/E	D,Ps	Supplies school and house.
28.422	Walker and Hinkle	-	-	-	380+	-	-	IPm	A	C/E	D	-
28.424	do.	-	-	-	281M	257.7	10- 4-63	IPm	-	N	N	Dry hole.
28.444	do.	-	-	-	500+	-	-	IPm	N	N	N	Reported dry hole.
30.131	Dugan Guest	-	-	-	-	-	-	IPm	N	N	N	Do.
30.132	do.	-	-	-	280?	-	-	IPm	N	N	N	Reported dry hole; inferred water level 380 feet.
30.321	Paul Northam	-	1941	5	450M	412.4	3-15-50	IPm	-	C/W	S	-
33.442	Walker and Hinkle	-	1962	-	410	-	-	IPm	-	C/W	S	-
35.231	J. D. Hill	-	-	5	274	220.1P	2-24-50	IPm	A	C/W	D	Pumped shortly before measured; water reported much softer than from surrounding wells.
11. 5. 4.322	B. L. Abruzzo	-	1961	10	380	-	-	IPm	N	N	N	Plugged and dry 1962 at 226 feet.
24.113	G. E. Farwell	-	1949	-	61	-	-	Qal	-	J/E	D	-
24.113a	V. E Baker	-	-	8	19M	7.9	7-18-62	Qal	-	N	N	Former domestic supply.
24.114	Cabaniss	-	1959	7½	185	148.2	7-13-62	Pa	A	S/E	D	Top of producing zone 150 feet.
24.124	G. E. Farwell	-	1960	6	124	65.9	7-13-62	Pym	30	S/E	D	Top of producing zone 90 feet.
24.124a	L. Clausen	-	1960	-	130	-	-	Pym	40	S/E	D	-
24.132	Grabiel	X	-	-	-	-	-	Pys	-	C/W	D	-
24.133	Hilty	-	1954	-	70	-	-	Pys	5	-	D	-
24.134	A. C. Opperman	-	1961	6	70	34.6	7-13-62	Pys	30+	S/E	D	-
24.143	Bill Tilton	-	1948	6	55	20 R	1948	Qal	A	J/E	D	-
24.144	G. D. Grady	X	1962	7	198	47.9	7- 3-62	Pys,Qal	84M	S/E	Com.	Water cascades from 5½ feet above static level; seepage from nearby artificial fishing lake.
24.211	V. E. Baker	-	1963	-	130	-	-	Pym	30	S/E	D	Top of producing zone 105 feet.
24.221	D. C. Yearout	-	1954	6	240	182.5	7-18-62	Pys	-	N	N	Crooked well, replaced by well 11.5.24.211a
24.221a	do.	X	1955	-	260	-	-	Pys	A	C/E	D	28± feet from well 11.5.24.221.
24.223	-	-	1958	4½	-	-	-	Pg	-	S/E	D	-
24.232	Misses Dunn and Deschner	-	1962	6	340	180 R	1962	Pg	10	S/E	D	Top of producing zone 320 feet.
24.234	L. H. Harms	-	1946	-	200	-	-	Pg,Ps?	A	J/E	D,S	-
11. 5.24.314	E. G. Broaderick	-	1959	6	320	182.0	7-12-62	Pys	A	S/E	D	Top of producing zone 170 feet.
24.421	Schuler	X	1932	6	198M	173.6	7-18-62	Ps	A	C/E	D,S	-
24.434	-	-	1960?	6	150	-	-	TRc	A	J/E	D	-
24.441	Schwartz	-	1962	6	300	47.8	7-25-62	TRc	A	N	D	Unused new well when visited.
24.441a	do.	-	1956	6	195	-	-	TRc	A	S/E	D	Supplies 2 houses.
25.121	M. Rossiter	-	1955	-	127	57.8	7-13-62	TRs	A	C/E	D	Top of producing zone 117 feet; uncased.

TABLE 1 (continued)

Location (well no.)	Owner or name	Chem. anal.	Year com-pleted	Casing diam. (inches)	Well depth (feet)	Water level Depth (feet)	Water level Date	Geologic unit (aquifer)	Yield	Pump/ power	Use	Remarks
25.121a	do.	-	-	-	105	73.1	7-13-62	TRc?	-	J/E	D	Uncased; emergency supply.
25.141	Gertrude Pearl	-	1938	-	110	-	-	TRc	N	N	N	Went dry in 1954; replaced by well 11.5.25.141.
25.141a	do.	-	1954	7	252	94.0	7-25-62	TRc	A	S/E	D	Top of producing zone 185 feet; 25± feet from well 11.5.25.141; supplies 3 houses.
25.144	D. S. Dreesen	-	1956	-	159	139 R	1956	TRc	A	S/E	D	-
25.211	S. A. Wengerd	X	-	-	120	-	-	TRc	-	N	N	Hole reported plugged by blue clay that flows in at bottom.
25.221	Grant Montgomery	-	1949	6½	75	50.2	7-25-62	TRc	A	T/E	D	Supplies 3 houses.
25.231	Peterson	-	1962	5	160	66.9	7-12-62	TRc	-	S/E	D	-
25.232	Edwards	-	1962	10	592	-	-	Jm,TRc	-	N	N	Unfinished when visited; bottom 100± feet in TRc.
25.241	McGinn	-	1943	-	500	-	-	Jm,TRc?	A	C/E	D	May reach TRc.
25.321	-	-	1949	-	140	-	-	TRc	A	-	D	Top of producing zone 120 feet.
25.341	Mrs. Brophy	-	1960	6	200+	98.6	7-25-62	TRc	A	C/W	S	-
25.411	J. Harris	X	1960	6	230	206.8P	7- 6-62	TRc	A	S/E	D	Pumped shortly before measured; aquifer TRc beneath Jte.
25.414	Travis	-	1961	-	480	-	-	Jm	-	-	D	-
35.141	Dr. Jenkins	-	1960	-	140	-	-	Pys	A	J/E	D	Top of producing zone 117 feet; supplements spring.
35.144	Public Well?	-	-	48	55±	7.8	7-25-62	Qal,TRs	A	C/H	-	Dug well.
35.234	Hubert Overall	-	1961	-	75	55.5	7-26-62	TRc	A	-/E	D	Top of producing zone 65 feet; supplies 2 houses.
36.111	G. D. Bolduc	X	1958	-	100+	-	-	TRc	A	S/E	D	Top of producing zone 70 feet.
36.313	Myrtle Oxsheer	-	1954	-	90	-	-	TRc	A	J/E	D	-
1. 6. 7.124	-	-	-	-	54M	32.1	10-24-60	Pa	-	C/W	S	Not in use when visited.
19.124	Leo Chavez	-	1951	6	75	25.9	7- 6-62	Qal	A	J/E	D	-
19.134	Mrs. Farmer	-	-	7	135	39.6	7- 6-62	Qal	A	S/E	D	-
19.142	-	-	-	-	102	37.2	7- 6-62	Qal	A	J/E	D	-
19.311	Underwood	-	1959	6	135	75.8	7-26-62	Qal,TRc?	A	S/E	Com.	Service station.
19.313	W. A. Arias	X	1942	6	136	83.0	7- 6-62	Qal,TRc	15(-)M	S/E	Com.	Top of producing zone 103 feet; beer parlor.
19.342	Fred Denny	-	-	-	180	-	-	TRc	A	S/E	D	-
19.413	-	-	1960?	6	174M	90.0	7- 6-62	TRc?,Jte?	-	N	N	-
20.324	Robert Mayes	-	1958?	8	150	101.6	7- 5-62	TRc	A	S/E	D	Supplies 4 houses.
20.334	F. D. Roberts	X	1961	5	221	127±	7- 5-62	TRc	18	S/E	D,S	-
20.413	-	-	-	-	110	60 R	-	TRc	-	C/E	D	-
20.443	Independent Water Co.	-	1954	8	110	44.6	4-11-57	Ps,TRs	600(?)	Ce/E	Ps	-
23.221	Allen Wakefield	-	-	-	165	-	-	IPm	-	N	N	Hole probably doesn't reach saturated zone.

23.332	Marquez	-	-	-	400	-	-	IPm	-	N	N	Filled, abandoned.
23.344	-	-	-	-	300	-	-	IPm	-	C/W	S,D	Top of producing zone 260 feet?; pumps dry in ¼ hour recovers in 2 hours.
24.112	Garcia	-	1962	-	160	110 R	1962	IPm	13	-/E	D,S	Top of producing zone 110 feet.
24.212	Victor Chavez	-	-	6	100	68.2	7- 2-62	Qe,Pa	10	S/E	D,S	Base of Qe 80± feet.
24.430	Bill Thompson	-	1910?	-	400+	-	-	IPm	N	N	N	Dry hole.
25.422	-	-	-	-	500	-	-	IPm	N	N	N	Do.
26.221	Whittet	-	1959	-	470	-	-	IPm	N	N	N	Dry hole; second dry hole nearby 430 feet deep.
26.244	-	-	1961?	-	600	407+	6-20-62	IPm	N	N	N	Dry hole; plugged and dry at 407 feet.
26.344	M. W. Fox	X	1960	-	208	-	-	IPm	A	-/E	D	Top of producing zone 174 feet.
26.444	-	-	-	-	300±	-	-	IPm	N	N	N	Hole probably doesn't reach saturated zone.
27.322	-	-	-	-	90	Dry	6-19-62	Qal	N	B/H	N	Dug well; dried up about 1960.
27.334	-	-	-	36	65M	Dry	6-14-62	Qal	N	N	N	Dug well; 100 feet deep, caved in 1961; contained water until caved.
27.421	-	-	-	-	105M	104.5	6-19-62	IPm	-	C/W	N	Former stock and domestic well; caved?
28.123	M. J. Garcia	-	1956	6	125	96.2	7- 5-62	TRs	-	C/W	D	-
28.232	R. L. Riddle	X	-	6	200+	173.5	7- 3-62	Pg	12	C/E	D	Supplies 3 houses.
28.323	R. L. Ault	X	1957	6	340	222.1	7- 5-62	TRc	A	S/E	D,S	Downslop from nearby Todilto outcrop; potability problem.
11. 6.28.341	R. C. Dove	-	1959	-	325	228.5	7- 5-62	TRc	A	S/E	D,S	Top of producing zone 250 feet.
28.412	Underwood	-	1959	6	65	-	-	TRs	A	S/E	D	Top of producing zone 45 feet.
28.414	Nugent	-	-	6	83M	37.2	7- 3-62	TRc	-	N	N	-
28.431	Rael	-	-	-	80	33.2	7- 3-62	TRc,Qal	A	C/H	S	-
28.443	Fidel Garcia	-	1959	7	250	199.7	7- 3-62	Pa?	A	C/E	D,S	Produces from fault zone.
29.111	G. Thompson	-	1957	-	170	-	-	TRc	30	-/E	D	Top of producing zone 110 feet.
29.113	T. H. Proctor	-	1959	-	230±	105.9	7- 5-62	TRc	A	S/E	D	Top of producing zone 160 feet.
29.131	Duran	-	1962	6	139	56.1	7- 5-62	TRc,Jte?	A	S/E	D	-
29.214	Kitchel	-	1961	6	155	96.8	7- 5-62	Jte?,TRc ?	A	S/E	D	-
33.222	-	-	-	8	232M	Dry	7- 3-62	IPm	N	N	N	Dry hole.
33.324	L. P. Upton	-	1962	6	287	198	9-12-63	IPm	3	S/E	D	-
33.342	Wagner	-	-	-	300	-	-	IPm	15	-/E	D	-
33.442	Fletcher	-	1960	-	172	140 R	1960	IPm	8	-	D	After visited reported caved; replaced by 300 feet well.
34.122	Kendall	-	1962	-	-	-	-	IPm	-	S/E	D	-
34.211	H. O. Pierson	-	1962	-	220	-	-	IPm	A	S/E	D	-
34.214	do.	-	1961	-	332	215	6-19-62	IPm	I	C/E	D	-
34.244	Kelsey	-	1961	-	435M	Dry	6-19-62	IPm	N	N	N	Dry hole.
34.412	McGill	-	1958	-	400	313.2	6-14-62	IPm	N	N	N	Do.
35.111	-	-	1960?	5½	234±M	226.6	6-19-62	IPm	-	S/E	N	-

TABLE 1 (continued)

Location (well no.)	Owner or name	Chem. anal.	Year com- pleted	Casing diam. (inches)	Well depth (feet)	Water level Depth (feet)	Water level Date	Geologic unit (aquifer)	Yield	Pump/ power	Use	Remarks
35.132	C. B. Taft	-	-	-	298	-	-	IPm	N	N	N	Hole probably doesn't reach saturated zone.
35.132a	-	-	-	40	97M	71.4	6-19-62	IPm	-	B/H	-	Dug well; finished in perched water.
35.141	C. B. Taft	-	1962	-	310	180 R	1962	IPm	6(-)	-/E	D	Supplies 2 houses.
36.213	J. E. Crosby	-	-	-	305	-	-	IPm	N	N	N	Hole doesn't reach saturated zone.
36.230	do.	-	1960	-	315	-	-	IPm	N	N	N	Do.
36.231	do.	X	1964	-	1,004	735P R	1964	IPm	1½M	S/E	D	Pumped shortly before measured?; potabil- ity problem.
26.333	Vernon	-	1945	-	920	712.5P 610 R	6-27-62 1962	IPm	3(+)	C/E	D	Pumped recently; reported breaks suction at 720 feet after 3 hours pumping.
11. 7. 2.222	Simmons Bros.	-	1918?	6	500	-	-	Pa?	N	N	N	Replaced by well 11.7.2.222b.
2.222a	do.	-	1945	-	500	-	-	Pa?	N	N	N	Dry hole.
11. 7. 2.222b	Simmons Bros.	-	1959	-	500	-	-	Pa?	3/4	-/E	D,S	Geologist reported to owner red beds be- low 90 feet; "granite" at bottom; base of Qe 90 feet.
11.424	-	-	-	-	300	200+ R	-	Pa?	-	-	-	Base of Qe 200 feet?
13.122	Simmons Bros.	-	1919?	-	400	-	-	Pa?	10	C/W	S	Owner reported red beds in lower part of hole.
14.112	-	-	-	6	-	217.5	10-30-64	Pa?	-	-	-	-
14.121	-	-	-	6	-	206.5P	10-30-64	Pa?	-	-	-	Pumping slowly when measured.
15.333	-	-	-	-	200	-	-	Qe,Pa?	-	C/W	S	-
19.213	Tom Horton	-	-	-	225±	156.7	7- 2-62	Qe,Pa?	-	-	-	-
20.112	do.	-	-	-	376	-	-	Pa	1(-)	S/E	D,S	-
20.214	do.	-	-	-	103M	Dry	7- 2-62	Qe	N	N	N	Dug well.
21.144	Chavez	-	-	48	-	78.6	7- 2-62	Qe	-	C/W	-	Do.
21.322	Fernando Nieto	X	-	-	160	108.0	7- 2-62	Qe	A	C/W	D,S	Do.
24.121	-	-	-	-	180M	Dry	10-30-64	Qe	N	N	N	Reported to have been good well; later caved at 180 feet.
29.330	Tom Horton	-	1938?	-	500	-	-	IPm	N	N	N	Dry hole.
29.444	do.	-	-	-	400+	-	-	IPm	N	N	N	Do.
31.434	Howard Hill	-	-	-	166M	150.0	6-27-62	IPm	-	N	N	Stock water now piped 3 miles; other dry holes several hundred feet deep
33.424	W. Mooney	-	-	6	311	210.7	6-27-62	IPm,Qe?	A	C/W	S	-
34.111	do.	-	-	6	317	-	-	IPm,Qe?	A	C/W	D,S	-
12. 4. 1.223	Shannon Jackson	-	-	6	124	84.3	8- 9-62	Km	A	S/E	-	Drilled for domestic use, but water impotable.

35.234	Mrs. Venegas	X	-	5	172M	73.8	3-13-56	pC	-	C/W	N	Potability problem.
12. 5. 3.341	-	-	-	6	-	32.3P	11- 1-62	Qal	A	C/W	N	Pumping 1.3 gal/min when measured.
4.221	F. M. Calkins	-	1947	-	86	0 to ?R	8-16-62	IPm,Pa	A	-	Ir.	Reported flows annually April to June; on Abo outcrop; fault nearby.
4.221a	do.	-	1961	-	100	6 R	8-16-62	IPm	A	-/E	D	Top of producing zone 86 feet; flows annually approx. April to June.
12. 5. 4.222	L. D. Danfelser	X	1961	-	77	0 to 14R	8-16-62	IPm,Pa	A	J/E	D	Reported water level fluctuates from 14± feet in March to artesian flow in May.
4.442	R. S. Roller	-	1961	6	300±	162.5	11- 1-62	IPm	A	S/E	D	-
6.131	C. H. Goller	X	1957	7	120	54.9	8- 8-62	Qal,Kd?	A	J/E	D	Potability problem.
6.223	Garcia	-	-	-	22	10	8-14-62	Km?	-	N	-	Tunneled into base of hill; water quality reported poor.
6.224	Folkins	-	1957	-	143	6.2	8-14-62	Kd?	A	J/E	D	Reported flowed for 3 years; quality reported poor.
9.222	-	-	1962?	-	155M	85.8	11- 1-62	IPm	-	C/E	D	New, unused when visited.
9.242	Otto Paulson	-	1959?	6	150	99.1	8-16-62	IPm	A	J/E	D	-
9.244	Paulson	X	1962	6	159	120.6	8-16-62	IPm	A	S/E	D	-
24.430	Koch Bros.	-	-	-	417	-	-	IPm	-	N	-	Top of producing zone 332 feet.
25.120	do.	-	-	-	450	-	-	IPm	5	C/-	S	Top of producing zone 378 feet.
25.311	do.	-	1958	-	665	-	-	IPm	-	N	N	Dry hole.
25.331	do.	X	-	-	285	-	-	IPm	1(-)	-	S	Top of producing zone 198 feet.
26.423	-	-	-	-	485	-	-	IPm	-	N	N	Dry hole.
26.432	-	-	-	-	680	-	-	IPm	-	N	N	Do.
36.334	-	-	-	-	100	-	-	IPm	60	-/E	Ps	To supply La Madera.
12. 7.34.214	G. M Simmons	-	-	-	135	40.4	10-30-64	Qe	25-50	-/E	D	Water level measured at nearby well.
13. 4.36.133	C. R. Sebastian	-	1960	-	200+	-	-	QTs	15E	S/E	D	Use includes supply for swimming pool.
36.234	N. J. Eich	X	1960	6	230	-	-	Kmv	A	S/E	D	Pump set at 21C feet; potability problem.
36.322	J. Oreb	-	1959	-	260	30-40 R	-	Qal,Kmv	1/8±	S/E	D	Public Health Service analysis: dissolved solids; 1,369 mg/L SO_4; 300 mg/L; yield inadequate.
36.323	Mrs. E. McKinnon	-	1959	6	102	25.5	8- 8-62	Qal	-	C/H	-	25± feet of Qal on Kmv; water quality reported good.
36.334	A. W. Litka	X	1962	6	322	276.6	8- 9-62	QTs	12	S/E	D	-
36.432	U. C. Luft	-	1961	-	80±	40± R	-	Qal	-	S/E	D	Water quality reported good.
13. 5.15.223	L. M. Melick	-	1960	-	150	-	-	QTs?	½±	-/E	D	-
22.320	-	-	1963	-	230	130 R	-	QTs	20	-/-	D	-

TABLE 1 (continued)

Location (well no.)	Owner or name	Chem. anal.	Year com- pleted	Casing diam. (inches)	Well depth (feet)	Water level Depth (feet)	Water level Date	Geologic unit (aquifer)	Yield	Pump/ power	Use	Remarks
13. 5.31.341	Jack Ladd	-	1940	6	165	138.6	8-15-62	Kmv	I	S/E	D	Water quality reported very poor, garden use only.
31.342	do.	-	-	-	135	-	-	Kmv	-	-/E	D	Do.
32.211	Texas-New Mexico Pipeline Co.	-	1959	10	167	38.8	8-15-62	Kmv	7	-	N	Cooling water for compressor station; replaced by nearby well.
32.232	D. Berry	-	1962	6?	100	30 R	1961	Qal	-	J/E	D	Estimate 30+ feet Qal on Km; water reported potable, hard.
32.323	G. O. Bridgeman	X	1958	6	100	45.9	8-14-62	Jm	55	J/E	D	Potability problem.
32.334	Orlando Garcia	-	1954	72	-	37.6	8-14-62	Qal	-	N	N	Dug well; former domestic supply.
32.334a	do.	X	1956	-	89	39.4	8-14-62	Qal,TRc?	15(-)	J/E	D	-
32.442	R. R. Edwards	-	-	-	40	17.1	8-16-62	Qal	-	J/E	D	For garden and swimming pool.
33.330	B. T. Thomas	X	1954	6	130	-	-	Qal?	-	-	-	-
34.311	B. Moore	-	-	-	63M	46.9	11- 1-62	Qal	-	N	N	-

EXPLANATION:

TABLE 2—Records of selected springs in the Sandia and northern Manzano Mountains and vicinity.

Location: See explanation of well-numbering system in text.

Owner: Owner at time of visit.

Chem. anal.: Indicates chemical analyses in Table 3.

Geologic unit: Ql, landslide deposits, Qal, alluvium, QTs, Santa Fe Group; Kd, Dakota Sandstone; Jm, Morrison Formation; TRs, Chinle Formation; Ps, San Andres Limestone; Pg, Glorieta Sandstone; Psg, San Andres and Glorieta undifferentiated; Pys, San Ysidro Member of Yeso Formation; Pym, Meseta Blanca Sandstone Member of Yeso Formation; Py, Yeso Formation undifferentiated; Pa, Abo Formation; IPm, Madera Limestone; IPs, Sandia Formation; pЄ, Precambrian rocks.

Yield: Gallons per minute; M, measured; otherwise estimated; N, none.

Use: S, stock; D, domestic; Ps, public supply; Ir, irrigation; Com., commercial; N, none.

Remarks: "Potability problem", one or more of the constituents iron, sulfate, chloride, fluoride, and nitrate do not meet U.S. Environmental Protection Agency drinking water standards; see Table 3 and text.

Location (Spring no.)	Owner	Name	Chem. anal.	Geologic unit aquifer	Character of material	Geologic or topographic situation	Yield Rate (gpm)	Yield Date	Use	Temp. (°C)	Remarks
6. 5. 2.134	Cibola Natl. Forest	-	-	IPm	Limestone	Fault across canyon	1	11-18-49	-	-	-
2.142	do.	Big Spring	-	IPm, IPs	do.	do.	1	11-18-49	-	-	Well 6.5.2.124 in Smith (1957).
11.114	do.	-	X	IPm	do.	Fault along canyon floor	2/3M	10-25-63	S	9	-
14.111	do.	-	-	pЄ,Qal	Schist	-	10	10-25-63	-	-	Qal on canyon floor overlies pЄ.
6. 6. 5.340	-	-	-	IPm,Qal	Alluvium	Canyon floor	few	10-29-63	S	-	Qal overlies IPm on valley floor; few shallow wells in Qal.
7. 5.35.234	Cibola Natl. Forest	Fourth of July Spring	-	IPm,Qal	do.	Fault across canyon floor	1 M few	11-18-49 10-25-63	Ps	-	Thin Qal over IPm on canyon floor; picnic ground.
35.421	do.	Fourth of July Spring (lower)	-	IPm,Qal	Limestone	do.	1	11-18-49	Ps	-	Do.
7. 6. 2.410	-	-	-	IPm,Qal	-	Valley Qal wedges out downstream	few	10- 2-63	S	-	Feeds perennial stream flow.
5.322	-	Ojo los Caso	-	IPm	-	Valley side; fault across valley downstream	N	10- 2-63	S	-	-
11.133	Chilili Grant	Deer Spring	-	IPm	Limestone	Head of canyon	½(-)	11-13-63	-	-	-
7. 6.29.213	-	Riley Ranch Spring	-	IPm	-	Valley floor; perched	N	11-14-63	-	-	200+ feet above inferred potentiometric surface.
8. 5.12.422	Isleta Pueblo	-	-	IPm,Qal?	Limestone	Canyon floor	20-30	9-19-62	S?	-	Spring discharge from limestone added to underflow?.
12.432	do.	-	-	Qal	Alluvium	do.	1(-)	9-19-62	S?	-	Underflow.
14.434	do.	-	-	IPm	Limestone, shale?	Fault across canyon	10	9-19-62	S?	-	Old seep from 1-foot shale between massive limestones marked by traver time festooning wall 15 feet above arroyo.

TABLE 2 (continued)

Location (Spring no.)	Owner	Name	Chem. anal.	Geologic unit aquifer	Character of material	Geologic or topographic situation	Yield Rate (gpm)	Yield Date	Use	Temp. (°C)	Remarks
23.343	do.	-	-	Qal, IPm?	Alluvium	Canyon floor	1-5	9-19-62	S?	-	Underflow from Qal wedge-out.
26.113	do.	-	X	IPm	Limestone	Dammed by gouge on falt at canyon	9 M	9-19-62	S	15	-
28.124	do.	-	X	Qal	Alluvium	Canyon floor	1(-)	9-19-62	S	23	Underflow where Qal thins, channel narrows.
8. 7. 3.443	-	-	-	IPm	Arkose, limestone	Intersecting joints; head of box canyon	1(-)	10- 3-63	S	-	-
11.113	-	-	-	IPm	Arkose, shale?	do.	1-5	10- 3-63	S	-	-
30.444	-	-	-	IPm	Shale	Jointed shale; valley floor	20-30	9-27-63	S	17	Discharge flows through Chilili; reported never dry.
8. 8. 6.440	Ross Thompson	Buffalo Springs	-	IPm	Shale?	Fault across valley floor	2-7	10- 3-63	D,S	-	Reported never dry.
9. 4.24.210	Military Reserv.	Coyote Springs	X	p€	-	-	-	-	N	16	Potability problem.
9. 6. 6.132	-	-	-	IPm	Limestone?	Confluence two canyons	1(-)	11- 8-62	N	-	-
.36.312	-	-	X	IPm	-	Fault across valley downstream	1(+)	12-21-60	S	-	-
9. 7.21.341	Ballinger	-	-	IPm	-	Fault along valley	1-5	10-16-63	S	-	Numerous springs and seeps upstream for 3+ miles.
29.214	-	-	-	IPm	-	Fault intersection	10	10-16-63	S	-	-
29.441	-	-	-	IPm	-	Valley floor	-	-	S	-	-
31.334	-	-	-	IPm	Limestone	do.	3	10-16-63	D,S	-	Evolves small amount of gas.
32.111	Paul Dannevie	-	-	IPm	-	do.	1-5	10-16-63	S	-	-
10. 4.13.242	L. Petrino	Embudo Spring	X	p€,Qal	Granite,	Fault across	-	-	S	13	-
10.4½.13.213	-	Embudo Spring	X	p€	Granite	Fault across canyon	2-5	12- 6-61	S	-	-
24.342	-	-	-	p€	do.	Canyon along fault	1(-)	10-21-60	-	-	-
25.121	F. C. Fach	-	X	p€	do.	Dike along canyon side	1(-)	10-21-60	D	-	Flow reported constant.
10. 5. 7.432	Cibola Natl. Forest	Three Gun Spring	X	p€	do.	Junction of two canyons	2-3	12- 7-61	-	-	-
10.423	-	-	X	Pg	Sandstone	Anticline breached by canyon	50-75	8-10-62	D,S	13	Travertine deposit below spring; used by residents of San Antonio.
10.432	-	-	-	Psg,Py	do.	Fault?; canyon	3	8-10-62	N	-	-
10.434	Charles Hobbie	-	X	Pys	-	Fault; canyon	2	8-10-62	Ps	-	Water used by trailer park residents.

11.333	-	-	-	Kd	Sandstone	Steeply dipping sandstone breached by canyon	1	8-10-62	D	-	-
15.142	Cibola Natl. Forest	-	-	IPm	Limestone	IPm near fault contact with Pys; canyon	5	6-12-62	-	-	Travertine coats face of 30-foot drop off in stream channel.
15.212	Charles Hobbie	-	-	Ps?	-	Major fault	5-10	8- 9-62	Ps	-	Used by trailer park residents; discharge fluctuates seasonally.
15.223	do.	-	X	TRc	-	TRc faulted against Jm	1	8-10-62	N	14	Iron stain in channel; considerable iron-using(?) algae.
15.331	J. D. Grenko	Carlito Spring	-	IPm, IPs	Limestone	Small horst; canyon wall	500	11- 8-63	D	-	Water may be from upper part IPs; travertine.
21.223	R. A. Curtis	-	X	IPm	do.	Fault; on canyon wall	5-10	8-10-62	D	14	Travertine.
21.412	John Giannini	7-Springs	X	p€,Qal?	-	Canyon floor; Qal over p€; joints in p€	20	6-15-62	Com	11	Trout ponds, cafe, service station.
22.143	-	-	-	Qal	Alluvium	Qal wedges out; canyon floor	30	6-21-62	S	-	-
10. 6. 7.342	-	-	-	Qal	do.	do.	1(-)	5-15-62	-	-	-
11. 4. 1.313	Cibola Natl. Forest	La Cueva Spring	X	p€	-	-	-	-	-	17	-
11.232	do.	-	-	p€	Granite	Fault across canyon	N	12-29-61	N	-	Dry when visited; formerly used for domestic supply?.
11. 4.11.424	Cibola Natl. Forest	-	-	p€	Granite	Fault across canyon	2	12-29-61	S	-	-
11. 5.10.133	do.	Tree Spring	-	IPm	Limestone	Canyon along fault	1(+)M	7-27-62	Ps	8	-
14.342	do.	Sulphur Spring	-	Pa	Sandstone	Fault across valley	1(-)	7-19-62	Ps	17	Picnic ground.
23.111	do.	Cienega Spring	X	IPm	Limestone	Fault across canyon	10-15	6-20-62	Ps	10	Travertine in channel below spring; picnic ground.
26.333	do.	-	-	Qal,Pys	Alluvium limestone?	Qal thins in valley	25	7-26-62	D	11	-
27.423	do.	-	-	IPm	Limestone	Fault across canyon	25	7-25-62	D	11	Travertine in past and present channels below spring; supplies Cañoncito through acequia.
34.243	do.	Cole Spring	X	Ql	Landslide rubble	-	6 M	6-21-62	Ps	9	Picnic ground.
35.131	Dr. Jenkins(?)	-	-	Pym	Sandstone	Canyon confluence	1(-)	8- 2-62	D	-	Piped to Jenkins.
12. 4. 1.234	-	-	-	TRc	do.	-	½(-)	8- 8-62	N	-	Small amount white precipitate.
12. 5. 4.120	Placitas Community	-	-	IPm	Limestone	Slope near fault	-	-	Ir	-	Placitas for gardens; Spr 13.5.33.240, drinking water.
4.222	L. D. Danfelser	-	-	Pa	-	On or near fault	N	8-16-62	N	-	Rept. usually flows from spring until late summer.

TABLE 2 (continued)

Location (Spring no.)	Owner	Name	Chem. anal.	Geologic unit aquifer	Character of material	Geologic or topographic situation	Yield Rate (gpm)	Yield Date	Use	Temp. (°C)	Remarks
5.334	Cibola Natl. Forest	Tunnel Spring	X	ℙs	Shaley sandstone	Intersecting faults	20	8-10-62	D ?	12	Formerly supplied fish hatchery.
33.141	Robert Cooper	Head Spring	X	ℙs, ℙm	-	ℙm faulted against ℙs	30-40	7-27-62	D, ps	6	Travertine downstream; church campground.
33.214	do.	-	-	ℙs, ℙm	Limestone	Fault across canyon	20	7-27-62	D	-	Abundant travertine in stream channel.
33.214a	do.	House Spring	X	ℙs, ℙm	do.	do.	10-20	7-27-62	D	8	Do.
33.214b	do.	-	-	ℙs	-	ℙs faulted against p€	5	7-27-62	-	-	Do.
33.434	Cibola Natl. Forest	Capulin Spring	-	ℙm	Limestone	Slope near fault	-	-	Ps	-	Picnic ground.
36.323	-	-	-	Qal	Alluvium	Qal over faulted p€	-	-	S	-	-
36.334	-	-	-	Qal	do.	do.	N	10-24-60	N	-	Probably dry--well nearby
13. 4.36.323	Edna McKinnon	-	X	Qal	do.	Qal-filled channel on Kmv	½(-)	8- 8-62	S	20	-
13. 5.14.331	-	-	-	ℙm	Shale	Shale exposed at fault	2-3	11- 2-62	S,D	-	Piped to swimming pool.
15.241	J. H. Stapleton	-	X	Pys	Sandstone?	do.	6 M	11- 2-62	D,Ir	23	Irrigates orchard; travertine at spring.
15.242	Mrs. O. G. Schau	-	-	Pys?	do.	do.	1	11- 2-62	D	18	Several springs reported nearby.
22.224	-	-	-	ℙm?	-	Fault inter-section	-	-	D,S	-	-
22.421	R. Kirschner	-	-	ℙm	Limestone	ℙm faulted against QTs	3-5	11- 2-62	D,S	-	Travertine at spring.
28.322	-	-	-	QTs	Alluvium	Buried fault?	100	8-14-62	S	15.6	Seeps in and beside channel of arroyo.
32.123	-	-	-	Qal	do.	Qal over Km	½(-)	8-14-62	S	-	-
32.332	-	-	X	Jm, Qal	-	Arroyo cut nearly through Qal to Jm	1-5	8-14-62	S	21	Water from Jm probably added to Qal water.
32.421	-	-	X	Qal	Alluvium	Arroyo in Qal over Km	5	8-15-62	S	-	-
33.342	Placitas Community	-	X	ℙm	Limestone, Sandstone	Slope near fault	-	-	Ps	14	Placitas drinking water; low yield in early summer.
33.344	do.	-	-	ℙm	do.	do.	-	-	Ps	-	With spring 13.5.33.342, supplies about 100 families.
33.434	Placitas?	Del Oso Spring	-	ℙm	-	ℙm faulted against Pa	20	8-16-62	S	-	-
33.443	F. M. Calkins	-	-	Pa	-	-	0-5	8-16-62	N	-	Reportedly dries up in summer; wells 12.5.4.221 and 221a nearby.

TABLE 3—CHEMICAL ANALYSES OF WATER FROM SELECTED WELLS AND SPRINGS IN THE SANDIA AND NORTHERN MANZANO MOUNTAINS AND VICINITY. Chemical constituents in mg/L. Dissolved solids are the sum of the concentrations reported for the various dissolved constituents. Analyses by USGS.

EXPLANATION:

Location: See explanation of well-numbering system in text. S, indicates Spring.

Geologic unit: Ql, landslide deposits, Qal, alluvium; Qe, Valley fill of the Estancia Valley; QTs, Santa Fe Group; Kmv, Mesaverde Group; Km, Mancos Shale; Kd, Dakota Sandstone; Jm, Morrison Formation; ℞c, Chinle Formation; Ps, San Andres Limestone; Pg, Glorieta Sandstone; Pys, San Ysidro Member of Yeso Formation; Pa, Abo Formation; IPm, Madera Limestone; IPs, Sandia Formation; p€, Precambrian rocks.

Location (well or spring no.)	Date collected	Geologic unit	Temperature (°C)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na + K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$: Calcium magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH
S 6. 5.11.114	10-25-63	IPm	9	-	-	-	-	-	276	0	-	2.4	-	-	-	242	16	460	7.5
6. 6.14.113	2-16-51	IPm	-	11	0.34	11	4.0	160	377	23	22	8	3.2	0.5	428	44	0	676	-
	7-22-52	-	-	-	-	-	-	-	333	26	-	14	-	-	-	50	-	666	-
6. 7. 5.322	7- 6-54	IPm	12	37	.13	230	33	83	1,030	0	22	15	.6	.2	927	710	0	1,440	6.2
7. 6.26.412	2-16-51	IPm	-	-	-	-	-	-	383	0	-	12	-	-	-	-	-	648	-
7. 7.10.422	5-12-50	IPm	-	19	-	68	9.8	8.3	218	0	21	11	-	15	259	210	32	431	-
12.342	3-15-50	IPm	-	20	-	152	16	15	483	0	37	22	.1	14	514	445	49	861	-
23.112	9-15-50	IPm	-	18	-	102	24	33	476	0	14	14	.2	.3	440	353	0	776	-
29.341	9-15-50	IPm	-	16	-	103	10	13	328	30	30	15	.1	5.2	354	298	-	603	-
S 8. 5.26.113	9-19-62	IPm	15	23	-	25	16	27	135	0	45	19	.6	.6	222	128	18	360	8.2
S 28.124	9-19-60	Qal	23	-	-	-	-	-	370	0	-	28	-	-	-	338	35	745	7.6
8. 6.32.342	10- 2-63	IPm	12	-	-	-	-	-	411	0	-	16	-	-	-	364	27	717	7.6
8. 7.29.323	2-16-51	IPm	-	16	-	109	12	17	353	0	30	15	.1	19	392	322	32	651	-
S 9. 4.24.210	7-25-45	p€	16	15	.06	279	65	402	1,230	0	125	492	1.2	3.4	1,990	964	0	3,400	-
35.100	6-27-44	Qal	17	-	80?	179	36	98	696	0	59	116	-	14	892	594	-	1,480	7.5
9. 6.12.332	11-14-62	IPm	13	-	-	-	-	-	460	0	-	26	-	-	-	360	0	1,000	7.4
23.343	11-25-60	IPm	11	-	-	-	-	-	278	0	-	151	-	18	-	680	452	1,390	7.6
26.244	12-21-60	IPm	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	899	-
9. 6.26.333	6-18-54	IPm	-	28	0.19	109	22	29	384	0	63	32	0.3	0.2	473	362	48	770	-
29.142	10- 7-60	IPm	-	-	-	-	-	-	428	0	-	16	-	4.2	-	206	0	762	7.0

TABLE 3 (continued)

Location (well or spring no.)	Date collected	Geologic unit	Temperature (°C)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Sodium and Potassium (Na + K)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$: Calcium magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH
S 36.312	12-21-60	IPm	-	-	-	-	-		-		384	0	-	78	-	6.2	-	460	146	984	7.5
S10. 4.13.242	5- 7-56	p€,Qal	13	34	-	149	31		29		497	0	121	18	1.6	.2	628	500	92	963	7.7
25.431	6-15-62	Qal	-	-	-	-	-		-		272	0	-	26	-	7.1	-	344	121	743	7.3
36.124	9-12-62	Qal,p€	-	-	-	300	38		46		812	0	280	27	3.5	.0	1,140	904	238	1,610	6.6
S10.4½.13.213	12- 6-61	p€	-	-	-	-	-		20		335	0	76	10	-	.1	420	325	50	669	7.3
24.344	10-21-60	Qal	-	-	-	-	-	33		-	232	0	109	10	.2	43	465	280	90	679	7.6
	12- 6-61	Qal	-	-	-	-	-		-		-	-	-	16	-	37	-	-	-	695	-
	9-14-62	Qal	-	-	-	-	-		-		-	-	-	14	-	28	-	-	-	728	-
24.344a	11-13-63	Qal,p€	-	22	-	74	29		41		218	0	172	18	-	11	474	302	124	734	7.8
S 25.121	12- 6-61	p€	-	-	-	-	-		36		209	0	140	16	-	38	480	292	120	704	7.7
25.124	10-21-60	p€	-	-	-	-	-		-		220	0	-	14	-	64	-	298	118	721	7.7
	12- 6-61	p€	-	-	-	-	-		-		-	-	-	16	-	56	-	-	-	737	-
	9-14-62	p€	-	-	-	-	-		-		-	-	-	15	-	49	-	-	-	731	-
25.142	9-14-62	Qal,p€?	-	-	-	-	-		-		232	0	-	22	-	60	-	300	110	752	7.9
	11- 8-63	Qal,p€?	-	-	-	-	-		-		-	-	-	24	-	67	-	-	-	767	-
25.234	6-15-62	Qal	-	-	-	-	-		-		286	0	-	60	-	108	-	436	202	1,030	7.5
10. 5. 2.242	8- 2-62	Kmv	12	27	-	405	109		37		525	0	1,020	33	.4	.0	1,890	1,460	1,030	2,280	7.2
2.433	8- 2-62	Qal	12	-	-	-	-		15		304	0	110	32	-	1.4	498	376	127	750	7.7
S 7.432	12- 7-61	p€	-	-	-	-	-		-		184	0	43	4.6	-	-	-	184	33	391	7.6
S 10.423	1-30-53	Pg	-	-	-	-	-		-		299	0	-	-	-	-	-	256	11	478	7.8
S 10.434	8-10-62	Pys	-	24	-	77	7.3	7.8		0.7	257	0	18	3.2	.2	.5	246	222	12	426	7.7
11.211	7-24-62	Km	-	22	-	540	147		33		402	0	1,460	122	.1	.0	2,520	1,950	1,620	2,910	7.4
11.231	7-24-62	Km	-	-	-	-	-		-		406	0	-	216	-	-	-	730	398	1,640	7.5
10. 5.11.342	7- 7-52	Qal	-	16	-	106	15		18		342	0	68	9.0	0.1	2.2	402	326	46	647	-
11.431	8- 3-62	Kmv	-	-	-	-	-		36		440	0	299	18	-	.7	875	620	260	1,190	7.2
1/ 12.122	7-11-62	Km	14	17	1.4	154	89		319		784	0	564	58	.6	.0	1,520	750	108	2,010	6.9
14.324	8- 3-62	Pa	-	-	-	-	-		17		312	0	157	12	-	2.6	-	400	144	781	7.5
S 15.223	8-10-62	₸c	14	-	-	-	-		-		352	0	172	5.6	-	-	544	460	172	822	7.5
19.324	6-13-62	Qal	-	-	-	78	15		21		230	0	78	12	-	20	-	256	68	583	7.7
S 21.223	2-13-58	IPm	14	16	-	102	9.5		10		308	0	55	4.0	.2	.1	352	294	41	567	7.5
S 21.412	6-15-62	p€,Qal?	11	18	-	106	15		22		280	0	114	17	.3	2.9	470	328	98	692	7.7

	22.344	6-11-57	Pm	-	18	-	22	19		97		324	0	48	16	2.2	.0	373	133	0	627	7.7
	23.222	10-12-62	Pa	-	-	-	-	-		-		327	0	-	9.8	-	.6	-	270	2	629	7.2
	26.314	3-12-63	Pm	12	17	-	107	21		16		308	0	75	35	.4	8.2	428	352	100	713	7.3
	30.213	6-13-62	Qal	-	-	-	-	-		-		226	0	-	17	-	36	-	280	95	639	7.6
	30.324	6-20-62	Qal	-	-	-	-	-		-		-	-	-	28	-	6.7	-	-	-	756	-
	30.334	6-21-62	pC	-	-	-	-	-		47		334	0	145	29	-	6.6	-	368	94	874	7.7
	30.341	6-21-62	Qal?	-	-	-	-	-		-		-	-	-	32	-	19	-	-	-	893	-
	30.342	6-21-62	Qal	-	-	-	-	-		-		-	-	-	43	-	59	-	-	-	1,030	-
10.	6. 5.121	7-19-62	Pys	13	-	-	-	-		-		304	0	35	24	-	-	352	290	41	593	7.7
	6.324	9-13-63	Km	16	-	-	-	-		-		648	0	92	22	-	-	-	-	-	1,150	7.5
	7.241	5-10-62	Pa	-	-	-	60	17		55		320	0	51	16	-	.4	-	218	0	616	7.5
	13.224	6-25-62	Pm	-	14	-	2.6	1.1		288		573	35	50	19	11	.1	703	11	0	1,150	8.8
		9-13-62	Pm	18	-	-	-	-	280		-	590	31	-	-	14	-	-	-	-	1,150	8.8
	14.424	9-13-62	Pm	13	-	-	-	-		93		383	0	86	20	3.3	3.1	-	240	0	782	8.0
	16.432	5-22-62	Pm	-	-	-	-	-		-		370	0	110	38	-	-	-	420	117	862	7.6
10.	6.26.132	11- 9-62	Pm	13	-	-	-	-	278		-	624	0	-	33	11	0.3	-	56	0	1,200	8.2
10.	7. 9.444	6-27-62	Pm	14	20	-	170	30		12		616	0	32	21	.3	7.0	595	548	43	1,020	7.0
	23.212	8-29-50	Qe+Pm?	-	19	-	166	23		7.4		572	0	26	16	0	8.1	548	508	140	939	-
	24.433	8-29-50	Qe	-	16	-	80	13		7.4		230	0	30	26	.4	15	301	253	64	512	-
	25.211	8-29-50	Qe+Pm?	-	14	-	107	17		2.1		306	0	40	31	.6	5.3	368	337	86	642	-
S11.	4. 1.313	5- 8-56	pC	17	20	-	42	7.4		12		163	0	16	5.5	1.2	.1	186	136	2	297	7.2
S11.	5.23.111	6-20-62	Pm	10	-	-	-	-		-		312	0	13	2.6	-	-	-	270	14	503	7.6
	24.132	7-13-62	Pys	-	-	-	-	-	10		-	374	0	18	4.8	-	-	-	322	16	595	7.4
2/	24.144	7- 3-62	Surface water	13	-	-	-	-		1.6		304	0	21	3.2	-	.2	285	272	23	502	7.6
		7- 3-62	Pys,Qal	13	-	-	-	-		7.4		348	0	27	6.8	-	1.8	351	308	23	592	7.2
	24.221a	7-18-62	Pys	-	-	-	-	-		6.4		306	0	17	3.9	.3	1.0	302	262	11	502	7.5
	24.421	7-18-62	Ps	11	16	-	88	8.4	8.0		0.9	290	0	20	6.1	.3	1.5	285	254	16	485	7.6
	25.211	2-21-52	TRc	-	-	-	92	20		73		425	0	40	55	.2	3.8	493	312	0	872	-
	25.411	7-19-62	TRc	-	21	-	84	21		33		315	0	24	58	.3	2.9	399	296	38	700	7.6
S	34.243	6-21-62	Ql	-	-	-	-	-		-		355	0	-	2.3	-	-	-	306	15	564	7.1
	36.111	7-25-62	TRc	-	23	-	76	15		19		230	0	29	46	.4	7.9	360	250	62	567	7.6
11.	6.19.313	7-12-62	Qal,TRc	14	-	-	-	-		-		256	0	-	60	-	7.0	-	268	58	629	7.8
	20.334	7-12-62	TRc	-	-	-	-	-		-		322	0	-	51	.4	2.6	-	290	26	690	7.5
2/	26.344	6-20-62	Pm	-	22	-	73	8.8	13		2.0	200	0	21+?	28	.4	7.0	298	218	54	479	7.6

TABLE 3 (continued)

Location (well or spring no.)	Date collected	Geologic unit	Temperature (°C)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Sodium and potassium (Na + K)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$: Calcium magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH
28.232	7- 3-62	Pg	-	24	-	100	39		11		264	0	192	9.0	.3	2.9	547	408	192	766	7.6
28.323	7- 5-62	TRc	-	23	-	216	56		26		146	0	669	5.4	.3	.1	1,070	768	648	1,360	7.3
3/ 36.231	6-19-64	ℙm	16	17	0.42	174	27		203		1,110	0	46	18	1.3	.1	1,030	545	0	1,570	6.1
4/	6-19-64	ℙm	-	-	30	128	27		-		654	0	-	-	-	-	-	430	0	1,070	5.9
11. 7.21.322	7- 2-62	Qe	15	28	-	55	22		21		244	0	24	26	0.4	14	316	228	28	515	7.8
12. 4.35.234	9-21-50	p€	-	21	-	76	17		36		286	0	71	9	4.0	8.8	384	260	25	616	-
12. 5. 4.222	8-16-62	ℙm,Pa	-	-	-	-	-	5.2		0.7	256	0	20	4.3	-	1.0	208	225	15	434	7.4
S 5.334	8- 9-62	ℙs	12	-	-	-	-	3.6		.8	300	0	14	2.3	.5	1.4	234	264	18	483	7.6
6.131	8- 8-62	Qal,Kd?	-	-	-	-	-		120		270	0	384	8.8	.5	1.5	829	376	154	1,150	7.4
9.244	8-16-62	ℙm	-	-	-	-	-	4.7		.9	250	0	16	3.2	-	2.6	-	220	15	419	7.6
25.331	10-24-60	ℙm	12	-	-	-	-		-		308	0	38	18	-	-	365	290	38	580	7.5
S 33.141	7-27-62	ℙs,ℙm	6	-	-	-	-		-		286	0	-	1.4	-	-	-	-	-	458	7.4
	7- 8-63	ℙs,ℙm	7	-	-	98	2.6	1.6		-	288	0	13	2.6	-	1.4	-	255	19	470	7.6
S 33.214a	7-27-62	ℙs,ℙm	9	-	-	85	6.8	2.0		.6	280	0	14	11.8	-	2.1	-	240	10	459	7.8
13. 4.36.234	8- -60	Kmv	-	-	-	-	-		-		460	0	1,680	150	-	-	-	1,290	913	3,680	7.6
S 36.323	8- 9-62	Qal	20	-	-	-	-	10		1.2	291	0	57	6.4	-	.6	-	294	56	563	7.4
36.334	8- 9-62	QTs	-	19	-	79	4.9		11		258	0	21	3.7	.3	.9	258	217	6	439	7.5
S13. 5.15.241	11- 2-62	Pys	23	16	-	74	9.6		47		329	0	38	8.7	1.4	.9	360	224	0	590	7.4
32.323	8-14-62	Jm	-	24	-	610	29		56		204	0	1,500	23	.6	.1	2,340	1,640	1,470	2,490	7.2
S 32.332	8-14-62	Jm,Qal	21	-	-	-	-		-		232	0	-	42	-	-	-	648	458	1,350	7.6
32.334a	8-14-62	Qal,TRc?	-	-	-	-	-	5.0		.6	306	0	45	4.2	.6	.1	322	284	33	542	7.6
S 32.421	8-15-62	Qal	-	-	-	-	-		23		380	0	53	12	-	.6	374	334	22	673	7.6
33.330	5-30-55	Qal?	-	-	-	102	23		7.6		370	0	54	3	1.0	.3	373	349	46	659	7.3
S 33.342	8-16-62	ℙm	14	14	-	69	4.4	3.6		.9	205	0	16	2.3	.3	1.6	198	190	22	350	7.6

1/ Part of analysis run in field, part in laboratory. Sample also contained 1.5 ppm H_2S.

2/ Sulfate probably too low; insufficient sample for further analysis.

3/ Sampled after 20 minutes pumping; CO_2=1,400.

4/ Sampled after 2½ hours pumping; CO_2=1,310.

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