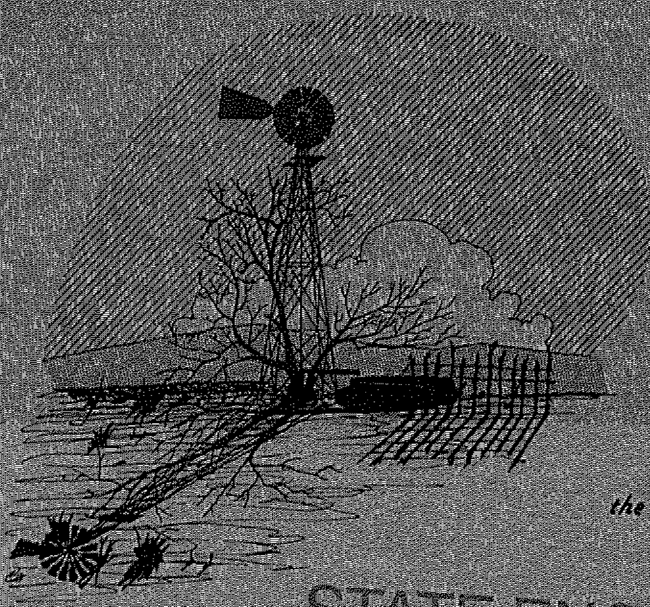
TECHNICAL REPORT 35

New Mexico State Engineer
Santa Fe, New Mexico

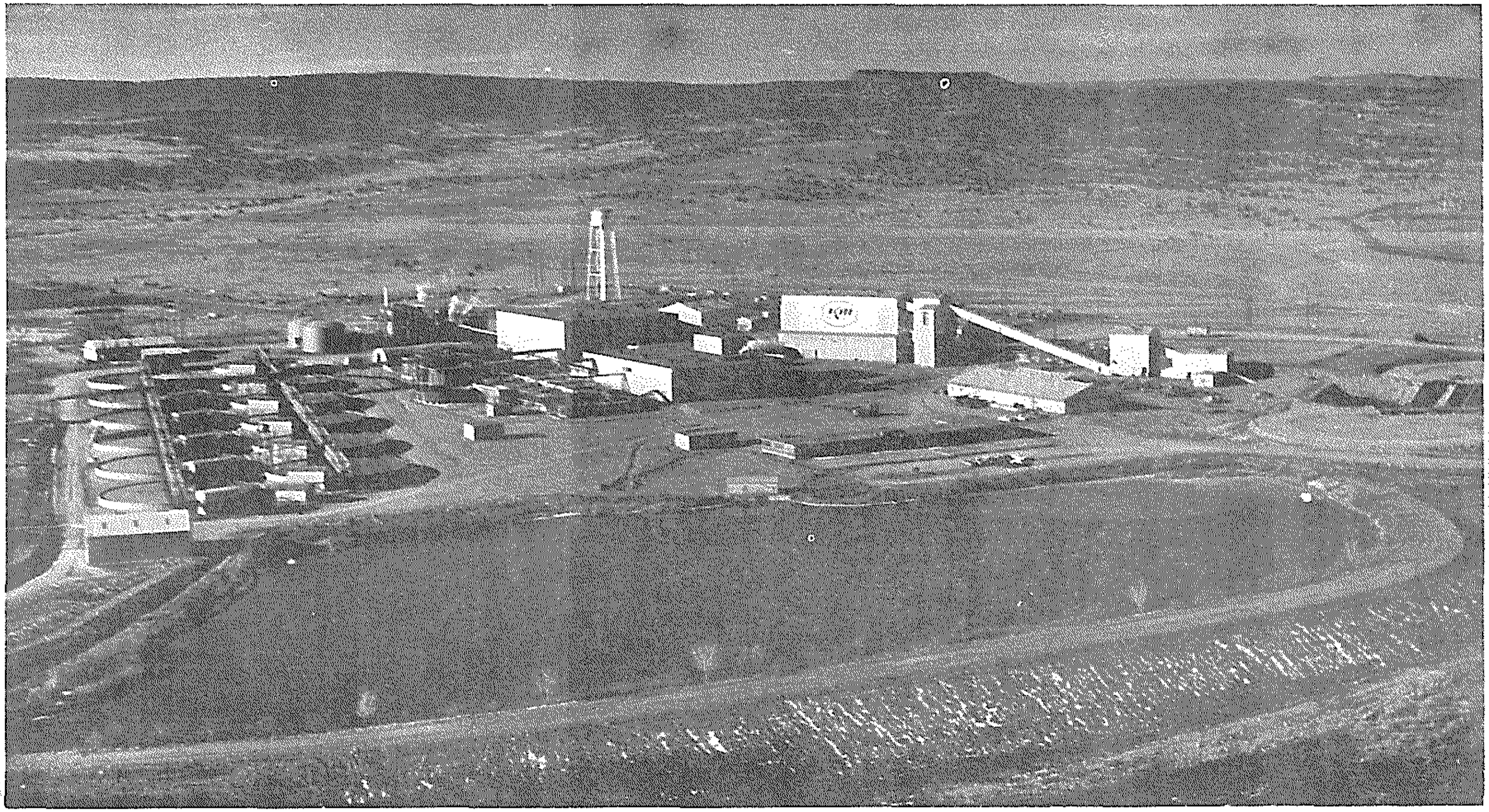
Geology and Ground-Water Occurrence in Southeastern McKinley County, New Mexico



By
James B. Cooper
&
Edward C. John

Prepared in cooperation with
the United States Geological Survey

Geology and Ground-Water Occurrence in Southeastern McKinley County, New Mexico



Nuclear Fuels uranium-processing plant at Ambrosia Lake in southeastern McKinley County, N. Mex. Waste-disposal pond in foreground, Haystack Mountain in center background, Zuni Mountains, far right background. Photograph courtesy Kerr-McGee Corporation.

TECHNICAL REPORT 35

New Mexico State Engineer
Santa Fe, New Mexico

Geology and Ground-Water Occurrence in Southeastern McKinley County, New Mexico

By
James B. Cooper & Edward C. John

United States Geological Survey

1968

REPRINTED 1978

CONTENTS

CONTENTS

ILLUSTRATIONS

TABLES

GEOLOGY AND GROUND-WATER OCCURRENCE IN SOUTHEASTERN MCKINLEY COUNTY, NEW MEXICO

By

James B. Cooper and Edward C. John

ABSTRACT

This report describes the geology and ground-water resources of southeastern McKinley County in northwestern New Mexico. This area of about 1,300 square miles is topographically diverse and contains mountains, broad flat valleys, steep escarpments, flat mesas, sloping plains, volcanic cones, lava flows, and solitary buttes. Altitudes of the land surface range from about 6,000 feet to about 9,000 feet. The climate is semiarid; average annual precipitation ranges from 10 to 20 inches, depending on altitude of the land surface. The area contains neither perennial streams nor large permanent bodies of surface water. Most of the area is sparsely populated; mining and ranching are the principal occupations.

Southeastern McKinley County is in the southern part of the San Juan structural basin. Rocks exposed range in age from Permian to Quaternary; the beds dip northward and northeastward, toward the center of the basin, at angles of 3° to 5°. Ground water, commonly under artesian pressure, is yielded to wells from at least 16 distinct aquifers. The principal aquifers in the southwestern part of the area are the Glorieta Sandstone and San Andres Limestone of Permian age and the Chinle Formation of Late Triassic age. The Westwater Canyon Member of the Morrison Formation of Late Jurassic age is the principal aquifer in the central part of the area. Units of the Mesaverde Group of Late Cretaceous age are aquifers in the remainder of the area.

Yields of 300 gallons per minute or more are obtained from wells that tap the aquifer in the Glorieta Sandstone and San Andres Limestone. The other aquifers commonly yield only 5 to 30 gallons per minute to wells; larger yields are obtained locally. Water wells range in depth from 20

feet to more than 1,200 feet. Water levels in wells range from above the land surface to about 800 feet below the land surface. The chemical quality of ground water is variable; most is suitable for livestock and domestic use. The general direction of ground-water movement is downdip to the north and northeast. Recharge to aquifers is from precipitation on the outcrops and from water moving along fault zones. Most aquifers receive only scant recharge directly from precipitation because their outcrop areas are small.

Withdrawals of ground water in southeastern McKinley County were insignificant before 1951. Since that time, mining of uranium ore from the water-bearing Westwater Canyon Member of the Morrison Formation in the Ambrosia Lake and Smith Lake areas has created widespread interest in the occurrence, control, and disposal of ground water associated with the ore. In addition, many new wells were drilled to supply water for uranium-processing mills and housing developments, and to support installations for the mining industry.

INTRODUCTION

Purpose and Scope of Investigation

Southeastern McKinley County, in northwestern New Mexico, is underlain by water-bearing rocks that, in places, contain extensive deposits of uranium ore. Mining of this valuable ore was begun in 1951, thus creating widespread interest in the occurrence, control, and disposal of ground water associated with the ore. Concurrent with the problem of disposing of unwanted ground water in the mines was a large increase in the demand for such water for domestic and industrial use in ore-processing mills and in allied industries near the mining districts.

Prior to the advent of uranium mining and processing, use of water in southeastern McKinley County was primarily for livestock and domestic supplies. The water needs of the ranches were satisfied by small-yield wells widely spaced over the grazing land. Closely spaced wells were found only in a few settlements. Almost no information on the ground-water resources of this area was available to the public.

As a part of the continuing program of investigation of the water resources in the State, southeastern McKinley County was studied by the U.S. Geological Survey in cooperation with the New Mexico State Engineer. The objectives of the investigation were to determine the general availability and chemical quality of ground water, with particular emphasis in those areas where water occurs in strata that contain large bodies of uranium ores, and to determine the principal aquifers, their areal extent, and their areas of recharge and discharge.

The ground-water data contained in this report were obtained by field investigations made between October 1957 and October 1962. Most of the geologic data in the report were obtained from published reports; reconnaissance observations only were made in the field.

Early phases of the field work were restricted mainly to collection of data concerning test wells, exploratory test holes, and mine-shaft excavations. These data were made available by mining companies active in the Ambrosia Lake mining district.

Field work later was extended throughout the area of investigation and consisted of collecting data concerning domestic, stock, and industrial wells from well owners, as well as of locating wells and springs, measuring water levels in wells, and collecting water samples for chemical analysis.

Information about the water-bearing formations was obtained in the field by observation and from logs of wells furnished by well owners and water-well drillers.

The well-inventory and water-sampling phases of the study were completed by E. C. John who joined the project in September 1962. The well-record table, chemical-analysis table, hydrologic map, and parts of the text were prepared by Mr. John.

The report contains records of 230 wells and 27 springs. The chemical quality of the ground water is shown by 121 analyses of water collected from selected wells, springs, and mines. The type and character of the subsurface formations that yield water to wells in the area are indicated by 49 logs of water wells, oil-test wells, and exploratory oil-test drill holes.

Location and Extent of the Area

McKinley County is in the northwest quarter of New Mexico. The southeastern part of the county, described in this report, is an area of about 1,300 square miles adjacent to Sandoval County to the east and Valencia County to the south (fig. 1). A small part of Valencia County which contains the community of San Mateo is also included in the report.

Previous Investigations

A descriptive report of Mount Taylor and the Zuni Plateau is contained in the earliest report of geological investigations in the area (Dutton, 1885). Darton (1928) described the Zuni Mountains and the general stratigraphy of the region. The geology and fuel resources of the sedimentary rocks in the eastern part of the area, near Mount Taylor, were described by Hunt (1936).

A great amount of geologic work has been done in the area since the 1930's by investigators interested primarily in mineral resources such as coal, oil, and uranium. As a result, the surface geology of the entire area has been mapped and described in numerous published reports. Some parts of the area have been studied several times and described in considerable detail. A list of reports dealing with various aspects of the

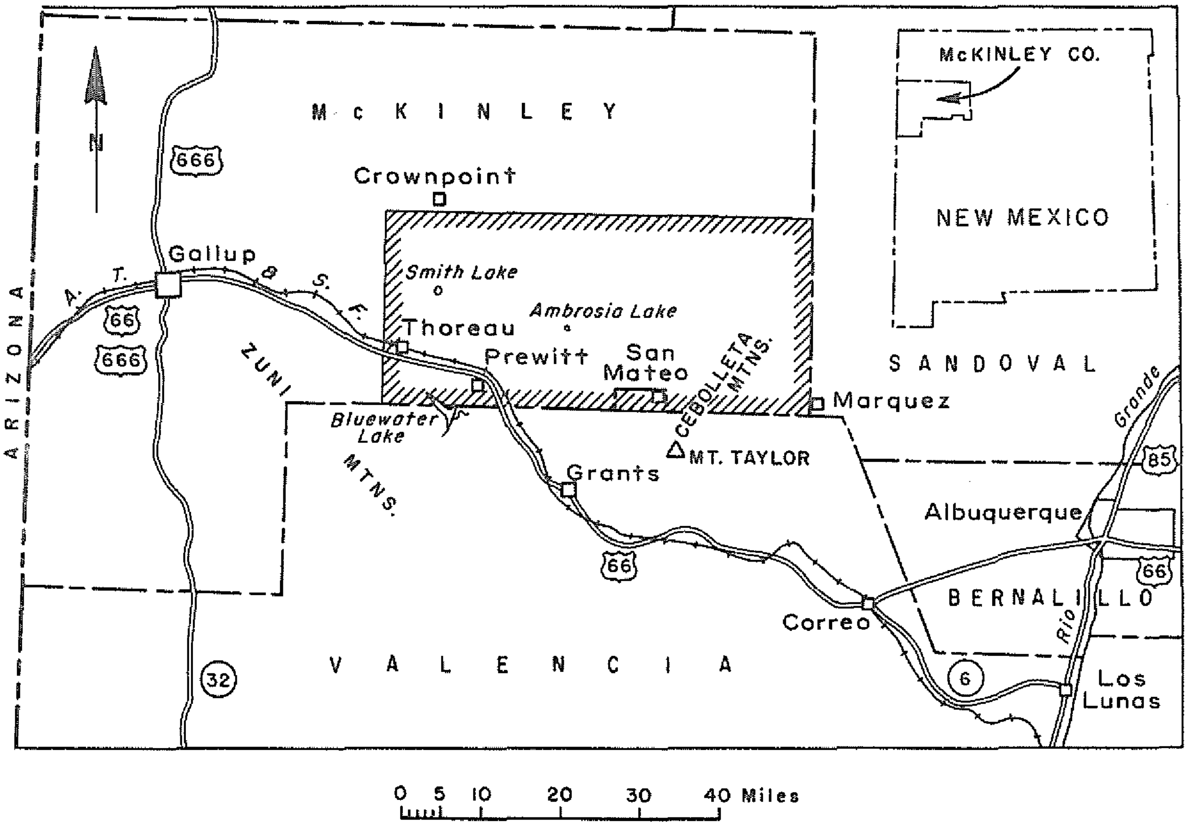


FIGURE 1. -- Area (outlined in hachures) discussed in this report.

geology of southeastern McKinley County is given in the "selected references" section of this report.

The ground-water resources of the area had not previously been studied in detail. Casual mention of flowing wells and of watering places are found in a few of the earlier geologic reports.

Water-supply investigations in the vicinity of Thoreau and Prewitt were made in 1948 by Halpenny and Whitcomb (1949). These investigations were made to determine the possibilities of obtaining additional water for Indian schools in the several communities.

A small part of the area, consisting of T. 13 N., Rs. 9-12 W., adjacent to the Valencia County line, was included in a report of the geology and ground-water resources of the Grants-Bluewater area (Gordon, 1961) prepared by the U.S. Geological Survey in cooperation with the New Mexico State Engineer.

Community water supplies and uses within the study area and in neighboring towns and villages also have been inventoried and reported (Dinwiddie and others, 1966).

Acknowledgments

Thanks are extended to the many well owners of the area who provided information regarding their wells and to personnel of the several mining companies who furnished records of exploratory holes and water wells, geologic information, and pumpage data. Particular recognition is given to Homestake-New Mexico Partners, Homestake-Sapin Partners, Kermac Nuclear Fuel Corp., and Phillips Petroleum Co. Logs of water wells were obtained from several sources, in particular from Fred and Paul Hubbell and the Navajo Tribe. Zane Spiegel, Robert L. Borton, and Francis G. West of the New Mexico State Engineer Office reviewed data pertaining to the San Juan structural basin and offered constructive criticism.

Well-Numbering System

The system of numbering wells (also springs and mines) in this report, which is used generally by the Geological Survey and the New Mexico State Engineer throughout the State, is based on the common subdivision of public lands into sections. The system is illustrated in figure 2. The number, in addition to designating the well, locates its position to the nearest 10-acre tract in the land network. The number is divided by periods into four segments. In this report, the first segment denotes the township north of the New Mexico base line, the second segment denotes the range west of the New Mexico principal meridian, and the third segment denotes the section; the fourth segment, which consists of three digits, locates the well in a particular 10-acre tract. For this purpose, the section is divided into four quarters, numbered 1, 2, 3, and 4, in the normal reading order--the northwest, northeast, southwest, and southeast quarters, respectively. The first digit of the fourth segment indicates the quarter section, which usually is a tract of 160 acres. Similarly, the quarter section is divided into four 40-acre tracts numbered in the same manner, and the second digit denotes the 40-acre tract. Finally, the 40-acre tract is divided into four 10-acre tracts, and the third digit denotes the 10-acre tract. Thus, well 14.10.24.342 in McKinley County is in the NE$\frac{1}{4}$SE$\frac{1}{4}$SW$\frac{1}{4}$ sec. 24, T. 14 N., R. 10 W. If a well cannot be located accurately to a 10-acre tract, a zero is used as the third digit, and if it cannot be located accurately to a 40-acre tract, zeros are used for both the second and third digits. If the well cannot be located more closely than the section, the fourth segment of the well number is omitted. Letters a, b, c, etc., are added to the last segment to designate the second, third, fourth, and succeeding wells in the same 10-acre tract. The designation of a well location should not be considered to be the absolute location, as the section lines and the well locations are not always accurately surveyed. Wells listed in this report were located mainly by automobile odometer and by inspection of aerial photographs and topographic maps and are believed to be accurate to within 0.1 mile.

In the eastern part of the study area several blocks of grant land have not been sectionized. To locate wells within these grants, by the numbering system described, section lines were projected from the sectionized parts of the area into the unsectionized parts. The projected lines are shown by dashes on maps accompanying this report.

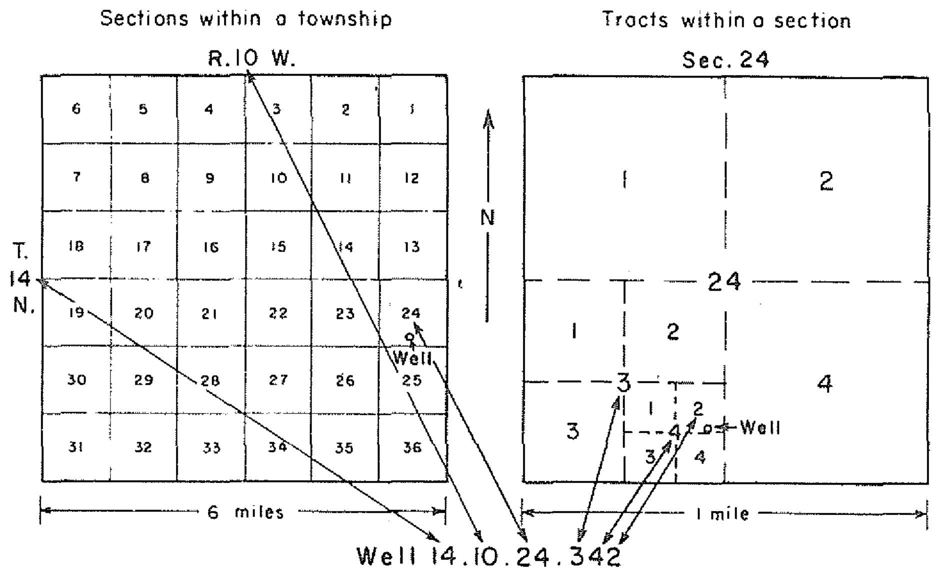


FIGURE 2. -- System of numbering wells in New Mexico.

GEOGRAPHY

Population and Transportation

Southeastern McKinley County is a sparsely populated land used mostly for grazing of cattle and sheep. Vegetation likewise is sparse, and grazing ranges of several thousand acres commonly are used by a single rancher. Temporary camps for herders and ranch workers are scattered over the ranges; however, only a few working ranch headquarters are maintained within the area and many of the ranch operators reside in nearby villages and towns. About 40 percent of the land is privately owned (New Mexico Land Resources Association, 1958), and the largest units are in land grants such as Cebolleta Grant, Bartolome Fernandez Grant, and Ignacio Chavez Grant, all in the eastern part of the area. In the western and northwestern parts, off-reservation Navajo Indian lands total about 300 square miles. The Cibola National Forest, mainly in the southeastern part of the area, accounts for nearly 200 square miles. The remainder of the land, most of which is leased for stock-grazing, is public domain or State owned.

Thoreau and Prewitt, along the main line of the Atchison, Topeka, and Santa Fe Railway and U.S. Highway 66 in the southwestern part of the area in McKinley County, and San Mateo, in Valencia County, are the largest communities. In 1965, Thoreau had an estimated population of 400, San Mateo of 300 (Dinwiddie and others), Prewitt of somewhat less.

Smith Lake, San Antonio Spring, and the Borrego Pass Trading Post are permanent settlements inhabited by Indian missionaries and Indian traders and their families. The community of Marquez in the extreme southeastern part of the area is divided by the McKinley-Sandoval County line (pl. 2).

Several hundred people reside in trailers and temporary housing at and near the mining district of Ambrosia Lake, and trailer courts have been established near Thoreau and Smith Lake.

An Indian population is scattered over the western quarter of the area, and non-Indian families are concentrated near Bluewater Lake, Thoreau, Smith Lake, and Borrego Pass. Only rarely do the Navajo reside in year-round, permanent quarters. Two or more temporary camps, with hogans for shelter, commonly are occupied seasonally in accordance with availability of forage for the flocks of sheep which are the main source of income for the Navajo living in this area.

The population of the Crownpoint census district, which includes the entire eastern half of McKinley County, is given in the 1960 census as 7,271. It is estimated that less than half of that number reside in the area of this investigation.

The nearest major trade centers are Grants in Valencia County and Gallup in McKinley County. Albuquerque, about 100 miles to the east, is the principal cultural and economic center for the area.

The most populous parts of the area are connected by all-weather roads. State Highway 56 crosses the northwestern part of the area and junctions with U.S. Highway 66 at Thoreau. State Highway 53 from San Mateo junctions with ranch road 509 to Ambrosia Lake, and connects with U.S. Highway 66 in Valencia County. The few other roads in the area range from graded gravel-surface to unmarked trails suitable only for travel in good weather by four-wheel-drive vehicles.

Economic Development

According to records of the New Mexico State Inspector of Mines (1962) the value of uranium production in McKinley County in the year ending June 30, 1962, was $57,431,391. Most of the uranium was produced from the 30 or so operating mines, both deep-shaft and incline, at or near Ambrosia Lake, and from a few mines near Smith Lake. More than 2,000 people were employed in the uranium-mining industry.

Two uranium-processing mills are at Ambrosia Lake. The Kermac Mill, operated by the Kermac Nuclear Fuels Corp., employs about 100 people. The Phillips Mill, formerly owned and operated by the Phillips Petroleum Co., employed about 125 persons but was closed in early 1963.

The area produces no other notable minerals. Minor amounts of coal and limestone, sand and gravel, and volcanic cinders for road metal are mined whenever a local market warrants.

Petroleum has not been produced within the area. A number of oil-test wells have been drilled; however, the small show of oil found in a few wells has been insufficient to produce economically.

An oil pipeline connects oil fields at Hospah, about 6 miles north of the area, with a refinery at Prewitt. This refinery, owned by the El Paso Natural Gas Products Co., is on standby status and was not in operation at the time of the investigation. Two transcontinental gas pipelines traverse a part of the area; the Bluewater Compressor Station of the El Paso Natural Gas Co. and Compressor Station No. 5 of the Transwestern Pipe Line Co. are near Thoreau.

In the past, the timber industry flourished in forest areas near Thoreau and east of San Mateo; at present, logging is confined to an occasional thinning of timber stands.

Indian trading posts, small businesses, and tourist courts are spaced along U.S. Highway 66. The U.S. Bureau of Indian Affairs maintains schools for several hundred Indian pupils at the Baca Day School, just west of Prewitt; at the Thoreau Day School, at Thoreau; and at the Borrego Pass Day School, just south of Borrego Pass.

The economy of the remainder of southeastern McKinley County is based on livestock production; cultivation is not practiced except for small irrigation developments at Marquez and San Mateo.

Physical Features

Southeastern McKinley County occupies parts of two sections of the Colorado Plateau physiographic province--the Navajo, with young plateaus, and the Datil, with lava flows and volcanic necks (Fenneman, 1931, pl. 1).

Dominating regional features visible from most parts of the area are the Zuni Mountains, which rise to altitudes of more than 9,000 feet above sea level, and Mount Taylor, both south of the study area. Mount Taylor rises 11,389 feet above sea level and is surrounded by widespread basalt flows that form flat-topped mesas, studded with numerous volcanic vents, at altitudes up to 9,000 feet. These basalt flows cover about 200 square miles in the southeastern part of the area and form the Cebolleta Mountains.

The Continental Divide crosses the western part of the area, from just west of Thoreau to a few miles northeast of Borrego Pass. Prominent landmarks on and near the Continental Divide are Mount Powell (altitude 8,748 feet) and Hosta Butte (altitude 8,620 feet).

The Zuni Mountains form a northwest-southeast-trending domal uplift which crosses the southwest corner of the area. Sedimentary rocks of the uplift dip northward or northeastward under younger rocks.

Within the area, the topographic and physical features are quite diverse and include broad flat valleys, steep escarpments, flat mesas, sloping plains, volcanic cones, lava flows, and solitary buttes.

The most striking physical features of southeastern McKinley County are the alternating steep cuestas, long dip slopes, and valleys which have developed in the tilted sedimentary rocks, parallel to the trend of the Zuni uplift. Several canyons breach the northwest-southeast-trending rock escarpments and at places divide them into mesas. The three major valleys north of the uplift contain the settlements, ranches, and mining districts of the area.

Altitudes range from about 6,200 feet in the northeast corner to 9,000 feet in the Cebolleta Mountains in the southeast corner. The Zuni Mountains slope northwestward from an altitude of 7,800 feet to about 7,000 feet.

The valley that contains the communities of Thoreau and Prewitt is traversed by U.S. Highway 66 and the Santa Fe Railway and extends northwestward from the mesas west of the Cebolleta Mountains through the southwestern part of the area. This valley averages about 3 miles in width and is delineated on the south by rocks that dip off the Zuni uplift and disappear beneath the alluvium in the valley at altitudes between 6,800 and 7,200 feet. Sheer walls of orange-red sandstone, more than 200 feet in height, rise abruptly from the northern valley edge. Capping these sandstone cliffs are younger sedimentary rocks that form slopes and escarpments at altitudes over 8,200 feet. This colorful topographic feature is particularly evident north of the railway in the vicinity of Thoreau and Prewitt.

Another valley, averaging about 4 miles in width with numerous restrictions and reentrants, extends from the Cebolleta Mountains to the northwest corner of the area. The mining districts of Ambrosia Lake and Smith Lake are in this valley. The valley's south edge is marked by rocks dipping northeastward off the southernmost escarpment. Massive beds of sandstone and shale form steep cliffs along the northern edge. Altitudes of the valley floor range from 6,900 feet in the southeast to about 7,600 feet in the northwest.

San Mateo Mesa, overlooking the Ambrosia Lake district, is about 1,300 feet above the valley floor and crests at an altitude slightly above 8,200 feet.

The northeast slopes, or back slopes, of San Mateo Mesa and of most of the central escarpment descend to altitudes of 7,000 to 7,400 feet within an average distance of about 6 miles. The valley into which these rocks slope, comprising nearly the entire north-northeastern one-third of southeastern McKinley County, is a desolate region. The surface of this wide valley slopes gently northward and eastward and is heavily eroded and incised by north- and east- trending arroyos. Outcrops of shale are numerous and only a thin soil mantle is present at most places.

A valley about a mile wide within the Zuni Mountains south of Thoreau contains a few ranch headquarters along Azul Creek, an intermittent stream that drains the area from the mountains to Bluewater Lake. The altitude of this valley is about 7,400 feet.

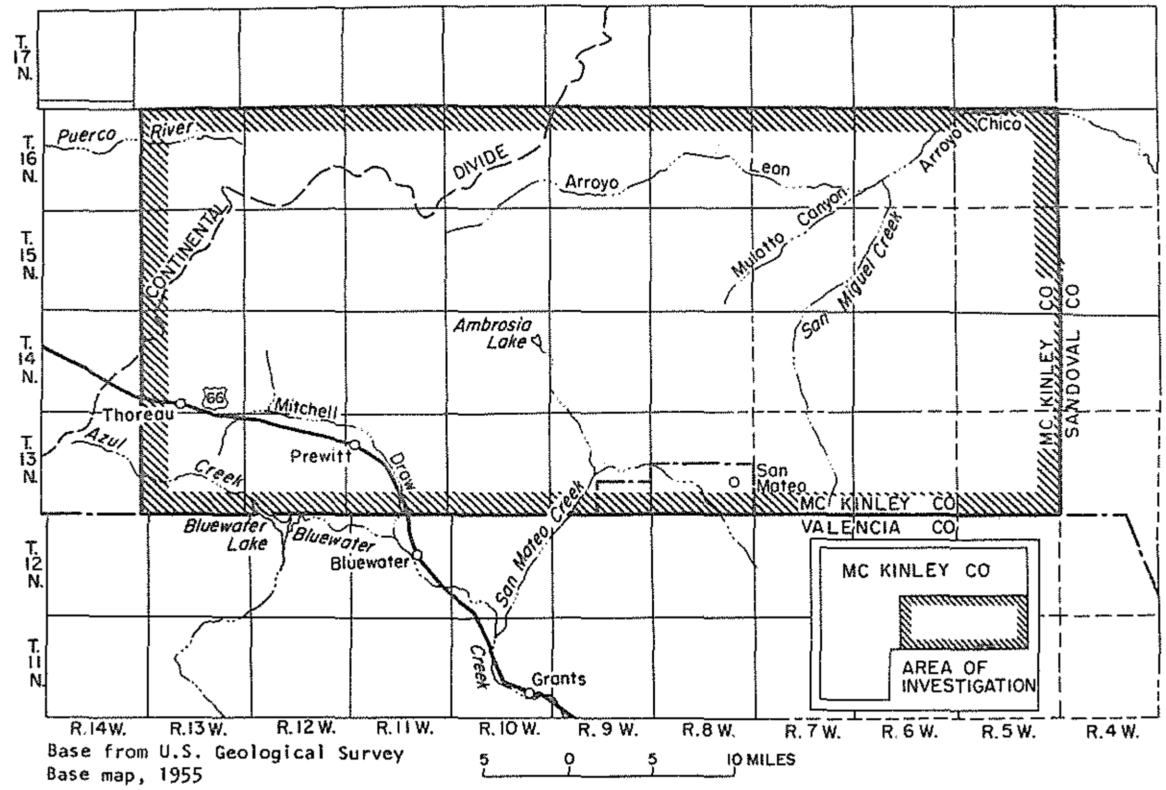


FIGURE 3. -- Major surface-drainage courses in southeastern McKinley County, N. Mex.

Prominent topographic features in the south-central part of the area are Haystack Mountain, a large flat-topped butte, and El Tintero (Spanish: ink bottle), a conical basaltic crater. Haystack Mountain is about 5 miles east of Prewitt and, in 1950, was the site of the discovery of uranium minerals which triggered the large-scale mining boom in the general area. El Tintero, about 1 mile south of Haystack Mountain, is the source of a basalt flow which covers about 10 square miles in McKinley County and extends many miles south and east into Valencia County.

Several volcanic necks are in the Bartolome Fernandez Grant, adjacent to the northwest edge of the Cebolleta Mountains. The most impressive of these volcanic rocks is Cerro Alesna (awl hill), a beautiful, columnar, volcanic neck which rises 1,200 feet above the surrounding plain to an altitude of 8,000 feet. The neck and its enclosing talus slope cover an area of about 1 square mile.

No perennial streams are within the area. The most prominent drainages are Azul Creek, in the Zuni Mountains; Mitchell Draw, which heads a few miles east of Thoreau; San Mateo Creek, which drains the Ambrosia Lake area and the highlands near San Mateo; and Mulatto Canyon, San Miguel Creek, Arroyo Leon, and Arroyo Chico, which drain the northeastern part of the area (fig. 3). Azul Creek and Mitchell Draw drain to the southeast. San Mateo Creek drains to the west and southwest and joins Bluewater Creek near Grants in Valencia County. The northern arroyos trend eastward and northeastward and discharge to Rio Puerco in Sandoval County. Drainage west of the Continental Divide is to the Puerco River that heads near Hosta Butte.

Ambrosia Lake, Casamero Lake, and Smith Lake are natural depressions that are normally dry and contain water only after heavy rains. Intermittent lakes and ponds are in the volcanic craters of the Cebolleta Mountains. The only permanent body of water in the area is an arm of Bluewater Lake which extends up the valley of Azul Creek. Bluewater Dam, a concrete structure 80 feet high, was constructed in 1927 at the junction of Azul Creek and Bluewater Creek in Valencia County as an irrigation venture. The Game and Fish Commission maintains a permanent pool in the lake and its waters are used largely for fishing and boating. Since 1960, the lake levels have been high enough to allow release of some water for irrigation of lands adjacent to Bluewater Creek in Valencia County.

Climate

The climate of southeastern McKinley County is semiarid. In most years, sunshine is abundant and relative humidity is low. The average annual temperature is about 51°F; however, there is considerable variation in annual and daily temperatures. Maximum summer temperatures rarely exceed 100°F; minimum winter temperatures may be lower than 0°F. Daily variation in temperature commonly ranges as much as 30°F. The topographic diversity of the area and the correlative differences in altitude cause considerable variations in temperature and precipitation within short distances.

Average annual precipitation in the higher parts of the Cebolleta Mountains is about 20 inches (New Mexico State Engineer Office, 1956). Precipitation ranges from 12 to 16 inches along the Continental Divide and from 10 to 12 inches at lower elevations in the area. Figure 4 shows annual precipitation at weather stations in and near southeastern McKinley County.

The months of heaviest rainfall are generally July, August, and September, when 50 percent or more of the total annual precipitation is commonly recorded. This precipitation falls almost entirely during brief, frequently intense, thundershowers. Some snow accumulates at higher altitudes during winter.

The Cebolleta and Zuni Mountains support large stands of ponderosa pine and douglas fir. Spruce, aspen, and several varieties of fir grow at higher elevations. Widespread woodlands of pinon and juniper are on the lower slopes of the mountains, in belts generally along the dip slopes of the northwest-trending escarpments, and on the mesas. Extensive grasslands are in the two southernmost valleys. The northernmost valley has a sparse growth of grasses and contains much sagebrush and tumbleweed.

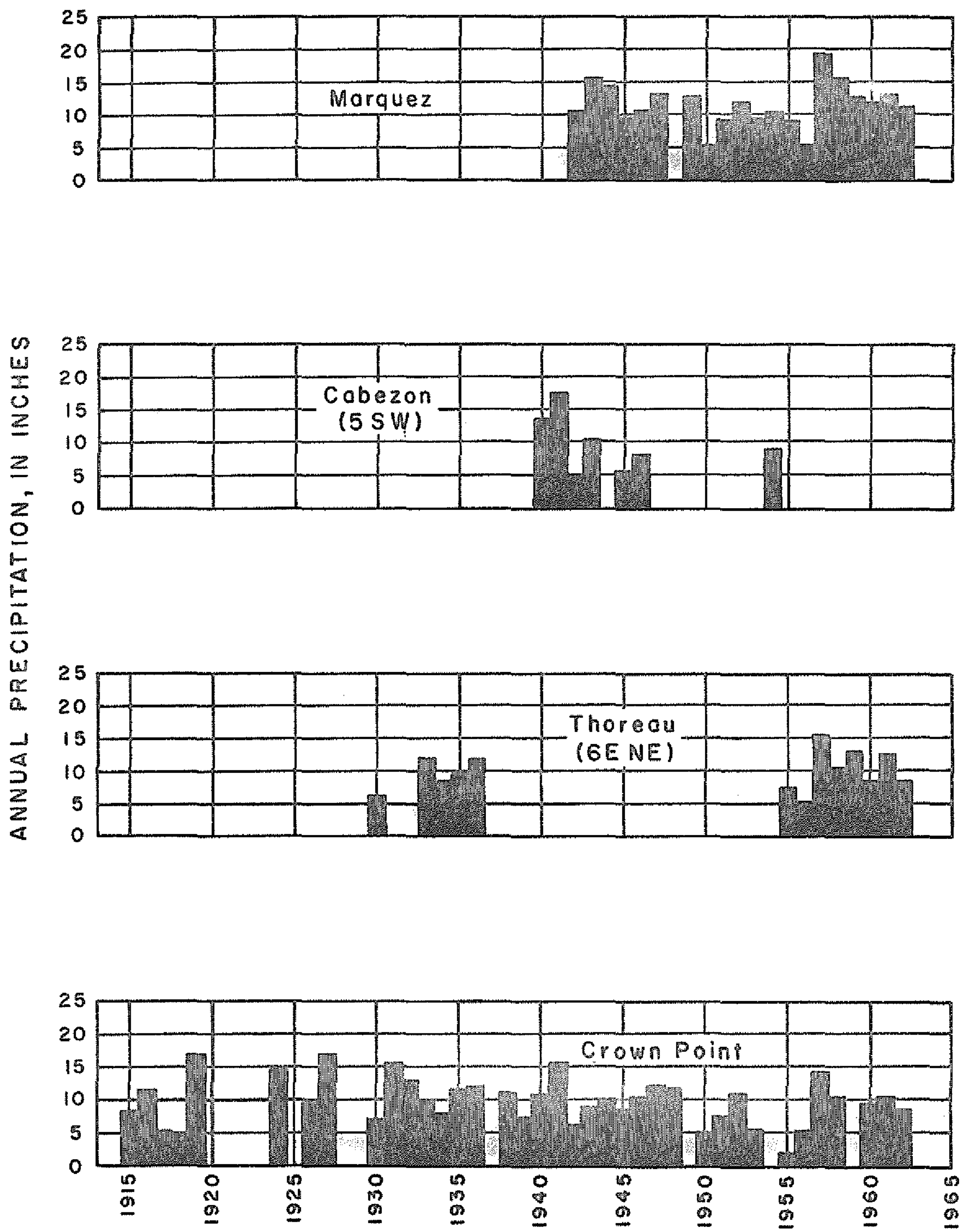


FIGURE 4. -- Annual precipitation at selected weather stations in or near area of investigation.

GEOLOGIC STRUCTURE

The study area is in the southern part of the San Juan structural basin. This structural basin is a roughly circular depression about 25,000 square miles in area that lies mostly in the northwestern part of New Mexico but extends slightly into Colorado and Arizona. The average negative structural relief is nearly 5,000 feet, but the structural relief against the San Juan dome is about 20,000 feet and against the Nacimiento uplift about 14,000 feet (Kelly, 1957, p. 44).

Elements of the San Juan structural basin (fig. 5) were outlined and discussed by Kelley (1950, p. 102) (1957, p. 46). Southeastern McKinley County is within parts of three of these elements--the Zuni uplift, the Acoma sag, and the Chaco slope. The Zuni uplift is about 55 miles long and 20 miles wide and occupies the southwestern corner of the study area. Sedimentary rocks dip northerly at angles of 3° to 5° from the central core of the Precambrian rocks of the uplift. The structural relief is at least 5,000 feet. The Acoma sag, in the southeastern corner of the area, slopes very gently northward and is strongly asymmetric with a relatively short western limb, which is also the eastern flank of the Zuni uplift. Steeper dips are prevalent where the rocks of the sag dip into the McCartys syncline. McCartys (Mt. Taylor) syncline is a broad, shallow, northward-plunging fold that passes under the Mount Taylor area and the Chaco slope. The Chaco slope occupies about 75 percent of the central and northern part of the study area. It is a strip of land of low, northerly, regional dip that is 110 miles long and as wide as 40 miles. The average dip is about 1° and the structural relief is nearly 2,500 feet.

The San Juan structural basin is mostly within the boundaries of the San Juan river basin. In an attempt to avoid confusion between the two distinct basins the approximate boundaries of both basins are shown in figure 5. The boundaries of the San Juan river basin enclose land areas in which drainage courses contribute surface-water runoff to the San Juan River. This drainage heads on the Continental Divide in the San Juan Mountains north of Pagosa Springs, Colorado, and extends through northwestern New Mexico into Utah where the San Juan River joins the Colorado River. In this report the boundaries of the San Juan structural basin are drawn approximately along the structural divides of the various elements around its margin so as to enclose land areas where the rocks have pronounced dips inward toward the lowermost regional structural point. Because of discontinuity of the structural elements and local variations in the dip of the rocks, and erosion, the boundaries of the San Juan structural basin do not coincide with the boundaries of the San Juan river basin.

The general regional dip of the sedimentary rocks in most of southeastern McKinley County is northward and northeastward across the Chaco slope into the Central basin, or "San Juan Basin proper" (Kelley, 1957, p. 48).

The major surface structures of the study area are the north flank of the Zuni uplift and the north end of the McCartys syncline. Numerous smaller structural features that have surface expression in the study area include the Miguel Creek dome, the San Mateo dome, and the Ambrosia anticline (Hunt, 1936, pl. 18).

The Miguel Creek dome is a faulted dome that has a closure of 500 feet (Hunt, 1936, p. 58). The structure is roughly circular, with nearly parallel east-west faults cutting the flanks. The south and east flanks of the dome join the northwestern part of McCartys syncline. The west flank joins the east side of a broad, shallow, north-south syncline, and the north flank is a continuation of the regional northward dip of the Chaco Slope.

The San Mateo dome has a closure of 150 feet (Hunt, 1936, p. 58). The north and east flanks descend steeply for a vertical distance of about 1,500 feet. The east flank is highly faulted and coincides with part of the west side of the McCarty syncline. The north flank dips into the trough of the syncline west of the Miguel Creek dome, and the southwest flank has only a slight reversal of dip before the beds resume their regional rise toward the Zuni Uplift.

The Ambrosia anticline is northward-plunging; the west flank dips steeply into the north-south Ambrosia fault (Hunt, 1936, p. 59). Faulting has caused a series of horsts and grabens along the northeast flank.

The area has been subjected to considerable faulting and contains numerous faults and fault zones. Many of the faults are of small throw; however, a number have displacements of several hundred feet. Hunt (1936, p. 22) inferred a close genetic relationship between the folds and faults of the area, as the amount of faulting is roughly proportional to the degree of folding, and he stated that faults are not common where the gentle regional northward dip prevails, but wherever folds have developed faults are prominent.

The Bluewater fault extends northward from near Bluewater Lake to near Smith Lake. It is obscured by alluvium in the valley north of Highway 66 but is well exposed near both its north and south ends. Maximum throw along the Bluewater fault zone ranges from 200 to 400 feet (Smith, 1954, p. 22).

The Ambrosia fault, just west of Ambrosia Lake, trends northward for a distance of about 10 miles. The vertical displacement is 200 feet at the southern end and 400 feet in the central part (Hunt, 1936, p. 61).

A rather striking fault zone extends northeastward for several miles adjacent to State Highway 53 along the valley of San Mateo Creek. At the junction of the highway with the road to Ambrosia Lake, the displacement on the southeast, or downthrown, side of the fault is about 250 feet.

About 7 miles east of the Bluewater fault zone, and north of Prewitt, Smith (1954, p. 22) reported a fault with a throw of more than 700 feet. Hunt (1936, p. 62) observed a north-south fault with a maximum displacement of 725 feet about 3 miles west of San Mateo.

RELATION OF GROUND WATER TO THE GEOLOGIC ENVIRONMENT

Wells are the most dependable and widely used source of water in southeastern McKinley County. Water wells range in depth from less than

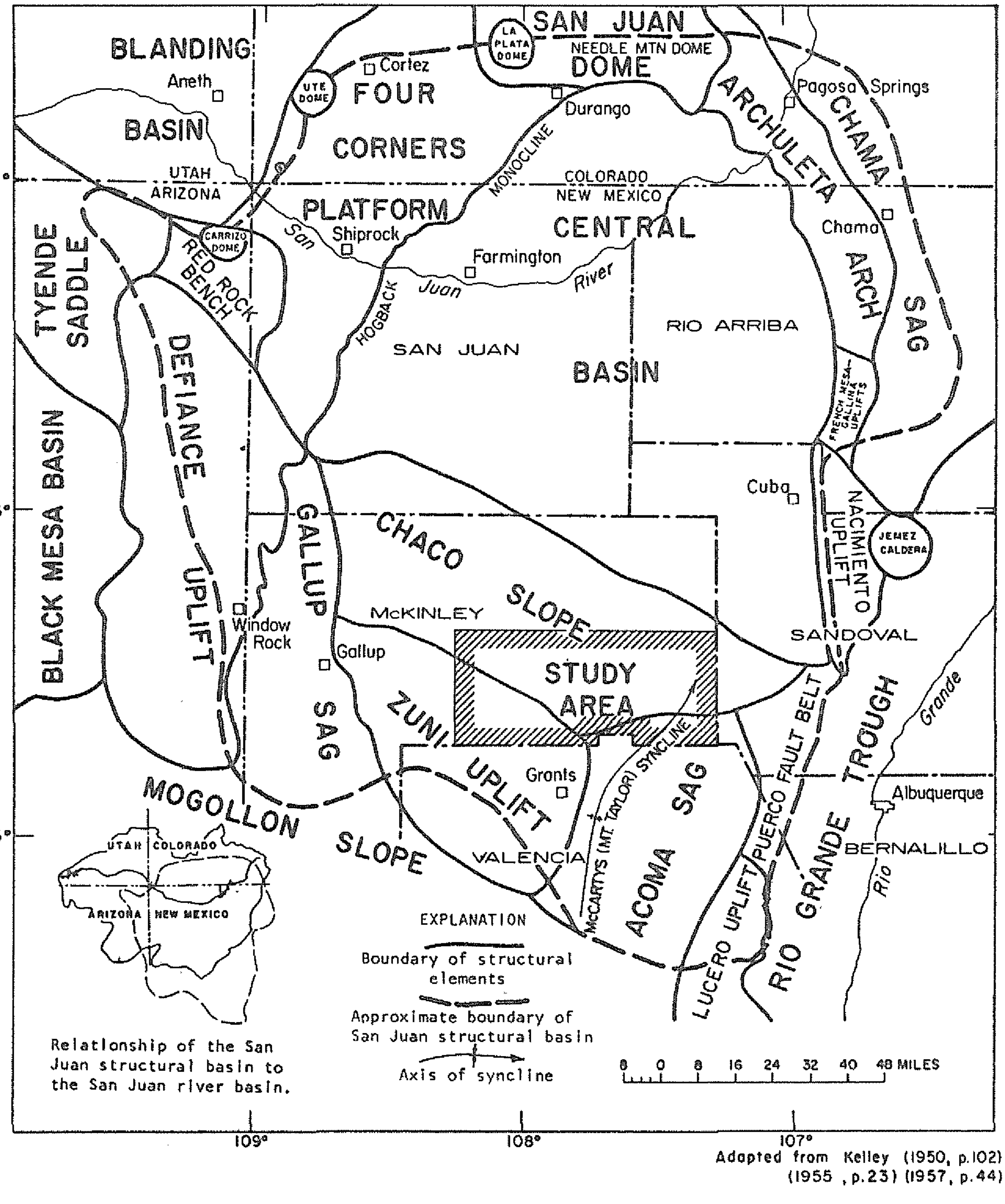


FIGURE 5. -- Elements of the San Juan structural basin.

20 feet to more than 1,200 feet. Several wells that presently yield water were drilled to greater depths as oil tests; when abandoned as oil-test wells, they were converted to water wells. Two water-test wells near Ambrosia Lake were drilled to depths of more than 3,000 feet. The locations of many wells in southeastern McKinley County are shown in plate 2. Records of these wells appear in table 1.

Perennial supplies of surface water do not exist, except for a few springs (pl. 2 and table 2), principally in and near the mountainous areas. A few earthen dams in drainageways store surface runoff for stock use; however, high rates of evaporation and seepage cause this ponded water to be available for use only during parts of the year. Wells are used throughout the area to provide domestic, stock, and industrial water supplies.

Southeastern McKinley County has aquifers in rocks of several geologic ages. The presence, character, and depth of many of these aquifers are indicated at places by the logs of wells drilled for water, oil, or for exploratory purposes. Table 5 contains logs of 48 wells and gives descriptions of formations penetrated during drilling of the wells. Many of the logs also contain hydrologic and well-construction data.

The geologic framework of the area controls the occurrence of ground water. Precipitation and runoff have little chance to infiltrate because the outcrops of the aquifers are mostly in narrow bands and often stand as cliffs or steep slopes. Recharge is further limited because much of the precipitation occurs in summer thunderstorms and the water runs off rapidly. The water that infiltrates the aquifers moves by gravity downward to the water table. It then moves downgradient in the saturated zone of the aquifer to the northeastward, which in this area is also the general direction of dip of the formations.

Several of the logs in table 5 were used in preparation of a diagrammatic section (fig. 6) which shows the structure of the formations in the subsurface from southwest to northeast across a part of the area. The section shows that progressively younger formations are exposed basinward (northeastward), beginning with rocks of Triassic age and ending with rocks of Late Cretaceous age. As the older formations become more deeply buried basinward, the younger formations become more economical and more available aquifers. Varied geologic conditions in the area, such as faulting and folding of the rocks, account for some of the variances in yield and chemical quality of water from wells in some formations.

The wide range in concentrations of chemical constituents in ground water within the area is due to the type and composition of the rocks that constitute the aquifers, the depths of the aquifers, and the distances of the sampling points from sources of recharge. As the water moves away from the outcrop area, the soluble components of the rocks are dissolved by the water; therefore, as a general rule, the greater the distance from the outcrop the greater the concentration of dissolved solids in the water. Rocks which contain calcite, dolomite, gypsum, carbonaceous material, or other minerals that are soluble will contain water of poorer quality than will rocks composed of clean quartz sand. Dissolved solids are also contributed to water from clay through the process of ion exchange. This often

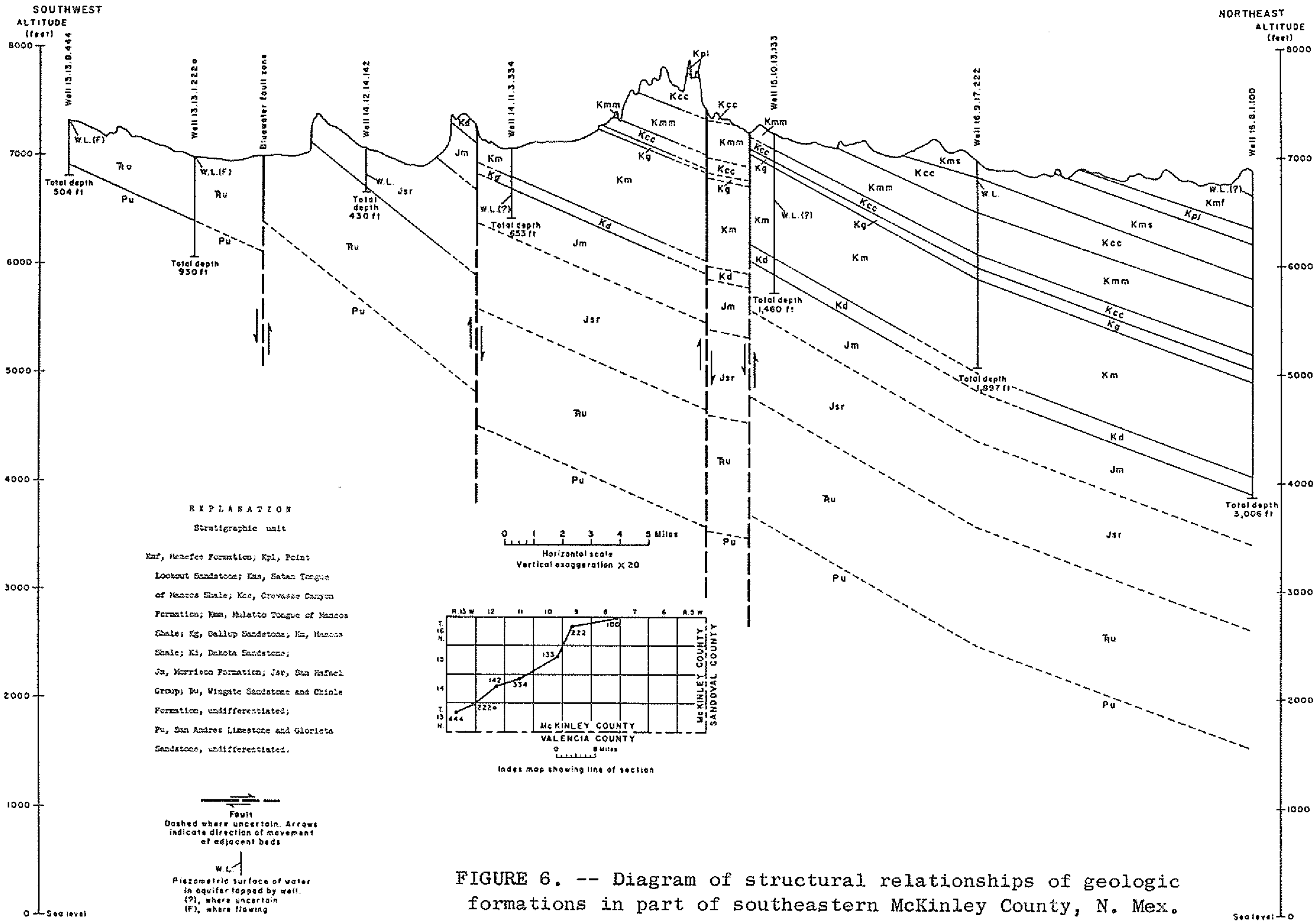


FIGURE 6. -- Diagram of structural relationships of geologic formations in part of southeastern McKinley County, N. Mex.

results in water of poor quality in aquifers containing, or confined by, clay. Parts of the aquifer with better circulation may have most of the dissolvable solids flushed out; also, as the water is in contact with soluble constituents for less time fewer solids will be dissolved. Thus water of better chemical quality is found in aquifers that are low in soluble constituents, carbonaceous material, and clay, or that have good circulation of water.

Water moves more easily through cracks and solution channels than through interstitial voids within the rocks. Rocks such as sandstone and limestone, which are brittle, are likely to be fractured and to have openings of sufficient size to allow water to move through them. Much of the permeability in beds of sandstone and limestone is in fractures and joints. Rocks such as shale usually do not have openings of sufficient size to allow water to move readily. Thus, as the stratigraphic sequence in the area is one of alternating sandstone, limestone, and shale, the water is confined by the low permeability of the shales and it has artesian head in the beds of sandstone and limestone. In most areas, water in wells rises to levels above the aquifers; wells will flow at places where the potentiometric surface is above the altitude of the ground surface.

The levels at which water stands in wells differ widely in different aquifers and even in the same aquifer, depending upon the location of the well and the altitude of the land surface at the well with respect to the outcrop of the aquifer. Water levels in wells, shown in table 1 and plate 2, range from above the land surface to a depth of about 800 feet. In general, the lowest water levels are in wells at places where the aquifer is most deeply buried.

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES

Rocks of Late Cretaceous age are exposed over most of the area, except in the southwest part where rocks of Permian age crop out in the Zuni Mountains and where rocks of Triassic and Jurassic ages are exposed in the valley and on the escarpments and mesas north and northeast of the mountains. In the southeastern corner, rocks of Cretaceous age are mostly covered by lava flows of Tertiary age. The areal distribution of the rocks is shown in plate 1.

A few deep oil-test wells have penetrated rocks older than Permian age and have reached basement rocks of Precambrian age. Little is known about these older rocks and they are not discussed in this report; however, it is believed that they contain saline water and that they are too deep to be considered as sources of water in southeastern McKinley County.

The stratigraphic sections of the geologic formations discussed in this report and brief descriptions of their physical character and water-bearing properties are shown in plate 1. Lithologic details of most of these formations, as observed by drillers in the field and by geologists from microscopic examination of drill cuttings, are given in the drillers' logs and sample-description logs of wells and test holes listed in table 5.

Permian System

Two formations of the Permian System, the Glorieta Sandstone and the overlying San Andres Limestone, crop out in southeastern McKinley County. They extend in the subsurface from the Zuni Mountains northward and northeastward to near the northern boundary of the area. The northward termination of the formations is the result of depositional thinning and later truncation (Baars, 1961, p. 118).

In the Ambrosia Lake area, about 15 miles northeast of their outcrops, both formations were reported present in a drill hole in sec. 22, T. 14 N., R. 10 W. Kermac Nuclear Fuels Corp. water well 1 (well 14.10.22.414) penetrated 110 feet of San Andres, from 2,918 feet to 3,028 feet, and was finished in Glorieta Sandstone at a depth of 3,081 feet (tables 1 and 5).

Glorieta Sandstone and San Andres Limestone

Small outcrops of Glorieta Sandstone are present in the extreme southwestern corner of the area. The thickness of the sandstone at its outcrops ranges from 120 to 220 feet (Smith, 1954, p. 7).

The Glorieta generally is a well-sorted, medium-grained, white to buff, quartz sandstone that contains thin beds of siltstone. Exposures of the sandstone weather to yellowish brown and exhibit sharply defined, alternating crossbedded and evenly bedded units. The upper part of the formation is tightly cemented, resistant to erosion; the lower part often is soft and friable.

The San Andres Limestone conformably overlies the Glorieta Sandstone. The maximum thickness of the San Andres in southeastern McKinley County is nearly 150 feet and most exposures average about 110 feet (Smith, 1954, p. 8). The thickness varies greatly because the surface of the San Andres has been subjected to a long period of erosion. At places, the limestone has been entirely removed and rocks of Late Triassic age lie directly on the Glorieta Sandstone.

The lower part of the San Andres is a bluish-gray limestone with interbedded sandstone near the base. Light-gray to yellowish-buff sandstone commonly overlies the lower unit. The upper third of the formation is grayish-pink, cherty, fossiliferous limestone or, at places, sandy limestone or calcareous sandstone. The limestone units of the San Andres are massive and in outcrop generally form continuous ledges separated by the more friable sandstone layers.

The Glorieta Sandstone and the San Andres Limestone commonly form a single aquifer. Several springs issue from these formations in the Zuni Mountains, and they yield water to wells in the mountains and in the valley along the northern edge of the mountains.

In most of southeastern McKinley County, the formations are too deeply buried to be utilized as aquifers except near Thoreau and Prewitt, and in the area to the south of these communities. Wells (14.9.28.441 and

14.10.22.414) were drilled into the aquifer near Ambrosia Lake; but, owing to the poor chemical quality of the water and the availability of better water, these wells are unused. Yields of water from the aquifer are adequate for domestic, stock, and some industrial use. Well 13.13.1.221 was reportedly pumped at about 100 gpm (gallons per minute) and well 14.13.33.334 yielded 140 gpm; smaller yields were reported at Prewitt where well 13.11.17.123 was pumped at 45 gpm. Complete penetration of the aquifer would probably increase the yield of wells near Prewitt.

In the Grants-Bluewater area, southeast of Prewitt, the Glorieta and San Andres form the principal aquifer and yield large quantities of water for irrigation, industrial, and municipal supplies (Gordon, p. 29). In that area, the Glorieta is reported to yield less water than the San Andres because the San Andres contains connected cavernous zones and solution channels which result in high transmissibilities in the aquifer. Such openings do not appear to be as highly developed in the San Andres Limestone beneath southeastern McKinley County, perhaps accounting for the moderate yields of wells that tap the aquifer in this area.

Water in the Glorieta Sandstone and San Andres Limestone is under artesian pressure northeastward from their recharge area. Numerous springs issue from the outcrop of the formations; however, elsewhere the lower part of the Chinle Formation, which has low permeability, acts as a confining unit for water in the aquifer.

Except for being rather hard, water in the Glorieta Sandstone and San Andres Limestone near Thoreau and Prewitt is of good quality, acceptable for domestic, stock, and some industrial use; at greater distances from the outcrop, the chemical quality of the water becomes inferior (table 3).

The Glorieta Sandstone and San Andres Limestone are recharged at their outcrops on the flanks of the Zuni Mountains in Valencia County where runoff from spring snowmelt and summer thunderstorms infiltrates the formations. Little infiltration can be expected in most of southeastern McKinley County where the aquifer is overlain by shale of the Chinle Formation.

Water discharges naturally from the Glorieta Sandstone and San Andres Limestone in the southwestern part of the area, where springs issue from outcrops in several valleys, and in areas beyond the boundaries of southeastern McKinley County, such as the Grants-Bluewater area and the central basin. Water in the Glorieta and San Andres moves northeastward into the central basin and southeastward towards the Grants-Bluewater area (pl. 2).

Triassic System

Formations of the Triassic System in southeastern McKinley County are, in ascending order, the Chinle Formation and the Wingate Sandstone. Darton assigned the lowermost strata of Triassic age in this area to the Moenkopi Formation of Early and Middle(?) Triassic ages; however, McKee

(1951, p. 85) indicates that the Moenkopi probably does not extend this far east. Cooley (1959, p. 66) identified deposits which fill channels and caverns, formed on the erosional surface of the San Andres Limestone in the Thoreau and Bluewater Lake areas, as "Upper Moenkopi(?)" sediments which lie stratigraphically between typical Moenkopi deposits and the Chinle Formation.

The Chinle Formation underlies all but a small part of southeastern McKinley County. The extent of the Wingate Sandstone is not well known but it probably is restricted to the western part of the area.

Chinle Formation

The Chinle Formation is of Late Triassic age, and it unconformably overlies the San Andres Limestone or, at places, the Glorieta Sandstone. A complex and diverse nomenclature has been given to units of the Chinle by workers in Arizona (Cooley, p. 66). In this report, the Chinle Formation is divided into three parts that have a total thickness of more than 1,600 feet and that are readily identifiable in exposures and in subsurface sections--a lower part about 400 feet thick, a middle part about 225 feet thick, and an upper part nearly 1,000 feet thick (Smith, 1954, p. 8-11).

Members of the formation are exposed on the slopes of the Zuni Mountains, along U.S. Highway 66 between Prewitt and Thoreau, and at places in the valley and at the base of the escarpment north of the highway.

The lower part of the Chinle is purple to white, silty, thin-bedded sandstone and chocolate-brown to purple siltstone and mudstone. Beds of coarse-grained to conglomeratic sandstone are common near the base of the unit, and petrified wood is often present near the top of the unit. The unit ranges in thickness from 300 to 400 feet.

The middle part of the Chinle is yellow to gray sandstone with partings of purple to gray siltstone and mudstone. At places, a pebble to cobble conglomerate containing fragments of petrified wood is present within, or at the base of, the unit. The thickness of the unit is variable as it intertongues with the overlying and underlying units. The unit ranges in thickness from about 60 to 225 feet.

The upper part of the Chinle Formation is predominantly a red, brown, and purple siltstone and mudstone with thin sandstone lenses and thin layers of nodular limestone. The contact with the overlying Wingate Sandstone is an erosional surface of slight relief. The unit ranges in thickness from 900 to 1,000 feet.

Water from the Chinle Formation is used extensively near Thoreau and Prewitt for stock, domestic, and industrial supplies. The sandstone in the middle part of the Chinle is a persistent aquifer and yields most of the water to wells in these areas. Some water is also found, at places, in sandstone and silty sandstone within the upper and lower parts of the formation. Pumping rates of as much as 30 gpm are reported in these areas, but rates of 5 to 20 gpm are much more common and probably represent the maximum yields of most wells. The heterogeneous sand and clay in the aquifer tend to cause yields from wells in proximity to differ widely.

Water in the Chinle Formation is under artesian pressure owing to the northeastward dip of the beds from slopes of the Zuni Mountain uplift into the structural basin. The water does not flow above the land surface from wells drilled into the formation but does rise some distance above the depth at which it is tapped in wells (pl. 2).

The chemical quality of water in the Chinle Formation is variable. Most of the water sampled from the aquifer is of good to fair quality; however, some is of poor quality (table 3). Principal constituents of the dissolved solids in water from the aquifer are sodium, bicarbonate, sulfate, and--in waters of poor chemical quality--chloride. The wide range in quality of water in the Chinle is caused largely by the clay content of the formation, by the ion-exchange capabilities within the formation, and by the movement and flushing action in the aquifer by recharge of fresher water through the outcrop.

The Chinle Formation is recharged principally in outcrops. The more permeable sandstone middle part forms a dip slope on the flank of the Zuni Mountains south of Thoreau and Prewitt. There conditions are favorable for recharge; however, much of the precipitation is during summer thunderstorms with rapid runoff, so that much of the water does not have an opportunity to infiltrate. Some recharge is through the alluvium in the valley north of Thoreau and Prewitt.

Discharge of water from the Chinle Formation in southeastern McKinley County is by pumpage from wells. Most of the movement of water in the aquifer, as indicated in plate 2, is to the southeast, beneath the valley north of Thoreau and Prewitt. Data concerning water levels in the Chinle in the northern part of the area are not available; it is assumed that water also moves northeastward from the recharge area of the formation into the central basin.

Wingate Sandstone

The Wingate Sandstone is assigned to the Glen Canyon Group, which overlies the Chinle Formation and underlies rocks of Middle and Late Jurassic age (Imlay, 1952, p. 963). The formation as originally described by Dutton (p. 136-137) included units now recognized as Upper Jurassic Entrada Sandstone of the San Rafael Group. The Wingate Sandstone is now restricted to the lower half of Dutton's section (Harshbarger, Repenning, and Irwin, 1957, p. 8) and is of Late Triassic age.

The Wingate Sandstone crops out in isolated exposures and in narrow sinuous bands near the base of the escarpment north of U.S. Highway 66 in the southwestern part of the area. It is a light-reddish-brown to orange, massive, cross-bedded, coarse-grained sandstone. Smith (1954, p. 12) stated that the sandstone probably is no more than 35 feet thick north of Prewitt but more than 90 feet thick north of Thoreau.

The Wingate Sandstone yields water to shallow wells near the base of the cliffs north of Thoreau and Prewitt where wells 14.11.19.124 and 14.11.19.322 tap this aquifer. Farther north, deeper wells such as 14.12.9.221 and 14.12.14.142 also tap the Wingate. Near San Antonio Spring, a surface seep from the outcropping sandstone of the Wingate is a source of stock water for herds of sheep in the area. Although only a few wells utilize water from the Wingate in southeastern McKinley County, it is a good aquifer for stock and domestic use where it is present beneath the water table. Pumping rates from wells finished in the Wingate range from 5 to 10 gpm.

The chemical quality of water from the Wingate Sandstone is good to fair in the areas sampled (table 3). Spring 14.12.17.333 at San Antonio yields water reported as unsafe for human consumption, but the chemical quality of the water is good. The main chemical constituents in water from the Wingate are sodium, bicarbonate, and sulfate. The sulfate concentration is variable and accounts for most of the differences in dissolved-solids content.

Recharge to the Wingate Sandstone is from precipitation on the narrow, steep outcrop of the formation along the cliffs north of Thoreau and Prewitt. The outcrop receives only small amounts of recharge, and only small quantities of water are thought to be stored within the aquifer. The water in the aquifer north of its outcrop is under artesian pressure but does not flow above the land surface. Discharge from the Wingate is through scattered seeps or springs near the base of the outcrop and by pumpage from wells.

Jurassic System

Sedimentary rocks of Jurassic age exposed in southeastern McKinley County consist, in ascending order, of formations of the San Rafael Group and the Morrison Formation. The individual formations of the San Rafael Group and members of the Morrison Formation are not shown on the geologic map (pl. 1) because the scale of the map is too small.

Because of intertonguing and variations from type sections, the rocks of Jurassic age in this area have received much attention from various workers and have been the subject of much controversy as to their identification and relationship with the classic section of Jurassic rocks of the Colorado Plateau. The problem is not yet resolved.

The stratigraphic terminology used in the Colorado Plateau is in general use by the mining companies in the area and has been used extensively by geologists of the U.S. Atomic Energy Commission and others. As many of the data for this report were obtained from the mining companies, and as much of the recent literature on the geology of southeastern McKinley County uses this terminology, it is used in this report; it follows Rapaport, Hadfield, and Olson (1952, p. 20), Craig and others (1955), Freeman and Hilpert (1956, p. 312), and Hilpert (1963, p. 13).

San Rafael Group

Formations of the San Rafael Group crop out along the southwestward-facing escarpments and associated isolated mesas in the southwestern third of the area. Owing to the steepness of the escarpments, their outcrops generally are in elongated narrow belts. The formations of the San Rafael Group in southeastern McKinley County are, in ascending order, the Entrada Sandstone, Todilto Limestone, Summerville Formation, and Bluff Sandstone.

The Entrada Sandstone unconformably overlies the Wingate Sandstone and forms the massive red cliffs north of U.S. Highway 66. Near Thoreau, the sandstone consists of an upper sandy member, 159 feet thick, and an underlying silty member, 45 feet thick (Harshbarger, Repenning, and Irwin, p. 36). The upper member is a massive, reddish-orange to pink, medium- to fine-grained, quartz sandstone with conspicuous crossbedding. This facies has been referred to as the "slick-rim," as it weathers into massive, rounded cliffs. The silty member has been called the "hoodoo." It is a red, silty, very fine-grained, massive sandstone with mudstone partings. The sandstone often weathers into rectangular blocks. The Entrada ranges in thickness from 100 to 300 feet. North and northeast from its outcrop, the Entrada probably is continuous in the subsurface of southeastern McKinley County.

The Todilto Limestone caps the cliffs of Entrada Sandstone and rests with sharp unconformity upon the sandstone at many places; at other places it grades into the sandstone. The limestone is dark gray to greenish, fine-grained, thin-bedded, and platy. It is unfossiliferous and often is strongly fetid where freshly fractured. Locally, gypsum overlies the limestone or occurs as cement, or as lenticular masses, in the thin partings of clay or siltstone within the limestone unit. The limestone weathers readily into rubbly, rectangular blocks and forms a slope above the massive Entrada Sandstone. Near Haystack Mountain, in the vicinity of Prewitt, the limestone is about 25 feet thick (Rapaport, Hadfield, and Olson, p. 23). The thickness varies considerably and probably averages between 12 to 15 feet in most of southeastern McKinley County.

Near Haystack Mountain, and along its outcrop southeastward to Valencia County, the limestone contains uranium deposits of considerable value that have been mined extensively. These ore deposits are in the limestone as erratic yellow patches of carnotite and other uranium minerals.

The Todilto Limestone is continuous in the subsurface of southeastern McKinley County northeast of its outcrop.

The Summerville Formation is gradational with the underlying Todilto Limestone and the overlying Bluff Sandstone. It weathers into a talus-covered slope with occasional knobby outcrops between the exposed dip slope of the Todilto and cliffs of the Bluff. The formation is composed of red-brown to light-green and white, fine, interstratified sandstone, siltstone, and shale. In southeastern McKinley County, the Summerville Formation is about 75 to 200 feet thick and is extensive in the subsurface northeast of its outcrop.

The Bluff Sandstone is exposed at many places in the cliffs north of

U.S. Highway 66, in southeastern McKinley County, where it forms blocky, vertical cliffs above the slope of the Summerville Formation and beneath the lower member of the Morrison Formation. It is a gray to buff, fine-grained, massive, crossbedded, quartz sandstone. The sandstone thickens from east to west across the area. Rapaport, Hadfield, and Olson (p. 51) reported that the sandstone is about 220 feet thick in sec. 34, T. 13 N., R. 9 W. At Haystack Mountain, the sandstone is about 280 feet thick, and 2 miles north of Thoreau it is 328 feet thick.

Sparse data are available on the hydrology of the San Rafael Group as only a few widely scattered wells tap the formations. In much of the area, aquifers lie at shallower depths; where formations of the San Rafael Group are not deeply buried, they may be above the water table.

The Entrada Sandstone is not considered to be an aquifer in Southeastern McKinley County as it apparently receives only minor recharge on its outcrop and contains water only at places where it is overlain by water-bearing formations.

No wells are known to obtain water from the Todilto Limestone within the area, as at most places its great depth precludes its use as an aquifer, although it probably contains small quantities of water. Near its outcrops, several mines have encountered water in the limestone. As much as 350 gpm has been pumped from the Todilto in the "Faith" mine (13.9.29.144). The large section of limestone exposed by mining accounts for the large water yield from the formation. Well 13.9.29.341, near the mine, is completed in the Todilto and, prior to dewatering of the mine, was reported to yield small quantities of water for stock use.

No wells are known to obtain water from the Summerville Formation in southeastern McKinley County. The clastic units of the formation undoubtedly contain water where they lie below the regional water table.

The Bluff Sandstone contains ground water in southeastern McKinley County but is not extensively used as an aquifer, as yields are generally not more than 10 gpm, and at most places sufficient water is found in the overlying formations. At Ambrosia Lake, three wells are known to tap the Bluff. Wells 14.10.11.434 and 14.10.14.221 are on the Ambrosia anticline where the formations above the Bluff that normally contain water lie above the regional water table. Well 14.9.30.222 is finished in the Bluff Sandstone and well 14.10.22.214 was drilled into the sandstone for testing purposes before completion as a water well in a shallower aquifer. Well 15.13.12.144, northwest of Smith Lake, is finished in the Bluff and supplies water for mining and domestic use.

The chemical quality of the water in the aquifers of the San Rafael Group is variable (table 3). Where gypsum is present in the Todilto Limestone, the quality of the water is poor. The analysis of a water sample collected at a seep from a fracture in the limestone in the "Faith" mine indicates that the water in the Todilto at this location is high in dissolved solids and sulfate. The water is only mildly radioactive; however, it does contain radium somewhat in excess of the recommended maximum limit. A water sample from well 14.10.11.434, which taps the Bluff Sandstone, contained 2,260 ppm dissolved solids. Sulfate led in concentration; other principal constituents were calcium, sodium, and bicarbonate. Water from well 15.13.12.144, which also taps the Bluff, has a dissolved-solids content of 528 ppm, with only moderate amounts of sodium, bicarbonate, and sulfate. This indicates that potable water is present in the Bluff in the western part of the area.

Recharge to the San Rafael Group is slight in the eastern part of southeastern McKinley County, as the outcrops form steep cliffs with narrow lateral exposure. Outcrops are considerably more extensive in the western part of the area and recharge to the aquifer should be greater. Water in the San Rafael Group moves basinward as indicated by the isolated points of water-level measurement (pl. 2); the amount of natural discharge of water from these formations within the area is not known.

Morrison Formation

Approximately the upper third of the rocks beneath the caprock of Dakota Sandstone that form the escarpments north of U.S. Highway 66 are members of the Morrison Formation. Their areal extent and pattern of outcrop is similar to that of the formations of the San Rafael Group. In ascending order, the members of the Morrison Formation in southeastern McKinley County are the Recapture, Westwater Canyon, and Brushy Basin.

The Recapture Member of the Morrison Formation conformably overlies the Bluff Sandstone of the San Rafael Group. At places, it grades laterally into the Bluff Sandstone and into the overlying Westwater Canyon Member. The Recapture is composed of red-brown, chocolate-brown, light-green, and white interstratified siltstone, shale, and fine sandstone. Sandstone predominates in the upper part of the section where the beds are 5 to 10 feet thick. At places, the Recapture contains conglomeratic, coarse-grained sand, and thin, mottled, red and green limestone. The thickness of the Recapture differs from place to place because it intertongues with underlying and overlying rocks. Near Thoreau, the member is 126 feet thick and at Haystack Mountain it is about 94 feet thick (Rapaport, Hadfield, and Olson, p. 51). Within southeastern McKinley County, the member probably ranges in thickness from about 75 to more than 200 feet. It usually weathers into steep, detritus-covered slopes and, at places, into irregular terrain of pedestal rocks and narrow pinnacles.

The Recapture underlies the area northeast of its outcrop and is 100 to 130 feet thick in the subsurface at Ambrosia Lake.

The Westwater Canyon Member forms steep cliffs above the slope of the Recapture Member and below the slope of the Brushy Basin Member. The Westwater Canyon is a gray to white and light yellow-brown, fine to coarse, poorly sorted sandstone. It is massive and crossbedded and locally contains conglomeratic zones with inclusions of clay, chert pebbles, and small fragments of silicified wood. The member varies in thickness within the area as it interfingers with the Brushy Basin Member and the Recapture Member. One of the sandstone units of the Westwater Canyon, intertonguing with the Brushy Basin Member in this area, has been called the Poison Canyon Sandstone (Zitting and others, 1957, p. 55). This sandstone extends eastward and northeastward from the outcrop of the Westwater Canyon in the Ambrosia Lake area and contains rich deposits of uranium ore.

Outcrop thicknesses of the Westwater Canyon Member reported by Rapaport, Hadfield, and Olson (p. 51) are 166 feet near Thoreau, about 165 feet at Haystack Mountain, and 47 feet in sec. 34, T. 13 N., R. 9 W. North of its outcrop, the Westwater Canyon underlies all of southeastern McKinley County. In the Ambrosia Lake area, the sandstone is 30 to 270 feet thick (Granger and others, 1961, p. 1185).

The Westwater Canyon Member contains extensive deposits of uranium and vanadium ores which are mined in the Ambrosia Lake and Smith Lake areas. The ore is in the sandstone in large masses, tabular bodies, lenses, and thin elongated pods. Near Ambrosia Lake, bodies of ore as thick as 120 feet have been found. The ore deposits may be as much as a mile long and more than 1,000 feet wide. The principal uranium mineral is coffinite, often associated with carbonaceous material, that coats the sand grains or occurs as pellets.

The Brushy Basin Member conformably overlies and intertongues with the Westwater Canyon Member. It is composed of greenish-gray, incompetent, gypsiferous and bentonitic mudstone with yellowish-brown to white, coarse-grained sandstone lenses and a few thin beds of limestone. At places, carbonaceous material is interbedded with the sandstone and mudstone. The Brushy Basin Member weathers into fairly steep slopes. Granger and others (p. 1185) reported that in the Ambrosia Lake area the Brushy Basin ranges in thickness from 62 to 128 feet. However, because of its intertonguing relationships, it may be thinner or thicker locally. Near Thoreau, about 50 feet of the member is exposed and near Smith Lake about 150 feet of section is present in the subsurface.

The sandstone lenses in the Brushy Basin Member contain many deposits of uranium ore. The so-called Poison Canyon Sandstone of the Westwater Canyon Member contains particularly rich deposits. Several mines are on the outcrop of the Brushy Basin and Westwater Canyon Members south of Ambrosia Lake. The member has also been mined at Ambrosia Lake and at Smith Lake.

Only the Westwater Canyon Member of the Morrison Formation is known to be an aquifer in southeastern McKinley County. The Recapture Member is not believed to contain water, except possibly in some of the sandstone units that interfinger with the thick overlying and underlying sandstone units. No wells are known to be finished in the Brushy Basin Member; however, the sandstone units of the Brushy Basin do contain water where they lie below the water table. In sec. 18, T. 15 N., R. 13 W., about 8 miles west of Smith Lake, the lower sandstone lense within the Brushy Basin (the so-called Poison Canyon) contains water in a uranium mine (Hoskins, 1963, p. 49).

In the Ambrosia Lake area and northwestward to Smith Lake, the Westwater Canyon Member is the principal aquifer. The sandstone yields adequate supplies of water for several trailer parks, for minor industrial use, and for stock watering. Most of the ore bodies being mined at Ambrosia Lake are fully or partly saturated and must be drained prior to mining. The Westwater Canyon is a persistent aquifer where it is below the water table. Yields from wells that fully penetrate the aquifer could be expected to exceed 20 gpm.

The chemical quality of the water in the Westwater Canyon Member is good to fair and the water is suitable for domestic, stock, and industrial uses. Analyses of water samples collected from 12 wells and mines (table 3) indicate that the water generally contains less than 1,000 ppm dissolved solids in the Ambrosia Lake and Smith Lake areas. Calcium, sodium, bicarbonate, and sulfate are the main constituents.

Water from wells 14.9.29.312 and 14.11.3.334, which tap the Westwater Canyon, contains 1,410 ppm and 2,310 ppm dissolved solids, respectively. These abnormally high dissolved-solids contents are thought to be due to inflow of water from the overlying Dakota Sandstone. A well drilled into the Westwater Canyon Member should be so constructed that water from overlying aquifers cannot enter the hole.

Water samples collected from the Westwater Canyon Member in seven mines and four wells in the Ambrosia Lake area were analyzed for beta activity and radium (table 3). In all samples beta activity was below the recommended maximum limit; however, the radium concentration in three samples collected from mines and in one sample collected from wells was above the recommended limit for radium in drinking water. An extremely low radium content of 0.2 ± 0.1 pc/l (picocuries per liter) was in the only sample collected from a well (15.12.17.123a) away from the Ambrosia Lake area.

Recharge to the Westwater Canyon is presumably through its outcrop in the western part of the report area; however, the exposures of the sandstone are not extensive. The aquifer may receive recharge from overlying aquifers by downward percolation of water through fault zones. Water in the aquifer is under artesian pressure and water levels in wells rise several tens of feet above the top of the aquifer at most places where it is tapped.

Natural discharge of water from the Westwater Canyon Member in the area is not known. Water in the sandstone, at least in the Ambrosia Lake area where water levels have been measured, moves to the northeast, presumably downdip into the central basin.

Cretaceous System

Rocks of Cretaceous age are exposed in much of southeastern McKinley County; they are covered by basalt flows in the southeastern part of the area and have been removed by erosion in the southwestern part of the area. The strata consist of a thick sequence of marine and continental deposits of shale and sandstone that intertongue, thicken, thin, and change lithology abruptly (fig. 7). The depositional concepts and relationships of these strata are discussed thoroughly in the classic paper on the Cretaceous deposits in the southern part of the San Juan Basin by Sears, Hunt, and Hendricks, (1941, p. 101-121).

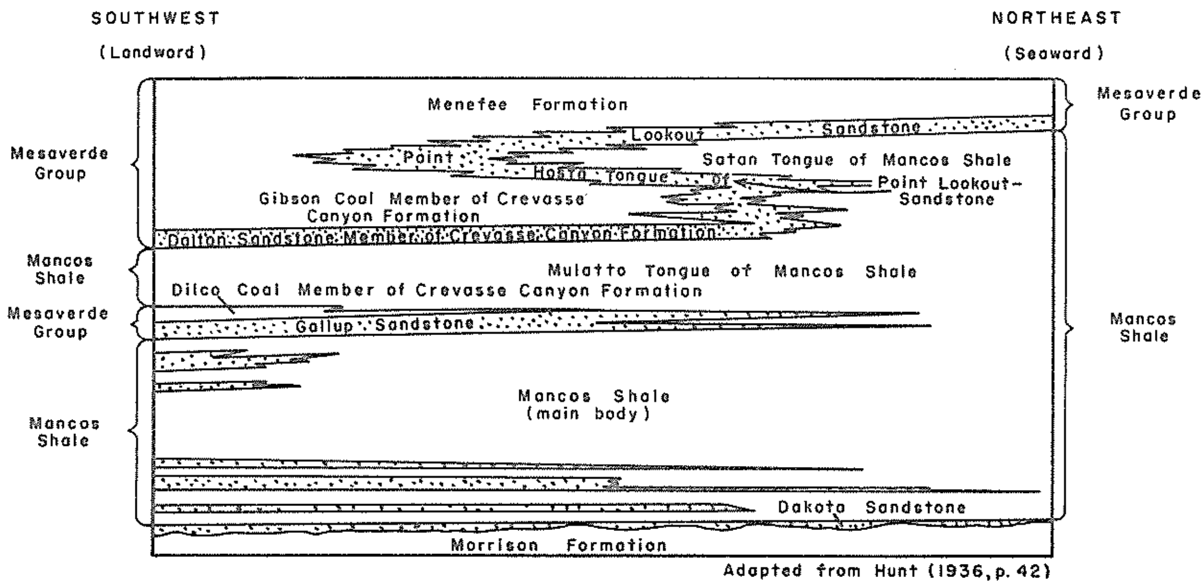


FIGURE 7. -- Diagram of intertonguing relationship of Mancos Shale and Mesaverde Group in a part of southeastern McKinley County, N. Mex.

From oldest to youngest, rocks of Cretaceous age exposed in southeastern McKinley County consist of the Dakota Sandstone, Mancos Shale, and Mesaverde Group.

Dakota Sandstone

The Dakota Sandstone of Cretaceous age unconformably overlies rocks of Late Jurassic age. The sandstone forms the caprock on the escarpments and mesas north of U.S. Highway 66 in southeastern McKinley County and crops out over large areas on the back slopes of the escarpments where it dips northward and northeastward into the subsurface beneath the floor of the middle valley.

The Dakota is composed of yellowish-buff to gray, massive, quartz sandstone with local beds and lenses of conglomerate and impure coal. The lower part of the sandstone commonly is crossbedded; it also is coarser, more conglomeratic, and contains more carbonaceous shale than the upper part. The sandstone in the upper part generally is fairly clean and evenly bedded, with rounded sand grains cemented with silica.

The Dakota weathers into resistant, iron-stained benches and blocky cliffs. At places, cliffs separated by a siltstone and shale layer as thick as 20 feet are apparent. The slope of the Morrison Formation outcrop, beneath the Dakota outcrop, commonly is littered with large blocks of sandstone which have been separated by erosion from the face of the steep Dakota cliffs. The Dakota Sandstone in southeastern McKinley County generally is 50 to 150 feet thick. The thickness varies due to the gradational contact and because, at places, the sandstone intertongues with the overlying Mancos Shale. The Dakota is continuous in the subsurface of southeastern McKinley County northward from its outcrop.

The Dakota Sandstone contains scattered small deposits of uranium ore that are mined at a few places near Ambrosia Lake. The ore generally is near the base in association with carbonaceous material.

The Dakota Sandstone contains water where it lies beneath the water table. In the eastern part of the Ambrosia Lake area, several mine shafts encountered water in the Dakota in quantities large enough to create dewatering problems. Yields of wells finished in the Dakota generally do not exceed 10 gpm.

The chemical quality of water in the Dakota Sandstone is variable (table 3). Commonly the water is high in dissolved solids and may be unsuitable for domestic use. For this reason, well 15.12.17.123 at Smith Lake, used for several years by Indian families as a source of water supply, was replaced in 1961 by a well tapping the Westwater Canyon Member of the Morrison Formation. The inferior quality of water in the Dakota is probably due to carbonaceous material and sulfide minerals within the sandstone. The Dakota is not generally used as an aquifer in southeastern McKinley County because water of better chemical quality can be obtained from other aquifers.

Radioactivity in water in the Dakota Sandstone is indicated by analyses of water from three mines in the Ambrosia Lake area (table 3). The beta activity of the water is quite low. Radium concentration (27±5 pc/l) was considerably above the recommended maximum limit in a sample collected from the "Cliffside" mine (14.9.36.313). The other two samples contained radium in amounts near the recommended limit.

The Dakota Sandstone is recharged by precipitation on its outcrops and probably by downward percolation of water through fault zones. Water in the aquifer is generally under artesian pressure; however, pressures are not sufficient to cause flow above the land surface through wells that tap the aquifer. Points of natural discharge within the area are not known.

Mancos Shale

The Mancos Shale of Late Cretaceous age forms the floor of the valley that contains the mining districts of Ambrosia Lake and Smith Lake. The shale is obscured by alluvium in broad areas of the inner valley, but exposures are common along the edges. The Mancos is a thick lithologic unit composed predominantly of dark gray, calcareous, fissile-clay shale of marine origin. The lower 300 to 350 feet of the unit generally contains three fossiliferous beds of sandstone, each of which ranges in thickness from 30 to 75 feet. In the Ambrosia Lake region, these beds were called, in ascending order, first Mancos, second Mancos, and third Mancos (Young, 1956, map 7). A thin lenticular sandstone near the top of the shale unit was called the fourth Mancos sandstone. This terminology has been adopted by some of the mining-company geologists. The three lower sandstones may be equivalent to the Tres Hermanos Sandstone Member of the Mancos Shale which is recognized east and south of the area. The upper bed of sandstone of the Mancos in this area probably is a unit of the overlying Mesaverde Group.

The Mancos Shale ranges in thickness from about 250 to 1,100 feet in southeastern McKinley County. In the Ambrosia Lake area, the thickness averages 910 feet (Young, p. 7). Logs of oil-test wells 16.10.12.144 and 15.6.4.423 record thicknesses of about 1,000 feet (table 5). At places near the north and east boundaries of the area, greater thicknesses may be present because of the thinning and wedging out of the sandstone members of the Mesaverde that separate the two main tongues of the Mancos Shale--the Mulatto Tongue and the Satan Tongue--from the main body of the Mancos (fig. 7).

The Mulatto, or lower, tongue of the Mancos Shale separates the Dilco Coal Member and the Dalton Sandstone Member of the Crevasse Canyon Formation. The Mulatto is widely exposed in the escarpments of the central and northwestern part of the area. The tongue is composed of light-tan, marine, sandy shale with a few thin beds of sandstone and dark-gray shale; the thickness ranges from 200 to 400 feet within the area.

The Satan, or upper, Tongue of the Mancos Shale splits the Point Lookout Sandstone and separates the main body of the sandstone from the underlying Hosta Tongue of the Point Lookout. The Satan Tongue does not extend as far westward and southwestward as does the Mulatto Tongue and it crops out only in the north-central and west-central parts of southeastern McKinley County. The tongue is composed of beds of shale and sandstone lithologically similar to those of the Mulatto Tongue. The thickness of the Satan Tongue ranges from 20 to 500 feet within the area.

The lower beds of sandstone in the Mancos Shale are known to contain water in the Ambrosia Lake area. Well 14.9.5.341, just north of Ambrosia Lake, and well 14.8.15.244 (table 5), on the northeast flank of the San Mateo Dome, are finished in this aquifer and reportedly yield adequate supplies of stock water. In the southern part of the Ambrosia Lake region, a mine shaft reportedly encountered several hundred gpm of water in the sandstones of the Mancos. Elsewhere in southeastern McKinley County, the sandstones may also contain water; however, they are not known to be used as aquifers. The Mulatto and Satan Tongues of the Mancos Shale are not known to yield water to wells.

The chemical quality of water in the Mancos Shale, as indicated by one analysis in table 3, is poor. Water of better quality may be present elsewhere in the Mancos; however, because of clays and carbonaceous material commonly associated with the sandstones it is more likely that the aquifer contains water of inferior chemical quality throughout southeastern McKinley County.

Water-level measurements in the few wells tapping the Mancos Shale indicate that the water is under artesian pressure, although the pressure is insufficient to raise water in the wells above the land surface. Data pertaining to movement of water in the aquifer and to the areas of major recharge and natural discharge in the area are not available.

Mesaverde Group

Rocks of the Mesaverde Group of Late Cretaceous age form the high and often precipitous cliffs and mesas that border the northeast side of the valley that contains Ambrosia Lake and Smith Lake. Formations of the Mesaverde extend down the back slope of the escarpments and underlie all of southeastern McKinley County north and northeast of the valley.

The Mesaverde Group is composed of a series of alternating, irregularly bedded sandstone, clay, and coal more than 1,500 feet thick. The rock types are predominantly of continental--nonmarine--origin, and most of the units intertongue in a northeasterly direction with the marine Mancos Shale (fig. 7). In southeastern McKinley County, the Mesaverde Group consists, in ascending order, of the Gallup Sandstone, Crevasse Canyon Formation, Point Lookout Sandstone, and the Menefee Formation.

Gallup Sandstone

The Gallup Sandstone is the basal sandstone of the Mesaverde Group; it forms a narrow, nearly continuous, arcuate outcrop from near San Mateo to the northwest corner of southeastern McKinley County. The Gallup consists, at some places, of two sandstone units that are separated by about 90 feet of dark-gray shale, a tongue of the Mancos Shale. The lower sandstone ranges in thickness from a few feet to nearly 75 feet. It is composed of a buff to gray, fine-grained, silty, sandstone, commonly with a dark-brown ironstone bed at the top. The upper sandstone is 60 to 125 feet thick and is pink to buff and light gray. It forms cliffs and ledges that commonly weather into rounded, beehive forms. The sandstone commonly is crossbedded and contains inclusions of large, spheroidal, brown, carbonate concretions. The sandstone generally is fine- to medium-grained, although locally it contains coarse-grained, arkosic sandstone. At places, carbonaceous shale and one or more coal beds are present.

The Gallup Sandstone yields water to several wells in the northern part of southeastern McKinley County. The chemical quality of the water is fair to poor (table 3) and is undesirable for domestic use; however, it is suitable for livestock.

Water in the Gallup Sandstone is under artesian pressure. In the northeastern part of the area, the water flows above the land surface from wells that tap the aquifer. Well 16.5.19.414 flows about 120 gpm and well 16.7.26.221 flows about 25 gpm. In the northwest, near Borrego Pass, the altitude of the land surface and the altitude of the aquifer are such that water does not rise to land surface. Data concerning movement of water in the Gallup Sandstone are not available.

Crevasse Canyon Formation

The Crevasse Canyon Formation is that part of the Mesaverde Group between the Gallup Sandstone and the Point Lookout Sandstone. In southeastern

McKinley County, three members of the formation are recognized. These, in ascending order, are the Dilco Coal Member, the Dalton Sandstone Member, and the Gibson Coal Member. The Dilco Coal Member is separated from the upper two members by the Mulatto Tongue of the Mancos Shale (fig. 7).

In the northwestern part of the area, the Gallup Sandstone and the Dilco Coal Member of the Crevasse Canyon Formation were mapped as a single unit, where both are present, and the two are not differentiated on the geologic map (pl. 1).

The Dilco Coal Member which directly overlies the Gallup Sandstone is composed of 120 to 200 feet of thin, irregular sandstone, light-colored clay, shale with some carbonaceous material, and several lenticular coal beds. In the northwestern part of the area, a massive bed of sandstone having a maximum thickness of about 75 feet lies between typical beds of the Dilco and the overlying Mulatto Tongue. This sandstone is referred to as the "stray sandstone" by Sears, Hunt, and Hendricks (p. 113). The Dilco Coal Member crops out as a gentle slope above the cliffs of the Gallup Sandstone; where the "stray sandstone" is exposed, the Dilco is a cliff-forming unit.

The Dalton Sandstone Member overlies the Mulatto Tongue of the Mancos Shale and is about 35 to 200 feet thick. It generally is a clean, white to buff, massive sandstone that weathers into large blocks along cliffs and benches.

The Gibson Coal Member, uppermost member of the Crevasse Canyon Formation, generally ranges in thickness from 275 to 400 feet. In most of the area, the Gibson is composed of clay, irregular beds of sandstone, and numerous beds of coal. Toward the eastern edge of the area, the beds of coal and clay are apparently replaced by sandstone. Sears, Hunt, and Hendricks (p. 114) reported that a well drilled on the Miguel Creek dome penetrated a section of rocks assigned to the Gibson, which consisted chiefly of sandstone. The Gibson crops out as a thick shale unit directly beneath the sandstone caprocks of the high mesas and escarpments of the north-central part of southeastern McKinley County.

Adequate water for stock and domestic use is obtained from members of the Crevasse Canyon Formation in the northern half of southeastern McKinley County where the rocks lie below the water table. All members of the formation are aquifers; the upper two members--Dalton Sandstone and the Gibson Coal--at places are hydraulically connected. The lower member, Dilco Coal, is a separate aquifer, although at places water in the Dilco Coal is undoubtedly interrelated with water in the underlying Gallup Sandstone. Only a few wells tap the aquifers in the Crevasse Canyon and available data on their hydrologic characteristics are sparse.

Near Borrego Pass, wells that penetrate the Dilco Coal Member and the Gallup Sandstone yield as much as 20 gpm. In the north-central part of the area, wells tapping the Gibson Coal Member yield from 5 to 10 gpm. Well 15.6.20.331, a uranium-exploratory hole on the southeast edge of the Miguel Creek dome, flows about 100 gpm, probably from highly fractured zones of the Gibson Coal and Dalton Sandstone Members.

The chemical quality of water in the Crevasse Canyon Formation is variable (table 3). A water sample from well 14.8.4.334 that taps the Dalton Sandstone Member contains 4,470 ppm dissolved solids, including 2,880 ppm sulfate. Well 15.6.20.331, finished in the Gibson Coal and Dalton Sandstone Members, yields water with a dissolved-solids content of 243 ppm, most of which is bicarbonate. Wells near Borrego Pass yield water with dissolved-solids contents of about 1,500 ppm. The water is high in sulfate, sodium, and bicarbonate. Generally, the quality of water deteriorates with distance from outcrop.

Recharge to the Crevasse Canyon Formation is along the outcrop and, as the outcrop forms steep cliffs, recharge probably is quite small. Beneath the volcanic rocks of the Cebolleta Mountains, considerable recharge may take place along faults and fractures. Movement of the water is into the central basin (pl. 2).

Point Lookout Sandstone

The Point Lookout Sandstone of the Mesaverde Group is a thick, massive sandstone unit that forms the caprock on the high escarpments and mesas in the central and northern part of southeastern McKinley County. The Point Lookout is composed of dark-orange to yellowish-gray, massive, faintly crossbedded, medium- to coarse-grained, arkosic sandstone with abundant iron-oxide concretions and thin beds of fissile, silty sandstone or silty shale. The sandstone weathers into ledges and, at places, into beehive forms similar to those of the Gallup Sandstone.

The Point Lookout Sandstone ranges in thickness from about 75 to 300 feet. The differences in thickness are due to the presence, in part of the area, of the Satan Tongue of the Mancos Shale which splits the sandstone into a lower and an upper unit (fig. 7). The lower sandstone is the Hosta Tongue of the Point Lookout Sandstone. Where Point Lookout is not split by the Satan Tongue, it maintains a rather uniform thickness of about 250 feet.

The Hosta Tongue of the Point Lookout Sandstone crops out mainly in the north-central part of the area. It is lithologically similar to the Point Lookout except for the presence of scattered thin beds of clay and small coal lenses; it may also be lighter in color. The Hosta Tongue generally is better cemented than the Point Lookout, and its outcrops form very massive and nearly continuous cliffs. The Hosta Tongue underlies most of southeastern McKinley County northeast of a line from the northwest corner to the southeast corner of the area. Near its outcrop, the Hosta Tongue is about 150 to 180 feet thick. The sandstone thins to the northeast, as the shale wedge of the Satan Tongue thickens, and only a few feet of the Hosta Tongue is present near the Miguel Creek dome (Hunt, 1936, p. 49).

The Point Lookout Sandstone and the Hosta Tongue, where the Satan Tongue of the Mancos Shale splits the sandstone, have similar hydrologic characteristics and are discussed as a single aquifer. At places where the shale wedge is thin, wells penetrate both sandstones and each yield water to the well. In the north-central and eastern parts of the area, about 15 wells tap the sandstone and well 13.5.7.123 (table 5), which was drilled through the volcanic rocks of the Cebolleta Mountains, probably is completed in the Point Lookout.

Water in the Point Lookout Sandstone and Hosta Tongue is under artesian pressure and, at places, flows above the land surface from wells. Well 15.8.13.444 flows about 10 gpm. Several springs issue from the sandstone (table 2); near Marquez, spring 13.5.26.134 flows about 25 gpm; along San Miguel Creek, on the Miguel Creek dome, spring 16.6.29.231 flows from the Hosta Tongue at a rate of about 20 gpm, and spring 16.6.21.432 flows about 5 gpm from the Point Lookout Sandstone. Average yields from wells finished in this aquifer are about 20 gpm, but individual wells may yield considerably more or less.

The chemical quality of water from 15 wells and springs supplied by the Point Lookout Sandstone or the Hosta Tongue is good to fair (table 3). Most of the water sampled contained less than 1,000 ppm dissolved solids. The water from wells and springs near, and in, the Cebolleta Mountains contained less than 500 ppm dissolved solids; water near the Miguel Creek dome contained less than 1,000 ppm. Only well 15.9.13.144, finished in both the Hosta Tongue and the Crevasse Canyon Formation, wells 16.7.13.224, and 16.8.14.111, finished in both the Point Lookout Sandstone and the Hosta Tongue, and well 16.10.22.232, finished in the Point Lookout Sandstone, yield water with a dissolved-solids content of more than 1,000 ppm. These wells are all located considerable distances from the outcrop area of the sandstone. The main constituents of the dissolved solids are sodium, sulfate, and bicarbonate.

Recharge to the Point Lookout Sandstone is along the outcrops and through the volcanic rocks of the Cebolleta Mountains. The aquifer probably receives as much recharge as any in southeastern McKinley County, since it apparently underlies much of the volcanic cover in the eastern part of the area, and water that moves downward through the volcanic rocks has ample opportunity to reach the water table. The movement of ground water in the aquifer is outward from the volcanic rocks toward springs at the edge of the mesa, northward into the central basin, and toward discharge points such as the spring on the Miguel Creek dome.

Menefee Formation

The Menefee Formation is the upper unit of the Mesaverde Group in southeastern McKinley County and is widely exposed in the eastern third of the area. The formation is composed of beds of gray, brown, and drab, continental claystone and shale, thin beds of coal, carbonaceous shale, tan and brown sandstone, and some layers of ironstone and limestone concretions. The beds dip gently northeastward and form a barren plain, at places cut deeply by arroyos.

The continental, coal-bearing, and non-coal-bearing deposits overlying the Point Lookout Sandstone in this area were called the "upper part of the Gibson coal member and overlying barren beds" by Hunt (1936, p. 66).

Beaumont, Dane, and Sears (p. 2157) restricted the name Gibson Coal Member to the upper member of the Crevasse Canyon Formation and applied the name Cleary Coal Member to the 250-300 feet of coal-bearing beds of the Menefee Formation that directly overlie the Point Lookout Sandstone. Thus, the beds above the Cleary Coal Member, which contain little or no coal, probably belong to the Allison Member of the Menefee. The two members of the Menefee Formation are not differentiated on the geologic map (pl. 1). Where present, the Menefee ranges in thickness from about 400 to 1,000 feet.

The Menefee Formation contains small amounts of water in most of the area of its outcrop and is an aquifer that yields water to wells in only a few localities--principally near the community of San Mateo. Many small seeps and springs issue from the thin sandstone beds of the Menefee near the edges of the Cebolleta Mountains, north and west of the mesa, and near the Miguel Creek dome. Spring 15.7.23.132 (Doctor Spring) flows about 15 gpm; however, most of the springs flow less than 2 gpm. Springflow fluctuates widely, depending upon the amount of precipitation. Most wells finished in the Menefee are pumped at about 5 gpm, although some wells probably would yield more.

Seven samples of water from the Menefee Formation were collected for chemical analysis; all analyses indicate the water is of good quality (table 3), suitable for domestic and stock use. Most of the water samples contained less than 500 ppm dissolved solids and none contained more than 900 ppm. The chemical quality of water from springs near the edges of the Cebolleta Mountains is excellent; none of the samples contained more than 200 ppm dissolved solids. The main constituents in the water are sodium and bicarbonate.

The presence of water in the Menefee Formation near the Cebolleta Mountains and the general absence of water elsewhere in its outcrop area suggest that the formation is recharged principally in the Cebolleta Mountains where volcanic rocks predominate.

Seasonal and yearly fluctuations in flow of springs that issue from the Menefee Formation are indicative of nearby recharge and small storage capacity. Also, the good chemical quality of the water indicates that the water has not been long in storage; otherwise it would contain more mineral constituents dissolved from the sandstone and shale in the formation.

Tertiary System

Basalt, rhyolite, andesite, and other igneous rocks of late Tertiary age cap the high mesas and cover many square miles in the southeastern part of McKinley County. They are mainly extrusive rocks that erupted as lava flows from the craters on and near Mount Taylor. Several igneous intrusive dikes and plugs are near the northern edge of the extrusive rock mass.

The Cebolleta Mountains are capped by sheet basalt and andesite that overlie rocks of Cretaceous age and form a flat mesa, the top of which is about 1,500 feet above the bordering valleys. Many volcanic vents, marked by extinct cinder cones, are scattered over the top of the flat lava cap. Some of these cones are several hundred feet tall and often are clustered in groups. Several separate lava flows, interbedded with pumiceous ash, underlie the surface of the mesa. Well 13.5.7.123 (table 5) penetrated 543 feet of volcanic rocks which include at least seven separate basalt flows. The flows ranged in thickness from about 35 to 75 feet. Interbeds of ash range in thickness from about 5 to 50 feet.

Cerro Alesna, in the northeast corner of the Bartolome Fernandez Grant and a few miles west of the edge of the lava flows, is the most spectacular example of intrusive rock in the area. This volcanic neck is nearly circular and rises 1,200 feet above the surrounding plain. The neck is composed of dense andesite, jointed in nearly vertical columns, and is connected by a dike with outliers of andesite to the southwest.

No wells are known to be finished in volcanic rocks of late Tertiary age in southeastern McKinley County. The extrusive rocks create a large area of recharge for the underlying rocks of Cretaceous age and the intrusive rocks form barriers to the lateral movement of ground water.

Springs (table 2) such as 13.7.11.131 (San Miguel), 13.7.20.121 (San Lucas), 13.7.31.414 (San Mateo), along with numerous unnamed springs, issue from the edges of the sheet basalt flows, either at the contact of the lowest flow with the underlying sedimentary rocks or from the interbeds of ash between the flows. Several of these springs flow 50 gpm or more. San Mateo Springs (13.7.31.414) flow into a reservoir, release from which is used to irrigate farms at San Mateo.

An intrusive dike southwest of Cerro Alesna has created a spring known as Cerro Spring (14.7.10.333) that flows about 10 gpm. Other smaller springs (16.5.15.112 and 16.5.15.233) are along basalt dikes. In years of heavy rainfall, many more springs probably are evident along other dikes in the area.

Tertiary and Quaternary(?) Systems

Basalt flows of late Tertiary and early Quaternary(?) ages overlie rocks of Cretaceous age in the western part of the area a few miles northwest of Thoreau. The basalt occurs as small erosional remnants which cap Mount Powell and an adjacent ridge. The basalt is about 75 feet thick on Mount Powell and may represent several flows (Smith, 1954, p. 20). Source of the basalt at these locations is undetermined. The basalt is not known to contain water.

Quaternary System

Rocks of Quaternary age exposed in southeastern McKinley County consist of basalt flows, alluvium, and landslide and talus materials.

Part of the Bluewater basalt flow covers an area of about 10 square miles along U.S. Highway 66 southeast of Prewitt. The flow originated at El Tintero volcanic crater, near the north edge of the basalt sheet, and it appears to be composed of several alternate layers of vesicular and dense basalt (Gordon, p. 38); near the northwest edge of the flow, well 13.11.27.314 penetrated 30 feet of basalt. Close to the crater, the basalt probably is as much as 200 feet thick. The crest of El Tintero is more than 300 feet higher than the surrounding terrain.

Clay, silt, sand, and gravel of Recent age underlie the major valleys and stream courses, and thin deposits of windblown sand are present at places. The maximum thickness of alluvium within the area is about 150 feet.

Alluvium of Pleistocene age may be present beneath the Bluewater basalt flow. Well 13.11.27.314 (table 5) penetrated 10 feet of brown sand which is probably of alluvial origin and which underlies the basalt and overlies sandy shale.

The landslide and talus materials occupy relatively small patches on the slopes and near the bases of the mesas and escarpments that are capped by sedimentary rocks--in particular by the Dakota Sandstone. Much larger bodies of these slump materials are near the edges of the high, basalt flows northeast of San Mateo.

In southeastern McKinley County, the basalt and landslide debris of Quaternary age do not contain water, and only minor amounts of water are in the alluvium. A few wells yield water from the alluvium along San Mateo Creek and in the valley of Azul Creek. Saturated alluvium may also be present near Ambrosia Lake and Thoreau, although no wells are known to obtain water from the alluvium at these localities. Several dug wells, such as 14.12.20.112 at San Antonio Springs, are in narrow valleys and reentrants throughout much of the area. These dug wells are usually at places where there is surface runoff or direct recharge to the alluvium from underlying sedimentary rocks.

Chemical quality of water in the alluvium depends on source of the water and on the thickness and composition of the aquifer. Well 13.9.22.212, recharged by San Mateo Creek, yields water of good quality containing only 592 ppm dissolved solids (table 3). Well 15.10.32.214, finished in thin alluvium and recharged largely by the underlying Mancos Shale, yields water containing 3,580 ppm dissolved solids, of which 2,550 ppm is sulfate.

GROUND WATER IN THE AMBROSIA LAKE AREA

Development of the large uranium deposits of southeastern McKinley County, principally in the Ambrosia Lake area, increased demand for water both in the mining districts and in the surrounding areas. In the early days of uranium exploration, water was needed by the drilling rigs, and the existing wells were pumped heavily. As the size and importance of the deposits became evident, an influx of people into the area began. Water supplies for trailer camps, for mines, and eventually for milling had to be developed. It became evident during exploration for the uranium that the most promising aquifer in the area was the Westwater Canyon Member of the Morrison Formation of Late Jurassic age, that most of the ore was associated with the Westwater Canyon, and that most of the ore lay within the zone of saturation in the rocks.

The uranium deposits at Ambrosia Lake were mined first at locations where the ore lay above the water table and later-- as information on the conditions of water occurrence became available--at places where the ore lay at deeper levels. Tests were made on wells finished in the Westwater Canyon Member to determine the amount of water within the sandstone, also whether water levels could be lowered, and the sandstone dewatered by pumping from wells, to permit dry mining of the ore.

An aquifer-performance test of the Westwater Canyon Member performed by the Phillips Petroleum Co., using well 14.9.28.234 as the pumped well and well 14.9.28.234a as the observation well, indicated a transmissibility of about 1,300 gallons per day per foot and a storage coefficient of about 0.007. The values obtained from the test are questionable because the pumped well was open only in the lower part of the formation, whereas the observation well was open throughout the formation. Individual water-bearing beds within the aquifer are hydrologically separated by clay lenses; thus, water levels measured in the observation well were composites of the undisturbed water levels from the upper part of the formation and the lowered water levels from the deeper part of the formation. As a consequence, the measurements of drawdown obtained during the test were short on the actual drawdown, and the calculated transmissibility was greater than the actual value.

In addition to testing the Westwater Canyon Member in sec. 28, T. 14 N., R. 9 W., extensive tests of the aquifer were made by various companies in sec. 23 and sec. 25, T. 14 N., R. 10 W., and in sec. 32, T. 14 N., R. 9 W. Because of the low transmissibility of the aquifer, it was determined that dewatering the aquifer by pumping from wells was not feasible. The saturated sandstone interferred with shaft construction and made mining of the ore, within the saturated zone, extremely hazardous.

Quantities of water pumped from various shafts, when the shafts were bottomed in the Westwater Canyon Member, were reported as follows: Phillips "Ann Lee" mine, 365 gpm; Kermac "Section 17" mine, 420 gpm; Kermac "Section 22" mine, 100 gpm; Kermac "Section 24" mine, 400 gpm; Kermac "Section 30" mine, 108 gpm; Kermac "Section 33" mine, 80 gpm; Homestake-Sapin Partners "Section 23" mine, 475 gpm; Homestake-Sapin Partners "Section 25" mine, 725 gpm. Data on other mines are not available, although mines in the eastern part of the area are reported to have yielded larger amounts of water owing to the greater depth of the water-bearing formations, and fractures caused by faulting and folding of the formations. The "Sandstone" mine shaft reportedly yielded 890 gpm from the middle bed of sandstone of the lower part of the Mancos Shale, and the "Rare Metal" mine shaft reportedly yielded 2,000 gpm from the same zone. Water pumpage from the Homestake-Sapin Partners "Section 23" mine and "Section 25" mine amounted to 1 billion gallons and 2.6 billion gallons, respectively, during the period October 1958-September 1962. Early pumpage from the mines yielded much more water than did later pumpage, probably a reflection of dewatering of the aquifer and interference of the cones of depression formed in the piezometric surface. At the "Ann Lee" mine, Phillips Petroleum Co. reports that inflow to the shaft from the Dakota Sandstone is mostly from the updip side, indicating that the sandstone has been drained almost to the level of the shaft on the downdip side. Similar conditions can be expected to occur in all the mines if activity continues over a long period of time.

The volume of water encountered during mining was not the major problem. The wetted mass of saturated rock was hard to load because the muck had many properties of a viscous fluid. Once in the mine car or skip, the water drained away and the loose muck then became a compact mass that adhered to the car or skip, creating dumpage problems. Also, the fine sand that remained suspended in the water wore out loading equipment and sump pumps. Drainage of the work areas before mining became the answer to the wet-muck problem and also created safer working conditions, as the drained rock had greater strength than the wet rock. Jenkins (1959) and Stoehr (1959) describe the drainage methods, wet-rock problems, and solutions.

A suitable water supply for milling of the ore also was a problem in the early phase of mining at Ambrosia Lake. Deep wells were drilled near the two mill sites to test the aquifers; however, these wells were not used because of the poor chemical quality of the water and the relatively small yields. Water for milling ultimately was obtained from the mines themselves.

Much of the water pumped from the mines is channeled into a formerly dry arroyo that carries the effluent southward out of the Ambrosia Lake area. The arroyo joins San Mateo Creek near the junction of State Highways 53 and 334. Flow in the arroyo to San Mateo Creek has been continuous for several years. In San Mateo Creek, the water flows southwestward for several miles before sinking into the alluvium.

In the Ambrosia Lake area, the mining problems created by water in the ore zones have largely been solved and--temporarily, at least--the problem of a source of water for ore processing also has been solved. However, if mining continues a long time, water in the Westwater Canyon Member may be depleted locally and ore-process water may have to be obtained from other sources. Also, since the start of pumpage from the mines, at least one domestic well near the mines has had to be deepened. If this trend continues, the Westwater Canyon Member may no longer be an adequate aquifer and water supplies for domestic and stock use may have to be obtained from the underlying Bluff Sandstone.

QUALITY OF WATER

Ground water in southeastern McKinley County is of suitable chemical quality for stock use, and most of it is acceptable for domestic use. Chemical analyses of 121 ground-water samples are given in table 3. The significance and effects of the most common dissolved-mineral constituents and properties in water are given in table 4.

The radioactivity of the water is remarkably low in view of the extensive uranium deposits associated with several of the aquifers. However, a number of the samples contained radium somewhat in excess of the recommended upper limit. Larger concentrations of radioactive elements, as expected, were present in water samples collected from uranium mines. The concentrations of radium and beta activity in 15 analyses are shown in table 3. The upper limits for beta activity and radium in drinking water, as recommended by the Federal Radiation Council (1961) and adopted by the U.S. Department of Health, Education, and Welfare (1962, p. 9), are 3 pc/l for radium and 1,000 pc/l for beta activity.

Specific conductance is a measure of the electrical conductance of water; it is related to the dissolved-solids concentration, which indicates the concentration of all the dissolved mineral constituents in a water. Specific conductance is more easily determined than is concentration of dissolved solids in chemical analyses; therefore, it is frequently used as a guide to the suitability of water for various uses. In southeastern McKinley County the ratio of the dissolved-solids content, in parts per million, to the specific conductance, in micromhos per centimeter, ranges from 0.59 to 0.99 and averages 0.68. Thus, an approximation of the dissolved solids in a water in southeastern McKinley County can be obtained by multiplying the specific conductance by a factor of 0.68.

The specific conductance of water samples collected in southeastern McKinley County is shown on the well-location map (pl. 2). In this report, water is classified as "good" if the specific conductance is less than 1,500 (dissolved solids 1,000± ppm), "fair" if it is from 1,500 to 3,650 (dissolved solids 1,000± ppm to 2,500± ppm), "poor" if it is more than 3,650.

SUMMARY

Ground water in adequate quantities and of usable quality for stock and domestic use is available throughout southeastern McKinley County. Moderately large quantities suitable for industrial uses are present in a few locales.

Water is yielded to wells from at least 16 distinct aquifers in rocks that range in age from Permian to Quaternary. Large quantities of ground water are stored within these rocks; however, owing to the physical characteristics and low permeability of most of the aquifers, yields from individual wells are small.

Water wells range in depth from 20 feet to more than 1,200 feet. Water levels in wells range from above the land surface to about 800 feet below the land surface. Quality varies widely, but most ground water is chemically suitable for stock and domestic use.

Artesian conditions predominate, except near outcrops of the aquifers where the water may be unconfined. The general direction of water movement is to the north and northeast.

Recharge to the aquifers in southeastern McKinley County is mainly from precipitation upon, or runoff over, the outcrops of the rocks. Some recharge, or interchange of water in buried aquifers, probably also occurs along fault zones. As many of the aquifers crop out only in narrow bands, or in steep cliffs, they receive only scant recharge. Moreover, precipitation is only moderate in most of the area. The largest area of recharge is in the Cebolleta Mountains where relatively permeable volcanic rocks overlie beds of sandstone of Cretaceous age.

Ground water pumped from wells, or taken from springs, is utilized throughout southeastern McKinley County for stock and domestic use. Only minor amounts of surface water are available. Because of the ranching economy of most of the area, water withdrawals are insignificant in comparison with the amount of water stored in the aquifers. Larger amounts of water for community and industrial use are withdrawn at Thoreau, Prewitt, and Ambrosia Lake. At Prewitt, water levels in the middle sandstone of the Chinle Formation probably have been lowered slightly.

In the Ambrosia Lake area, uranium mines discharge millions of gallons of water yearly. Some of this water is used in the mills but most is pumped to waste. The water in the mines is from the Westwater Canyon Member and at some places from the Dakota Sandstone and the Mancos Shale. Water levels have been lowered many tens of feet near the mines; however, noticeable lowering of water level has not been found outside the mining areas.

Ground water associated with the uranium deposits is slightly radioactive. Extremely high radioactivity was not found in water samples from mines or wells; however, several samples contained concentration of radium somewhat above the recommended maximum limit for drinking water.

The principal aquifer in the Zuni Mountains south of Thoreau and Prewitt combines the San Andres Limestone and Glorieta Sandstone. Yields of more than 300 gpm are obtained from these rocks. At Thoreau and Prewitt, the middle sandstone of the Chinle Formation yields 5 to 30 gpm and is the principal aquifer. Near Smith Lake and Ambrosia Lake, the Westwater Canyon Member is the principal aquifer and yields 5 to 20 gpm to wells. North of Smith Lake and Ambrosia Lake, the principal aquifers are various sandstone members of the Mesaverde Group from which yields of 5 to 120 gpm are obtained.

The availability, quantity, and quality of the ground water are directly dependent upon the geologic regimen at the well site. Ground water is present in certain rocks beneath all parts of the area; however, because of the diversity of the geologic formations and the steep dip of the rocks into the central basin element of the San Juan structural basin, subsurface conditions vary widely.

The sequence, approximate thicknesses, character, and general water-bearing characteristics of the various formations underlying a specific locality in southeastern McKinley County can be established by reference to the geologic map (pl. 1) which accompanies this report. In most instances the sequence of rocks beneath the site will correspond to that indicated in the map explanation. Approximate thicknesses and general water-bearing characteristics of the formations are also indicated in the map explanation. The well logs (table 5) more closely define formation thicknesses and physical characteristics of the rocks.

Approximate depths to water and direction of water movement in most areas can be determined from the hydrologic map (pl. 2). The chemical quality of the water yielded by aquifers in southeastern McKinley County also can be determined from the hydrologic map and from the chemical analyses given in table 3.

SELECTED REFERENCES

Baars, D. L., 1961, Permian strata of central New Mexico, in New Mexico Geol. Soc. Guidebook, 12th Field Conf., The Albuquerque Country: p. 113-120.

Baker, A. A., Dane, C. H., and Reeside, J. B., Jr., 1936, Correlation of the Jurassic formations of parts of Utah, Arizona, New Mexico, and Colorado: U.S. Geol. Survey Prof. Paper 183, 66 p.

____________ 1947, Revised correlation of Jurassic formations of parts of Utah, Arizona, New Mexico, and Colorado: Am. Assoc. Petroleum Geologists Bull., v. 31, p. 1664-1668.

Beaumont, E. C., Dane, C. H., and Sears, J. D., 1956, Revised nomenclature of Mesaverde group in San Juan Basin, New Mexico: Am. Assoc. Petroleum Geologists Bull., v. 40, p. 2149-2162.

Beaumont, E. C., and O'Sullivan, R. B., 1957, Geologic map of the Satan Pass-Thoreau area, McKinley County, New Mexico, in Four Corners Geol. Soc. Guidebook, 2d Field Conf., Geology of Southwestern San Juan Basin: map.

[California] State Water Pollution Control Board, 1952, Water quality criteria: Pub. No. 3, 512 p.; Addendum No.1, 164 p., 1954; 2d printing (including addendum), 1957, 548 p.

Cooley, M. E., 1959, Triassic stratigraphy in the state line region of west-central New Mexico and east-central Arizona, in New Mexico Geol. Soc. Guidebook, 10th Field Conf., West-Central New Mexico: p. 66-73.

Craig, L. C., and others, 1955, Stratigraphy of the Morrison and related formations, Colorado Plateau region, a preliminary report: U.S. Geol. Survey Bull. 1009-E, p. 125 -168.

Dane, C. H., 1936, Geology and fuel resources of the southern part of the San Juan Basin, New Mexico, pt. 3, The LaVentana-Chacra Mesa coal field: U.S. Geol. Survey Bull. 860-C, p. 81-161.

Dane, C. H., and Bachman, G. O., 1957, Preliminary geologic map of the northwestern part of New Mexico: U.S. Geol. Survey Misc. Geol. Inv. Map I-224.

Darton, N. H., 1928, "Red beds" and associated formations in New Mexico, with an outline of the geology of the State: U.S. Geol. Survey Bull. 794, 356 p.

Dinwiddie, G. A., Mourant, W. A., and Basler, J. A., 1966, Municipal water supplies and uses, northwestern New Mexico: N. Mex. State Engineer Tech. Rept. 29C, 197 p.

Dutton, C. E., 1885, Mount Taylor and Zuni Plateau [New Mexico], in U.S. Geol. Survey 6th Ann. Rept.: p. 105-198.

Federal Radiation Council, 1961, Radiation protection guidance for federal agencies, Memorandum for the President, Sept. 13, 1961: reprint, The Federal Register, Sept. 26, 1961.

Fenneman, N. M., 1931, Physiography of western United States: New York, McGraw-Hill, 534 p.

Foster, R. W., 1957, Stratigraphy of west-central New Mexico, in Four Corners Geol. Soc. Guidebook, 2d Field Conf., Geology of Southwestern San Juan Basin: p. 62-72.

Four Corners Geological Society, 1957, Geology of southwestern San Juan Basin: Four Corners Geol. Soc. Guidebook, 2d Field Conf., 198 p.

Freeman, V. L., and Hilpert, L. S., 1956, Stratigraphy of the Morrison Formation in part of northwestern New Mexico: U.S. Geol. Survey Bull. 1030-J, p. 309-334.

Gordon, E. D., 1961, Geology and ground-water resources of the Grants-Bluewater area, Valencia County, New Mexico: N. Mex. State Engineer Tech. Rept. 20, 109 p.

Granger, H. C., and others, 1961, Sandstone-type uranium deposits at Ambrosia Lake, New Mexico -- An interim report: Econ. Geol., v. 56, no. 7, p. 1179-1210.

Gregory, H. E., 1916, The Navajo country: U.S. Geol. Survey Water-Supply Paper 380, 219 p.

Halpenny, L. C., and Whitcomb, H. A., 1949, Water-supply investigations at Baca School near Prewitt, McKinley County, New Mexico: U.S. Geol. Survey open-file rept. 16 p.

Harshbarger, J. W., Repenning, C. A., and Irwin, J. H., 1957, Stratigraphy of the uppermost Triassic and the Jurassic rocks of the Navajo country: U.S. Geol. Survey Prof. Paper 291, 74 p.

Hem, J. D., 1959, Study and interpretation of the chemical characteristics of natural water: U.S. Geol. Survey Water-Supply Paper 1473, 269 p.

Hilpert, L. S., 1963, Regional and local stratigraphy of uranium-bearing rocks, in Kelley, V. C., 1963, Geology and technology of the Grants uranium region, Soc. Econ. Geol.: N. Mex. Inst. Min. and Tech., State Bur. Mines and Mineral Res. Mem. 15, p. 6-18.

Holzle, A. F., 1960, Photogeologic map of the Cabezon-3 quadrangle, McKinley and Sandoval Counties, New Mexico: U.S. Geol. Survey Misc. Geol. Inv. Map I-317.

Hoskins, William G., 1963, Geology of the Black Jack No. 2 Mine, Smith Lake area, in Kelley, V. C., 1963, Geology and technology of the Grants uranium region, Soc. Econ. Geol.: N. Mex. Inst. Min. and Tech., State Bur. Mines and Mineral Res. Mem. 15, p. 49-52.

Hunt, C. B., 1936, Geology and fuel resources of the southern part of the San Juan Basin, New Mexico, pt. 2, The Mount Taylor coal field: U.S. Geol. Survey Bull. 860-B, p. 31-80.

__________ 1938, Igneous geology and structure of the Mount Taylor volcanic field, New Mexico: U.S. Geol. Survey Prof. Paper 189-B, p. 51-80.

Hunt, C. B., and Dane, C. H., 1954, Map showing geologic structure of the southern part of the San Juan Basin, including parts of San Juan, McKinley, Sandoval, Valencia, and Bernalillo Counties, New Mexico: U.S. Geol. Survey Oil and Gas Inv. Map OM-158.

Imlay, R. W., 1952, Correlation of Jurassic formations of North America, exclusive of Canada: Geol. Soc. America Bull., v. 63, no. 9, p. 953-992.

Jenkins, Ray, 1959, Ambrosia Lake--Mining at the Ann Lee Mine: Min. Cong. Jour., v. 45, no. 3, p. 47-49.

Kelley, V. C., 1950, Regional structure of the San Juan Basin, in New Mexico Geol. Soc. Guidebook, 1st Field Conf., San Juan Basin, New Mexico and Colorado: p. 101-108.

__________ 1951, Tectonics of the San Juan Basin, in New Mexico Geol. Soc. Guidebook, 2d Field Conf., South and West Sides of the San Juan Basin, New Mexico and Arizona: p. 124-131.

__________ 1955, Regional tectonics of the Colorado Plateau and relationship to the origin and distribution of uranium: Univ. N. Mex. Pub. Geol. Ser., No. 5, 120 p.

Kelley, V. C., 1957, Tectonics of the San Juan Basin and surrounding areas, in Four Corners Geol. Soc. Guidebook, 2d Field Conf., Geology of Southwestern San Juan Basin: p. 44-52.

______________ 1963, Geology and technology of the Grants uranium region: N. Mex. Inst. Min. and Tech., State Bur. Mines and Mineral Res. Mem. 15, 277 p.

Kover, A. N., 1960, Photogeologic map of the Chaco Canyon-2 quadrangle, McKinley County, New Mexico: U.S. Geol. Survey Misc. Geol. Inv. Map I-315.

McKee, E. D., 1951, Triassic deposits of the Arizona-New Mexico border area, in New Mexico Geol. Soc. Guidebook, 2d Field Conf., South and West Sides of the San Juan Basin, New Mexico and Arizona: p. 85-92.

New Mexico Geological Society, 1950, Guidebook of the San Juan Basin, New Mexico and Colorado, 1st Field Conf., 1950: 153 p.

______________ 1951, Guidebook of the south and west sides of the San Juan Basin, New Mexico and Arizona, 2d Field Conf., 1951: 167 p.

New Mexico Land Resources Association, 1958, New Mexico land ownership status map, in Land resources of New Mexico: N. Mex. State Land Office unnumbered publication, p. 71.

New Mexico State Engineer Office, 1956, Climatological summary, New Mexico--Temperature 1850-1954, frost 1850-1954, evaporation 1912-1954: N. Mex. State Engineer Tech. Rept. 5, 277 p.

New Mexico State Inspector of Mines, 1962, Fiftieth annual report: Office of the State Inspector of Mines, 84 p.

O'Sullivan, R. B., and Beaumont, E. C., 1957, Preliminary geologic map of western San Juan Basin, San Juan and McKinley Counties, New Mexico: U.S. Geol. Survey Oil and Gas Inv. Map OM-190.

Pike, W. S., Jr., 1947, Intertonguing marine and nonmarine Upper Cretaceous deposits of New Mexico, Arizona, and southwestern Colorado: Geol. Soc. America Mem. 24, 103 p.

Rapaport, Irving, Hadfield, J. P., and Olson, R. H., 1952, Jurassic rocks of the Zuni uplift, New Mexico: U.S. Atomic Energy Comm. RMO-642, 47 p.

Sears, J. D., 1934, Geology and fuel resources of the southern part of the San Juan Basin, New Mexico, pt. 1, The coal field from Gallup eastward toward Mount Taylor: U.S. Geol. Survey Bull. 860-A, p. 1-29.

Sears, J. D., Hunt, C. B., and Hendricks, T. A., 1941, Transgressive and regressive Cretaceous deposits in southern San Juan Basin, New Mexico: U.S. Geol. Survey Prof. Paper 193-F, p. 101-121.

Smith, C. T., 1951, Problems of Jurassic stratigraphy of the Colorado Plateau and adjoining regions, in New Mexico Geol. Soc. Guidebook, 2d Field Conf., South and West Sides of the San Juan Basin, New Mexico and Arizona: p. 99-102.

____________1954, Geology of the Thoreau quadrangle, McKinley and Valencia Counties, New Mexico: N. Mex. Inst. Min. Tech., State Bur. Mines and Mineral Res. Bull. 31, 36 p.

____________1957, Geology of the Zuni Mountains, Valencia and McKinley Counties, New Mexico, in Four Corners Geol. Soc. Guidebook, 2d Field Conf., Geology of Southwestern San Juan Basin: p. 53-61.

Smith, C. T., and others, 1959, Geologic map of Foster Canyon quadrangle, Valencia and McKinley Counties, New Mexico: N. Mex. Inst. Min. Tech., State Bur. Mines and Mineral Res. Geol. Map 9.

Stoehr, R. J., 1959, Ambrosia Lake--Mining at Homestake-New Mexico Partners: Mining Cong. Jour., v. 45, no. 3., p. 46, 49-50.

U.S. Bureau of the Census, 1960, Census of population, 1960, number of inhabitants: Final Report PC (1)-33A, New Mexico, U.S. Govt. Printing Office, 12 p.

U.S. Department of Health, Education, and Welfare, 1962, Drinking water standards: U.S. Public Health Service Pub. 956, U.S. Govt. Printing Office, 61 p.

Young, R. G., and Ealy, G. K., 1956, Uranium occurrences in the Ambrosia Lake area, McKinley County, New Mexico: U.S. Atomic Energy Comm. Rept. RME-86, 15 p.

Zitting, R. T., and others, 1957, Geology of the Ambrosia Lake area uranium deposits, McKinley County, New Mexico: Mines Mag., v. 47, no. 3, p. 53-58.

TABLE 1

RECORDS OF WELLS IN SOUTHEASTERN MCKINLEY COUNTY, N. MEX.

EXPLANATION:

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

Owner or name: The owner of, or name used for, well at time of visit.

Altitude: Elevation above sea level of land surface at well; extrapolated from topographic map or furnished by owner.

Depth of well: M, measured; otherwise reported.

Water level: Measured depths given to nearest one-tenth foot; reported depths given to nearest foot.

Stratigraphic unit: Qal, alluvium; Kmf, Menefee Formation; Kpl, Point Lookout Sandstone; Kplh, Hosta Tongue of Point Lookout Sandstone; Kcg, Gibson Coal Member of Crevasse Canyon Formation; Kcda, Dalton Sandstone Member of Crevasse Canyon Formation; Kcdi, Dilco Coal Member of Crevasse Canyon Formation; Kg, Gallup Sandstone; Km, Mancos Shale; Kd, Dakota Sandstone; Jmw, Westwater Canyon Member of Morrison Formation; Jb, Bluff Sandstone; Jt, Todilto Limestone; Je, Entrada Sandstone; ℞w, Wingate Sandstone; ℞c, Chinle Formation; Psa, San Andres Limestone; Pg, Glorieta Sandstone.

Type of pump: C, cylinder; Ce, centrifugal; N, none; S, submersible; T, turbine.

Type of power: B, butane; E, electric; G, gasoline; H, hand pump; N, none; W, windmill.

Use of water: D, domestic; I, industrial; O, observation; Ps, public supply; S, stock; U, unused.

Remarks: Ca, chemical analysis in table 3; L, well log in table 5.

Location	Owner or name	Driller	Year completed	Altitude	Depth of well (feet)	Water level: Depth below surface (feet)	Water level: Date of measurement	Principal water-bearing unit: Character of material	Principal water-bearing unit: Stratigraphic unit	Diameter of casing (inches)	Type of pump	Type of power	Use of water	Remarks
13. 4.31.114	Community of Marquez	-	1954(?)	6,860	250	-	-	Sandstone	Kg	-	C	G	D	Ca; reported drilled to depth of 400 ft and plugged back.
13. 5. 7.123	Fernandez Co.	Hoard Drlg. Co.	1959	8,680	676	590	-	do.	Kpl	8	S	E	D,S	Ca; water from this well piped to other parts of the range; "Laguna Grande water well 3"; L.
13. 8.14.422	Ernest Michael	Scott Bros.	-	7,180	200	71.5	9-10-62	Sandstone and shale	Kmf	6	C	N	S	-
22.242	Fernandez Co.	-	-	7,110	-	37.5	10-23-62	do.	Kmf	8	S	E	D,S	Headquarters well.
23.432	Horacio Marquez	-	1950	7,180	92	38.2	9-11-62	do.	Kmf	4	J	E	D	Water supply for trailer court.
24.223	Arthur Candelaria	Smith Drlg. Co.	-	7,320	-	140.7	9-10-62	do.	Kmf	5	S	E	D,S	Ca.
24.334	F. Gonzales	do.	-	7,290	200	50	-	do.	Kmf	6	S	E	D	Water supply for trailer court; another well 75 ft south.
24.334a	Nabor Marquez	O. Carter	-	7,300	140	89.5	9-10-62	do.	Kmf	6	N	N	U	Old well; upper water cased out; new well 40 ft west.
24.334b	do.	Franklin-Layne Co.	1961	7,295	200	40	-	do.	Kmf	6	S	E	D	Ca.
25.111	Pablo Pena		-	7,295	21 M	19.5	9-11-62	Sand	Qal	72	C	W	D	Dug well; cribbed with pinon logs.
25.112	Jose T. Gonzales	Atwater Drlg. Co.	-	7,320	150	43.0	9-10-62	Sandstone and shale	Kmf	6	J	E	D	Water reportedly found at 80 ft.
25.114	Ernest Michael	Howard Sheets	-	7,310	120	35.9	9-11-62	Gravel and sandstone	Qal, Kmf	6	J	E	D	Water found in gravel at about 30 ft and in sandstone deeper in well.
26.211	Procopio Sandoval	-	-	7,215	40	33.2	9-11-62	Sandstone	Kmf	84	J	E	D	Dug well; cribbed with railroad ties.
26.221	Community of San Mateo	-	1955	7,240	336	281	-	do.	Kpl	7	S	E	Ps	Ca; water above 100 ft reported, but sealed off in well.
13. 9.13.111	Nabor Marquez	-	-	6,935	155 M	142.9	2-13-58	do.	Kd	-	N	N	U	Eight-inch uncased hole.
15.343	J. D. Ragland	N. H. Wade	1957	6,840	260	223.7	12- 5-57	do.	Jmw	6	S	E	D	Ca; water supply for trailer court; L.
16.333	Buck Willcoxson	-	1954	6,910	97 M	87.6	12-17-57	do.	Kd	7	N	N	U	Exploratory drill hole.
16.341	do.	Hubbell Bros.	1953	6,810	91 M	75.9	12-17-57	do.	Kd	-	N	N	U	Drilled to 700 ft; plugged back to 91 ft.
16.341a	do.	-	1920	6,810	100	-	-	do.	Kd	6	C	W	U	Oil-test well drilled to 1,500 ft; plugged back to 100 ft; water reported at 90 ft.
16.413	do.	-	1954	6,820	250	-	-	do.	Jmw	6	C	E	D,S	Exploratory drill hole.
21.412	Nabor Marquez	-	-	6,785	165	141.7	10-30-57	do.	Jmw	6	C	W	S	-
22.112	Ingersoll-Rand Co.	Hubbell Bros.	1958	6,830	297	204.8	12-15-58	do.	Jmw	8-6	S	E	I	L.

TABLE 1 (continued)

RECORDS OF WELLS IN SOUTHEASTERN MCKINLEY COUNTY, N. MEX.

Location	Owner or name	Driller	Year completed	Altitude	Depth of well (feet)	Water level: Depth below surface (feet)	Water level: Date of measurement	Principal water-bearing unit: Character of material	Principal water-bearing unit: Stratigraphic unit	Diameter of casing (inches)	Type of pump	Type of power	Use of water	Remarks
13. 9.22.121	James W. McAvoy	Coffee	-	6,835	330	198.5	10-16-62	Sandstone	Jmw	5	S	E	Ps	Water supply for trailer court; use of 9000 gpd reported 10-17-62.
22.212	P.O. and Carlos Sandoval	O. Carter	1955	6,830	95	87.5	12-18-57	Sand	Qal	5	C	W	S	Ca.
24.221	Nabor Marquez	-	-	6,910	80	56.5	12- 6-57	do.	Qal	5	C	W	S	-
24.221a	Calumet Hecla Inc.	-	1955	6,910	80	56.6	12- 6-57	do.	Qal	8	C	E	I,D	Exploratory drill hole.
29.341	Westvaco Min. Dev.	-	-	6,755	190 M	dry	10-30-57	Limestone	Jt	5	N	N	U	Well reported to have gone dry when "Faith" mine was dewatered.
29.343	Mount Taylor Corp.	C. C. Smith	1958	6,760	455	228	-	Sandstone	TRc (?)	5	S	E	D	-
13.10. 8.211	U.S. Bureau of Indian Affairs	C. N. Carroll	1936	7,000	357	330.7	10-29-57	do.	TRw	7	C	W	S	BIA well 16B-38; L.
11.242	Adrian Berryhill	Prewitt Drlg. Co.	1962	7,240	805	732	-	do.	Jmw	6	C	W	S	-
33.443	Duane Berryhill	do.	1956	6,720	110	38.7	10-16-62	do.	TRc	6	C	W	S	L.
13.11. 6.313	Elkins Ranch, Inc.	-	-	6,795	74 M	38.9	9- 5-62	do.	TRc	7	N	N	U	Drilled for sand-pit operations; supply inadequate.
6.424	do.	Tom Elkins	-	6,785	100	45.3	6-23-48	do.	TRc	6	C	W	U	-
6.424a	do.	O. Carter	-	6,785	352	50	-	do.	TRc	6	S	E	S	Water not used for drinking; reported bad taste.
7.344	Justin La Font	O. Carter	-	6,840	-	-	-	do.	TRc	-	S	E	D	Ca.
7.431	Elkins Ranch, Inc.	Prewitt Drlg. Co.	1958	6,810	220	52.4	8- 3-61	do.	TRc	7	S	E	U	L.
7.433	Justin La Font	-	-	6,820	147	-	-	do.	TRc	5	C	N	U	Ca.
8.212	Elkins Ranch, Inc.	-	-	6,785	100	37.0	6-23-48	do.	TRc	6	C	W	S	Ca.
17.113	El Paso Natural Gas Co.	Bledsoe	-	6,805	200	79.6	8- 2-61	do.	TRc	5	N	N	U	Gasoline on top of water; Prewitt refinery.
17.113a	do.	do.	1946	6,805	240	79.9	8- 2-61	do.	TRc	6	N	N	U	Ca; Prewitt refinery; "Bluewater" well.
17.114	do.	-	1953	6,795	790	67.0	8- 2-61	do.	TRc, Psa	6	N	N	U	Prewitt refinery; "New" railroad well.
17.114a	do.	Bledsoe	-	6,795	200	59.4	8- 2-61	do.	TRc	6	N	N	U	Ca; gasoline on top of water; Prewitt refinery "Gas" well 3.
17.123	do.	do.	1946	6,795	774	145	-	do.	TRc, Psa	6	C	N	U	Prewitt refinery; "Old" railroad well.
17.133	do.	-	-	6,820	-	111.2	8- 2-61	do	TRc	6	N	N	U	Prewitt refinery; "House" well.
17.141	do.	Hubbell Bros.	1954	6,810	196	75.2	8- 2-61	do.	TRc	7	N	N	U	Prewitt refinery.
17.411	Zuni Mt. Trading Post	Masters	-	6,805	180	84.8	9-18-62	do.	TRc	6	S	E	D	Ca.
17.442	F. H. Hubbell and Lawrence Elkins	F. H. Hubbell	1955	6,825	208	145	-	do.	TRc	7	J	E	D	-
17.442a	F. H. Hubbell	do.	1960	6,825	150	100	-	do.	TRc	8	S	E	D	-
18.122	El Paso Natural Gas Co.	-	-	6,825	187 M	82.3	9- 5-62	do.	TRc	7	N	N	U	Prewitt refinery.
18.122a	Volton Tietjen	Berryhill	-	6,840	200	86.8	9- 5-62	do.	TRc	6	C	E	D	-
18.221	El Paso Natural Gas Co.	Hubbell Bros.	1954	6,805	201	73.5	8- 2-61	do.	TRc	7	N	N	U	Prewitt refinery.
18.223	do.	do.	1952	6,815	803	-	-	Limestone and sandstone	Psa, Pg	8	C	E	I	Prewitt refinery; "Shop" well; yield 13 gpm; L.
18.224	do.	Bledsoe	-	6,805	200	87.6	8- 2-61	Sandstone	TRc	6	N	N	U	Ca; Prewitt refinery; "West" well.
18.444	Roy Navarre	Hubbell Bros.	1955	6,930	540	381.0	10-24-62	do.	TRc	6	C	N	S	L.
23.324	Elkins Ranch, Inc.	do.	-	6,780	800	303.8	8- 3-61	do.	TRc	7	C	W	S	Basalt to 60 ft; water in red sand near 800 ft.
27.314	do.	Hubbell Bros.	1951	6,720	204	125.9	8- 3-61	do.	TRc	7	C	W	S	L.
34.433	Henry Andrews Jr.	do.	-	6,710	-	181.9	9-19-62	do.	TRc	6	J	E	D	Water pumped to house and trading post.
13.12. 3.142	Elkins Ranch, Inc.	-	-	6,855	-	49.2	8- 4-61	do.	TRc	6	C	W	U	-
4.343	U.S. Bureau of Indian Affairs	-	-	6,940	24 M	18.7	6- 3-59	do.	TRc	48	J	E	D,S	Dug well; reported to flow in wet years.
8.121	C. Williams	-	-	7,005	124	54	-	do.	TRc	6	C	W	D	-

TABLE 1 (continued)

RECORDS OF WELLS IN SOUTHEASTERN MCKINLEY COUNTY, N. MEX.

Location	Owner or name	Driller	Year completed	Altitude	Depth of well (feet)	Water level: Depth below surface (feet)	Water level: Date of measurement	Principal water-bearing unit: Character of material	Principal water-bearing unit: Stratigraphic unit	Diameter of casing (inches)	Type of pump	Type of power	Use of water	Remarks
13.12.10.242	U.S. Bureau of Indian Affairs	Burt Cravath	1944	6,930	215	74.2	12- 3-48	Sandstone	TRc	8	C	W	S	BIA well 16K-317; L.
12.142	Elkins Ranch, Inc.	-	-	6,820	165	41.4	8- 4-61	do.	TRc	4	C	W	S	-
12.424	B. B. South	Hubbell & Wallace	1953	6,825	182	61.6	6- 4-59	do.	TRc	5	S	E	D	-
12.441	U.S. Bureau of Indian Affairs	Burt Cravath	1943	6,840	475	79.8	6-25-48	do.	TRc	6	C	E	D	Ca; Baca Day School; well drilled to 1,987 ft, plugged back to 475 ft for better quality water; L.
34.331	Carrol Gunderson	-	-	7,460	-	167	-	Limestone	Psa	-	-	E	D	-
34.332	H. C. Jones	-	1960	7,480	250	187	-	do.	Psa	5	S	E	D	Ca.
34.334	T. F. Ray	O. Carter	-	7,395	125	90	-	do.	Psa	6	S	E	D	-
13.13. 1.221	A. T. & S. F. Railroad	Lyman & Clampitt	1902	6,995	707	Flowing	7-10-61	Limestone and sandstone	Psa, Pg	10	N	N	U	Ca; "North Chavez" well 1.
1.222	do.	Gus Mulholland	1911	6,995	725	do.	7-10-61	do.	Psa, Pg	10	N	N	U	"North Chavez" well 2.
1.222a	do.	Clampitt & Moss	1918	7,000	930	do.	7-10-61	do.	Psa, Pg	12	N	N	U	Ca; "North Chavez" well 3; L.
4.144	Dave Huffman	-	-	7,190	210	120.4	6- 3-59	Sandstone	TRc	4	C	W	D,S	-
5.114	Donald Kimbler	Hubbell Bros.	1950	7,215	625	Flowing	6- 3-59	Limestone and sandstone	Psa, Pg	5	N	N	D,S	Reported to flow 8 gpm; L.
5.214	Wilson Brock	Prewitt Drlg. Co.	1959	7,195	717	-	-	do.	Psa, Pg	5	C	E	D,S	Flows in winter.
5.221	do.	O. Carter	-	7,160	695	-	-	do.	Psa, Pg	7	N	N	S	Do.
8.444	Clay Hardin	Paul Dunning	1959	7,325	504	Flowing	7-19-61	do.	Psa, Pg	5	N	N	S	Ca; measured flow 2 gpm; L.
9.411	do.	O. Carter	-	7,255	71 M	47.1	6- 4-59	Sandstone	TRc	7	C	W	S	-
20.223	do.	Jack Carter	1962	7,495	350	15.9	12-11-62	Limestone and sandstone	Psa, Pg	5	S	E	S	Bailed at 48 gpm; drawdown of 25 ft.
21.331	do.	Fountain	-	7,425	30 M	19.7	6- 4-59	Sand and gravel	Qal	16	N	N	U	Drilled for irrigation, insufficient yield.
22.133	do.	O. Carter	-	7,415	54	15.8	6- 1-59	do.	Qal	4	C	W	S	-
26.143	Ford & Williams Ranch	-	-	7,410	17 M	9.8	6- 2-59	do.	Qal	48	C	W	D,S	Dug well, cribbed with rock.
27.434	V. O. Stalling	-	-	7,440	12 M	3.6	6- 2-59	do.	Qal	48	C	W	D	Do.
28.131	do.	Jack Carter	1962	7,470	130	Flowing	9- 4-62	Sandstone	Psa	5	N	N	S	Ca; flow of 12 gpm.
30.122	Donald Kimbler	-	-	7,510	12 M	10.6	6- 1-59	Sand, gravel and limestone	Qal, Psa	24	Ce	G	D,S	Dug well, cribbed with metal barrels.
30.214	Charles Bass	-	1955	7,510	70	11.1	6- 1-59	Limestone	Psa	6	C	W	I,S	Waters small garden.
33.431	do.	Fred Schalk & B. B. Floyd	-	7,700	310	216.5	6- 3-59	Sandstone	Pg	7	C	W	S	-
14. 5. 3.342	Evans Ranch	Bill Ayer	1945	8,510	750	670	-	do.	Kpl	6	C	G	S	Water is piped to other parts of range from this well.
14.422	do.	Turner Bros.	-	8,100	360	280	-	do.	Kpl	6	C	G	S	Ca; test pumped at 17 gpm.
14. 7.16.314	Fernandez Co.	-	-	6,830	58	-	-	do.	Kmf	8	J	E	D,S	"San Miguel Canyon" well; reported to yield 50 gpm.
14. 8. 4.334	do.	-	-	7,050	-	150.3	10-16-62	do.	Kcda	5	C	G	S	Ca; "Mariana Ortega" well.
15.244	do.	-	1924	7,210	1,320	500	-	do.	Km	10	C	G	S	Ca; drilled as Midwest Refining Co. No. 1, San Mateo oil-well test; L.
14. 9. 5.341	Buck Willcoxson	Hubbell Bros.	1952	7,245	858	414.1	12-16-57	do.	Km	7	N	N	U	L.
18.243	Adrian Berryhill	do.	1957	7,200	800	744	-	do.	Jmw	7	S	E	D	Ca; reported water level in December 1957 was 600 ft; pumping level was 663 ft at 10 gpm.
28.143	Phillips Petr. Co.	Scott Bros.	1956	6,987	710	440.5	9-28-56	do.	Jmw	5	C	E	D,I	Ca.
28.233	do.	-	1956	7,003	700	-	-	do.	Jmw	2	N	N	O	Observation well of Phillips Petroleum Co.; "Core hole 279."
28.234	do.	-	1957	7,022	801	529	10-30-57	do.	Jmw	8	S	E	I	Water test well of Phillips Petroleum Co.; "shallow well."
28.234a	do.	-	1956	7,021	700	-	-	do.	Jmw	2	N	N	O	Observation well of Phillips Petroleum Co.; "special hole."

TABLE 1 (continued)

RECORDS OF WELLS IN SOUTHEASTERN MCKINLEY COUNTY, N. MEX.

Location	Owner or name	Driller	Year completed	Altitude	Depth of well (feet)	Water level: Depth below surface (feet)	Water level: Date of measurement	Principal water-bearing unit: Character of material	Principal water-bearing unit: Stratigraphic unit	Diameter of casing (inches)	Type of pump	Type of power	Use of water	Remarks
14. 9.28.234b	Phillips Petr. Co.	-	1956	7,022	835	445	-	Sandstone	Jmw	2	N	N	O	Observation well of Phillips Petroleum Co.; "core hole 72."
28.234c	do.	-	1956	7,032	840	-	-	do.	Jmw	2	N	N	O	Observation well of Phillips Petroleum Co.; "core hole 96."
28.412	do.	-	1956	7,008	840	-	-	do.	Jmw	2	N	N	O	Observation well of Phillips Petroleum Co.; "core hole 286."
28.441	do.	Lynn Drlg. Co.	1956	6,982	3,275	542	10-22-57	Limestone	Psa	13	S	E	I	Water-test well; Phillips Petroleum Co. "Sandstone Minerals" water well 1; L.
29.312	A & J Trailer Park	Hubbell Bros.	1958	6,980	735	450	2-28-58	Sandstone	Jmw	6	S	E	D	Ca.
30.221	Kermac Nuclear Fuels Corp.	-	-	6,884	-	478	12-20-57	do.	Jmw	6	C	E	I	-
30.222	Adrian Berryhill	-	-	6,990	925	-	-	do.	Jmw, Jb	6	S	E	D,S	Drilled as New Mexico Royalty No. 2, L. A. Barton, oil-test well; L.
32.122	Homestake-New Mexico Partners	C. T. Henderson	1957	6,942	644	413	4-30-57	do.	Jmw	32	N	N	U	Ca; water-test well, converted to air vent for the Homestake-New Mexico Partners "Sec. 32" mine; Homestake-New Mexico Partners well "32 H_2O."
32.122a	do.	-	1957	6,942	620	412	4-30-57	do.	Jmw	2	N	N	O	Observation well of Homestake-New Mexico Partners; well "32 O-B1."
32.122b	do.	-	1957	6,943	620	414	11- 8-57	do.	Jmw	2	N	N	O	Observation well of Homestake-New Mexico Partners; well "32 O-B2."
32.122c	do.	C. T. Henderson	-	6,948	500	-	-	do.	Jmw	6	C	E	E	Water supply for Homestake-New Mexico Partners "Sec. 32" mine.
32.314	Adrian Berryhill	-	-	6,910	550	397.4	12-20-57	do.	Jmw	5	C	G	S	Ca.
32.314a	do.	-	-	6,910	550	-	-	do.	Jmw	-	C	W	S	Not used for some time.
34.422	Phillips Petr. Co.	-	1958(?)	7,008	1,004	508	1958	do.	Jmw	N	N	N	U	Ca; exploratory drill hole at Phillips Petroleum Co. "Sandstone" mine shaft; L.
36.313	do.	-	1958(?)	7,070	1,500	582	1958	do.	Jmw	N	N	N	U	Ca; exploratory drill hole at Phillips Petroleum Co. "Cliffside" mine shaft; L.
14.10. 9.112	Buck Willcoxson	Hubbell Bros.	1951	7,240	912	-	-	do.	Jmw	7	C	W,G	S	Bailed at 40 gpm; drawdown to 650 ft.
10.413	Kermac Nuclear Fuels Corp.	Smith Drlg. Co.	1957	7,123	735	-	-	do.	Jmw	4	C	E	D,I	Test pumped at 20 gpm; pumping level 660 ft.
11.434	Rio De Oro Uranium Mines	Van L. Turner	-	7,060	750	460	-	do.	Jb	-	S	E	D,I	Ca; water supply for Rio De Oro Mine.
11.441	Ambrosia Investment Co.	-	1941	6,707	1,720	-	-	-	-	N	N	N	U	Ambrosia Investment Co. No. 1, oil-test well; L.
14.221	Buck Willcoxson	-	1925	7,060	702	-	-	Sandstone	Jb	6	C	W	S	Bailed at 45 gpm; drawdown to 600 ft.
22.214	Kermac Nuclear Fuels Corp.	-	1957	7,077	1,003	525	-	do.	Jmw	13	S	E	I	Ca; water-test well; casing plugged at 800 ft; perforated at intervals below 568 ft. Pumped at 90 gpm, pumping level 710 ft. "Kermac" water well 2.
22.414	do.	-	1956	7,016	3,081	574	3-22-57	Limestone	Psa	16	N	N	U	Ca; water-test well; "Kermac" water well 1; L.
22.422	do.	-	1955	7,023	745	450	9-10-56	Sandstone	Jmw	4	N	N	U	Ca; water-supply well for drilling operations at well 14.10.22.414.
23.114	Homestake-Sapin Partners	Franklin & Cowan Drlg. Co.	1956	7,053	796	502	5- 7-57	do.	Jmw	8	C	E	I	Water supply for Homestake-Sapin Partners "Sec. 23" mine; drilled as test well for hydrologic studies; well "23 H_2OA."
23.132	do.	-	1957	7,034	780	485	5- 7-57	do.	Jmw	2	N	N	O	Observation well of Homestake-Sapin Partners; well "23 O-B1."
23.134	do.	Franklin & Cowan Drlg. Co.	1956	7,030	825	491	5- 8-57	do.	Jmw	6	N	N	O	Observation well of Homestake-Sapin Partners; well "23-H_2O."
23.141	do.	-	1957	7,047	770	498	5- 7-57	do.	Jmw	2	N	N	O	Observation well of Homestake-Sapin Partners; well "23 O-B2."
23.142	do.	-	1955	7,037	707	489	5-17-57	do.	Jmw	2	N	N	O	Observation well at Homestake-Sapin Partners; well "D5A4."
23.232	do.	Wheeler & Henderson	1957	7,022	720	473	5-17-57	do.	Jmw	12	N	N	O	Drilled as test well for hydrologic studies; well "23 H_2O B."

TABLE 1 (continued)

RECORDS OF WELLS IN SOUTHEASTERN McKINLEY COUNTY, N. MEX.

Location	Owner or name	Driller	Year completed	Altitude	Depth of well (feet)	Water level: Depth below surface (feet)	Water level: Date of measurement	Principal water-bearing unit: Character of material	Principal water-bearing unit: Stratigraphic unit	Diameter of casing (inches)	Type of pump	Type of power	Use of water	Remarks
14.10.23.232a	Homestake-Sapin Partners	-	1957	7,022	715	479	5-17-57	Sandstone	Jmw	2	N	N	O	Observation well of Homestake-Sapin Partners; well "23 O-B3."
23.232b	do.	-	1957	7,022	720	477	5-17-57	do.	Jmw	2	N	N	O	Observation well of Homestake-Sapin Partners; well "23 O-B4."
24.423	Kermac Nuclear	-	-	6,980	-	449.4	12-18-57	do.	Jmw	5	N	N	U	-
25.132	Homestake-Sapin Partners	Franklin & Cowan Drlg. Co.	1956	6,476	766	431	4-25-57	do.	Jmw	8	N	N	O	Ca; drilled as test well for hydrologic studies; well "25 H_2O A." Test pumped at 150 gpm; pumping level 654 ft.
25.132a	do.	-	1956	6,974	720	424	4-25-57	do.	Jmw	2	N	N	O	Observation well of Homestake-Sapin Partners; well "46."
25.132b	do.	-	1956	6,974	735	425	4-11-57	do.	Jmw	2	N	N	O	Observation well of Homestake-Sapin Partners; well "47."
25.132c	do.	-	1956	6,974	735	424	4-11-57	do.	Jmw	2	N	N	O	Observation well of Homestake-Sapin Partners; well "48."
25.132d	do.	-	1956	6,975	725	426	4-11-57	do.	Jmw	2	N	N	O	Observation well of Homestake-Sapin Partners; well "51."
25.321	do.	-	1957	6,971	735	430	5-24-57	do.	Jmw	2	N	N	O	Observation well of Homestake-Sapin Partners; well "25 O-B3."
25.411	do.	Wheeler & Henderson	1957	6,970	753	430	5-24-57	do.	Jmw	12	N	N	O	Drilled as test well for hydrologic studies; well "25 H_2O B."
25.411a	do.	-	1957	6,971	750	432	5-24-57	do.	Jmw	2	N	N	O	Observation well of Homestake-Sapin Partners; well "25 O-B1."
25.413	do.	-	1957	6,971	722	432	5-24-57	do.	Jmw	2	N	N	O	Observation well of Homestake-Sapin Partners; well "25 O-B2."
35.221	G. P. Roundy	Hubbell Bros.	1954	7,015	760	461.4	12-18-57	do.	Jmw	6	C	N	S	-
14.11. 3.334	Adrian Berryhill	C. C. Smith Drlg. Co.	1956	7,055	653	440	-	do.	Jmw	5	C	G	S	Ca; exploratory drill hole converted to water well; L.
11.134	do.	-	-	7,030	-	-	-	-	-	6	C	W	S	-
19.124	Henry E. Andrews	-	1920(?)	6,880	60	60	-	Sandstone	ℛw	5	C	W	D,S	Ca.
19.322	do.	-	1950(?)	6,870	94 M	60.5	8- 3-61	do.	ℛw	7	C	W	S	-
30.211	Elkins Ranch, Inc.	-	-	6,845	87 M	61.3	8- 3-61	do.	ℛc	7	N	N	U	-
14.12. 8.331	U. S. Bureau of Indian Affairs	-	-	7,240	-	-	-	Sand	Qal	240	C	H	D,S	Old dug well; rehabilitated by the Navajo Tribe in 1961.
9.221	Elkins Ranch, Inc.	Hubbell Bros.	1962	7,380	762	500	-	Sandstone	ℛw	6	C	G	S	Ca.
14.142	do.	do.	1952	7,090	430	245.3	9- 5-62	do.	ℛw	6	C	W	S	Ca; L.
19.431	Crosslands Foundation, Inc.	Prewitt Drlg. Co.	1958	7,120	784	-	-	do.	ℛc	7	S	E	D	-
20.111	U. S. Bureau of Indian Affairs	Sartin & Hayes	1941	7,150	430	95	-	do.	ℛc	8	N	N	U	Ca; BIA well 16K-303; casing plugged with rocks.
20.111a	do.	-	-	7,150	12 M	3.7	7-21-61	Sand	Qal	48	N	N	S	Water dipped out with bucket for sheep; dug well, cribbed with logs.
20.112	Christian Reformed Mission	-	-	7,150	36 M	32.7	7-21-61	do.	Qal	36	C	W	D	Dug well, cribbed with concrete.
20.121	do.	O. Carter	1953	7,150	731	400	-	Sandstone	ℛc	-	-	-	-	Ca; well plugged because of poor-quality water.
32.434	Elkins Ranch, Inc.	-	-	6,905	200	53.1	6-24-48	do.	ℛc	8	C	W	S	-
14.13.20.413	Transwestern Pipeline Co.	Layne Texas Co.	1960	7,323	735	317	-	do.	ℛc	9	S	E	I	Ca; well 3: Compressor Station 5.
20.414	do.	do.	1959	7,315	750	309	-	do.	ℛc	9	S	E	I	Well 1: Compressor Station 5; L.
20.431	do.	do.	1960	7,300	743	338	-	do.	ℛc	9	S	E	I	Well 2: Compressor Station 5.
25.133	U. S. Bureau of Indian Affairs	Perry Bros.	1958	7,140	677	160.3	7-11-61	do.	ℛc	9	C	W	S	BIA well 16T-349.
27.342	do.	O. C. Robinson	1959	7,140	435	153.1	7-20-61	do.	ℛc	9	C	G	D,S	BIA well 16T-352; Thoreau Chapter House; L.
28.123	do.	Kiersey & Co.	1933	7,130	730	385.8	6- 4-59	do.	ℛc	12	C	W	S	Ca; BIA well 16B-39; L.
32.242	Maria Ramirez	-	-	7,130	150	64.8	7-19-61	do.	ℛc	6	C	W	D	-
32.322	Charles Bass	O. Carter	1949	7,150	183	140	-	do.	ℛc	4	S	E	D	Thunderbird bar at Thoreau.
32.322a	Paul Dunning	Paul Dunning	1947	7,150	175	125.2	7-19-61	do.	ℛc	7	C	E	D	Thoreau Trading Post.
33.113	A. J. Mahler	Prewitt Drlg. Co.	1960	7,160	247	-	-	do.	ℛc	-	S	E	D	AJ Cafe at Thoreau.
33.123	McKinley County	E. D. Bennett Drlg. Co.	1955	7,155	-	-	-	do.	ℛc	8	S	E	D	Thoreau Elementary School.
33.124	U. S. Bureau of Indian Affairs	-	1935	7,150	505	122.0	7-30-48	do.	ℛc	10	C	E	D	Ca; Thoreau Boarding School Well 1; BIA well 16K-302; L.

TABLE 1 (continued)

RECORDS OF WELLS IN SOUTHEASTERN McKINLEY COUNTY, N. MEX.

						Water level		Principal water-bearing unit						
Location	Owner or name	Driller	Year com-pleted	Altitude	Depth of well (feet)	Depth below surface (feet)	Date of measure-ment	Character of material	Stratigraphic unit	Diameter of casing (inches)	Type of pump	Type of power	Use of water	Remarks
14.13.33.124a	U. S. Bureau of Indian Affairs	Payne & Ballard	1952	7,150	1,350	Flowing	6-21-52	Sandstone	Pg	6	N	N	U	Ca; Thoreau Boarding School well 3; BIA well 16K-302A; well filled with sand; L.
33.132	do.	-	-	7,150	-	79.2	7-18-61	do.	T̄Rc	7	N	N	U	-
33.132a	Elmer Bowman	Stuart Bros.	1961	7,150	280	-	-	do.	T̄Rc	5	S	E	D	L.
33.141	O. Carter	O. Carter	1937	7,150	227	60	-	do.	T̄Rc	6	C	W	D	Ca.
33.143	Clay Hardin	-	-	7,150	230	-	-	do.	T̄Rc	7	S	E	D	-
33.143a	A. T. & S. F. Railroad	-	-	7,150	500-600	-	-	do.	T̄Rc	8	J	E	D	Supplies water to Thoreau R. R. station.
33.211	U. S. Bureau of Indian Affairs	W. J. McCray	1951	7,160	420	115.8	9-18-52	do.	T̄Rc	-	C	W	D	Ca; Thoreau Boarding School well 2; BIA well 16K-326; L.
33.231	Southwest Indian Mission	O. Carter	1954	7,145	-	138.0	7-19-61	do.	T̄Rc	6	S	E	D	-
33.314	J. J. Rodosevich	do.	1942	7,120	235	-	-	do.	T̄Rc	6	C	W	D	Ca; Johnnies Inn at Thoreau.
33.333	El Paso Natural Gas Co.	El Paso Natural Gas Co.	1953	7,150	750	37.3	6-29-61	Limestone and sandstone	Psa, Pg	13	T	E	I	Flows during winter; Bluewater Compressor Station well 1.
33.334	do.	do.	1953	7,147	872	41.0	6-29-61	do.	Psa, Pg	13	T	E	I	Ca; flows during winter. Bluewater Compressor Station well 2; L.
34.311	U. S. Bureau of Indian Affairs	-	-	7,105	98 M	80.7	6- 4-59	-	T̄Rc	7	C	W	S	Not in use.
15. 6. 4.411	Richfield Oil Corp.	-	1946	6,620	7,143	-	-	-	-	N	N	N	U	Richfield Oil Corp., No. 1, Drought-Booth, oil test well; L.
4.423	Ignacio Chavez Grant	-	1923	6,665	2,154	Flowing	10- 3-62	Sandstone	Kg, Kd	8	-	-	S	Drilled as Midwest Refining Co. & Stanolind Oil & Gas Co., No. 1, Chavez Grant, oil-test well; flows small amount; H_2S odor; L.
20.331	Albert Michael	Dunn Bros. Uranium Co.	-	6,610	1,000	do.	10-17-62	do.	Kcg, Kcda	-	-	-	S	Ca; well began flowing several years after drilling; H_2S odor; exploration drill hole.
22.312	do.	Glen Isaacson	-	6,800	200	64.2	10- 3-62	do.	Kmf	6	C	E	S	Ca.
15. 7.13.142	Fernandez Co.	-	-	6,620	600	Flowing	10- 3-62	do.	Kcg, Kcda	8	-	-	S	Ca; "El Dado" artesian water well.
15. 8. 3.342	do.	-	-	6,795	495	77.7	10- 2-62	do.	Kpl, Kplh	6	S	E	S	Well in pit; "Laguna Lucero" water well.
13.444	do.	-	-	6,685	400	Flowing	10- 3-62	do.	Kpl, Kplh	5	-	-	D,S	Ca; "Four Corners" water well.
21.442	do.	-	-	6,855	325	109.8	9- 2-62	do.	Kpl, Kplh	8	S	E	S	Ca; "New" well.
15. 9. 6.213	Pablo Pena & Sons	Turner	1940	7,030	120	66.8	9-12-62	do.	Kcda	6	C	W	S	Ca.
9.243	do.	Howard Sheets	-	7,050	502	318.4	9-12-62	do.	Kcdi	6	C	E	S	Ca.
13.144	do.	O. Carter	-	7,035	400	174.6	9-12-62	do.	Kplh, Kcg	6	C	W	S	Ca; Pena summer camp.
34.431	do.	-	-	7,745	1,600	326.7	9-12-62	-	-	4	C	E	S	Cased to 400 ft; exploratory drill hole.
15.10. 6.242	U. S. Bureau of Indian Affairs	Ed. Cowley	1954	7,480	1,000	485	-	Sandstone	Kcdi	7	C	W	D,S	Ca; BIA well 15K-338; L.
13.131	R. E. Albers & Son	-	-	7,225	-	-	-	do.	Kg(?)	12	C	W,B	S	Ca; reported to be abandoned oil-test well.
13.133	Midwest Refining Co.	-	1923	7,220	1,460	-	-	-	-	N	N	N	U	Midwest Refining Co., No. 1 Walker Dome, oil-test well; L.
32.214	U. S. Bureau of Indian Affairs	-	-	7,460	13	9.1	9-18-62	Sand	Qal	144	C	H	S	Ca; dug well.
15.11.18.222	do.	C. M. Carroll	1937	7,195	812	360	-	Sandstone	Kd	-	S	E	D,S	Ca; BIA well 16B-37; L.
25.334	do.	Cowley Bros.	1959	7,280	995	665	-	do.	Kd	8	C	G	D,S	BIA well 16T-501.
26.323	do.	-	-	7,365	7 M	Flowing	8- 2-61	do.	Kcdi	48	C	H	S	Dug well.
15.12.17.123	do.	O. Carter	1952	7,250	701	398.5	9- 8-55	do.	Kd	7	N	N	U	Ca; old well at Chapter House at Smith Lake; BIA well 16K-325; L.
17.123a	do.	-	-	7,250	1,221	-	-	do.	Jmw	-	S	E	D,S	Ca; new well at Chapter House at Smith Lake; BIA well 16T-525A.
19.141	Mrs. Ollie Morris	-	1957	7,290	53 M	33.3	7-12-61	do.	Km	5	-	-	U	-
19.212	do.	-	-	7,240	31	22	-	do.	Km	48	N	N	U	Dug well, filled to about 7 ft.
19.223	do.	Fred Bentley	-	7,305	1,100	-	-	do.	Jmw	4	C	W,E	D,S	Ca; formerly water supply for Morris Trading Post (Trading post no longer exists at this location)
15.13. 5.431	Tidewater Oil Co.	O. Carter	1948	7,400	292	230	10- 3-48	do.	Kd	6	N	N	U	Ca; well cannot be located; BIA well 16K-318.

TABLE 1 (concluded)

RECORDS OF WELLS IN SOUTHEASTERN MCKINLEY COUNTY, N. MEX.

Location	Owner or name	Driller	Year completed	Altitude	Depth of well (feet)	Water level: Depth below surface (feet)	Water level: Date of measurement	Principal water-bearing unit: Character of material	Principal water-bearing unit: Stratigraphic unit	Diameter of casing (inches)	Type of pump	Type of power	Use of water	Remarks
15.13. 8.213	Tidewater Oil Co.	O. Carter	1948	7,621	4,686	-	-	-	-	-	N	N	U	Tidewater Assoc. Oil Co. No. 1, Mariano Dome oil-test well; L.
12.144	Lance Corp.	-	1958	7,434	1,100(?)	800	-	Sandstone	Jb	-	C	E	D	Ca; water supply for "Blackjack No. 1" mine.
12.144a	do.	-	1961	7,434	1,012	800	-	do.	Jb	-	-	-	D	Pump set in "Blackjack No. 1" mine 800 ft below surface; L.
13.100	U. S. Bureau of Indian Affairs	O. Carter	1957	-	740	-	-	-	-	N	N	N	U	Dry hole; BIA well 16T-345.
16. 5.19.414	Joe Montoya	-	1956	6,465	1,251	Flowing	9-19-62	Sandstone	Kg	12	N	N	S	Ca; H_2S odor; drilled as Basin Natural Gas Co. No. 1 Woodward, oil-test well.
16. 6.20.443	Fernandez Co.	-	-	6,425	1,028	do.	10- 3-62	do.	Kg	5	N	N	U	Drilled as Sinclair Oil and Gas Co. No. 1 Santa Fe-Miguel, oil-test well; some oil seeping from casing.
16. 7. 9.333	do.	-	-	6,675	-	118.0	10- 2-62	do.	Kpl, Kplh	5	N	N	U	-
13.224	do.	-	-	6,490	327	27.5	10- 2-62	do.	Kpl, Kplh	6	S	E	S	Ca; "Huerfano" water well.
26.221	do.	-	1957	6,625	1,403	Flowing	10- 2-62	do.	Kg	-	N	N	S	Ca; drilled as Cities Service Oil Co. Davis-Skinner No. 1, oil-test well; flowing 25 gpm.
32.413	do.	-	-	6,695	451	38.9	10- 2-62	do.	Kpl, Kplh	6	S	E	S	Ca.
16. 8. 1.100	Petro. Minerals, Inc.	-	1956	6,880(?)	3,006	-	-	-	-	N	N	N	U	Petro. Minerals, Inc. No. 1 Fernandez, oil-test well; L.
14.111	Fernandez Co.	-	-	6,700	-	157.4	10- 2-62	Sandstone	Kpl, Kplh	7	S	E	S	Ca.
20.131	do.	-	-	6,750	316	36.8	10- 2-62	do.	Kplh	5	S	E	S	Ca; "Vogt Homestead" water well.
25.233	do.	-	-	6,665	560	108.0	10- 2-62	do.	Kpl, Kplh	8	S	E	S	-
33.134	do.	-	-	6,805	381	46.5	10- 2-62	do.	Kpl, Kplh	8	S	E	S	Ca; "Sabino" well.
16. 9. 1.132	do.	-	1928	6,925	904	209.0	9-20-62	do.	Kcg	8	S	E	S	Drilled as Jenkins Oil Co. Santa Fe R. R. No. 1, oil-test well.
14.121	do.	-	-	6,620	172.0	89.7	9-20-62	do.	Kplh	6	S	E	S	-
17.222	do.	Locke & Taylor Drlg. Co.	-	6,970	1,897	179.6	9- 9-62	do.	Kcg	10	S	E	S	Ca; drilled as Locke & Taylor, No. 1 Santa Fe R. R., oil-test well; L.
22.444	do.	-	-	6,930	350	205.0	9-20-62	do.	Kcg	6	S	E	S	Ca.
16.10. 8.312	U. S. Bureau of Indian Affairs	C. M. Carroll	1936	6,940	477	234	-	do.	Kcg	7	C	W	S	Ca; BIA well 15B-36; L.
12.144	Hogback Oil Co.	-	1927	7,140	2,350	-	-	-	-	N	N	N	U	Hogback Oil Co., No. 1 O. G. Horton, oil-test well; L.
15.222	R. E. Albers & Son	O. Carter	-	7,095	-	396.7	9-19-62	do.	Kplh	5	C	E	S	-
22.232	do.	Hubbell Bros.	1950	7,265	645	580	-	do.	Kplh	5	C	E	D,S	Ca; L.
16.11. 5.121	U. S. Bureau of Indian Affairs	-	1935	6,810	715	33.5	7-31-61	do.	Kcdi, Kg	9	C	W	S	Ca; BIA well 15B-35; L.
16.331	do.	Cowley Bros.	1959	7,065	570	265	-	do.	Kcdi	7	C	W	D,S	Ca; BIA well 15T-505; Little Water Chapter House; L.
33.224	D. R. Smouse	C. C. Smith	1960	7,440	900	280	-	do.	Kcdi	4	S	E	D,S	Borrego Pass Trading Post.
33.311	U. S. Bureau of Indian Affairs	Shamrock Drillers	1961	7,390	500	221.9	8- 1-61	do.	Kcdi	6	-	-	U	Borrego Pass Day School; drilled to 600 ft; plugged back to 500 ft.
33.411	do.	Myers Drlg. Co.	1957	7,410	830	300	-	do.	Kcdi, Kg	6	T	E	D	Borrego Pass Day School; L.
16.13.11.440	do.	Cowley Bros.	1954	6,930	340	109.4	7-11-61	do.	Kcdi	10	C	W	S	Ca; BIA well 16K-332; L.

TABLE 2

RECORDS OF SPRINGS IN SOUTHEASTERN McKINLEY COUNTY, N. MEX.

EXPLANATION:

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

Altitude: Elevation, above sea level, of land surface at spring; extrapolated from topographic map.

Stratigraphic unit: Te, basalt, andesite, and other extrusive rocks; Kmf, Menefee Formation; Kpl, Point Lookout Sandstone; Kplh, Hosta Tongue of Point Lookout Sandstone; TRw, Wingate Sandstone; Psa, San Andres Limestone.

Yield: M, measured; E, estimated.

Use of water: B, bath; D, domestic; I, irrigation; S, stock.

Remarks: Ca, chemical analysis in table 3.

Location	Owner or name	Topographic situation	Altitude (feet)	Principal water-bearing unit: Character of material	Principal water-bearing unit: Strati-graphic unit	Yield: Rate of flow (gpm)	Yield: Date of measure-ment	Use of water	Improvements	Remarks
13. 5.26.134	Community of Marquez	East edge of Cebolleta Mtns.	7,380	Sandstone	Kplh	25E	8-27-62	D,I,S	Spring dug out and water diverted into irrigation system	Ca; water is used to irrigate fields near Marquez; several smaller springs nearby.
13. 7. 9,323	Cibola Natl. Forest	Northwest edge of Cebolleta Mtns.	7,810	Volcanics, sandstone, and shale	Te,Kmf	50E	10-23-62	S	None	Ca.
9.423	do.	do.	7,840	do.	Te,Kmf	50E	10-23-62	S	do.	-
11.131	Fernandez Co. (San Miguel Springs)	Head of San Miguel Creek	7,950	Contact of two basalt flows	Te	75E	10-23-62	S	One spring piped to watering trough	Series of springs in creek bottom and on canyon sides.
20.121	Cibola Natl. Forest (San Lucas Spring)	Head of small canyon	7,850	Basalt	Te	20E	8-29-62	S	-	Ca; series of small seeps.
31.414	Community of San Mateo & Fernandez Co. (San Mateo Springs)	Sides of San Mateo Creek	8,120	Tuff	Te	250-300E	10-24-62	D,I	Reservoir and irrigation system	Ca; five springs of 25 gpm flow; many small springs nearby.
13.13.30.223	Charles Bass	Azul Creek Valley	7,495	Sandstone and limestone	Psa	10E	6- 2-59	S	Stock tank	Spring is in bottom of stock tank, valved to discharge into nearby pond.
34.233	Hollis Howie	Stream bed	7,475	do.	Psa	20E	6- 2-59	D,I,B	Concrete floor and house over spring opening	Ca; reported to flow several hundred gpm in wet years; Cottonwood Gulch Foundation summer camp.
14. 7.10.333	Fernandez Co. (Cerro Spring)	Arroyo bottom	6,820	Sandstone	Kmf	10E	10-23-62	S	None	Near andesite dike.
28.132	Fernandez Co. (Saphole Spring)	High ground between two arroyos	6,910	Sandstone and shale	Kmf	½E	10-23-62	S	Old seep tank and concrete watering trough	On east-west trending fault.
28.424	Fernandez Co. (Fort Miguel Spring)	Bank and bottom of San Miguel Creek	6,900	Shale	Kmf	1E	10-23-62	S	None	Spring has caused slump of shale into stream.
14.12.17.333	U. S. Bureau of Indian Affairs (San Antonio Spring)	Hillside	7,175	Sandstone	TRw	1E	7-21-62	D,S	Rock walled; piped across road to stock tanks.	Ca; reported unfit for human consumption.
15. 6.19.321	Fernandez Co. (El Dado Springs)	Flat	6,595	Sandstone and shale	Kmf	5E	7-21-62	D,S	Seep tanks, watering troughs and old domestic storage tank.	This spring was a stagecoach stop; supports abundant grass.
20.121	Albert Michael	Arroyo bottom	6,600	Sandstone, shale, and coal	Kmf	¼E	10- 3-62	D,S	Concrete seep tank and storage with pipe to house.	Ca; other unimproved springs of same size and character nearby.
32.231	do.	Hillside	6,725	Sandstone and shale	Kmf	2E	10-22-62	S	Seep tanks and pond	Highly polluted by animals; several springs in immediate area.
15. 7.10.321	Fernandez Co. (Sandoval Spring)	Arroyo bottom	6,535	do.	Kmf	1E	10-16-62	S	None	Ca; another spring 0.25 mile to the east with very small flow.
15.243	Fernandez Co. (Burro Spring)	Hillside and arroyo bottom	6,555	Sandstone, shale, and coal	Kmf	2E	10-15-62	S	do.	Series of springs issue from same horizon to the east.
22.131	Fernandez Co.	Edge of low hill	6,595	Sandstone and shale	Kmf	¼E	9-19-62	S	Seep tank	Spring enters bottom of seep tank and flows over the top of the tank 18 inches above land surface.

TABLE 2 (concluded)

RECORDS OF SPRINGS IN SOUTHEASTERN McKINLEY COUNTY, N. MEX.

Location	Owner or name	Topographic situation	Altitude (feet)	Principal water-bearing unit: Character of material	Principal water-bearing unit: Stratigraphic unit	Yield: Rate of flow (gpm)	Yield: Date of Measurement	Use of water	Improvements	Remarks
15. 7.23.132	Fernandez Co. (Doctor Spring)	Edge of low hill near head of arroyo	6,595	Sandstone, shale, and coal	Kmf	15E	10- 3-62	S	Spring dug out and concrete stock tank built	Ca.
29.344	Fernandez Co. (San Ysidro Spring)	Head of arroyo	6,665	Sandstone and shale	Kmf	1E	10-15-62	S	Two seep tanks and one watering trough	Several other smaller springs in the area.
16. 5.13.422	Ernesto Montoya	Edge of low hill	6,325	do.	Kmf	1/8E	9-19-62	S,D	Fenced seep tank with water trough	Flow stronger in spring and in wet years.
14.442	Joe Montoya	Arroyo bottom	6,360	Sandstone	Kmf	½E	9-19-62	S	None	Domestic spring reported 0.25 mile up arroyo; similar size and characteristics.
15.122	do.	Head of arroyo	6,330	Sandstone, shale, and basalt	Kmf	2E	9-19-62	S	do.	Spring occurs along basalt dike near small plug.
15,233	do	Near crest of low hill	6,395	do.	Kmf	½M	9-19-62	S	Spring covered and water piped to trough	Ca; spring is along basalt dike at old stagecoach station; another spring 0.4 mile to the north.
16.124	Mr. Sandoval	Arroyo bottom	6,330	Sandstone, shale, and coal	Kmf	2E	9-19-62	S	None	-
16. 6.21.432	Fernandez Co.	do.	6,370	Sandstone and shale	Kpl	5E	10- 3-62	S	do.	Flow creates area of clear water in murky stream.
29.231	do.	do.	6,410	do.	Kplh	20E	10- 3-62	S	do.	Ca.

TABLE 3

CHEMICAL ANALYSES OF WATER FROM WELLS, SPRINGS, AND MINES IN SOUTHEASTERN McKINLEY COUNTY, N. MEX.

(Analyses by U.S. Geological Survey. Chemical constituents are in parts per million. Values reported for dissolved solids are calculated from determined constituents. Radioactive elements are in picocuries per liter.)

EXPLANATION:

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

Stratigraphic unit: Qal, alluvium; Te, basalt, andesite, and other extrusive rocks; Kmf, Menefee Formation; Kpl, Point Lookout Sandstone; Kplh, Hosta Tongue of Point Lookout Sandstone; Kcg, Gibson Coal Member of Crevasse Canyon Formation; Kcda, Dalton Sandstone Member of Crevasse Canyon Formation; Kcdi, Dilco Coal Member of Crevasse Canyon Formation; Kg, Gallup Sandstone; Km, Mancos Shale; Kd, Dakota Sandstone; Jmw, Westwater Canyon Member of Morrison Formation; Jb, Bluff Sandstone; Jt, Todilto Limestone; Ŧw, Wingate Sandstone; Ŧc, Chinle Formation; Psa, San Andres Limestone; Pg, Glorieta Sandstone.

Location	Stratigraphic unit	Date of collection	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	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	Remarks
13. 4.31.114	Kg	8-27-62	58	26	0.03	120	52	109	8	340	0	424	27	0.4	0.0	933	512	234	1,300	7.3	-
13. 5. 7.123	Kpl	9-21-62	56	39	.23	23	9.4	13	6.3	150	0	3.8	3.6	.2	1.1	174	96	0	247	7.7	-
26.134	Kplh	8-27-62	63	34	.00	31	13	20	4.4	186	0	15	6.4	.2	.8	216	131	0	329	7.7	Spring
13. 7. 9.323	Te,Kmf	10-23-62	52	51	.01	19	7.2	13	3.5	127	0	1.2	2.9	.3	.1	160	77	0	203	7.9	Do.
20.121	Te	8-29-62	54	52	.01	27	6.2	10	3.8	108	0	2.6	26	.3	.2	181	93	4	255	7.2	Do.
31.414	Te	10-24-62	56	10	.00	9.6	2.4	10	3.4	68	0	.6	1.6	.3	.5	71	34	0	117	8.0	Do.
13. 8.24.223	Kmf	9-10-62	57	12	.02	1.6	.0	206	.9	379	33	70	4.2	1.9	.4	517	4	0	833	9.0	-
24.334b	Kmf	9-10-62	56	11	.02	14	3.4	179	1.7	370	0	102	14	.9	8.3	516	49	0	814	8.1	-
26.221	Kpl	9-11-62	57	14	.02	74	24	76	3.0	365	0	103	22	1.0	14	510	284	0	808	8.1	-
30.100	Jmw	4-25-63	-	22	.01	45	7.2	69	3.2	249	0	88	3.5	.7	.2	382	142	0	572	7.7	El Paso Natural Gas Co. "San Mateo" mine; Beta activity 36±5 as of 5-23-63; Radium 8.5±1.7.
30.200	Kd	4-25-63	-	27	.28	124	25	48	4.8	346	0	206	11	.2	.9	617	284	129	912	7.5	El Paso Natural Gas Co. "San Mateo" mine; Beta activity 12±2 as of 5-23-63; Radium 2.9±0.6.
13. 9.15.343	Jmw	2-13-58	58	16	-	169	18	153		451	0	405	21	.3	7.7	1,010	496	126	1,430	7.2	-
22.212	Qal	12- 6-57	55	20	-	37	9.5	159		292	0	189	20	1.2	12	592	132	0	912	7.6	-
29.144	Jt	2-28-58	59	16	.00	264	9.7	324	3.2	194	0	1,130	22	1.2	25	1,890	698	540	2,340	7.6	Westvaco Mineral Development Co. "Faith" mine; Beta activity 150; Radium 5.1.
13.11. 7.344	Ŧc	9- 5-62	65	11	.00	20	7.3	103	2	304	0	41	8.7	.8	.0	343	80	0	553	7.8	-
7.433	Ŧc	6-24-48	-	11	-	9.0	3.5	128		270	0	61	17	.6	5.6	369	37	0	597	8.3	-
8.212	Ŧc	6-23-48	55	16	-	160	69	452		322	0	1,260	60	.4	5.5	2,160	682	418	2,860	7.9	-
17.113a	Ŧc	6-23-48	56	-	-	-	-	-		338	-	-	16	-	-	-	-	-	770	-	-
17.114a	Ŧc	6-23-48	55	-	-	-	-		-	332	0	-	13	-	-	-	-	-	641	-	-
17.411	Ŧc	6-23-48	54	-	-	75	29	97		334	-	210	16	.5	0	602	306	-	925	-	-
18.224	Ŧc	6-23-48	56	-	-	-	-	-		327	0	-	14	-	-	-	-	-	693	-	-
13.12.12.441	Ŧc	6-23-48	56	12	-	45	17	104		332	0	102	15	3.5	.5	462	182	0	727	8.1	-
34.332	Psa	9- 4-62	55	12	.00	155	60	20	1.8	277	0	419	8.1	.6	.1	813	634	407	1,120	7.8	-
13.13. 1.221	Psa,Pg	6-25-48	62	-	-	-	-	-		271	-	-	5	-	-	-	-	-	762	-	-
1.222a	Psa,Pg	6-23-48	65	-	-	125	37	23		256	-	285	5	.2	-	615	464	-	889	-	-
Do.	Psa,Pg	8- 4-61	66	15	.58	128	33	27	1.7	252	0	294	3.8	.4	.1	627	456	250	905	7.4	-
Do.	Psa,Pg	12-11-62	65	11	.53	129	32	28	1.9	250	0	295	6.4	.7	.0	627	453	248	901	7.8	-
8.444	Psa,Pg	7-19-61	63	16	.01	78	19	9.5	.8	261	0	63	8	.3	.4	323	272	58	529	7.3	-
28.131	Psa	9- 4-62	53	16	.02	76	15	7.4	.9	273	0	32	6.9	.4	.8	289	250	26	479	7.9	-
Do.	Psa	12-11-62	53	14	.00	76	14	8.0	.9	267	0	33	9.6	.4	.7	288	248	29	476	8.0	-
34.233	Psa	9- 4-62	52	14	.02	72	16	6.2	1.2	290	0	11	8	.2	.8	272	244	6	462	8.1	Spring
14. 5.14.422	Kpl	8-29-62	58	37	.00	20	8.5	10	3.4	116	0	5.8	5.4	.3	1.4	149	85	0	211	7.8	-
14. 8. 4.334	Kcda	10-16-62	54	11	.02	420	200	691	13	383	0	2,880	50	1.2	14	4,470	1,870	1,560	4,950	8.1	-
15.244	Km	10- 1-62	72	6.5	.00	3.1	1.8	1120	.1	194	85	1,940	76	2.5	5.8	3,340	15	0	4,610	9.6	-
14. 9.17.400	Jmw	8- 8-62	-	18	.00	29	6.2	172	6.0	275	0	230	8.8	.7	.1	606	98	0	926	7.7	Kermac Nuclear Fuels Corp. mine.
Do.	Kd	8- 8-62	57	16	.00	71	27	356	6.5	296	0	772	14	.5	.2	1,410	290	48	1,980	7.5	Do.
Do.	Kd	4-30-63	-	20	.00	140	56	276	7.6	319	0	850	17	.3	1.0	1,525	162	319	2,065	7.7	Kermac Nuclear Fuels Corp. mine; Beta activity 18±3 as of 8-14-63; Radium 2.7±0.5
18.243	Jmw	10-17-62	62	15	.01	90	26	485	5.6	253	0	1,110	22	1.1	1.2	1,860	332	124	2,520	7.9	-
18.400	Jmw	4-30-63	-	14	.05	25	9.2	178	6.2	300	0	222	7.9	.6	.2	611	100	0	904	8.0	Kermac Nuclear Fuels Corp. mine; Beta activity 37±6 as of 9-14-63; Radium 5.6±1.1.
28.143	Jmw	12-12-56	63	16	4.0	59	24	186	4.8	314	0	381	7	.5	.0	834	240	0	1,230	7.6	Beta act. 69, 12-63; Radium 1.1.
28.233	Kd	10-10-57	63.5	-	-	-	-	188		335	0	506	6	.5	.5	-	402	128	1,440	8.0	Phillips Petroleum Co. "Ann Lee" mine.
Do.	Jmw	10-10-57	67	-	-	-	-	150		287	0	119	7	.6	.3	-	44	0	697	8.1	Do.
29.312	Jmw	8-13-59	62	16	.43	211	62	127	4.2	256	0	794	10	.6	15	1,410	782	572	1,710	7.8	Beta activity 39±7 as of 11-3-59; Radium 10±2.

TABLE 3 (continued)

CHEMICAL ANALYSES OF WATER FROM WELLS, SPRINGS, AND MINES IN SOUTHEASTERN McKINLEY COUNTY, N. MEX.

Location	Stratigraphic unit	Date of collection	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	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	Remarks
14. 9.30,200	Jmw	5- 3-63	-	14	0.00	20	7.3	136	7.8	249	0	164	5.2	0.3	0.2	478	80	0	742	8.1	Kermac Nuclear Fuels Corp. mine; Beta activity 12±2 as of 8-14-63; Radium 2.0±0.4.
32,122	Jmw	2-14-58	65	16	2.1	5.6	.5	145	2.4	238	4	123	6.0	.4	.0	426	16	0	667	8.3	Homestake-New Mexico Partners "Sec.32" mine; Beta activity 49; Radium 42.
32,314	Jmw	8-11-59	62	10	.00	46	12	114	7.6	220	0	218	8.0	.4	.0	512	164	0	796	7.3	Beta activity 18±4 as of 11-3-59; Radium 1.1±0.2.
34,422	Jmw	4-24-63	-	14	.00	15	4.9	226	3.7	252	0	322	7.7	.3	.2	718	58	0	1,103	8.2	*United Nuclear Co. "Sandstone" mine; Beta activity 9.0±1.3 as of 5-24-63; Radium 1.4±0.3.
36,313	Kd	5- 6-63	-	18	.02	102	33	200	4.2	340	0	500	25	.4	.7	1,050	278	112	1,490	7.6	*United Nuclear Co. "Cliffside" mine; Beta activity 75±11 as of 8-18-63; Radium 27±5.
Do.	Jmw	4-24-63	-	19	.08	53	13	252	5.2	209	0	536	8.7	.9	.3	945	172	14	1,360	7.8	*United Nuclear Co. "Cliffside" mine; Beta activity 6.5±0.9; as of 5-23-63; Radium 1.2±0.2.
14.10.11,434	Jb	10-18-60	68	13	.00	26	3.9	700	3.6	168	4	1,360	60	2.4	1.1	2,260	81	0	2,830	8.3	-
22,200	Jmw	8- 8-62	-	22	-	30	10	119	6.2	243	0	158	8.0	.8	3.9	477	116	0	729	7.6	Kermac Nuclear Fuels Corp. mine.
22,214	Jmw	3-19-57	70	16	-	15	7.1	169		230	0	212	13	1.0	4.6	551	66	0	858	8.2	-
22,414	Psa	11-21-66	115	23	-	262	94	373		531	0	1,030	242	.6	.6	2,370	1,040	605	3,100	6.7	-
22,422	Jmw	9-28-56	63	-	-	-	-	-		533	0	262	10	-	-	633	302	0	945	7.9	-
24,100	Jmw	4-29-63	-	16	.02	32	17	90	7.4	247	0	136	5.6	1.0	.0	437	150	0	692	7.8	Kermac Nuclear Fuels Corp. mine; Beta activity 56±8, as of 8-13-63; Radium 2.3±0.5.
24,400	Jmw	8-18-59	-	16	-	34	16	111		253	0	165	8	.6	.1	-	151	0	745	8.0	Kermac Nuclear Fuels Corp. mine.
25,100	Jmw	8-18-59	-	12	-	36	16	181		285	0	293	5.5	.3	.0	-	154	0	1,060	8.0	Homestake-Sapin Partners mine.
25,132	Jmw	9-28-56	64	-	-	-	-	-		306	0	306	11	-	-	721	240	-	1,090	7.7	-
14.11. 3,334	Jmw	3-13-57	70	14	-	210	106	372		303	0	1,440	12	.5	4.0	2,310	960	712	2,870	7.4	-
19,124	TRw	8- 4-61	63	15	.33	115	43	206	2.6	332	0	579	22	.3	4.8	1,160	464	192	1,590	7.7	-
14.12. 9,221	TRw	9- 5-62	59	10	.03	2.6	.6	254	2.2	395	29	115	34	7.0	5.7	656	9	0	1,040	9.0	-
14,142	TRw	9- 5-62	62	19	.10	6.6	1.1	195	2.6	322	31	54	37	.9	20	527	21	0	825	8.9	-
17,333	TRw	11-15-48	45	-	-	2.0	3.3	219		436	0	77	33	1.2	8.6	559	18	0	881	-	Spring.
20,111	TRc	5-11-50	54	5.6	-	12	13	807		408	45	509	770	2.3	1.1	2,460	84	0	4,130	-	-
20,121	TRc	3- 9-53	-	-	-	-	-	-		114	0	-	4,650	-	-	-	373	260	13,400	-	-
14.13.20,413	TRc	7-12-61	67	14	.15	.4	.5	165	1.7	261	32	50	31	.4	1.1	425	3	0	701	9.1	-
28,123	TRc	12- 3-48	62	-	-	1.2	.5	141		244	16	54	19	.4	.9	353	5	0	576	-	-
Do.	TRc	2- 5-54	-	-	-	-	-	-		222	26	-	16	-	-	-	-	-	581	-	-
33,124	TRc	8-18-48	58	-	-	26	10	760		254	9	515	705	1.0	4.5	2,160	106	0	3,590	-	-
Do.	TRc	8-19-48	-	-	-	18	3.8	867		246	7	534	705	1.0	2.4	2,260	60	0	3,630	-	-
Do.	TRc	9- 8-51	56	-	-	-	-	-		248	8	-	735	-	-	-	-	-	3,710	-	-
Do.	TRc	4- 3-53	-	9.1	-	7.0	1.2	299		323	13	170	148	.4	1.4	808	22	0	1,350	-	-
33,124a	Pg	6-30-52	-	11	3.4	136	29	9.9		265	0	245	5	.4	.0	568	458	242	836	-	-
Do.	Pg	7-18-61	56	12	4.1	124	25	29	2.2	265	0	230	14	.2	.0	567	412	195	842	7.2	-
33,141	TRc	12- 6-48	-	-	-	26	7.0	217		334	13	184	50	.5	10	672	84	0	1,090	-	-
33,211	TRc	1-24-51	56	8.1	-	.5	1.2	196		356	12	103	16	.6	.6	518	18	0	837	-	-
Do.	TRc	1-27-51	56	8.7	-	13	2.8	207		394	6	127	19	.4	.7	579	44	0	935	-	-
33,314	TRc	12- 6-48	-	-	-	52	11	85		261	14	64	34	.2	9.3	398	174	0	679	-	-
33,334	Psa,Pg	7-19-61	66	13	2.7	90	15	10	1.2	280	0	72	4.8	.2	.0	344	286	56	563	7.4	-
15. 6.20,121	Kmf	10- 3-62	62	22	.02	2.5	.5	109	1.4	270	6	10	3.9	.4	1.2	290	8	0	451	8.4	Spring.
20,331	Kcg,Kcd	10-16-62	65	14	.02	1.3	.2	95	.9	204	20	9.2	1.4	.5	.2	243	4	0	392	9.1	-
22,312	Kmf	10-22-62	61	9.7	.23	2.1	.2	275	1.8	640	31	1.8	4.4	4.8	1.0	647	6	0	1,040	8.7	-
15. 7.10,321	Kmf	10-16-62	54	13	.03	5.7	1.7	176	1.6	254	8	170	2.8	.7	.6	505	21	0	780	8.6	Spring.
13,142	Kcg,Kcd	10- 3-62	60	21	.01	73	35	54	2.6	297	0	188	3.7	.7	.3	524	327	84	795	7.5	-
23,132	Kmf	10- 3-62	57	15	.01	4.6	1.1	81	1.5	207	4	11	1.5	.5	.3	223	16	0	350	8.4	Spring. -

* Drilled as exploration holes by Phillip Petroleum Co.

TABLE 3 (concluded)

CHEMICAL ANALYSES OF WATER FROM WELLS, SPRINGS, AND MINES IN SOUTHEASTERN McKINLEY COUNTY, N. MEX.

Location	Stratigraphic unit	Date of collection	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	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	Remarks
15. 8.13.444	Kpl,Kplh	10- 2-62	58	12	0.00	1.5	0.4	118	1.1	204	30	8.0	2.2	0.6	0.7	294	5	0	489	9.2	-
21.442	Kpl,Kplh	10-16-62	59	22	.02	144	57	32	3.0	567	0	188	4.8	.6	.7	731	593	128	1,090	7.5	-
15. 9. 6.213	Kcda	8- -51	-	12	-	630	245	299		288	0	2,480	47	.5	427	4,280	2,580	2,340	4,480	-	-
Do.	Kcda	9-12-62	59.5	8.7	.02	590	221	330	2.4	226	0	2,440	47	.9	377	4,130	2,380	2,200	4,400	6.8	-
9.243	Kcdi	9-12-62	59	9.1	.02	88	23	994	7.6	166	0	2,190	40	2.0	2.7	3,440	314	178	4,480	7.5	-
13.144	Kplh,Kcg	8- -51	-	15	-	355	182	39		563	0	1,150	7	.5	.1	2,010	1,570	1,120	2,390	-	-
Do.	Kplh,Kcg	10- 4-62	58	14	.00	330	162	54	4.9	546	0	1,100	7.7	.8	.3	1,940	1,490	1,040	2,340	7.0	-
15.10. 6.242	Kcdi	2-17-54	66	8.6	-	143	67	204		312	0	768	14	.7	.1	1,360	632	377	1,830	-	-
Do.	Kcdi	8- 1-61	62	15	3.6	108	44	290	7.2	266	0	842	10	.4	.2	1,450	452	234	1,960	7.5	-
13.131	Kg(?)	9-18-62	68	15	.57	3.1	.9	401	1.8	348	18	444	73	1.2	.4	1,130	11	0	1,730	8.8	-
32.214	Qal	9-18-62	59	18	.00	530	330	51	9.5	142	0	2,550	12	1.6	10	3,580	2,680	2,560	3,620	7.5	-
15.11.18.222	Kd	10-23-52	66	13	-	7.0	2.7	236		298	12	202	44	1.8	.2	666	28	0	1,060	-	-
Do.	Kd	7-31-61	72	16	.03	6.0	1.7	147	2.8	247	2	124	9.6	.6	.4	431	22	0	678	8.4	-
15.12.17.123	Kd	4- 8-53	-	20	-	177	70	43		341	0	509	9	.1	.2	996	730	450	1,330	-	-
Do.	Kd	5-21-56	-	-	7.8	-	-	44		331	0	520	8.0	-	.4	-	730	458	1,330	7.6	-
17.123a	Jmw	5- 4-63	-	17	.26	29	5.8	52	3.4	216	3	22	4.6	.4	.7	245	97	0	395	8.3	Beta activity 9.8±1.4 as of 5-24-63; Radium 0.2±0.1.
19.223	Jmw	9- 2-49	-	15	-	29	9.0	66		237	0	44	7	.6	2.3	290	110	0	468	-	-
15.13. 5.431	Kd	11-15-48	56	-	-	39	27	29		274	0	156	6	.3	.4	443	333	108	690	-	-
12.144	Jb	7-11-61	75	16	.39	36	5.8	141	4.8	228	0	164	47	.5	1.0	528	114	0	829	7.9	-
16. 5.15.233	Kmf	9-19-62	69	15	.00	3.0	.6	273	1.5	361	39	191	24	1.8	1.1	729	10	0	1,150	9.1	Spring.
19.414	Kg	9-19-62	76	13	.20	9.5	2.1	718	3.2	308	0	1,250	42	.8	.1	2,190	32	0	3,130	8.2	-
16. 6.29.231	Kplh	10- 3-62	55	11	.04	3.2	.7	315	2.0	376	16	329	11	.9	.9	875	11	0	1,350	8.7	Spring.
16. 7.13.224	Kpl,Kplh	10- 2-62	56	11	.00	62	24	573	4.3	326	0	1,130	37	.8	1.5	2,000	254	0	2,800	7.6	-
26.221	Kg	10- 2-62	75	14	.02	9.4	5.0	365	3.2	276	0	563	12	.8	1.8	1,110	44	0	1,650	7.9	-
32.413	Kpl,Kplh	10-15-62	58	11	.00	5.9	1.8	222	1.8	317	11	201	13	1.0	.6	625	22	0	969	8.7	-
16. 8.14.111	Kpl,Kplh	10- 2-62	59	10	.31	5.8	2.3	557	2.3	826	10	397	74	3.7	.5	1,470	24	0	2,260	8.3	-
20.131	Kplh	10- 2-62	57.5	10	.10	6.6	1.8	342	2.2	395	10	387	9.1	.6	.8	964	24	0	1,480	8.5	-
33.134	Kpl,Kplh	10- 2-60	60	12	.03	3.2	1.7	290	3.6	130	130	277	24	.7	.4	807	15	0	1,350	10.0	-
16. 9.17.222	Kcg	9-20-62	63	5.5	.00	18	10	502	4.5	226	20	898	18	.4	.0	1,590	88	0	2,280	8.8	-
22.444	Kcg	9-20-62	57	8.0	.00	6.8	.0	482	2.7	393	19	648	28	1.4	.8	1,390	17	0	2,070	8.7	-
16.10. 8.312	Kcg	8- 1-61	60	15	2.9	112	67	232	6.4	388	0	696	16	.5	.5	1,340	556	238	1,830	7.5	-
22.232	Kplh	9-19-62	69	15	.00	96	53	338	6.1	307	0	876	15	.5	.6	1,550	456	204	2,110	7.4	-
16.11. 5.121	Kcdi,Kg	7-31-61	61	24	1.5	66	26	178	3.7	266	0	418	7.2	.5	1.4	856	272	54	1,230	7.6	-
16.331	Kcdi	7-10-59	62	13	-	139	27	222		260	0	684	11	.4	.0	1,220	458	245	1,640	7.5	-
16.13.11.440	Kcdi	3-18-54	-	17	-	552	231	91		638	0	1,890	23	.4	.2	3,120	2,330	1,800	3,400	-	-
Do.	Kcdi	7-11-61	68	18	3.2	622	231	107	11	712	0	2,050	23	.3	1.1	3,410	2,500	1,920	3,590	7.0	-

TABLE 4

COMMON CHEMICAL CONSTITUENTS AND CHARACTERISTICS OF WATER AND SUMMARY OF ANALYSES OF WATER IN SOUTHEASTERN McKINLEY COUNTY, N. MEX.

[Derivation, significance, and recommended limits are mostly those set forth by the California State Water Pollution Control Board (1957). Constituent has no harmful physiological effect, unless specified. Chemical constituents are in parts per million.]

Constituent or property	Derivation	Significance	Recommended limits for selected uses	Range in concentration for samples analyzed	Number of determinations	Number of determinations more than (>) recommended limits	
Silica (SiO_2)	Siliceous materials present in virtually all rocks.	Forms hard scale in boilers and pipes. Inhibits deterioration of zeolite-type water softeners. May prevent corrosion in pipes by forming a protective coating.	1 ppm for high-pressure-boiler feed. 10 to 50 ppm for other industrial processes.	5.5 to 61	100	>2	50
Iron (Fe)	Iron-bearing minerals present in most rocks. Iron may be added to water in contact with iron objects such as well casing, pipes, and storage tanks.	Oxidizes to a reddish-brown precipitate. More than about 0.3 ppm stains laundry and utensils. Objectionable for many industrial, food processing, and beverage uses. Supports growth of certain bacteria. Imparts objectionable taste when greater than about 1.0 ppm.	Less than 1.0 ppm for most industrial use. 0.3 ppm for the sum of iron and manganese in domestic supplies.	0.0 to 7.8	78	>17 >10	0.3 1.0
Calcium (Ca)	Limestone, dolomite, gypsum or gypsiferous shale, sewage, and industrial waste.	With magnesium causes most of the hardness and scale-forming properties of water. Beneficial in irrigation water where unfavorable sodium ratio exists in soil.	5 ppm for boiler feed.	0.4 to 630	109	>93	5
Magnesium (Mg)	Dolomite and most igneous rocks.	Similar to calcium in flocculating soil colloids, imparting the property of hardness, and forming scale. Salts of magnesium act as cathartics.	125 ppm for drinking and culinary waters.	0.0 to 330	109	>8	125
Sodium (Na) plus potassium (K)	Feldspars, salt beds, other common minerals, sewage, and industrial wastes.	Causes foaming in boilers when concentration of sodium plus potassium exceeds 50 ppm. High concentrations are toxic to plants, harmful to soil, and will act as cathartic. High ratio of sodium to calcium plus magnesium is harmful to soil structure.	50 ppm of sodium plus potassium for boiler water. 115 ppm sodium maximum for domestic use.	7.4 to 1,120.1	112	>90 >72	50 125
Bicarbonate (HCO_3) and carbonate (CO_3)	Carbonate rocks and calcareous materials.	In combination with calcium and magnesium forms scale and releases corrosive carbon dioxide gas. A high ratio of carbonate and bicarbonate to alkaline earths may cause the water to be unsuitable for irrigation.	100 ppm for boiler use.	68 to 836	121	>120	100
Sulfate (SO_4)	Gypsum, anhydrite, pyrite, and oxidized organic matter in the sulfur cycle.	In combination with calcium and magnesium forms hard scale. As magnesium or sodium sulfate acts as a cathartic. High concentrations may be toxic to plants.	250 ppm for domestic use. 250 ppm in carbonated beverages.	0.6 to 2,880	114	>55	250
Chloride (Cl)	Most rocks and soils, sewage, and industrial effluents.	High concentrations of chloride salts impart salty taste. May be toxic to plants. May accelerate corrosion in pipes.	250 ppm for domestic use. 200 ppm for kraft paper pulp.	1.4 to 4,650	121	>6 >5	200 250
Fluoride (F)	Fluorite, apatite, and hydrothermal solutions.	Reduces incidence of tooth decay in children when concentration is 0.5 to 1.5 ppm; more than about 1.5 ppm causes mottling of tooth enamel in children. Concentrations of more than 5 ppm may cause fluorosis.	1.5 ppm for domestic use. 1.0 ppm for food canning.	0.1 to 7.0	111	>19 >12 >1	1.0 1.5 5
Nitrate (NO_3)	Decayed organic matter, sewage, nitrate fertilizers, and nitrates in the soil.	Values higher than 5 to 10 ppm may suggest pollution. More than about 44 ppm may cause methemoglobinemia (infant cyanosis). Generally nitrate in water used for irrigation is desirable for its fertilizing value.	44 ppm for domestic use.	0.0 to 427	111	>8 >2	10 44
Dissolved solids	Rocks, soils, industrial and sewage effluents.	High concentrations are harmful to plant and animal life and can cause foaming in boilers.	1,000 ppm for domestic use, although more saline waters are used by some communities without harmful effects. 1,000 ppm for most industrial uses.	71 to 4,470	109	>37	1,000
Hardness (as $CaCO_3$)	Mainly calcium and magnesium in solution; certain other cations cause hardness but are ordinarily present in small amounts.	Hard water causes excessive soap consumption, scale in boilers and pipes, toughening of cooked vegetables. Tends to prevent corrosion of metals. Produces finer grained structure in baking. Very hard water retards fermentation.	Water having a hardness of more than 121 ppm generally considered to be hard. 0 to 50 ppm for laundering. 80 ppm for boiler feed water at 0 to 150 pounds per square inch	3.0 to 2,680	114	>82 >76 >62	50 80 120
Specific conductance (micromhos at 25°C)	Ion concentration in water.	An increase in value indicates an increase in dissolved solids.	More than 1,500 generally exceeds standards for domestic water. More than 3,000 unsuitable for irrigation under most conditions.	117 to 13,400	121	>37 >15	1,500 3,000
pH (hydrogen-ion concentration expressed as pH)	Hydrogen-ion concentration.	Values from 1 to 7 indicate decreasing acidity; of more than 7 indicate increasing alkalinity. Affects taste, corrosivity, and treatment processes such as coagulation. Low value desirable where irrigation water applied to alkaline soils.	7.5 for food canning and freezing. More than than 9.0 unsuitable for irrigation use.	6.7 to 10.0	93	>79 >8	7.5 9.0

TABLE 5

LOGS OF SELECTED WATER WELLS, OIL-TEST WELLS, AND EXPLORATORY DRILL HOLES IN SOUTHEASTERN McKINLEY COUNTY, N. MEX.

The following logs were furnished by drillers, well owners, mining companies, and other organizations, or were prepared by the Geological Survey from examination of drill cuttings. The drillers' logs have been slightly modified for uniformity of presentation. The rock descriptions are those of the driller and the stratigraphic correlations are by J. B. Cooper and E. C. John, unless otherwise noted.

Five of the sample-description logs prepared by the Geological Survey contain color symbols in parentheses following the color of the rock. These numbers are from the "Rock-Color Chart," 1948, distributed by the National Research Council, Washington, D. C. The authors of the rock descriptions and stratigraphic correlations are listed on the individual logs. The names of the drillers and other pertinent data for many of the water wells and drill holes are given in table 1.

The individual logs are headed by the well number and the name of the owner. Unless otherwise noted the log is that of a well drilled for water. Where available, the casing record and hydrologic data are given. The well number on many of the logs is followed by a second number in parentheses. This second number is the number assigned to the well by the U.S. Bureau of Indian Affairs.

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
13.5.7.123 Fernandez Co.		
Casing record: 8-inch pipe to 635 feet, perforated 600 to 620 feet; 7-inch liner pipe 631 to 676 feet, perforated 640 to 670 feet. Sample description and stratigraphic correlation by: J. B. Cooper		
Basalt, grayish-black	65	65
Ash, gray, soft	5	70
Basalt, grayish-black	66	136
No sample	5	141
Ash, gray, soft	11	152
Basalt, grayish-black	16	168
Basalt, grayish-black and red	21	189
Basalt, black	4	193
Conglomerate, basalt, chert, quartz	8	201
Ash, white to light-gray, vitric, fibrous	31	232
Basalt, black	18	250
Ash, light-gray, soft	44	294
Basalt, light-gray	5	299
No sample	27	326
Ash, brown to gray	15	341
Basalt, black	4	345

TABLE 5 (continued)

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
13.5.7.123 Fernandez Co. (concluded)		
TERTIARY (continued):		
Basalt, black and red	15	360
Basalt, black	14	374
No sample	6	380
Basalt, black	5	385
Ash, light-gray, compact	6	391
Basalt, grayish-black	74	465
No sample	10	475
Basalt, grayish-black	68	543
UPPER CRETACEOUS:		
Mesaverde Group:		
Point Lookout Sandstone:		
Sandstone, tan, loose, frosted, subrounded, medium to coarse with few pebbles, quartz, trace chert	26	569
Sandstone, tan to clear, loose, subangular to subrounded, well-sorted, fine, trace calcareous cement	5	574
Sandstone, as above with white, sandy, calcareous clay	16	590
Sandstone, as above with fragments of well-cemented sandstone	6	596
Sandstone, as 569 to 574	14	610
Sandstone, as above with white calcareous cement	5	615
Sandstone, as 569 to 574	17	632
No sample	15	647
Sandstone, as 569 to 574	21	668
Satan Tongue of Mancos Shale:		
Shale, dark-gray, carbonaceous	8	676

13.9.15.343 J. D. Ragland

Casing record: 6-inch pipe to 225 feet

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
QUATERNARY:		
Alluvium:		
Sand	30	30
Clay	25	55
CRETACEOUS:		
Dakota Sandstone:		
Sand	40	95
Sand and gravel	15	110

TABLE 5 (continued)

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
13.9.15.343 J. D. Ragland (concluded)		
UPPER JURASSIC:		
Morrison Formation:		
Brushy Basin Member:		
Shale	60	170
Shale and sandstone	45	215
Westwater Canyon Member:		
Sandstone	45	260
13.9.22.112 Ingersoll-Rand Co.		
Casing record: 8-inch pipe to 100 feet; 6-inch pipe 95 to 297 feet; perforated 277 to 297 feet		
QUATERNARY:		
Alluvium:		
Adobe and blow sand	60	60
CRETACEOUS:		
Dakota Sandstone:		
Sand, loose, clean	38	98
Sandstone and gravel	12	110
Sand, gray	10	120
UPPER JURASSIC:		
Morrison Formation:		
Brushy Basin Member:		
Shale, black and blue	80	200
Lime, gray	5	205
Shale, gray, sandy	65	270
Westwater Canyon Member:		
Sand, white; water	20	290
Sand, white	7	297
13.10.8.211 (16B-38) U.S. Bureau of Indian Affairs		
Casing record: 7-inch pipe to 268 feet; 5-inch pipe 267 to 357 feet; perforated 309 to 357 feet		
Quick sand	25	25
UPPER JURASSIC:		
San Rafael Group:		
Entrada Sandstone:		
Sand, red, soft	245	270

TABLE 5 (continued)

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
13.10.8.211 (16B-38) U.S. Bureau of Indian Affairs (concluded)		
UPPER TRIASSIC:		
Wingate Sandstone:		
Sand, gray, hard (1 gpm)	5	275
Sand, soft (10 gpm)	12	287
Sand, gray, hard (water)	51	338
Chinle Formation:		
Sand, red, soft	19	357
13.10.33.443 Duane Berryhill		
Casing record: 7-inch pipe to 110 feet		
Top soil	10	10
UPPER TRIASSIC:		
Chinle Formation:		
Shale, gray	30	40
Shale, blue	30	70
Shale, tan	10	80
Sand, yellow	20	100
Shale, tan	10	110
13.11.7.431 Elkins Ranch, Inc.		
Casing record: 7-inch pipe to 220 feet.		
Soil and sand	20	20
UPPER TRIASSIC:		
Chinle Formation:		
Red bed	150	170
Sand	30	200
Red bed	20	220
13.11.18.223 El Paso Natural Gas Co. Prewitt Refinery		
Samples described by: P. D. Helmig, Malco Refineries, Inc.		
No samples	130	130

TABLE 5 (continued)

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
13.11.18.223 El Paso Natural Gas Co. Prewitt Refinery (continued)		
UPPER TRIASSIC:		
Chinle Formation:		
Middle part:		
Sand, white, coarse, quartz with some frosted grains	5	135
Sand, white, quartz, with some frosted grains, 90 percent; lime, dark-gray, dense, hard, 10 percent	10	145
Sand, white, coarse, quartz, 90 percent; chert, gray, 5 percent; lime, dark-gray, dense, 5 percent	10	155
Sand, white, fine, quartz, 90 percent; gilsonite, black, solid hydrocarbon mineral, 5 percent; lime, light-gray, dense, 5 percent	10	165
Sand, white to gray, fine, some well-cemented, 90 percent; lime, light-gray, 5 percent; shale, gray to brown, 5 percent	20	185
Sand, white to buff, fine; some pyrite and glauconite	5	190
Sand, white to buff, fine; some chert and quartz	5	195
Lower part:		
Lime, dark-gray, shaly earthy limestone	10	205
Shale, purple to green	10	215
Shale, red; some siltstone and gypsum	20	235
Shale, purple, with trace of green and buff shale and buff shale and siltstone	65	300
Shale, purple and red, limy shale and redbeds	10	310
Sand, red, very fine, trace red shale	10	320
Sand, red, very fine, 50 percent; shale, red, 50 percent	10	330
Sand, red, fine, 50 percent; shale, red, 45 percent; lime, gray, dense, 5 percent	10	340
Siltstone, red, very very fine grained, quartz, 90 percent; shale, red, 5 percent; lime, gray, dense, 5 percent	10	350
Shale, red	20	370
Siltstone, red, some green, trace shale	10	380
Sand, white, very fine, quartz, 90 percent; shale, red, 10 percent	10	390
Siltstone, reddish-brown, trace of gray limestone and gray shale	10	400
Lime, red to gray, dense, 35 percent; shale, red, 35 percent; sand, red, fine, 30 percent	10	410
Shale, green, micaceous, with trace of white limestone	30	440
Sand, white, fine, quartz; trace red beds	10	450

TABLE 5 (continued)

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
13.11.18.223 El Paso Natural Gas Co. Prewitt Refinery (concluded)		
UPPER TRIASSIC (continued):		
Chinle Formation (continued):		
Lower part (continued):		
Sand, white, fine, quartz; trace red beds, 50 percent; shale, red and green, trace white limestone 50 percent	10	460
Sand, white, fine, quartz 35 percent; shale, red and green, 35 percent; lime, brown, dense, 30 percent	10	470
Sand, white, fine-grained quartz, 80 percent; lime, white, dense, 10 percent; shale, red and green, 10 percent	10	480
Sand, white, fine, quartz; trace red and green shale	30	510
Shale, green and red	10	520
Shale, green and red, 90 percent; lime, buff, dense, 10 percent	10	530
Shale, green, trace green lime	10	540
Sand, white, very fine, quartz, clean	30	570
Sand, reddish-buff, very fine, quartz	10	580
Sand, red, very fine, quartz; trace white limestone	20	600
Sand, red, very very fine, quartz	10	610
Sand, red, very very fine, quartz, 50 percent; shale, green, 50 percent	10	620
Siltstone, buff, green	10	630
PERMIAN:		
San Andres Limestone:		
Lime, white, dense; trace green shale	10	640
Lime, white, dense to finely crystalline	20	660
Lime, buff to brown, crystalline with some porosity	10	670
Lime, buff to brown, dense, sandy in part	10	680
Glorieta Sandstone:		
Sand, white, fine, quartz, clean	10	690
No samples	60	750
Siltstone, white, powder; some quartz grains	10	760
No samples	30	790
Siltstone, white, powder; some quartz grains	10	800
No samples	3	803

13.11.18.444 Roy Navarre

Casing record: 6-inch pipe to 540 feet, perforated from 520 to 530 feet

Top soil	10	10

TABLE 5 (continued)

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
13.11.18.444 Roy Navarre (concluded)		
UPPER TRIASSIC:		
Chinle Formation:		
Middle part:		
Sand, white, hard	30	40
Shale, white	10	50
Sand, white	60	110
Sand, white, hard	40	150
Lower part:		
Shale, purple	10	160
Shale, gray	10	170
Shale, purple	40	210
Lime, white	10	220
Shale, purple	10	230
Shale, red	10	240
Shale, gray	10	250
Shale, red	50	300
Shale, gray	50	350
Shale, red	30	380
Shale, purple	30	410
Shale, gray	10	420
Sand, gray	10	430
Shale, red	70	500
Shale, gray	20	520
Sand, gray; (water)	10	530
Shale, red	10	540
13.11.27.314 Elkins Ranch, Inc.		
Casing record: 7-inch pipe to 204 feet		
QUATERNARY:		
Alluvium and basalt:		
Soil and sand	10	10
Malpais	30	40
Sand, brown	10	50
UPPER TRIASSIC:		
Chinle Formation:		
Middle part:		
Shale, sandy	20	70
Sand, gray	20	90
Shale, sandy	20	110
Shale, gray, sandy	30	140
Sand, pink	10	150
Shale, sandy	20	170
Sand, white	20	190
Sand, gray	10	200
Shale, gray	4	204

TABLE 5 (continued)

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
13.12.10.242 (16K-317) U. S. Bureau of Indian Affairs		
Casing record: 8-inch pipe to 215 feet, perforated 94 to 180 feet		
Hydrologic data: 3 holes 8 feet apart at this location. Hole 1 drilled to 215 feet; hole 2 drilled to 106 feet; hole 3 drilled to 115 feet; holes shot with 300 pounds of powder to make reservoir for 1,500 gallons of water. Well will yield 30 gpm for 65 minutes before storage is depleted. Yielded 4 gpm when drilled		
UPPER TRIASSIC:		
Chinle Formation:		
Middle part:		
Sandstone, broken	3	3
Sandstone, light-colored	19	22
Shale, purple	15	37
Sandstone, light-colored	33	70
Sandstone, light red	18	88
Sandstone, brown	6	94
Sandstone, red, soft	12	106
Sandstone, red	12	118
Sandstone, dark brown	15	133
Sandstone, gray	6	139
Lower part:		
Shale, gray, sandy	13	152
Sandstone, hard	4	156
Shale, gray, sandy	24	180
Shale, purple	24	204
Shale, light-colored	11	215
13.12.12.441 U.S. Bureau of Indian Affairs Baca Day School		
Casing record: 8-inch pipe to 580 feet, perforated 195-225 feet; hole plugged at 1,200 feet and 603 to 475 feet		
Sand, surface	5	5
UPPER TRIASSIC:		
Chinle Formation:		
Upper part:		
Sand, hard	4	9
Shale, purple	7	16
Sand, dark gray	5	21
Shale, dark blue	6	27
Shale, gray	11	38
Shale, red	6	44

TABLE 5 (continued)

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
13.12.12.441 U.S. Bureau of Indian Affairs Baca Day School (continued)		
UPPER TRIASSIC (continued):		
Chinle Formation (continued):		
Upper part (continued):		
Shale, purple	8	52
Lime, gray	36	88
Shale, purple	22	110
Lime, gray	4	114
Shale, green	4	118
Middle part:		
Sand, dark gray (5gpm, water)	6	124
Shale, gray, sandy	23	147
Sand, gray	27	174
Shale, gray, sandy	12	186
Sand, gray ($4\frac{1}{2}$ gpm, water)	28	214
Lower part:		
Shale, gray	15	229
Shale, red	14	243
Shale, gray	26	269
Shale, purple	30	299
Shale, red	16	315
Shale, brown	9	324
Shale, gray	30	354
Lime shell	4	358
Shale, red and hard; conglomerate	22	380
Lime, sandy	6	386
Sand, gray	16	402
Sand; little water	3	405
Shale, red	35	440
Shale, red, and lime shell	32	472
Shale, gray	40	512
Sand, gray, hard	14	526
Lime shell, gray	26	552
Lime, gray	19	571
Sand; little water	6	577
Shale, brown, sandy	4	581
Shale, red	23	604
Sand, gray	13	617
PERMIAN:		
San Andres Limestone:		
Lime, gray	46	663
Glorieta Sandstone:		
Sand, white	8	671
Sand, white, hard	5	676
Sand, gray, hard	8	684
Sand, white	112	796
Shale, gray	3	799
Sand, white	52	851

TABLE 5 (continued)

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
13.12.12.441 U.S. Bureau of Indian Affairs Baca Day School (concluded)		
PERMIAN (continued):		
Yeso(?) Formation:		
Shale, gray	3	854
Sand, red	12	866
Sand, red, and shale streaks	17	883
Shale, red, sandy	17	900
Sand, red	14	914
Shale, red	12	926
Sand, red; (37 gpm, water)	7	933
Shale, red	6	939
Clay, red, sticky	6	945
Shale, red	17	962
Shale, red, sandy	49	1,011
Lime shell	5	1,016
Sand, gray	6	1,022
Lime, dark-gray	12	1,034
Shale, blue	2	1,036
Sand, gray	4	1,040
Shale, gray, sandy	11	1,051
Sand, gray	3	1,054
Shale, red, sandy	4	1,058
Sandstone, red	14	1,072
Lime, dark-gray	2	1,074
Lime, black	5	1,079
Lime, gray, sandy	5	1,084
Shale, red, sandy	38	1,122
Lime, dark-gray	2	1,124
Shale, red, sandy	66	1,190
Shale, red	6	1,196
Shale, red, sandy	254	1,450
Sand, red	66	1,516
Abo(?) Formation:		
Shale, red, sandy	24	1,540
Shale, red	22	1,562
Shale, red, sandy	70	1,632
Sandstone, red	38	1,670
Shale, red, sandy	14	1,684
Shale, red	16	1,700
Shale, red, sandy	10	1,710
Sand, hard, and iron pyrite	6	1,716
Shale, red, sandy	12	1,728
Hard shell	5	1,733
Shale, red	83	1,816
Hard shell	4	1,820
Shale, red	87	1,907
Sand, red (33 gpm, water)	17	1,924
Shale, red	8	1,932
Shale, red, sandy	5	1,937
Sand, red	7	1,944
Shale, red	43	1,987

TABLE 5 (continued)

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
13.13.1.222a A. T. and S. F. Railroad, North Chaves Well 3		
Casing record: 16-inch pipe to 258 feet, perforated 60 to 95 feet; 12-inch pipe 210 to 566 feet. Hole plugged 930 to 850 feet		
Hydrologic data: Flowing 5 gpm, pumped at 50 gpm; water level, 200 feet when pumping at rate of 50 gpm		
Sandrock and shale	55	55
UPPER TRIASSIC:		
Chinle Formation:		
Middle part:		
Sand rock, white	45	100
Sand rock and shale	52	152
Sand rock, white, hard	33	185
Lower part:		
Sand rock and shale	198	383
Sandstone, very hard	7	390
Shale, red	130	520
Shale, gray	45	565
Sandstone, gray, hard	10	575
Sand rock with slate streaks	25	600
PERMIAN:		
San Andres Limestone:		
Sandstone, gray	25	625
Sandstone, white, on limerock	25	650
Glorieta Sandstone:		
Sandstone, brown	30	680
Sandstone, gray	10	690
Sandstone, white	145	835
Yeso Formation:		
Sandstone, white and yellow	50	885
Sandstone, reddish-brown	45	930
13.13.5.114 Donald Kimbler		
Casing record: 5-inch pipe to 545 feet, 4-inch pipe 540 to 625 feet, perforated		
Hydrologic data: Flowing 8 gpm		
Topsoil	3	3

TABLE 5 (continued)

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
13.13.5.114 Donald Kimbler (concluded)		
UPPER TRIASSIC:		
Chinle Formation:		
Middle part:		
Shale, gray, sandy	22	25
Shale, tan, sandy	35	60
Sand, coarse	60	120
Lower part:		
Shale, gray	60	180
Shale, red	140	320
Shale, tan	90	410
Shale, red	105	515
Shale, gray	30	545
Shale, tan	15	560
Shale, tan, hard	15	575
PERMIAN:		
San Andres Limestone:		
Lime, hard	15	590
Glorieta Sandstone:		
Sand, gray; water	25	615
Shale, gray	10	625
13.13.8.444 Clay Hardin		
Casing record: 5-inch pipe to 422 feet, open hole 422 feet to 504 feet		
Hydrologic data: Flowing 2 gpm		
UPPER TRIASSIC:		
Chinle Formation:		
Middle part:		
Sand, white	20	20
Lower part:		
Shale, red	355	375
Lime, gray	13	388
Shale, red	17	405
PERMIAN:		
San Andres Limestone:		
Lime, gray	55	460
Glorieta Sandstone:		
Sand, buff	44	504

TABLE 5 (continued)

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
14.8.15.244 Fernandez Co. (Drilled as Midwest Refining Co. No. 1, San Mateo oil-test well)		
Casing record: 10-inch pipe to 854 feet, perforated at 600 and 800 feet; 5-inch pipe 830 to 927 feet		
UPPER CRETACEOUS:		
Mesaverde Group:		
Crevasse Canyon Formation:		
Dilco Coal Member:		
Sand, yellow	25	25
Shale, brown	70	95
Gallup Sandstone:		
Sand, gray	75	170
Mancos Shale:		
Shale, blue	45	215
Shale, gray	605	820
Shale, sandy	87	907
Sand, gray	7	914
Shale, gray, sandy; talc, specks	4	918
Sandstone	2	920
Shale, sandy; talc, specks	15	935
Shale, gray	17	952
Shale, brown	123	1,075
CRETACEOUS:		
Dakota Sandstone:		
Sand, white, fine, dry	23	1,098
Sand	35	1,133
Sand, fine, very hard	52	1,185
Shale, black	15	1,200
Sand, pure	42	1,242
UPPER JURASSIC:		
Morrison Formation:		
Brushy Basin Member:		
Sand, red shale	29	1,271
Sand (700 feet of water in hole)	49	1,320
14.9.5.341 Buck Willcoxson		
Casing record: 7-inch pipe to 856 feet		
Hydrologic data: Bailed at 45 gpm: water level 600 feet (bailing)		
UPPER CRETACEOUS:		
Mesaverde Group:		
Gallup Sandstone:		
Sand, tan, soft	70	70
Sand, yellow, medium-soft	5	75

TABLE 5 (continued)

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
14.9.5.341 Buck Willcoxson (concluded)		
UPPER CRETACEOUS (continued):		
Mancos Shale:		
Shale, blue, soft	45	120
Lime, gray, hard	5	125
Shale, blue, medium-soft	115	240
Lime, gray, hard	5	245
Shale, gray, sandy	485	730
Shale, gray, sandy, medium-soft	10	740
Sand, gray, hard	20	760
Shale, gray, medium-soft	20	780
Lime, gray, hard	5	785
Shale, gray, medium-soft	50	835
Sand, gray, medium-soft; water	18	853
Shale, gray, medium-soft	5	858
14.9.28.441 Phillips Petroleum Co., Sandstone Minerals Water Well No. 1		
Casing record: 16-inch pipe to 1,458 feet, 10 3/4-inch pipe to 3,113 feet, 9 5/8-inch open hole 3,113 to 3,275 feet		
NO RECORD	391	391
CRETACEOUS:		
Dakota Sandstone	60	451
UPPER JURASSIC:		
Morrison Formation:		
Brushy Basin Member	96	547
Westwater Canyon Member	190	737
Recapture Member	84	821
San Rafael Group:		
Bluff Sandstone	285	1,106
Summerville Formation	335	1,441
Todilto Limestone	30	1,471
Entrada Sandstone	100	1,571
UPPER TRIASSIC:		
Wingate Sandstone	60	1,631
Chinle Formation:		
Undifferentiated	1,454	3,085
PERMIAN:		
San Andres Limestone and Glorieta Sandstone:		
Undifferentiated	190	3,275

TABLE 5 (continued)

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
14.9.30.222 Adrian Berryhill (Drilled as New Mexico Royalty No. 2. L. A. Barton, oil-test well)		
Casing record: 6-inch pipe to 524 feet		
QUATERNARY:		
Alluvium:		
Soil	5	5
Sandstone, very fine	54	59
UPPER CRETACEOUS:		
Mancos Shale:		
Shale, sandy	4	63
Shale, gray	8	71
Shale, light-blue	78	149
Soapstone	1	150
Shale, sandy	7	157
Sandstone, gray	32	189
Shale, sandy	9	198
Shale, light-blue	2	200
Shale, sandy	16	216
Shale, blue	14	230
Sandstone, dark-gray	11	241
Sandstone, light-gray	10	251
Shale, blue	1	252
Shale, sandy	16	268
Shale, light-gray	53	321
CRETACEOUS:		
Dakota Sandstone:		
Sandstone, dark-gray	9	330
Sandstone, light-gray	33	363
Shale, blue	4	367
Sandstone, fine	21	388
UPPER JURASSIC:		
Morrison Formation:		
Brushy Basin Member:		
Shale, red	12	400
Shale, very light-colored	80	480
Shale, red	4	484
Sandrock, very coarse (water)	12	496
Shale, very light-colored	5	501
Sandrock, coarse (water)	6	507
Shale, very light-colored	6	513
Westwater Canyon Member:		
Sandrock, coarse (water)	22	535
Shale, very light-colored	20	555
Sandrock, soft	153	708

TABLE 5 (continued)

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
14.9.30.222 Adrian Berryhill (Drilled as New Mexico Royalty No. 2. L. A. Barton, oil-test well) (concluded)		
UPPER JURASSIC (continued):		
Morrison Formation (continued):		
Recapture Member:		
Shale, red	12	720
Shale, light-colored, sandy	8	728
Shale, gray	22	750
Shale, white	8	758
Shale, red, sandy	72	830
Rock, sandy	25	855
San Rafael Group:		
Bluff Sandstone:		
Sandrock, gray	20	875
Sand, gray, very fine	50	925

14.9.34.422 Phillips Petroleum Co., exploratory drill hole (pilot hole at "Sandstone" mine shaft)

Hydrologic data: (Data from test operations during mining of "Sandstone" mine shaft) Initial yield of Dakota Sandstone reported to be 890 gpm; static water level reported to be 342 feet

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
QUATERNARY:		
Alluvium	22	22
UPPER CRETACEOUS:		
Mancos Shale:		
Shale	249	271
Sandstone	14	285
Shale	89	374
Sandstone	28	402
Shale	59	461
Sandstone	69	530
Shale	10	540
CRETACEOUS:		
Dakota Sandstone	71	611
UPPER JURASSIC:		
Morrison Formation:		
Brushy Basin Member	111	722
Westwater Canyon Member	187	909
Recapture Member	95	1,004

TABLE 5 (continued)

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
14.9.36.313 Phillips Petroleum Co., exploratory drill hole (located within 50 feet of "Cliffside" mine shaft)		
Hydrologic data: (Data from test operations during mining of "Cliffside" mine shaft) Sandstone at depth of 954 feet in Mancos Shale yielded 208 gpm flow through 2-inch pilot hole; calculated static water level, 430 feet		
QUATERNARY:		
Alluvium:		
Sand and clay	110	110
UPPER CRETACEOUS:		
Mancos Shale:		
Shale and siltstone	91	201
Sand, medium-hard	17	218
Shale	612	830
Sand, medium-hard	28	858
Shale	92	950
Sand, medium-hard	30	980
Shale	63	1,043
Sand, medium-hard	33	1,076
Shale	50	1,126
CRETACEOUS:		
Dakota Sandstone:		
Sandstone, hard	6	1,132
Shale	8	1,140
Sandstone, hard, brittle, blocky at base	48	1,188
UPPER JURASSIC:		
Morrison Formation:		
Brushy Basin Member:		
Shale and thin beds of fine, dense, sandstone	167	1,355
Westwater Canyon Member:		
Sandstone, soft, coarse; thin beds of shale	145	1,500
14.10.11.441 Ambrosia Investment Co. No. 1, oil-test well		
UPPER CRETACEOUS:		
Mancos Shale:		
Sandstone, varicolored and thin beds of gray shale	125	125
CRETACEOUS:		
Dakota Sandstone:		
Sandstone, gray with thin lime streaks	20	145
Sandstone, dark-gray, medium; gray shale; and black limestone	30	175

TABLE 5 (continued)

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
14.10.11.441 Ambrosia Investment Co. No. 1, oil-test well (continued)		
UPPER JURASSIC:		
Morrison Formation:		
Brushy Basin Member:		
Shale, gray, sandy, and some gray sandstone	40	215
Sandstone, light-gray, and gray shale	20	235
Shale, light-gray, and thin beds of light gray sandstone	30	265
Westwater Canyon Member:		
Sandstone, light-brown and gray, medium and some gray shale	10	275
Shale, gray, and gray sandstone	15	290
Sandstone, light-gray, and shale	20	310
Sandstone, brown and gray, coarse	10	320
Shale, gray, sandy	10	330
Sandstone, brown and gray, coarse	30	360
Sandstone, brown and gray, fine with gray shale	30	390
Recapture Member:		
Shale, gray	30	420
Shale, gray and brown sandstone	30	450
Sandstone, gray and brown, with gray shale	20	470
Shale, gray, sandy	20	490
Sandstone, brown and gray, coarse	10	500
Sandstone, brown and gray; some gray shale	20	520
Shale, gray; some gray sandstone	20	540
Shale, gray, very sandy	30	570
San Rafael Group:		
Bluff Sandstone:		
Sandstone, brown and gray, coarse	10	580
Sandstone, light gray, fine, with thin beds of black lime	30	610
Sandstone, gray, calcareous	40	650
Sandstone, brown and gray	40	690
Sandstone, brown and gray; some gray shale	10	700
Sandstone, gray and buff to white	80	780
Summerville Formation:		
Sandstone, reddish-gray	300	1,080
Shale, red	12	1,092
Todilto Limestone:		
Lime, white	4	1,096
Lime and gypsum	19	1,115
Lime, brown	35	1,150
Entrada Sandstone:		
Sand, red	145	1,295
Shale, red	40	1,335
Sand, red	10	1,345

TABLE 5 (continued)

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
14.10.11.441 Ambrosia Investment Co. No. 1, oil-test well (concluded)		
UPPER TRIASSIC:		
Chinle Formation:		
Upper part:		
Shale, red	42	1,387
Lime shell	3	1,390
Shale, red	60	1,450
Lime shell	5	1,455
Shale, red	190	1,645
Lime shell	2	1,647
Shale, red	73	1,720

14.10.22.414 Kermac Nuclear Fuels Corp. Water Well No. 1

Casing record: 16-inch pipe to 1,315 feet; 10 3/4-inch pipe, 1,250 to 2,969 feet; hole filled with cement at unknown intervals opposite pipe perforations

Hydrologic data: Reported to yield 340 gpm from pumping level of 1,216 feet

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
NO RECORD	279	279
CRETACEOUS:		
Dakota Sandstone	79	358
UPPER JURASSIC:		
Morrison Formation:		
Brushy Basin Member	172	530
Westwater Canyon Member	195	725
Recapture Member	103	828
San Rafael Group:		
Bluff Sandstone	100	928
Summerville Formation	326	1,254
Todilto Limestone	44	1,298
Entrada Sandstone	126	1,424
UPPER TRIASSIC:		
Chinle Formation:		
Undifferentiated	1,384	2,808
Sand	61	2,869
Shale	49	2,918
PERMIAN:		
San Andres Limestone:		
Lime	56	2,974
Shale	4	2,978
Lime	50	3,028
Glorieta Sandstone	53	3,081

TABLE 5 (continued)

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
14.11.3.334 Adrian Berryhill		
Casing record: 5-inch pipe to 645 feet; perforated 485 to 525 feet, 565 to 625 feet		
Stratigraphic correlation by: Kermac Nuclear Fuels Corp.		
UPPER CRETACEOUS:		
Mancos Shale	263	263
CRETACEOUS:		
Dakota Sandstone	93	356
UPPER JURASSIC:		
Morrison Formation:		
Brushy Basin Member	105	461
Westwater Canyon Member	136	597
Recapture Member	56	653
14.12.14.142 Elkins Ranch, Inc.		
Casing record: 8-inch pipe to 65 feet; record incomplete		
Soil	10	10
Clay, sandy	10	20
UPPER JURASSIC:		
San Rafael Group:		
Todilto Limestone:		
Shale, sandy	10	30
Sand, tan	10	40
Shale, sandy	10	50
Entrada Sandstone:		
Quick sand	10	60
Rock, red	220	280
Sand, (water)	20	300
Shale, red, sandy	50	350
UPPER TRIASSIC:		
Glen Canyon Group:		
Wingate Sandstone:		
Sand, red	30	380
Sand, (water)	30	410
Sand, red	20	430

TABLE 5 (continued)

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
14.13.20.414 Transwestern Pipeline Co. Compresser Station No. 5 Well 1		
Casing record: 8-inch pipe to 681 feet, cemented inside 664 feet of 10-inch pipe; 6-inch pipe 653 to 746 feet, slotted from 686 to 736 feet		
Hydrologic data: Pumped 22 hours at 20 gpm; pumping water level, 666 feet		
Soil, sandy	60	60
UPPER TRIASSIC:		
Chinle Formation:		
Upper part:		
Shale, red	194	254
Shale, red; hard ledges	24	278
Shale, red	262	540
Mudstone, brown	20	560
Shale, red	50	610
Mudstone, hard	25	635
Shale, red	34	669
Mudstone, hard	11	680
Middle part:		
Sand, white	15	695
Sand, brown	5	700
Sandstone	8	708
Sand, white	22	730
Sand; water	10	740
Lower(?) part:		
Shale, sandy	5	745
Shale, blue, sandy	5	750
14.13.27.342 (16T-352) U.S. Bureau of Indian Affairs; Thoreau Chapter House		
Casing record: 8-inch pipe to 435 feet, perforated 400 to 435 feet		
Hydrologic data: Bailed 1 hour at 50 gpm; bailing water level, 270 feet		
Sand and red clay	30	30
UPPER TRIASSIC:		
Chinle Formation:		
Upper part:		
Shale, red	65	95
Sand and boulders	65	160
Shale, red	95	255

TABLE 5 (continued)

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
14.13.27.342 (16T-352) U.S. Bureau of Indian Affairs; Thoreau Chapter House (concluded)		
UPPER TRIASSIC (continued):		
Chinle Formation (continued):		
Middle part:		
Sand and rock	95	350
Rock, red, hard	10	360
Rock, brown and sandstone	50	410
Sandstone, gray, (water)	25	435

14.13.28.123 (16B-39) U.S. Bureau of Indian Affairs

Casing record: 12-inch pipe to 95 feet, 16-inch pipe to 637 feet, 7-inch liner pipe 625 to 730 feet

Hydrologic data: Bailed at 9 gpm; bailing water level, 600 feet

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
UPPER TRIASSIC:		
Chinle Formation:		
Upper part:		
Shale, red	88	88
Shale, red, sandy	357	445
Shale, dark-red	110	555
Sand; water	14	569
Shale, red	36	605
Middle part:		
Sand; water	27	632
Sand, fine, dry	19	651
Sand; water	45	696
Shale, dark, sticky	18	714
Shale, dark, sandy	16	730

14.13.33.124 (16K-302) U.S. Bureau of Indian Affairs; Thoreau Boarding School Well No. 1

Casing record: 10-inch pipe to 365 feet, perforated 343 to 363 feet

Hydrologic data: Pumped for 6 hours at 13 gpm; pumping water level, 199 feet

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
QUARTERNARY:		
Alluvium:		
Blowsand	23	23
Quicksand	107	130

TABLE 5 (continued)

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
14.13.33.124 (16K-302) U.S. Bureau of Indian Affairs; Thoreau Boarding School Well No. 1 (concluded)		
UPPER TRIASSIC:		
Chinle Formation:		
Upper part:		
Shale, dark-red	18	148
Shale, light-red	55	203
Shale, light-gray	34	237
Middle part:		
Sand; water	5	242
Shale, purple	46	288
Sand, hard	12	300
Shale, light-gray	43	343
Sand; water	20	363
Shale, brown	18	381
Shale, gray, sandy	26	407
Lower part:		
Shale, dark-gray	68	475
Sand, hard	4	479
Shale, gray	26	505

14.13.33.124a (16K-302A) U.S. Bureau of Indian Affairs; Thoreau Boarding School Well No. 3

Casing record: 6-inch pipe to 1,080 feet, cemented 0 to 1,079 feet; open hole 1,080 to 1,250 feet

Hydrologic data: Flows 6 gpm. Pumped for 1 hour at 17 gpm; pumping water level, 310 feet

Samples described by: P. R. Stevens

Stratigraphic correlation by: J. T. Callahan, J. W. Harshbarger, and C. A. Repenning (Note: The terminology used by the stratigraphers for divisions of the Chinle Formation is shown in parentheses on the following log beneath the terminology as used in this report.)

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
QUARTERNARY:		
Alluvium(?):		
Eolian sand, light-brown, coarse to very fine, silty, calcareous; poorly sorted quartz	20	20
Sand, light-brown, very coarse to very fine, silty, calcareous; poorly sorted quartz with limestone fragments	60	80
Sand, grayish-orange pink, very coarse to very fine, silty, calcareous; poorly sorted limestone fragments	50	130

TABLE 5 (continued)

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
14.13.33.124a (16K-302A) U.S. Bureau of Indian Affairs; Thoreau Boarding School Well No. 3 (continued)		
UPPER TRIASSIC:		
Chinle Formation:		
Upper part (Petrified Forest Member):		
Siltstone, pale-red (10R-6/2), sandy, calcareous with mudstone fragments	40	170
Sand, pale-red (5R-6/2), medium to fine, sorting fair, quartz	10	180
Sand, pale-red (5R-6/2), coarse to very fine, silty, calcareous; poorly sorted quartz with limestone fragments	20	200
Siltstone, pale-red (10R-6/2), sandy, calcareous; limestone fragments	10	210
Sand, pale-red (10R-6/2), medium to very fine, silty, calcareous; poorly sorted quartz with limestone fragments	20	230
Siltstone, pale-red (10R-6/2), sandy, calcareous..	30	260
Middle part (Sonsela Sandstone bed of Petrified Forest Member):		
Sand, pale-red (10R-6/2), medium to very fine, calcareous; quartz with limestone fragments	20	280
Sand, pale-red (10R-6/2), medium to very fine, calcareous; poorly sorted quartz with fragments of limestone and siltstone	40	320
Mudstone, pale-red (10R-6/2), silty, calcareous ..	10	330
Siltstone, pale-red (10R-6/2), sandy with mudstone fragments	10	340
Sand, pale-red (10R-6/2), medium to fine, calcareous; fairly well sorted quartz with fragments of siltstone and limestone	20	360
Sand, pale-red, coarse to very fine, calcareous; poorly sorted quartz with limestone fragments	10	370
Siltstone, pale-red (10R-6/2), sandy; fragments of mudstone and limestone	10	380
Sand, pale-red (10R-6/2), very coarse to very fine, silty, calcareous; poorly sorted quartz with limestone fragments	10	390
Sand, pale-red (10R-6/2), very coarse to very fine, silty, calcareous; poorly sorted quartz with fragments of chert	30	420
Lower part (Sonsela Sandstone bed of Petrified Forest Member):		
Claystone, grayish-red to purple, calcareous	10	430
Siltstone, pale-red (10R-6/2), sandy, calcareous; limestone fragments	20	450
Mudstone, light-brownish-gray, silty, calcareous..	40	490
Sand, pale-red (10R-6/2), medium to fine, calcareous; fairly well-sorted quartz with fragments of chert and limestone	10	500

TABLE 5 (continued)

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
14.13.33.124a (16K-302A) U.S. Bureau of Indian Affairs; Thoreau Boarding School Well No. 3 (concluded)		
UPPER TRIASSIC (continued):		
Chinle Formation (continued):		
Lower part (Sonsela Sandstone bed of Petrified Forest Member) (continued):		
Mudstone, pale-red (10R-6/2), silty, sandy, calcareous	30	530
Siltstone, grayish-red, calcareous	10	540
Mudstone, grayish-red-purple, silty, calcareous	30	570
Siltstone, grayish-red (5R-4/2), calcareous	40	610
Lower part (Petrified Forest Member):		
Mudstone, pale-red (10R-6/2), silty, calcareous	50	660
Mudstone, and claystone, pale-red (5R-6/2), silty, calcareous	40	700
Siltstone, pale-red (5R-6/2), sandy; claystone fragments	20	720
Mudstone and claystone, pale-red (5R-6/2), sandy.	110	830
Mudstone, pale-red (5R-6/2),silty, calcareous; muscovite and limestone fragments	50	880
Mudstone, pale-red (5R-6/2), silty, calcareous; fragments of claystone, limestone, sand, and gypsum	160	1,040
Lower part (Shinarump Member):*		
Sand, very pale orange, fine to very fine; well-sorted quartz, calcareous	10	1,050
Mudstone and claystone, pale-red (5R-6/2), silty, calcareous with sand grains	30	1,080
PERMIAN:		
Glorieta Sandstone:		
Sand, very pale orange, medium to very fine; well-sorted quartz, calcareous	20	1,100
Sand, very pale orange, coarse to very fine; poorly sorted quartz, calcareous	10	1,110
Sand, very pale orange, medium to very fine; fairly well-sorted quartz, calcareous	20	1,130
Siltstone, pale red (10R-6/2), sandy, calcareous with biotite	10	1,140
Sand, very pale orange, fine to very fine; fairly well-sorted quartz, silty, calcareous	20	1,160
Mudstone, grayish-orange-pink, silty with biotite	10	1,170
Yeso Formation:		
Siltstone, pale-reddish-brown, sandy, calcareous	10	1,180
Siltstone, pale-red (10R-6/2), sandy, calcareous with gypsum	10	1,190
Siltstone, pale-red (10R-6/2), sandy, calcareous	60	1,250

* The section from 1,040 to 1,080 feet may be a silty phase of the San Andres Limestone.

TABLE 5 (continued)

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
14.13.33.132a Elmer Bowman		
Casing record: 5-inch pipe to 280 feet, perforated 180 to 280 feet; gravel packed in 8-inch hole 130 to 280 feet		
Sand	80	80
UPPER TRIASSIC:		
Chinle Formation:		
Upper part:		
Sandstone with shale	85	165
Shale, red, sticky	15	180
Sandstone, blue and red shale	10	190
Sandstone, colored, and shale	37	227
Shale, red	41	268
Middle part:		
Sandstone, colored, and shale	12	280
14.13.33.211 (16K-326) U.S. Bureau of Indian Affairs; Thoreau Boarding School Well No. 2		
Casing record: 6-inch pipe to 420 feet, perforated 240 to 263 feet, 365 to 397 feet		
Hydrologic data: Pumped for 5 hours at 12 gpm; pumping water level, 360 feet		
Samples described by: Sally Schminke		
Stratigraphic correlation by: C. A. Repenning (Note: The terminology used by the stratigrapher for divisions of the Chinle Formation is shown in parentheses on the following log beneath the terminology as used in this report.)		
QUATERNARY:		
Alluvium:		
Sand, bright-brown, fine, poorly sorted, quartz, calcareous	50	50
Sand, light-brown, medium, poorly sorted, quartz, calcareous	10	60
Sand, light-brown, fine, poorly sorted quartz, calcareous with limestone	40	100
UPPER TRIASSIC:		
Chinle Formation:		
Upper part (Petrified Forest Member):		
Claystone, pale-red, silty, calcareous	80	180
Siltstone, pale-red, clayey, calcareous	20	200
Clay siltstone, grayish-red-purple, and limestone	10	210
Siltstone, pale-red, clayey, and limestone	20	230
Claystone, pale-red, silty, calcareous	20	250

TABLE 5 (continued)

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
14.13.33.211 (16K-326) U.S. Bureau of Indian Affairs; Thoreau Boarding School Well No. 2 (concluded)		
UPPER TRIASSIC (continued):		
Chinle Formation (continued):		
Middle part:		
Sand, pale-red, medium, fairly well sorted, calcareous, and claystone and limestone fragments	20	270
Sand, pale-red, fine, silty, fairly well sorted, quartz, calcareous	10	280
Sand, pale-red-purple, medium, fairly well sorted, quartz, calcareous, and claystone fragments	10	290
(Sonsela Sandstone bed of Petrified Forest Member)		
Sand, pale-red, coarse, poorly sorted, calcareous	10	300
Sand, light-gray, medium, poorly sorted, quartz, calcareous	30	330
Claystone and limestone, light-brown-gray, calcareous	20	350
Sand, pinkish-gray, fine, fairly well sorted, quartz, calcareous, and claystone	30	380
Sand, light-olive-gray, medium, silty, poorly sorted, quartz, calcareous	30	410
Lower part (Petrified Forest Member):		
Siltstone, medium-light-gray, sandy, calcareous	10	420

14.13.33.334 El Paso Natural Gas Co.;
Bluewater Compressor Station Well No. 2

Casing record: 12-inch pipe cemented to 120 feet; 8-inch pipe cemented from 4 feet above ground to 616 feet

Hydrologic data: Flow 40 gpm; pumped at 120 gpm; pumping water level, 300 feet

Samples described by: El Paso Natural Gas Co. Geology Dept., Farmington, N. Mex

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
No sample	125	125
UPPER TRIASSIC:		
Chinle Formation:		
Upper part:		
Shale, grayish-red (10R-4/2), with some medium to coarse sand	30	155

TABLE 5 (continued)

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
14.13.33.333 El Paso Natural Gas Co.; Bluewater Compressor Station Well No. 1 (concluded)		
UPPER TRIASSIC (continued):		
Chinle Formation (continued):		
Middle part:		
Sand, white, coarse, frosted, subangular and subrounded with red, brown, and black chert (a few gpm of water between 155 and 161 feet)..	40	195
Coal and medium sand	10	205
Sand, medium	20	225
Lower part:		
Shale, grayish-red (5RP-4/2), and medium-gray (N4).	30	255
Sand, medium, with streaks of grayish-red-purple (5RP3/2) shale	50	305
Sand, medium and fine; trace mica	10	315
Alternating beds of sand and shale; shales vary from red-purple (5RP3/2) to red-brown (10R4/4) to dusky grayish-red (10R3/2); sands are fine to coarse, white, subangular to subrounded, clear to milky, slightly calcareous with traces of siltstone	190	505
Shale, dark-reddish-brown (10R3/4) to blackish-red (5R2/2) with trace of white sand	60	565
Sand, fine to medium, subrounded to subangular, and blackish-red shale (5R2/2)	40	605
Sand, very fine to coarse, slightly calcareous; streaks of grayish-red (10R4/2) shale	23	628
PERMIAN:		
Glorieta(?) Sandstone:		
Sand, as above (water from 628 to 685 feet)	67	695
Glorieta Sandstone:		
Sand, well-rounded, fine to medium, slightly micaceous, and calcareous	120	815
Yeso Formation:		
Sand, well-rounded, fine to medium, slightly micaceous and calcareous; trace of gypsum	57	872

15.6.4.411 Richfield Oil Corp. No. 1,
Drought-Booth, oil-test well

Stratigraphic correlation: modified from log No. 5,028, N. Mex. School of Mines, State Bur. Mines and Mineral Res., Well-Log Division

TABLE 5 (continued)

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
15.6.4.411 Richfield Oil Corp. No. 1, Drought-Booth, oil-test well (concluded)		
UPPER CRETACEOUS:		
Mesaverde Group:		
Undifferentiated:		
Shale and sand	880	880
Mancos Shale:		
Shale	1,080	1,960
CRETACEOUS:		
Dakota Sandstone:		
Sandstone	70	2,030
UPPER JURASSIC:		
Undifferentiated:		
Lime, sand, and shale	180	2,210
Sand and shale	690	2,900
Lime and anhydrite	80	2,980
Sandstone	180	3,160
UPPER TRIASSIC:		
Undifferentiated:		
Shale, red	1,370	4,530
PERMIAN:		
Undifferentiated:		
Shale, lime, and sand	330	4,860
Sand	770	5,630
Shale, lime, and sand	520	6,150
PENNSYLVANIAN:		
Undifferentiated:		
Shale and lime	990	7,140
PRECAMBRIAN:		
Granite	3	7,143
15.6.4.423 Ignacio Chavez Grant (Drilled as Midwest Refining Co. and Stanolind Oil and Gas Co. No. 1, Chavez Grant, oil-test well)		
UPPER CRETACEOUS:		
Satan Tongue of Mancos Shale:		
Shale, sandy	25	25
Mesaverde Group:		
Hosta Tongue of Point Lookout Sandstone:		
Sandrock, hard, sharp	27	52
Crevasse Canyon Formation and Mulatto Tongue of Mancos Shale:		
Undifferentiated:		
Shale, yellow, sandy, hard	13	65
Sand, gray, hard (water)	35	100

TABLE 5 (continued)

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
15.6.4.423 Ignacio Chavez Grant (Drilled as Midwest Refining Co. and Stanolind Oil and Gas Co. No. 1, Chavez Grant, oil-test well) (continued)		
UPPER CRETACEOUS (continued):		
Mesaverde Group (continued):		
Crevasse Canyon Formation and Mulatto Tongue of Mancos Shale (continued):		
Undifferentiated (continued):		
Sandrock, gray, hard	115	215
Shale, blue, sandy	10	225
Sandrock, gray, hard	60	285
Sandrock, gray, hard; thin streaks of blue shale	25	310
Shale	5	315
Sandrock	5	320
Shale	10	330
Shale, sandy, hard	20	350
Shale, sandy, and blue shale	10	360
Shale, blue	20	380
Shale, brown	50	430
Shale	85	515
Shale, brown, sandy	50	565
Sand, gray	15	580
Shale, gray	60	640
Sand, white	105	745
Shale, gray	40	785
Gallup Sandstone:		
Sand, white (water flowing over top from 815.5 feet)	80	865
Mancos Shale:		
Shale, black, sandy	40	905
Shale, gray	5	910
Shale, blue	14	924
Shale, dark-blue	16	940
Shale, brown, sandy	50	990
Shale, brown, sandy; mixed with hard lime shells	45	1,035
Shale, blue, sandy	40	1,075
Shale, blue	215	1,290
Shale, gray, soft, cavey	75	1,365
Shale, gray, caving	135	1,500
Shale, brown	90	1,590
Soft, white, chalky formation	40	1,630
Sand, gray, caving	20	1,650
Shale, caving	5	1,655
Shale, gray, sandy	35	1,690
Shale, gray	35	1,725
Water, sand (hole full of water)	15	1,740

TABLE 5 (continued)

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
15.6.4.423 Ignacio Chavez Grant (Drilled as Midwest Refining Co. and Stanolind Oil and Gas Co. No. 1, Chavez Grant, oil-test well) (concluded)		
UPPER CRETACEOUS (continued):		
Mesaverde Group (continued):		
Mancos Shale (continued):		
Water, sand, hard	10	1,750
Shale, blue	25	1,775
Shale, blue	33	1,808
Water, sand	15	1,823
Shale, blue	5	1,828
Water, sand, gray	5	1,833
Shale, blue	12	1,845
Shale, dark, sandy	8	1,853
Shale, dark	7	1,860
Shale, blue, and dark	15	1,875
Shale, dark	10	1,885
Shale, black	10	1,895
CRETACEOUS:		
Dakota Sandstone:		
Water, sand, gray	13	1,908
Shale, black, very hard	4	1,912
Shale, blue	2	1,914
Sand, gray, hard	28	1,942
Sand, white, soft	39	1,981
Sand, white, hard	9	1,990
UPPER JURASSIC:		
Morrison Formation:		
Undifferentiated:		
Shale, blue, sticky	3	1,993
Shale	3	1,996
Shale, blue-black, hard	22	2,018
Water, sand, very loose	22	2,040
Shale, white; or talc	3	2,043
Water, sand, hard	7	2,050
Clay or shale, red	4	2,054
Shale, blue-white	14	2,068
Shale, blue-white, very sticky	12	2,080
Shale, white	16	2,096
Shale, red	58	2,154

15.10.6.242 (15K-338) U.S. Bureau of Indian Affairs

Casing record: 7-inch pipe, perforated from 910 to 975 feet

Hydrologic data: Bailed 85 minutes at 20 gpm; pumping water level, 615 feet. Water 130 to 240 feet, 600 to 660 feet, and 940 to 970 feet (main aquifer)

TABLE 5 (continued)

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
15.10.6.242 (15K-338) U.S. Bureau of Indian Affairs (continued)		
Samples described by: P. R. Stevens		
Stratigraphic correlation by: J. T. Callahan		
UPPER CRETACEOUS:		
Mesaverde Group:		
Point Lookout Sandstone:		
Sandstone, grayish-dusky-yellow (5Y7/4), fine to very fine with silt, subrounded to subangular, poorly sorted, clear and stained quartz; argillaceous material common; feldspar rare; mica rare; dark accessory minerals rare; weak calcareous and argillaceous cement	40	40
Satan Tongue of Mancos Shale:		
Mudstone, light-gray (N7); silt and clay; mica common; dark, accessory minerals rare; coal fragments rare; weak, calcareous cement	20	60
Mesaverde Group:		
Hosta Tongue of Point Lookout Sandstone:		
Sandstone, light-gray (N7), fine to very fine silty, subrounded to subangular, poorly sorted, clear quartz; mica common; argillaceous material common; carbonaceous material common; dark accessory minerals common; mudstone rare to absent; weak, argillaceous and calcareous cement	20	80
Siltstone, medium-light-gray (N6); silt; mica common; dark, accessory minerals rare; argillaceous material rare; weak, calcareous cement	40	120
Sandstone, very light-gray (N8), very fine silty subrounded to subangular, poorly sorted, clear quartz; mica common; argillaceous material common; dark, accessory minerals rare; weak calcareous and argillaceous cement	120	240
Crevasse Canyon Formation:		
Gibson Coal Member:		
Siltstone, medium-light-gray (N6) to medium-dark-gray (N4), arenaceous, silt with fine to very fine sand subrounded to subangular, clear quartz; mica rare; coal common; pyrite rare to absent; mudstone fragments rare to absent; weak, calcareous cement	140	380
Siltstone, medium-dark-gray (N4), arenaceous, silt with fragments of sandstone, fine to very fine subrounded to subangular, poorly sorted, clear and stained quartz; argillaceous material abundant; mica common; dark, accessory minerals common, weak, argillaceous and calcareous cement	80	460

TABLE 5 (continued)

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
15.10.6.242 (15K-338) U.S. Bureau of Indian Affairs (continued)		
UPPER CRETACEOUS (continued):		
Crevasse Canyon Formation (continued):		
Dalton Sandstone Member:		
Sandstone, light-gray (N7), silty, fine to very fine, subrounded to subangular, poorly sorted, clear quartz; argillaceous material common; mica rare; weak, argillaceous and calcareous cement	130	590
Sandstone, light-gray (N7), silty, fine to very fine subangular to subrounded, poorly sorted, clear quartz; mica rare; feldspar rare; argillaceous material common to absent; platy minerals rare; weak, calcareous cement	70	660
Mulatto Tongue of Mancos Shale:		
Siltstone, light-gray (N7); silt; mica common; argillaceous material common; some sandstone aggregates; weakly calcareous and argillaceous cement	60	720
Siltstone, light-gray (N7); mica common; argillaceous material common; mudstone fragments rare to common; pyrite rare to absent; weakly calcareous and argillaceous cement	70	790
Siltstone and mudstone, light-gray (N7), silt and clay; coal fragments; weakly calcareous and argillaceous cement	50	840
Siltstone and mudstone, light-gray (N7), silt and clay, fine- to very very fine-grained sand, poor sorting; coal fragments; mica rare; peaty minerals rare; argillaceous material common; weakly calcareous and argillaceous cement	10	850
Mesaverde Group:		
Crevasse Canyon Formation:		
Dilco Coal Member:		
Sandstone, light-gray (N7) to medium-gray (N5), medium to very fine with silt, subrounded to subangular, poorly sorted clear quartz; argillaceous material common; mica rare; mudstone rare to absent; feldspar rare; weakly calcareous and argillaceous cement	50	900
Siltstone and mudstone, medium-gray (N5) to medium-dark-gray (N4); mica common; dark, accessory minerals rare; marcasite rare; gypsum rare; pyrite common to absent; coal fragments common to absent; carbonaceous material common to absent; weakly calcareous cement	30	930

TABLE 5 (continued)

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
15.10.6.242 (15K-338) U.S. Bureau of Indian Affairs (concluded)		
UPPER CRETACEOUS (continued):		
Mesaverde Group (continued):		
Dilco Coal Member (continued):		
Sandstone, very light-gray (N8), medium to very fine, angular to subrounded, well sorted, clear and stained quartz; feldspar rare; dark, accessory minerals rare; weak, calcareous cement ...	30	960
Sandstone, medium-light-gray (N6), silty, medium to very fine subrounded to subangular, poorly sorted, clear and stained quartz; feldspar rare; dark, accessory minerals rare, argillaceous material rare; mica rare; weakly, calcareous and argillaceous cement	10	970
No Samples	10	980
Siltstone, arenaceous, and mudstone, medium-light-gray (N6), silt and clay with fine to very fine sand; coal common; pyrite rare; argillaceous material rare; weak, calcareous and argillaceous cement	20	1,000
15.10.13.133 Midwest Refining Co. No. 1 Walker Dome, oil-test well		
UPPER CRETACEOUS:		
Mulatto Tongue of Mancos Shale:		
Shale, sandy	28	28
Shale, brown, sandy	27	55
Shale, sandy	85	140
Mesaverde Group:		
Crevasse Canyon Formation:		
Dilco Coal Member:		
Sand, very white	79	219
Shale, blue	11	230
Sand, gray	5	235
Adobe, black	15	250
Shale, blue, sandy	8	258
Gallup Sandstone:		
Sandstone, gray	32	290
Mancos Shale:		
Shale, dark	138	428
Sand, gray	2	430
Shale, dark	127	557
Sandstone, coarse	8	565
Shale, dark	105	670
Shale, blue	75	745
Shale, gray	131	876

TABLE 5 (continued)

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
15.10.13.133 Midwest Refining Co. No. 1 Walker Dome, oil-test well (concluded)		
UPPER CRETACEOUS (continued):		
Mancos Shale (continued):		
Sand, gray, coarse (dry)	87	963
Sand, gray, fine	7	970
Sand, fine (water)	55	1,025
Sand, fine	10	1,035
Shale, gray	39	1,074
Sand, white (water)	19	1,093
Shale, blue	32	1,125
CRETACEOUS:		
Dakota Sandstone:		
Sand, gray	41	1,166
Sand, gray, fine	97	1,263
Shale, black	5	1,268
UPPER JURASSIC:		
Morrison Formation:		
Brushy Basin Member:		
Shale, red and green	86	1,354
Westwater Canyon Member:		
Sand, gray,coarse	22	1,376
Sand, gray (water)	6	1,382
Shale, light-green	4	1,386
Sand, gray	29	1,415
Recapture Member:		
Shale, red, green, and black	27	1,442
Shale, as above, and red gravel (water)	9	1,451
Gravel, red, and sand	9	1,460

NOTE: Plymouth Oil Co. No. 1-A, Santa Fe R. R. oil-test well was drilled near this location and logged granite wash from 6,015 to 6,088 feet, granite from 6,088 to 6,210 feet.

15.11.18.222 (16B-37) U.S. Bureau of Indian Affairs

Casing record: 10-inch pipe to 42 feet, 7-inch pipe 0 to 601 feet, 5-inch pipe from 577 to 812 feet

Hydrologic data: Water level to 400 feet, pumping 15 gpm

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
Sand, soft	41	41
UPPER CRETACEOUS:		
Mancos Shale:		
Shale, brown	49	90
Shale, blue	30	120

TABLE 5 (continued)

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
15.11.18.222 (16B-37) U.S. Bureau of Indian Affairs (concluded)		
UPPER CRETACEOUS (continued):		
Mancos Shale (continued:		
Shale, brown	35	155
Shale, gray	355	510
Shale, brown	28	538
Shale, gray, hard	17	555
Shale, gray, sandy	15	570
Shale, brown	15	585
Shale, gray, sandy	15	600
Shale, brown	25	625
Shale, sandy	15	640
Sand, (½ gpm)	15	655
Shale, sandy	5	660
Shale, brown, sandy	25	685
Shale, gray, sandy	80	765
CRETACEOUS:		
Dakota Sandstone:		
Sand, (15 gpm)	30	795
Shale, gray, sandy	17	812

15.12.17.123 (16K-325) U.S. Bureau of Indian Affairs (Smith Lake Chapter House)

Casing record: 8-inch pipe to 93 feet, 6-inch pipe to 669 feet, cemented at 669 feet; open hole from 669 to 696 feet

Hydrologic data: Pumped 80 minutes at 11 gpm; pumping water level, 399 feet. Water from 657 to 701 feet

Samples described by: P. R. Stevens

Stratigraphic correlation by: J. T. Callahan

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
QUATERNARY:		
Alluvium:		
Sand, light-olive-gray (6Y6/1), fine to very fine, silty, quartz, fairly well sorted, calcareous	40	40
UPPER CRETACEOUS:		
Mancos Shale:		
Siltstone, light-olive-gray (5Y6/1), sandy, calcareous with fragments of jasper	10	50
Mudstone and claystone, medium-gray, calcareous	430	480
Mudstone, light-gray, calcareous with claystone and gypsum	10	490
Mudstone, medium-gray, calcareous with biotite	50	540

TABLE 5 (continued)

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
15.12.17.123 (16K-325) U.S. Bureau of Indian Affairs (Smith Lake Chapter House) (concluded)		
UPPER CRETACEOUS (continued):		
Mancos Shale (continued):		
Siltstone, medium-gray, calcareous with gypsum	10	550
Mudstone, medium-gray, silty, calcareous with gypsum	50	600
Siltstone, medium-light-gray, calcareous	50	650
CRETACEOUS:		
Dakota Sandstone:		
Siltstone, medium-light-gray, sandy, calcareous ...	10	660
Sand, light-gray, medium to fine, well-sorted quartz, calcareous	20	680
Sand, very light-gray, fine to very fine, silty, poorly sorted quartz, calcareous	20	700
Siltstone, brownish-gray, sandy, calcareous	1	701
15.13.8.213 Tidewater Assoc. Oil Co. No. 1, Mariano Dome, oil-test well		
CRETACEOUS:		
Dakota Sandstone:		
Sandstone	45	45
UPPER JURASSIC:		
Morrison Formation:		
Undifferentiated:		
Shale and sand	555	600
San Rafael Group:		
Undifferentiated:		
Sand, greenish-gray, fine	190	790
Shale, chocolate	10	800
Sand, red, fine, silty	10	810
Shale, chocolate	30	840
Sand, gray, fine and shale	130	970
Sand, pink	240	1,210
UPPER TRIASSIC:		
Undifferentiated:		
Limestone	10	1,220
Shale, red and green	100	1,320
Sand, salmon	20	1,340
Shale, red and green	80	1,420
Sand, red	40	1,460
Shale, red and green, sandy	10	1,470
Sand, red, silty	40	1,510
Shale, sandy	470	1,980
Shale, red, purple, and green	447	2,427

TABLE 5 (continued)

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
15.13.8.213 Tidewater Assoc. Oil Co. No. 1, Mariano Dome, oil-test well (continued)		
UPPER TRIASSIC (continued):		
Undifferentiated (continued):		
Sandstone	63	2,490
Shale, red	10	2,500
Sandstone	30	2,530
Shale, purple to red	180	2,710
Sandstone	10	2,720
Shale, sandy	20	2,740
Sandstone, gray, fine	30	2,770
Shale	20	2,790
Sandstone, red, fine, silty	10	2,800
Shale	70	2,870
Sandstone, gray to red, fine	20	2,890
PERMIAN(?):		
Undifferentiated:		
Shale; streaks of marl and anhydrite	130	3,020
PERMIAN:		
Undifferentiated:		
Sandstone, buff, fine	180	3,200
Siltstone	13	3,213
Sand, fine	17	3,230
Shale; streaks of sand	40	3,270
Sandstone	15	3,285
Siltstone; streaks of sand	50	3,335
Sandstone, fine, silty	45	3,380
Shale; streaks of fine sand	70	3,450
Sandstone, red	35	3,485
Shale, red	5	3,490
Sand, red, fine, silty	40	3,530
Shale, purple and red	115	3,645
Sand, red, fine, silty	25	3,670
Shale, blue-gray and red	130	3,800
Sandstone, fine, silty	30	3,830
Shale	50	3,880
Sand, fine, silty	30	3,910
Shale, red	10	3,920
Sand	25	3,945
Shale, sandy	25	3,970
Sand, red, fine, silty	15	3,985
Shale, blue, purple, and red	50	4,035
Sand	5	4,040
Shale, blue	90	4,130
Sandstone, red, fine, silty	40	4,170
Shale, blue	40	4,210
Sand, very fine, silty	20	4,230
Shale, varicolored	580	4,610

TABLE 5 (continued)

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
15.13.8.213 Tidewater Assoc. Oil Co. No. 1, Mariano Dome, oil-test well (concluded)		
PENNSYLVANIAN:		
Undifferentiated:		
Limestone; streaks of shale	7	4,617
Shale	13	4,630
Limestone	23	4,653
Sandstone, fine	5	4,658
Shale; streaks of fine sand	3	4,661
Limestone and shale	10	4,671
Limestone	7	4,678
Shale; streaks of lime	4	4,682
Limestone	2	4,684
Shale	1	4,685
PRECAMBRIAN:		
Granite	1	4,686
15.13.12.144a Lance Corp.		
Stratigraphic correlations by: Lance Corp.		
QUATERNARY:		
Alluvium	85	85
UPPER CRETACEOUS:		
Mancos Shale	205	290
CRETACEOUS:		
Dakota Sandstone	150	440
UPPER JURASSIC:		
Morrison Formation:		
Brushy Basin Member	140	580
Westwater Canyon Member	220	800
Recapture Member	105	905
San Rafael Group:		
Bluff Sandstone	107	1,012
16.8.1.100 Petro Minerals, Inc. No. 1, Fernandez, oil-test well		
UPPER CRETACEOUS:		
Mesaverde Group:		
Menefee Formation	530	530
Point Lookout Sandstone	150	680
Satan Tongue of Mancos Shale	320	1,000

TABLE 5 (continued)

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
16.8.1.100 Petro Minerals, Inc. No. 1, Fernandez, oil-test well (concluded)		
UPPER CRETACEOUS (continued):		
Mesaverde Group:		
Hosta Tongue of Point Lookout Sandstone:	-?-	-?-
Crevasse Canyon Formation:		
Gibson Coal Member:		
Dalton Sandstone:		
Undifferentiated	270	1,270
Mulatto Tongue of Mancos Shale	430	1,700
Mesaverde Group:		
Crevasse Canyon Formation:		
Dilco Coal Member	130	1,830
Gallup Sandstone	115	1,945
Mancos Shale	880	2,825
CRETACEOUS:		
Dakota Sandstone	160	2,985
UPPER JURASSIC:		
Morrison Formation:		
Brushy Basin Member	21	3,006
16.9.17.222 Fernandez Co. (Drilled as Locke and Taylor No. 1, Santa Fe R.R., oil-test well)		
QUATERNARY(?):		
Shale	6	6
Sand, brown	26	32
UPPER CRETACEOUS:		
Satan Tongue of Mancos Shale:		
Hosta Tongue of Point Lookout Sandstone recorded with unit, if present:		
Shale, sandy	103	135
Mesaverde Group:		
Crevasse Canyon Formation:		
Gibson Coal Member:		
Shale	3	138
Coal	2	140
Shale	22	162
Coal	3	165
Sand	50	215
Shale	5	220
Sand to shale	25	245
Shale, sandy	10	255
Sand, gray	40	295
Sand, gray (water)	30	325

TABLE 5 (continued)

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
16.9.17.222 Fernandez Co. (Drilled as Locke and Taylor No. 1 Santa Fe R.R., oil test well) (concluded)		
UPPER CRETACEOUS (continued):		
Mesaverde Group (continued):		
Crevasse Canyon Formation (continued):		
Dalton Sandstone Member:		
Sand, hard	15	340
Sand, gray, hard	120	460
Mulatto Tongue of Mancos Shale:		
Shale, blue	12	472
Sand, gray	43	515
Shale, blue	12	527
Sand, gray	3	530
Shale, blue	70	600
Shale, sandy	40	640
Shale, blue	40	680
Shale, sandy	10	690
Shale, blue	60	750
Shale, sandy	50	800
Shale, blue	45	845
Mesaverde Group:		
Crevasse Canyon Formation:		
Dilco Coal Member:		
Sand	10	855
Shale, blue	5	860
Sand (water)	10	870
Sandy	5	875
Shale, blue	20	895
Shale, sandy	10	905
Sand, fine (water)	57	962
Gallup Sandstone:		
Sand	63	1,025
Shale, sandy	9	1,034
Sand	16	1,050
Mancos Shale:		
Shale, black	10	1,060
Shale	685	1,745
Sand (water)	10	1,755
Shale	142	1,897
16.10.8.312 (15B-36) U.S. Bureau of Indian Affairs		
UPPER CRETACEOUS:		
Satan Tongue of Mancos Shale:		
Shale, yellow	15	15
Shale, blue	65	80
Shale, brown, sandy	30	110

TABLE 5 (continued)

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
16.10.8.312 (15B-36) U.S. Bureau of Indian Affairs (concluded)		
UPPER CRETACEOUS (continued):		
Satan Tongue of Mancos Shale (continued):		
Shale, gray, sandy	15	125
Shale, brown	55	180
Shale, gray, sandy	35	215
Shale, blue	40	255
Shale, blue and brown	32	287
Mesaverde Group:		
Hosta Tongue of Point Lookout Sandstone:		
Sand, (2 gpm)	8	295
Shale, brown	15	310
Sand, (3 gpm)	35	345
Crevasse Canyon Formation:		
Gibson Coal Member:		
Shale, gray	55	400
Sand, (15 gpm)	45	445
Shale, blue	32	477
16.10.12.144 Hogback Oil Co. No. 1, O. G. Horton, oil-test well		
UPPER CRETACEOUS:		
Mesaverde Group:		
Point Lookout Sandstone:		
Sandstone, brown	110	110
Satan Tongue of Mancos Shale:		
Shale	375	485
Mesaverde Group:		
Hosta Tongue of Point Lookout Sandstone:		
Sand streaks at 485 feet.		
Shale, gray	45	530
Shale, gray, sandy (water)	10	540
Crevasse Canyon Formation:		
Gibson Coal Member:		
Shale, gray	20	560
Sand (water)	20	580
No report	95	675
Dalton Sandstone Member:		
Sand and shale	40	715
Shale, blue, sandy, and gray lime	35	750
Mulatto Tongue of Mancos Shale:		
Shale, gray	170	920
Shale, gray, and bentonite	50	970
Shale, gray, sandy	58	1,028
Sand, gray, fine (water)	37	1,065
Shale, blue, sandy	25	1,090
Shale, gray	85	1,175

TABLE 5 (continued)

16.10.12.144 Hogback Oil Co. No. 1, O. G. Horton, oil-test well (concluded)

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
UPPER CRETACEOUS (continued):		
Mesaverde Group:		
Crevasse Canyon Formation:		
Dilco Coal Member:		
Shale, gray, sandy; streaks of white sand	89	1,264
Gallup Sandstone:		
Sand, white	16	1,280
Shale, blue with streaks of sand	35	1,315
No report	10	1,325
Mancos Shale:		
Shale, blue	65	1,390
Shale, blue, sandy	155	1,545
Shale, blue	365	1,910
Shale, gray	125	2,035
Sand (water)	7	2,042
Shale, gray, sandy, with lime	53	2,095
Lime, gray, sandy	100	2,195
Shale, black, sandy	45	2,240
Shale, sandy, coarse and lime	30	2,270
CRETACEOUS:		
Dakota Sandstone:		
Conglomerate, sandy (water)	5	2,275
Lime, white (water)	15	2,290
Sand, brown (water)	10	2,300
Sand, white, coarse (water)	50	2,350

16.10.22.232 R. E. Albers and Son

Casing record: 5-inch pipe to 640 feet

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
Soil, tan	1	1
Caliche, cream	4	5
UPPER CRETACEOUS:		
Mesaverde Group:		
Point Lookout Sandstone:		
Clay, yellow	5	10
Sand, yellow	8	18
Clay, yellow	9	27
Shale, brown, sandy	13	40
Shale, tan	5	45
Shale, gray, sandy	7	52
Sand, yellow	51	103
Satan Tongue of Mancos Shale:		
Shale, gray	517	620

TABLE 5 (continued)

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
16.10.22.232 R. E. Albers and Son (concluded)		
UPPER CRETACEOUS (continued):		
Mesaverde Group (continued):		
Hosta Tongue of Point Lookout Sandstone:		
Sandstone	20	640
Shale	5	645
16.11.5.121 (15B-35) U.S. Bureau of Indian Affairs		
Casing record: 9-inch pipe to 390 feet, 7-inch perforated pipe from 375 to 631 feet		
Hydrologic data: Water found at 418, 436, 442, and 555 feet		
Surface	0	10
UPPER CRETACEOUS:		
Mesaverde Group:		
Crevasse Canyon Formation:		
Dalton Sandstone Member:		
Shale, yellow, sandy	60	70
Mulatto Tongue of Mancos Shale:		
Shale, blue	64	134
Sand, gray	10	144
Shale, gray	271	415
Mesaverde Group:		
Crevasse Canyon Formation:		
Dilco Coal Member:		
Sand, gray	14	429
Shale, gray	2	431
Sand, gray	5	436
Shale, gray	3	439
Sand, gray	3	442
Shale, gray	13	455
Shale, brown	9	464
Shale, gray	24	488
Sand, gray	10	498
Shale, black	5	503
Sand, gray	2	505
Shale, black	28	533
Sand, gray	4	537
Shale, black	6	543
Sand, gray	5	548
Shale, brown	5	553
Sand, gray	2	555
Shale, black	9	564
Shale, gray	11	575

TABLE 5 (continued)

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
16.11.5.121 (15B-35) U.S. Bureau of Indian Affairs (concluded)		
UPPER CRETACEOUS (continued):		
Mesaverde Group (continued):		
Gallup Sandstone:		
Sand, white	51	626
Shale, black	7	633
Sand, gray	5	638
Shale, blue	24	662
Sand, gray	13	675
Shale, blue	40	715

16.11.16.331 (15T-505) U.S. Bureau of Indian Affairs
(Little Water Chapter House)

Casing record: 7-inch pipe to 570 feet, perforated from 470 to 570 feet

Hydrologic data: Water level at 345 feet after bailing 1 hour at 29 gpm

Stratigraphic correlation obtained from tribal records

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
Alluvium	0	10
UPPER CRETACEOUS:		
Mulatto Tongue of Mancos Shale	350	360
Mesaverde Group:		
Crevasse Canyon Formation:		
Dilco Coal Member	210	570

16.11.33.411 U.S. Bureau of Indian Affairs
(Borrego Pass Day School)

Casing record: 6-inch pipe to 830 feet; top of pipe string consists of 2 joints of 7-inch pipe plus ½ joint of 6-inch pipe stubbed above land surface. Pipe is perforated opposite all beds of sandstone below 300 feet

Hydrologic data: Bailed at 30 gpm for 1 hour, bailing water level 360 feet; bailed at 40 gpm for 1 hour, bailing water level 360 feet; bailed at 20 gpm for 1 hour, bailing water level less than 300 feet

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
Fill	5	5

TABLE 5 (continued)

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
16.11.33.411 U.S. Bureau of Indian Affairs (Borrego Pass Day School) (concluded)		
UPPER CRETACEOUS:		
Mesaverde Group:		
Crevasse Canyon Formation:		
Dalton Sandstone Member:		
Sandstone, yellow	47	52
Mulatto Tongue of Mancos Shale:		
Sandstone, gray	268	320
Shale, blue	5	325
Mesaverde Group:		
Crevasse Canyon Formation:		
Dilco Coal Member:		
Sandstone, gray	37	362
Shale, brown, and sandstone	38	400
Sandstone, light-gray	60	460
Sandstone, light-gray and brown	40	500
Sandstone, light-brown	20	520
Coal and shale	10	530
Gallup Sandstone:		
Sandstone, white	70	600
Sandstone, white and gray	28	628
Shale, blue	87	715
Sandstone, gray, with layers of lime at 715 feet	65	780
Mancos Shale:		
Shale, blue	50	830

16.13.11.440 (16K-332) U.S. Bureau of Indian Affairs

Casing record: 10-inch pipe to 128 feet; 8-inch liner pipe 112 to 340 feet, perforated 120 to 132 feet, 245 to 250 feet, and 300 to 310 feet; hole plugged 340 to 570 feet

Hydrologic data: Bailed dry in 30 minutes; yields estimated at 2 gpm; water from 245 to 250 feet

Samples described by: P. R. Stevens

Stratigraphic correlation by: J. T. Callahan

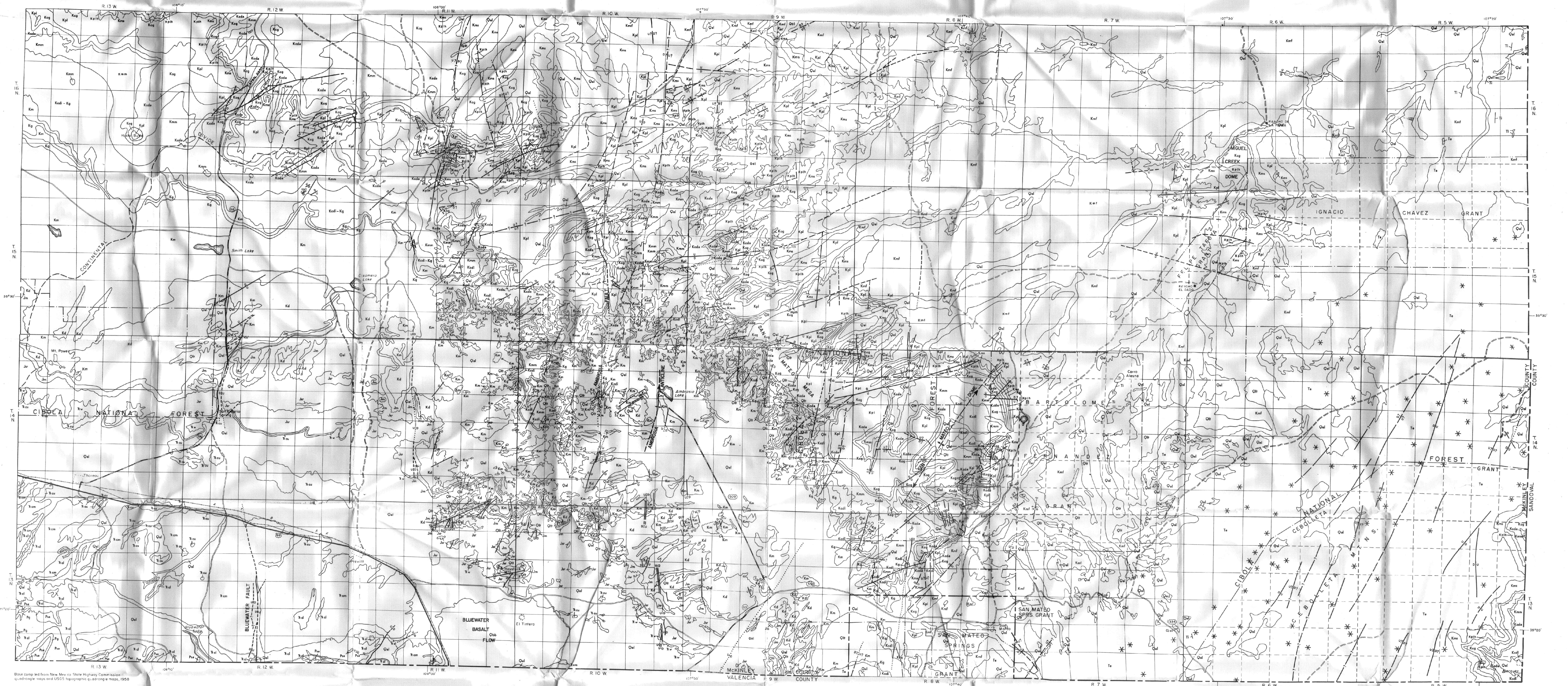
Stratigraphic unit and material	Thickness (feet)	Depth (feet)
QUATERNARY:		
Alluvium:		
Siltstone, light-olive-gray (5Y6/1), arenaceous; silt with fine to very fine, subrounded to subangular clear quartz; coal fragments rare; mudstone fragments rare; dark, accessory minerals rare; mica rare; weak, calcareous and argillaceous cement	50	50

TABLE 5 (continued)

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
16.13.11.440 (16K-332) U.S. Bureau of Indian Affairs (continued)		
QUATERNARY (continued):		
Alluvium (continued):		
Siltstone, yellowish-olive-gray (5Y6/2), arenaceous; silt with very fine, subrounded to subangular, clear and stained quartz; dark, accessory minerals rare; argillaceous material common; weak, calcareous and argillaceous cement	10	60
Siltstone, medium-light-gray (N6), arenaceous; silt with medium to very fine, subrounded to subangular, clear and stained quartz; dark, accessory minerals rare; argillaceous material rare; hematite concretions rare; limonite rare; mica rare; carbonaceous material rare to absent; weak, calcareous and argillaceous cement	80	140
UPPER CRETACEOUS:		
Mulatto Tongue of Mancos Shale:		
Siltstone, light-gray (N7); mica rare; argillaceous material common; weak, calcareous cement	20	160
Siltstone and mudstone, medium-light-gray (N6); mica rare; calcite fragments common; gypsum rare; dark, accessory minerals rare; weak, calcareous cement ..	50	210
Siltstone and mudstone, light-gray (N7) and medium-light-gray (N6); mica rare, calcite fragments common; gypsum rare; dark, accessory minerals rare; weak, calcareous cement	10	220
Mesaverde Group:		
Crevasse Canyon Formation:		
Dilco Coal Member:		
Siltstone, olive-gray (5Y4/1), fine to very fine, subangular, clear quartz; mica rare; argillaceous material common; carbonaceous material common; weak calcareous cement	40	260
Mudstone, medium-light-gray (N6), silty with chips of fine, subrounded to subangular, clear quartz; dark, accessory minerals rare; weak, calcareous cement	30	290
Sandstone, medium-light-gray (N6), coarse to fine, subrounded to subangular, fairly well sorted clear quartz; dark, accessory minerals rare; weak, calcareous cement	10	300
Mudstone and siltstone, medium-light-gray (N6), mica rare; dark, accessory minerals rare; coal fragments common; weak, calcareous cement ...	40	340
Sandstone, light-gray (N8), medium to very fine, silty, subrounded to subangular, poorly sorted, clear quartz; mica rare; dark, accessory minerals rare; feldspar rare; weak, calcareous cement	10	350

TABLE 5 (concluded)

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
16.13.11.440 (16K-332) U.S. Bureau of Indian Affairs (concluded)		
UPPER CRETACEOUS (continued):		
Mesaverde Group (continued):		
Crevasse Canyon Formation (continued):		
Dilco Coal Member (continued):		
Mudstone, medium-gray (N5) and light-gray (N7); silt and clay; mica common; coal fragments common to absent; dark, accessory minerals rare; weak, calcareous cement	80	430
Sandstone, white (N9), fine to very fine, silty, subrounded to subangular, poorly sorted, clear and stained quartz; feldspar rare; mica rare; dark, accessory minerals rare; weak, calcareous cement	10	440
Sandstone, very light-gray (N8), silty, fine to very fine, subrounded to subangular, poorly sorted, clear quartz; mica common; argillaceous material rare to common; dark, accessory minerals rare; weak, calcareous and argillaceous cement	10	450
Sandstone, very light-gray (N8), medium to very fine, rounded to subangular, fairly well to well sorted, clear quartz; feldspar common; dark, accessory minerals rare; weak, calcareous cement	40	490
Sandstone, light-gray (N7), silty, fine to very fine, subrounded to subangular, poorly sorted, clear quartz; mica common; dark, accessory minerals rare; weak, calcareous and argillaceous cement	10	500
Siltstone and mudstone, medium-gray (N5); mica common; dark, accessory minerals common; carbonaceous material rare; weak, calcareous cement	20	520
No sample	30	550
Siltstone, medium-light-gray (N6) and medium-gray (N5); dark, accessory minerals rare; mica rare; weak, calcareous cement	20	570



Base compiled from New Mexico State Highway Commission quadrangle maps and USGS topographic quadrangle maps, 1958

Compiled by James B. Cooper

1 0 1 2 3 4 5 Miles

Plate I.--Geologic map of southeastern McKinley County, N. Mex.

(Sheet 1 of 2)

Plate I.--Geologic map of southeastern McKinley County, N. Mex.

(Sheet 2 of 2)

EXPLANATION

QUATERNARY

Pleistocene and Recent

Qlt

Landslide and talus material.

Not known to yield water to wells

Qal

Alluvium

Unconsolidated clay, silt, sand, and gravel; includes wind-blown sand deposits; as much as 150 feet thick. Yields from 1 to 5 gpm of water of poor to good quality to wells at places along San Mateo and Azul Creeks

Qbb

Bluewater Basalt

Dark-gray to black, dense to vesicular basalt, ash, and cinders; occurs as valley flows and low cones; as much as 200 feet thick. Not known to yield water to wells

TERTIARY AND QUATERNARY

Pliocene and Pleistocene(?)

Qtb

Basalt

Erosional remnants of flow rocks capping Mt. Powell and an adjacent ridge; as much as 75 feet thick. Not known to yield water to wells

TERTIARY

Pliocene

Te ✳

Basalt, andesite, and other extrusive rocks

Flow rocks capping the Cebolleta Mountains; as much as 550 feet thick; include some rhyolite and tuff breccia, dikes, and other intrusive rocks; location of volcanic vents indicated by ✳. Not known to yield water to wells; forms a recharge area for the underlying rocks of Cretaceous age

Ti

Andesite and other intrusive rocks

Igneous rocks of varied composition and form. Not known to yield water to wells; often form barriers to movement of ground water and at places create springs

CRETACEOUS

Upper Cretaceous

Mesaverde Group

Kmf

Menefee Formation

Gray, brown, and drab claystone and shale; coal; tan and brown sandstone; and some layers of ironstone and limestone concretions; 400 to 1,000 feet thick. Yields about 5 gpm of water of good quality to wells near San Mateo; many springs near the Cebolleta Mountains and north and west of the mountains flow 2 to 15 gpm of water of good quality

Kpl
Kplh

Point Lookout Sandstone

Light-gray to yellow sandstone, massive; contains some gray shale; 75 to 300 feet thick.
Kpl, main body of the Point Lookout Sandstone.
Kplh, Hosta Tongue, as much as 180 feet thick; separated from main body of the Point Lookout Sandstone by the Satan Tongue (Kms) of the Mancos Shale.
Yields 5 to 20 gpm of water of good to fair quality; several wells flow at the land surface and many springs issue from both the Point Lookout Sandstone and the Hosta Tongue

Kcg
Kcda
Kcdi

Crevasse Canyon Formation

Drab shale and claystone; coal; and tan, irregularly bedded, and lenticular sandstone.
Kcg, Gibson Coal Member, 275 to 400 feet thick.
Kcda, Dalton Sandstone Member, 35 to 200 feet thick.
Kcdi, Dilco Coal Member, 120 to 200 feet thick; separated from upper two members by the Mulatto Tongue (Kmm) of the Mancos Shale.
The Gibson Coal Member and the Dalton Sandstone Member commonly are a single aquifer that yields 5 to 100 gpm of water of fair to poor quality to wells. The Dilco Coal Member forms a separate aquifer that yields 2 to 15 gpm of water of fair to poor quality to wells

Kg

Gallup Sandstone

Tan, brown and gray, thin- to thick-bedded sandstone with lesser amounts of carbonaceous shale, gray shale, and coal; 60 to 200 feet thick. In the northwestern part of map area, the Dilco Coal Member of the Crevasse Canyon Formation and the Gallup Sandstone are mapped together where both are present. Yields 25 to 120 gpm of water of poor quality to wells; is not generally used as a source of water

Kms
Kmm
Km

Mancos Shale

Light-gray to dark-gray shale with lesser amounts of tan, fine, sandstone and siltstone and bedded concretionary limestone.
Kms, Satan Tongue, 20 to 500 feet thick, and
Kmm, Mulatto Tongue, 200 to 400 feet thick, intertongue with the Mesaverde Group.
Km, main body of the Mancos Shale, 250 to 1,000 feet thick.
Yields 5 to 45 gpm of water of poor quality to wells from beds of sandstone in the main body of Mancos Shale; the Mulatto and Satan Tongues are not known to yield water to wells

Kd

Dakota Sandstone

Brown to tan or gray sandstone, conglomeratic sandstone, and conglomerate; locally contains interbedded siltstone, or gray carbonaceous to coaly shale beds; 50 to 150 feet thick. Yields 1 to 10 gpm of poor quality water to wells; is not generally used as a source of water

JURASSIC

Upper Jurassic

Jm

Morrison Formation

Gray, green, tan, and variegated clay and siltstone interbedded with gray, tan, or pink sandstone and conglomerate. Includes the Brushy Basin Member, 50 to 150 feet thick; Westwater Canyon Member, 30 to 300 feet thick; and Recapture Member, 75 to 200 feet thick. In the western part of the map area the Morrison Formation includes the Prewitt Sandstone Member of Smith (1954) and the Chaves Member of Smith (1954). The Westwater Canyon Member yields from 5 to 20 gpm of good to fair quality water to wells and is the principal aquifer at Ambrosia Lake and Smith Lake. The Recapture Member and Brushy Basin Member are not known to yield water to wells

Jsr

San Rafael Group

Varicolored sandstone and claystone, in part silty; contains limestone in lower part and reddish-brown to orange sandstone at base; includes Bluff Sandstone, 220 to 325 feet thick; Summerville Formation, 75 to 200 feet thick; Todilto Limestone, 6 to 30 feet thick; and Entrada Sandstone, 100 to 300 feet thick. In the western part of the map area the San Rafael Group includes the Thoreau Formation of Smith (1954). The Bluff Sandstone is the only formation of the San Rafael Group known to yield water to wells although it is not generally used as a source of water. In the Ambrosia Lake area the Bluff yields from 1 to 10 gpm of poor quality water to wells

TRIASSIC

Upper Triassic

Glen Canyon Group

TRw

Wingate Sandstone

Reddish-brown to orange sandstone; massive; cross-bedded; 35 to 100 feet thick. Yields 5 to 10 gpm of good to fair quality water to wells in the west-central part of the area

TRcu
TRcm
TRcl

Chinle Formation

Brick-red, maroon, gray, and greenish gray shale, siltstone, and sandstone; occasional limestone-pebble conglomerate.
TRcu, upper part, 900 to 1,000 feet thick; red, brown, and purple siltstone and mudstone with thin sandstone lenses and thin limestone beds.
TRcm, middle part, 60 to 225 feet thick; medium- to thick-bedded, yellow to gray, hard sandstone and pebble conglomerate, commonly with petrified wood, cross-bedded and with thin partings of purple to gray siltstone and mudstone.
TRcl, lower part, 300 to 450 feet thick; thin-bedded, fine, purple to white, silty sandstone and massive chocolate-brown to purple siltstone and mudstone.
Yields 5 to 30 gpm of fair to good quality water to wells from the sandstone in the middle part of the formation. The sandstone is the principal aquifer near Thoreau and Prewitt

PERMIAN

Psa

San Andres Limestone

Light-gray limestone, sandy limestone, and limy sandstone; thick-bedded to massive; 110 to 150 feet thick. Yields 10 to 150 gpm of good quality water to wells in the Zuni Mountains and near Thoreau and Prewitt. Wells in these areas commonly flow above the land surface; springs are numerous in the mountains. Commonly forms a single aquifer with the Glorieta Sandstone

Pg

Glorieta Sandstone

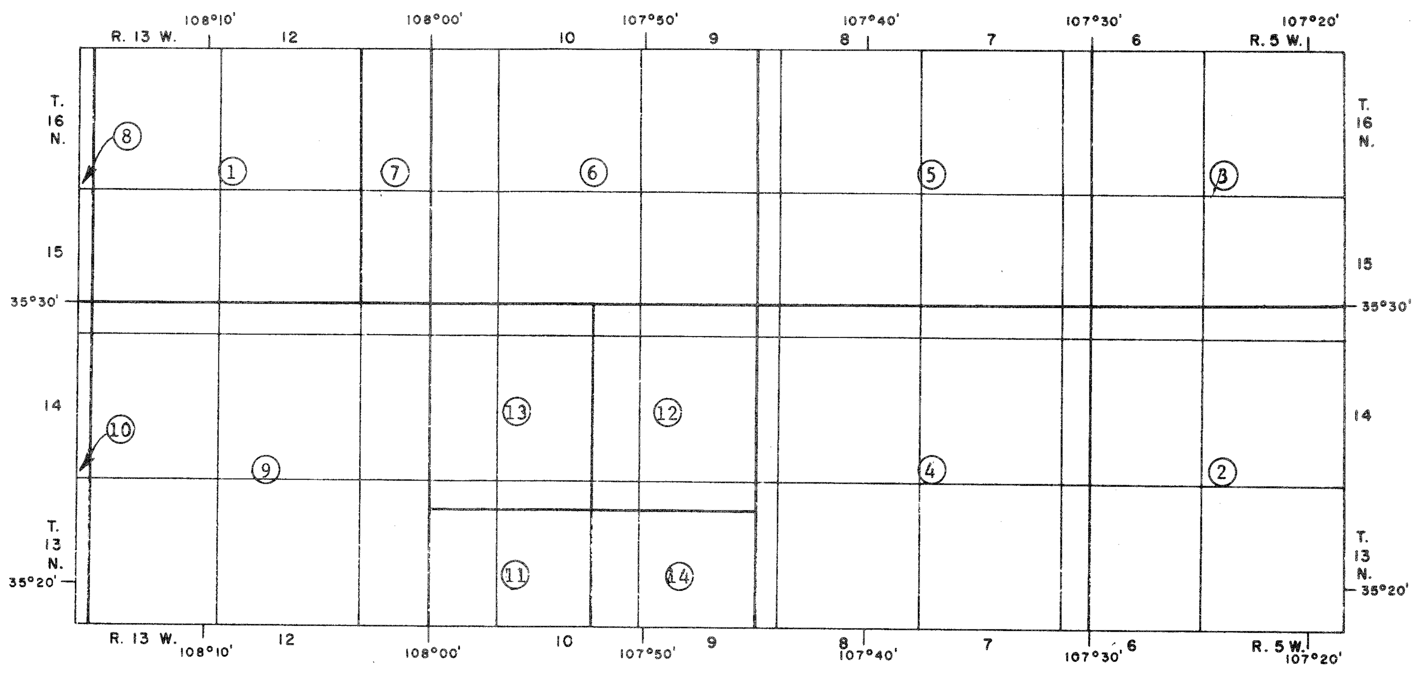
White to yellowish-gray sandstone, some siltstone in lower part; thick-bedded to massive; 120 to 220 feet thick. The Glorieta Sandstone and the San Andres Limestone commonly form a single aquifer which yields 10 to 340 gpm of good to poor quality water to wells. The quality of the water deteriorates northeast of the outcrop area in the Zuni Mountains

Contact between geologic formations

U
D
Fault

Dashed where approximately located; queried where probable; dotted where concealed; U, upthrown side; D, downthrown side

Anticline showing crest line and direction of plunge. Approximately located



INDEX MAP OF SOUTHEASTERN MCKINLEY COUNTY

Showing source of geologic data

(Encircled numbers refer to numbers in list of sources of data)

1. Beaumont, E. C., and O'Sullivan, R. B., 1957.*
2. Hackman, R. J., Photogeologic map of the Laguna-2 Quadrangle, McKinley, Sandoval, and Valencia Counties, New Mexico: U.S. Geol. Survey unpublished map.
3. Holzle, A. F., 1960.*
4. Knox, A. S., 1959, Photogeologic map of the Grants-1 Quadrangle, McKinley, and Valencia Counties, New Mexico: U.S. Geol. Survey unpublished map.
5. Kover, A. N., 1960.*
6. Kover, A. N., and Olson, A. B., 1959, Photogeologic map of Chaco Canyon-3 Quadrangle, McKinley County, New Mexico: U.S. Geol. Survey unpublished map.
7. Sears, J. D., 1934.*
8. Sears, J. D., 1934.*
9. Smith, C. T., 1954.*
10. Smith, C. T., and others, 1959.*
11. Thaden, R. E., and Ostling, E. J., Grants-2 NW New Mexico: U.S. Geol. Survey unpublished map.
12. Thaden, R. E., Santos, E. S., Armstrong, R. L., assisted by Miller, D. E., Grants-2 NE New Mexico: U.S. Geol. Survey Survey unpublished map.
13. Thaden, R. E., Santos, E. S., Ostling, E. J., and Armstrong, R. L., assisted by Miller, D. E., Grants-2 NW New Mexico: U.S. Geol. Survey unpublished map.
14. Thaden, R. E., Santos, E. S., and Ostling, E. J., assisted by Peikert, E. W., Grants-2 SE New Mexico: U.S. Geol. Survey unpublished map.

*See selected references.

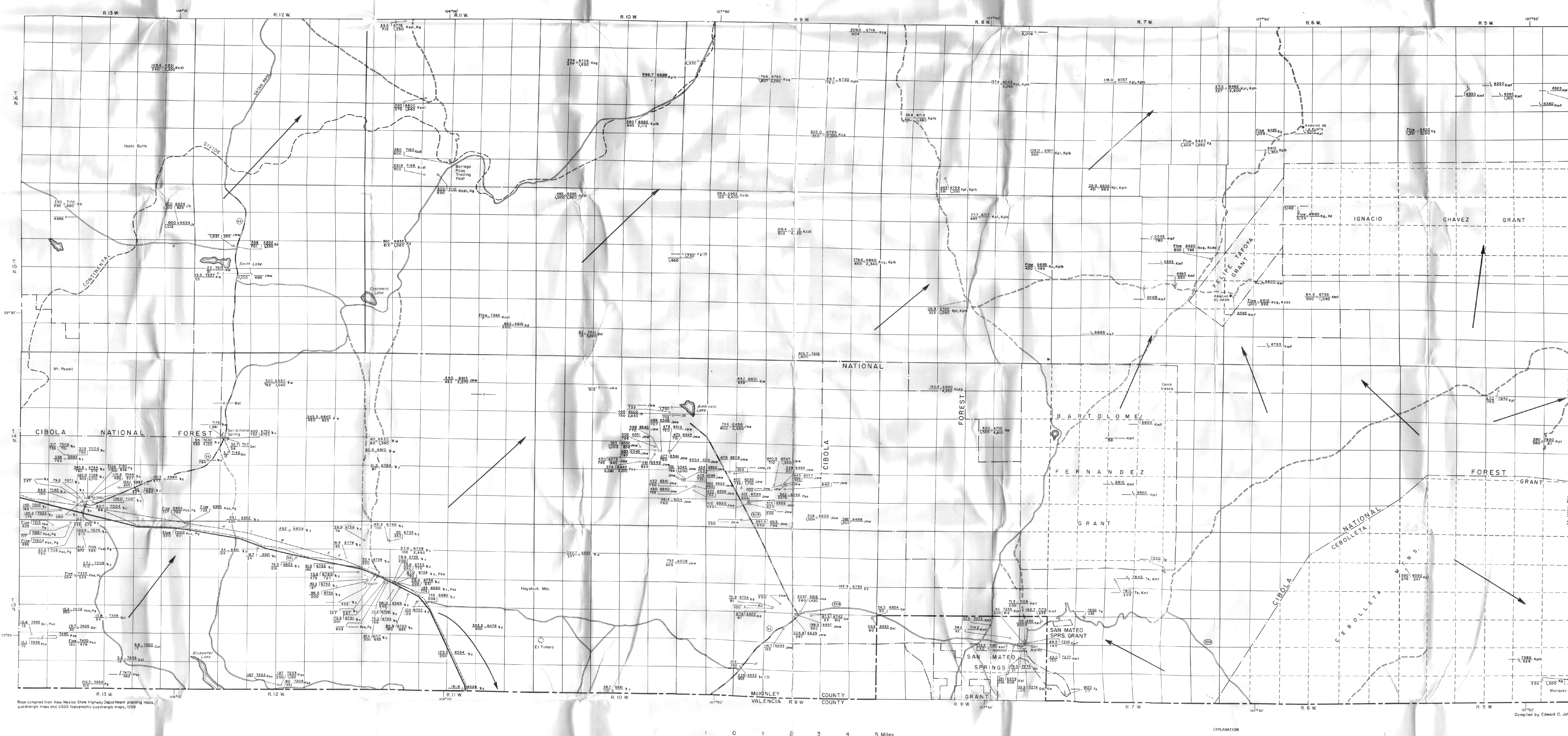


Plate 2.--Hydrologic map of southeastern McKinley County, N. Mex.
(showing locations of wells, direction of ground-water movement, and general chemical quality of water)

EXPLANATION

Well

Spring

Depth to water (feet)
Depth of well (feet)
Altitude of water level (feet)
Specific conductance (micromhos at 25°C)
$\frac{178}{250}$ o $\frac{7295}{1,120}$ Psa Principal water-bearing unit

Principal water-bearing units

Qal, alluvium; Te, basalt, andesite, and other extrusive rocks of Cebolleta Mountains; Kmf, Menefee Formation; Kpl, Point Lookout Sandstone; Kplh, Hosta Tongue of Point Lookout Sandstone; Kcg, Gibson Coal Member of Crevasse Canyon Formation; Kcda, Dalton Sandstone Member of Crevasse Canyon Formation; Kcdi, Dilco Coal Member of Crevasse Canyon Formation; Kg, Gallup Sandstone; Km, Mancos Shale; Kd, Dakota Sandstone; Jmw, Westwater Canyon Member of Morrison Formation; Jb, Bluff Sandstone; Jt, Todilto Limestone; ℞w, Wingate Sandstone; ℞c, Chinle Formation; Psa, San Andres Limestone; Pg, Glorieta Sandstone.

General direction of ground-water movement.

Majority of water levels measured in 1961 and 1962.

Water levels measured in Ambrosia Lake area in 1957.