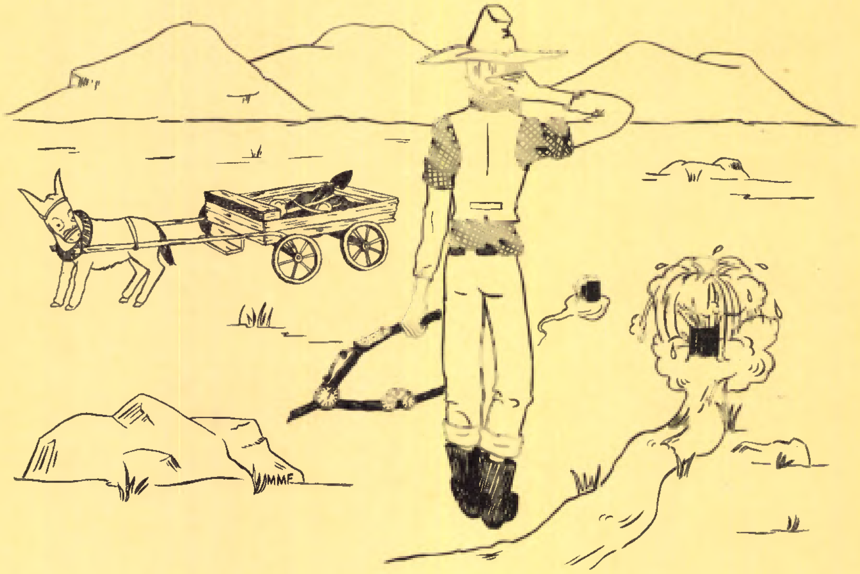
CIRCULAR 46

GUIDES FOR DEVELOPMENT OF IRRIGATION WELLS NEAR CLAYTON, UNION COUNTY, NEW MEXICO

By

Brewster Baldwin and F.X. Bushman



NEW MEXICO INSTITUTE OF MINING AND TECHNOLOGY

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STATE BUREAU OF MINES AND MINERAL RESOURCES

Alvin J. Thompson, Director

Socorro, June 1957

ERRATA

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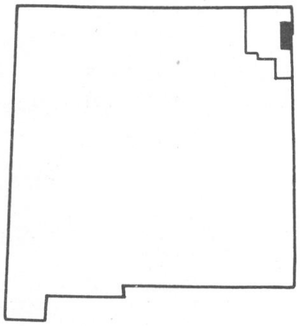


NEW MEXICO BUREAU OF MINES AND MINERAL RESOURCES

NEW MEXICO INSTITUTE OF MINING AND TECHNOLOGY
SOCORRO, NEW MEXICO

THE REGENTS

CONTENTS

ILLUSTRATIONS

TABLES

FIGURES

ABSTRACT

This preliminary report on part of Union County, in northeastern New Mexico, summarizes ground-water conditions in Clayton and Seneca 15-minute quadrangles. The text, written for residents of Union County, emphasizes the way well data can be used. Technical data are presented in figures and tables.

Geologic formations include basalt flows and the "Ogallala formation, " of late Cenozoic age; Graneros shale and Dakota group (Dakota and Purgatoire formations) sandstone and shale, of Cretaceous age; Morrison formation, "Wanakah formation," and Exeter (Entrada) sandstone, of Jurassic age; and Dockum group, of Triassic age.

Simplified geologic maps for the two quadrangles, scale of 2 in. per mile, show surface extent of basalt, Ogallala, and "bedrock"; bedrock includes Graneros shale and Dakota group. Fifty-foot contours on eroded bedrock surface beneath Ogallala formation, constructed from 1,000 shothole logs and some outcrops, indicate local relief of 50-200 ft. Regional dip, according to 100-ft contours on base of Dakota formation, is 40-50 ft per mile to the east-southeast. Geologic maps show location and elevation of 100 bench marks.

Hydrologic maps of the two quadrangles show data for wells. According to contour lines with 50-ft interval, the water table slopes eastward about 35 ft per mile. The maps also show areas where water will not be encountered in the Ogallala formation.

Low-yield wells may be developed almost anywhere in the area in the Ogallala formation or Dakota group at depths less than 200 ft. High-yield wells may be developed: (1) in buried valleys filled by Ogallala, (2) in sandstones in the lower half of the Dakota group, and (3) possibly in local sandstones at top of Morrison formation.

Table 1 lists data for 410 domestic, stock, municipal (Clayton), industrial, and irrigation wells. Table 2 lists quality of water data for 36 wells. Water is hard to extremely hard, and for irrigation purposes it is excellent to good.

Assuming a recharge rate of one-half in. a year, 27,000 acre-ft is recharged in and west of the quadrangles in the ground-water tributary area of perhaps 1,000 square miles. Annual discharge by wells and springs west of the quadrangles is about 1,000 acre-ft. Within the quadrangles, the estimated annual discharge of springs and low-yield wells is 500 acre-ft, of municipal and industrial wells is 500 acre-ft, and of present irrigation developments is about 5,000 acre-ft. A calculation made to check these figures indicates 14,000 acre-ft of ground water flows east across the New Mexico line annually.

INTRODUCTION

Field study of the geology and ground-water resources of Union County was carried on intermittently between 1953 and 1956, and a technical report is in preparation. The present preliminary report, which is concerned with about one-eighth of the county, is written primarily for residents of the county; therefore, the text is modified from the usual technical treatment. However, much technical information is given in tables and on maps.

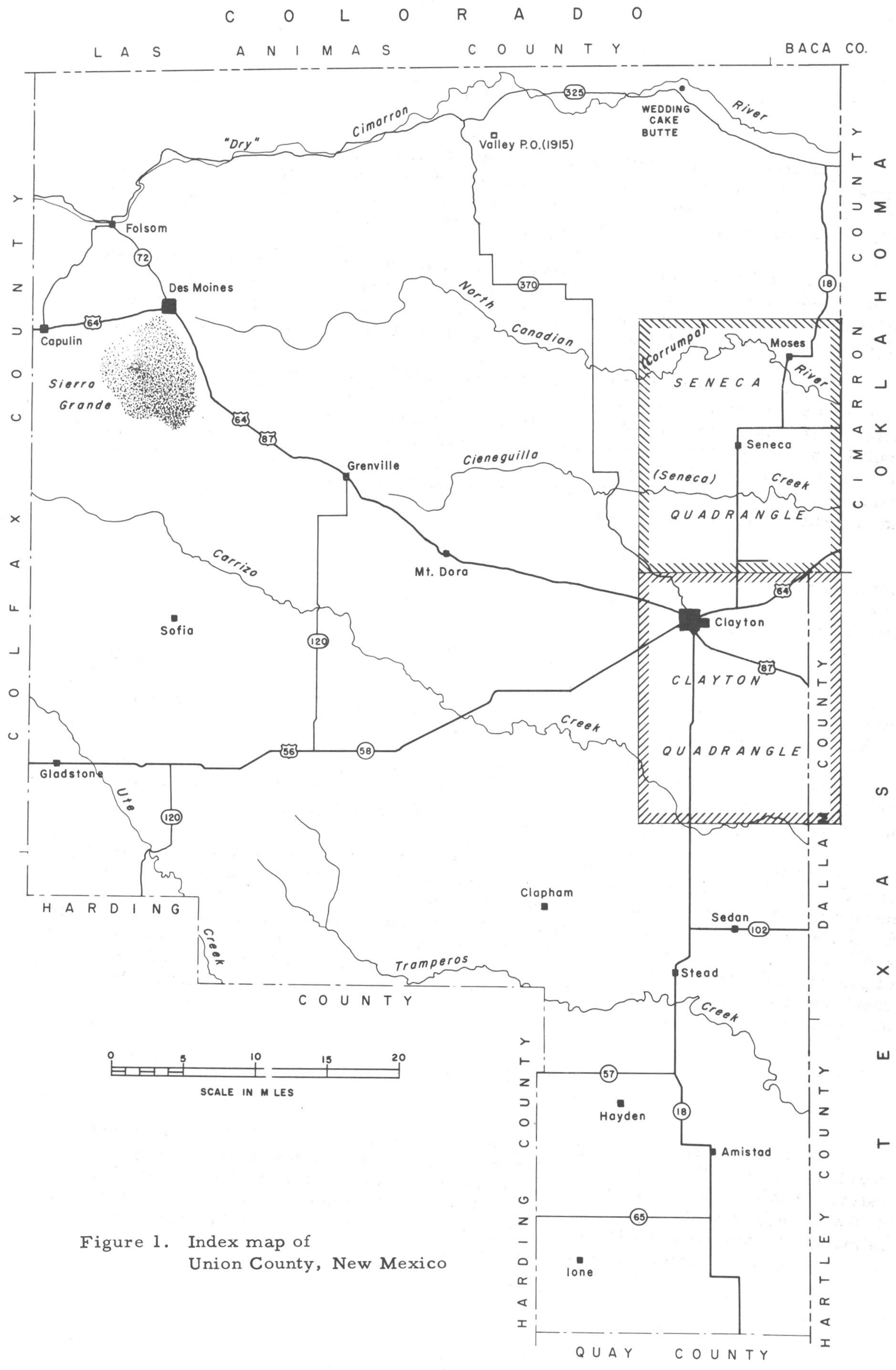


Figure 1. Index map of Union County, New Mexico

The area of this report was chosen to include most of the areas of recent seismic exploration by oil companies, because the drillers' logs of shotholes have supplied valuable information that is not available for the remainder of the county. Study of these logs made it possible to map an ancient land surface, with hills and valleys, that is now buried under 25-400 ft of younger sedimentary deposits. The buried valleys are sites recommended for irrigation tests.

The area of the report includes the municipal water supply of the town of Clayton, the largest town in the county, and in addition, includes some of the new irrigation wells in Union County. Although the report specifically treats only part of the county, description of geologic formations and of ground-water conditions generally apply to the remainder of the county.

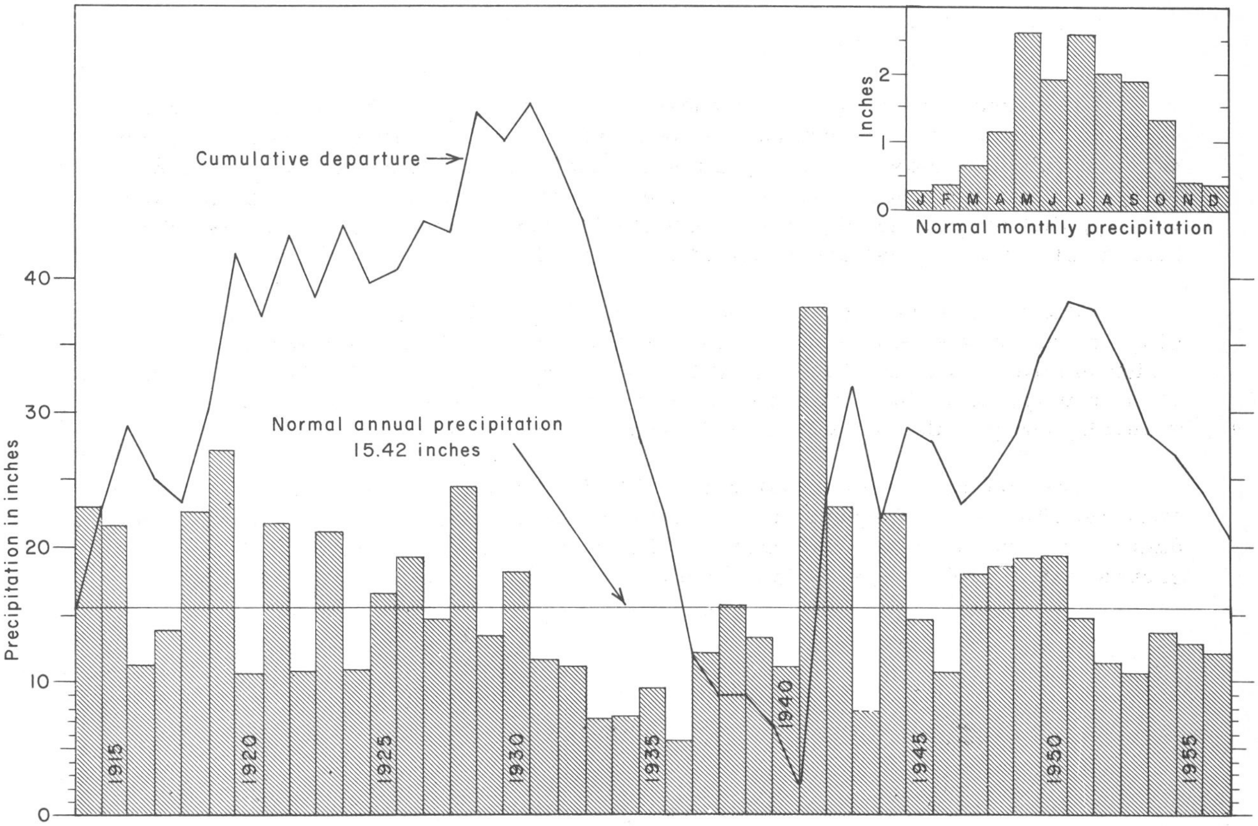
The amount of ground water available for irrigation is estimated from moderately reliable data. Throughout the report, emphasis is placed on the way new well data can be used to modify and improve the present understanding of geology and ground-water conditions in Union County.

Geography

This report describes the two 15-minute quadrangles designated Clayton quadrangle and Seneca quadrangle. These quadrangles, each 240 square miles in area, lie along the east edge of Union County in the northeast corner of New Mexico (fig. 1). The east part of Clayton quadrangle is in Texas and is not included in this study.

The town of Clayton, county seat of Union County, is in the northwest part of Clayton quadrangle. The population of Clayton in 1956 was reported as 3,951 by the New Mexico Economic Development Commission. Clayton serves an agricultural trade area that reaches into Colorado, Kansas, Oklahoma, and Texas. The economy of the area is based on cattle growing, dry farming, irrigation farming, and tourist trade. Paved highways extend from Clayton in six directions, and the Colorado & Southern Railway Company parallels U. S. Highway 87 through the area.

East-central Union County is rolling country typical of the High Plains, with flat uplands cut by valleys 100-200 ft deep. The Rabbit Ear Buttes northwest of Clayton are volcanoes; the larger butte rises to 6,062 ft, about 1,000 ft above the uplands. Clayton is on the divide between the Canadian River and North Canadian River drainages. Carrizo Creek, Sand Arroyo, Perico Creek, Rabbit Ear Creek (Apache Canyon), Cieneguilla Creek (Seneca Creek), and North Canadian River (Corrumpa Creek) drain southeast or east across the area. These creeks have water holes and some permanent flow, chiefly west of N. Mex. Highway 18. Surface water in these creeks runs out of the county and state only after heavy rains. The climate is semiarid, and average annual precipitation is 15 inches (fig. 2).



The bar graph shows total precipitation for each year from 1914 through 1956. The normal annual precipitation, based on the period 1921-1950, is 15.42 inches; this is essentially the same as the average of 15.52 inches for the period 1914-1956. Distribution of normal monthly precipitation is indicated by the bar graph in the upper right corner; precipitation in the half year from May through October accounts for three-fourths of normal annual precipitation.

Climatic fluctuations are indicated by the line of cumulative departure from normal annual precipitation. The general rise of the line from the beginning of 1914 through 1930 indicates above-normal precipitation that aggregates 37 inches. The below-normal precipitation from 1931 through 1940 causes the line to fall an aggregate of 50 inches from the 1930 point. In 1941 the 37.65 inches of precipitation causes the line to rise abruptly 22 inches. From 1942 through 1946 the annual departures above and below the normal of 15.42 inches average out. The moderately wet years from 1947 through 1950 cause a rise of some 15 inches, but the below-normal precipitation from 1951 through 1956 cancels out this gain.

In the 43 years of record, two types of precipitation patterns are suggested: alternation of above-normal and below-normal years, and a sequence of below-normal years. The variation from the normal annual precipitation is more significant than the few years of normal precipitation.

Figure 2. Precipitation data for Clayton, New Mexico

Previous Work

For those interested in learning more about the geology and ground water in this region, several technical reports are available. A report by Parker (1933) subdivided the Triassic sedimentary rocks of the "Dry" Cimarron River Valley into three parts. References in a report on the geology and ground-water resources of Cimarron County, Oklahoma (Schoff and Stovall, 1943), include essentially all of the earlier reports regarding the geology of the Dry Cimarron Valley. Griggs (1948) reported on the geology and ground-water resources of eastern Colfax County. A recent summary of the geologic formations of the region is included with the map of eastern Colfax County by Wood, Northrop, and Griggs (1953). A recent report (McLaughlin, 1954) on the geology and ground-water resources of Baca County, Colorado, just northeast of Union County, describes geologic and hydrologic conditions similar to those in Union County. Notes on the geology of the Dry Cimarron Valley in Union County were prepared by Baldwin (Oklahoma City Geological Society, 1956, p. 12-13, 23-31), and Foster (1956) reported on the subsurface stratigraphy. Geophysical study of a buried valley south of Clayton is included in a report on induced polarization (Vacquier, 1957).

Present Work

Photomosaics prepared by the Soil Conservation Service at a scale of one-half mile per inch were used as base maps in the field study of Union County. In the course of geologic mapping, Baldwin located many of the 3,000 operating or abandoned water wells in the county. Bushman scheduled wells as to total depth, depth to water, yield, quality, and formations encountered in drilling. For most wells the recorded data are those reported by the owner, but for many wells depths and water levels were measured. Altimeter traverses from bench marks to wells and to geologic contacts were run with an error generally of less than 10 ft.

The U. S. Coast and Geodetic Survey has established an excellent net of level lines in Union County requiring 800 bench marks. Most of the level lines were established in 1955 at the request of the State Bureau of Mines. Bench marks, which are brass caps usually set in concrete posts, are points of precisely determined elevations. They do not indicate the position of section or township lines, but many bench marks are set near section corners so that they may be found easily. Locations and elevations of bench marks in Clayton and Seneca quadrangles are given on the geologic maps (fig. 6, 8). Bench marks in Clayton are shown in Figure 3. Locations and elevations of bench marks in all of Union County are shown on manuscript maps available in ozalid reproduction from the State Bureau of Mines and Mineral Resources, Socorro, New Mexico.

Continental Oil Company and Skelly Oil Company initiated seismic exploration programs in east-central Union County in 1954 and 1955, while the Bureau's field study of Union County was in progress. A total of four weeks time, distributed over many months, was spent with the drillers in catching samples and exhibiting interest in good logs. The drillers generously responded with much better logs than were required for seismic exploration purposes by recording the color of clay and shale intervals. For many holes they also recorded the base of the Ogallala formation or the top of the Morrison formation. The companies later released to the State Bureau of Mines the drillers' logs, locations, and elevations for more than 1,000 shotholes.

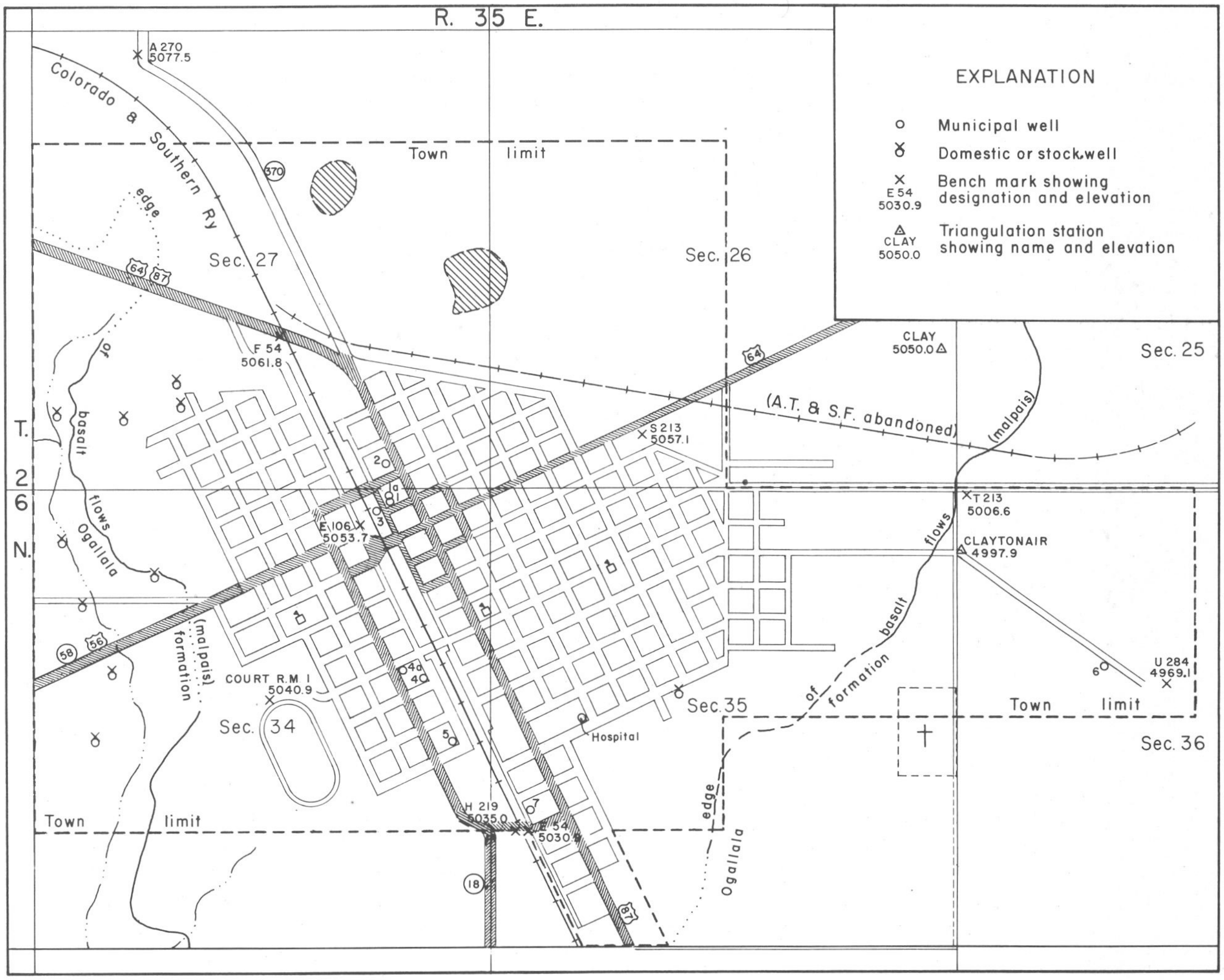


Figure 3. Wells and bench marks in town of Clayton, New Mexico

Acknowledgments

Eugene Callaghan, Director of the State Bureau of Mines and Mineral Resource; until February, 1957, initiated the Union County study, and gave his whole-hearted support to the thorough basic treatment. Appreciation is expressed for this support of the project.

Sincere thanks are extended to Continental Oil Company and Skelly Oil Company for release of data, and to the seismic exploration field parties for their generous cooperation. The U. S. Coast and Geodetic Survey made a major contribution to ground-water study in Union County by complying fully with request for level lines.

Many residents of Union County have supplied useful information and have taken a personal interest in the study. Among these are Manson Edmondson, City Manager of Clayton; members of the Soil Conservation Service staff in Clayton, and well drillers. It is the sincere wish of the writers that this report will contribute to the economy of Union County.

Well-Numbering System

To save space in the tables and text, an abbreviated numbering system is used for wells and other localities. The Stead irrigation well in Apache Canyon, for example, is 26. 35.16. 431b. The more familiar, but longer, designation of this well's location is the NW¼ SW¼ SE¼ sec. 16, T.26 N., R. 35 E. The location number consists of four sets of numbers:

Township		*Range*		*Section*		*Location within section*			
26	.	35	.	16	.	4	3	1	b
						160-	*40-*	*10-acre tract*	*(letter is used where there is more than one well in the same 10-acre tract)*

Numbers for location within a section are shown at the right. The NW $\frac{1}{4}$ is abbreviated as 1, the SW$\frac{1}{4}$ as 3, and so on. Some wells, like 25. 35. 15. 140, are located only to the 40-acre tract; the 10-acre tract number is therefore given as 0.

1	2
3	4

The designation of a well location is not to be considered the absolute location, because section lines have been drawn according to fence lines and roads on photomosaics, rather than from field surveying of recovered section corners.

GEOLOGIC FORMATIONS

In the Clayton area, the sedimentary rocks between the Precambrian "basement complex" and the present land surface are more than a mile in thickness, but only those formations to a depth of 800 ft are of interest for ground-water development. Figure 4 shows a typical section of these formations as they occur beneath Clayton. The figure is based on logs of municipal water wells, and on the character of these formations where they are exposed elsewhere in the county. The geologic maps (fig. 6, 8) show where these formations are exposed at the surface in Clayton and Seneca quadrangles. Two map units of late Cenozoic age cover most of the area: flows of basaltic lava, or "malpais" as they are known locally; and the tan sandy clay, silt, sand, and gravel of the Ogallala formation. A third map unit, which consists of dark-gray Graneros shale and brown to yellow sandstone and dark-gray shale of the Dakota group, of late Mesozoic age, is the "bedrock" on which the Ogallala formation was deposited in the vicinity of Clayton. Beneath the Dakota group is a sequence of older Mesozoic rocks which are not exposed in this area, but which are well exposed along the Dry Cimarron River.

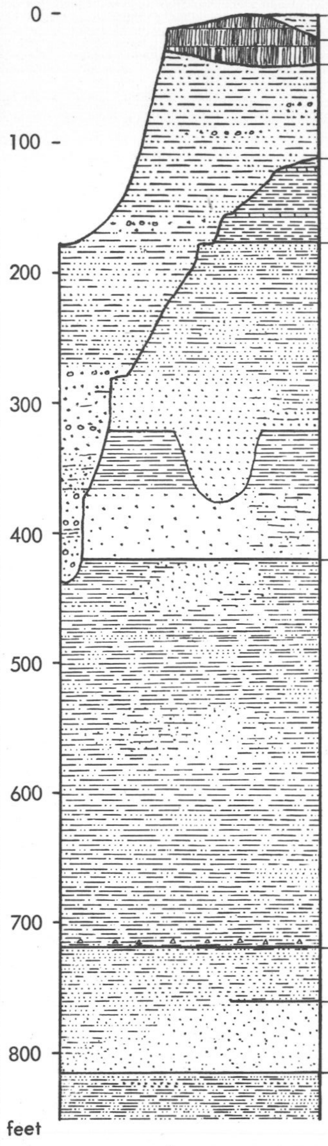
As this report is concerned with the location and drilling of irrigation wells, the geologic formations will be discussed in order, from the top down, from the youngest down to older formations. In the Clayton area, the malpais rests on the Ogallala formation. The Ogallala formation overlies either the Graneros shale or the Dakota formation in most of Clayton and Seneca quadrangles. Where the geologic maps show bedrock at the surface, the Ogallala formation has been eroded away and will not be found in wells. Also, once a well has been drilled into dark-gray ("blue") shale or brownish sandstone it is beneath the Ogallala.

Formations of Late Cenozoic Age

"Malpais" - - - Basalt Flows

Flows of basaltic lava or "malpais" cover much of the area of this report. Malpais south of Apache Canyon came from volcanic centers near Mt. Dora or even farther west. The lava, only 10-50 ft thick, followed the eastward courses of stream valleys which existed at that time. Several flows from distant volcanoes also underlie Rabbit Ear Mesa north of Clayton, but they are now largely buried beneath as much as 300 ft of somewhat younger lava and cinders that were erupted from the volcanoes of Rabbit Ear Buttes. Lava from these volcanoes are not distinguished on the geologic maps (fig. 6, 8) from the lava that was erupted from distant centers, but the latter flows can be seen and traced along the north rim of Apache Canyon and along the south side of Seneca Creek.

Much of the malpais is now covered by up to 20 ft of soil and caliche and by tan sandy clay similar to the Ogallala formation. About 12 miles south of Clayton and 3 miles east of N. Mex. Highway 18, drillers reported lava buried under about 40 ft of Ogallala-like material. In Clayton and Seneca quadrangles, malpais lies on the Ogallala formation. Flows, and cinders between flows, may yield some water to wells, but malpais is costly to drill, and where possible, a well should be located beyond the edge of a flow.



AGE		GEOLOGIC FORMATION		COLOR OF SHALES	THICKNFSS (feet)	DESCRIPTION	HIGH-YIELD WELLS
CENOZOIC	TERTIARY and QUATERNARY	Surface			0-20	Soil, sandy clay, caliche.	
		"Malpais"			10-50	Basaltic lava flows.	
		Ogallala formation		tan	20-400	Tan sandy clay, silt, sand, and gravel; caliche common near top; rests on ancient topography, therefore thicker where it fills ancient valleys.	Gravel and sand in buried valleys.
MESOZOIC	CRETACEOUS	Graneros shale		dark-gray	0-80	Dark-gray shale; limestone beds form hard "streaks" 20 ft and 50 ft above base.	
		DAKOTA GROUP	Dakota formation		150 ± 30	Upper member includes dark-brown to yellow sandstone, brown to gray shaly sandstone, and gray sandy to silty shale, all of local extent. Lower member is the basal massive sandstone, yellow to brown; locally grades into gray shaly sandstone.	Lower sandstone member, particularly where it cuts into Purgatoire sandstone.
			Purgatoire formation		40-100	Upper member is dark-gray shale with minor sandstone, locally cut out by channel of Dakota sandstone. Lower member is light-colored to white sandstone, locally absent.	Sandstone member, particularly where basal sandstone of Dakota, and possibly upper sandstone of Morrison, can be developed also.
	JURASSIC	Morrison formation		green and red	300 ± 50	Greenish-gray, green, and red-brown sandy clay, with local beds of white to brown sandstone, siltstone, minor limestone; nodules of red-orange "agate" (chalcedony) near base.	Local sandstone at top may yield water.
		"Wanakah formation"		brown	25-70	Light-brown silt with beds of yellow sandstone and red-brown mudstone.	
		Exeter (Entrada) sandstone			10-80	Light-colored fine-grained sandstone; grades into "Wanakah formation."	
	TRIASSIC	Dockum group		red	300 +	Red-brown mudstone with beds of light-colored sandstone, silt-pebble conglomerates, maroon and green mudstone.	

SYMBOLS

▩	malpais
⁘	gravel
⁚	sand, sandstone
▤	sandy clay or shale
☰	clay or shale
▭	limestone
▵	"agate"

Figure 4. Summary of geologic formations near Clayton, New Mexico

Ogallala Formation and Buried Valleys

The Ogallala formation is exposed over a large part of Clayton and Seneca quadrangles, and it also occurs directly beneath the extensive lava flows. The Ogallala consists of tan-to-pink sandy clay, silt, sand, and gravel. Layers of caliche are common at or near the surface. The areas of Ogallala shown on the maps include alluvial deposits of modern streams, because the availability of ground water in alluvium is similar to that in Ogallala. Essentially, all gravel penetrated in wells in the Clayton area is either in Ogallala or in alluvium, and pebbles are uncommon in the Mesozoic formations. In some parts of the area, the Ogallala is as much as 400 ft thick and where the maps show bedrock at the surface, the Ogallala has been removed by streams.

The Ogallala conceals hills and valleys of the bedrock surface, much as patching plaster conceals holes and cracks. One of the principal contributions of this report is to reconstruct the buried topography which is shown by contour lines in Figures 6 and 8. The buried valley that drains southeastward 8 miles south and 2 miles east of Clayton is 2 miles wide and 200 ft deep. This is similar in size to Apache Canyon.

The buried hills and valleys were carved during much of the Cenozoic era, when the Great Plains area was being eroded by streams which headed in mountains far to the west. These streams removed a thousand or more feet of sediments, and in the Clayton area, cut down to the Graneros shale with some of the valleys cut through the Dakota group into the Morrison formation. In the south panhandle of Union County, the Morrison formation, "Wanakah formation," Exeter sandstone, and Triassic red beds were exposed by stream erosion. The topography of this older surface must have been similar to the flat-to-rolling country in Union County today.

Some 10 or 20 million years ago, in late Cenozoic time, there was renewed uplift of the mountains, and streams became more vigorous. They removed material from the mountains and spread this debris as clay, silt, sand, and gravel over the bedrock topography of the plains. In this report, the Ogallala formation includes all of these late Cenozoic sedimentary deposits east of the mountains. This apron of sediments continued to accumulate until a few million years ago, when volcanoes began to erupt in Union County.

From then to the present, streams have been cutting down into and through the apron of the Ogallala formation, and volcanoes have intermittently been erupting, with lava flowing eastward along valleys. About 80 volcanic centers have been mapped in Union County, and most of these occur in sets of three or more on lines a few miles long. The most recent activity was in the northwest part of the county, where the Capulin Mountain, Baby Capulin, Twin Mountain, and Purvine Hills volcanoes erupted between 4,500 and 10,000 years ago, at or soon after the time of Folsom man (Muehlberger, 1955).

The Ogallala formation probably will yield large amounts of water from the buried valleys. The formation was deposited by streams that shifted course constantly, and so the sand and gravel of the stream channels are complexly interwoven with the more widespread silt and sandy clay of the floodplains. The individual stream-channel deposits cannot be traced by well logs, but sediments that filled valleys in the bedrock surface, in most cases, contain more stream channel deposits than do sediments that finally covered bedrock hills. These stream-channel deposits in the valleys act as a collecting gallery for ground water from adjacent less-permeable Ogallala or bedrock materials. Therefore, the location of buried valleys is an important clue for the location of irrigation wells.

Formations of Mesozoic Age - - - "Bedrock"

Although the Ogallala rests on different formations in different places, the sequence of Mesozoic formations is constant. These formations, in order from top down, are the Graneros shale, Dakota group of sandstone and shale, Morrison formation, "Wanakah formation," Exeter sandstone, and Dockum group (red beds). Light- to dark-gray shale is found in the Graneros shale and Dakota group, but not below, and greenish-gray or red mudstone is found in the Morrison and below, but not above. Two sandstone intervals in the Dakota group are important for irrigation wells, and to test them properly a well should be drilled into the green and red mudstones of the Morrison. Figure 4 shows the geologic ages, thicknesses, and other information regarding these Mesozoic formations.

Graneros Shale of Cretaceous Age

The Graneros shale is dark-gray somewhat silty shale about 150 ft thick. However, before the Ogallala was deposited, ancient streams had removed most of the Graneros from Union County. In most parts of the Clayton area, less than 60 ft of Graneros is preserved beneath the Ogallala formation. The Graneros is too soft to form good exposures, but several thin limestone beds, about 3 ft thick, form faint benches marked by slabs of platy limestone. About 50 ft above the highest sandstone of the Dakota group is a limestone characterized by a very fine-grained texture and by very thin bedding. A bench underlain by this limestone can be seen 100 yds west of Mountain Road (N. Mex. Highway 370), on the south side of Apache Canyon (26.35.21. 210), and also on a low hill along the trail two miles farther west (26.35.18.322). Another limestone bed, about 20 ft above the highest sandstone of the underlying Dakota group, is a brownish-gray, finely granular rock with tiny needles of calcium carbonate. This limestone, which was recognized in the town of Clayton wells no. 6 and 7, crops out at the top of a cut-bank northwest of Clayton (26.35.18.243). Fossil oyster shells in the limestone beds indicate that the Graneros was deposited in a shallow sea.

In the course of drilling, these limestone beds are commonly mistaken for sandstone, and without good samples of the so-called "hard streaks" it is difficult to determine the contact between the Graneros shale and the Dakota group. Sandstones in the Dakota group do not ordinarily react to acid, but a drop of dilute muriatic acid (one part acid to 5 parts tap water) on a chip of limestone will release bubbles of carbon dioxide. This test with acid is a valuable aid in distinguishing the Graneros shale from the Dakota group, because limestones are not found in the Dakota group nor are sandstones found in the Graneros shale.

Where the Ogallala rests on the Graneros, the upper ten or more feet of the Graneros is commonly altered to a yellow-gray color. Although this clay may somewhat resemble the tan sandy clay of the Ogallala, it is only slightly gritty, even between the teeth. Moreover, in drill cuttings the Graneros occurs as flat chips, whereas the Ogallala cuttings are irregular. A good log that records an interval of "yellow clay" will also indicate whether this is Ogallala or Graneros.

Although the Graneros shale does not ordinarily yield water, even for stock wells, it does serve in places to confine water in the Dakota group. Thus, in a well drilled through the Graneros into a water-bearing sandstone of the Dakota group, artesian pressure may cause water to rise above the sandstone.

Dakota Group of Cretaceous Age

In the Clayton area and in most of Union County, the Dakota group consists of about 250 ft of interbedded sandstone, shaly sandstone, and light- to dark-gray shale with some thin beds of coal. The columnar section in Figure 4 attempts to indicate the extreme variability between sandstone and shale in the Dakota group. For instance, it is possible to drill through the Dakota group and find very little sandstone, and yet to drill a second hole within a quarter of a mile and find very little shale. Also, a particular sandstone may be uncemented and quite permeable in one hole, and yet in a nearby hole the same sandstone may be so well cemented that there are only a few open spaces between the grains. These variations in the rock cannot be predicted. However, two sandstones are fairly persistent and in places are important sources of water for irrigation wells. Not much is known about these sandstones in the Clayton area, because most wells have not gone through the entire Dakota group, and only a few logs are on file. It is recommended that a hole drilled to test sandstones in the Dakota group be drilled 10 ft into the green or red mudstones of the Morrison formation, and that a careful log be prepared, emphasizing the color of shale and clay beds.

In this report, the Dakota group is divided into the Dakota formation and the Purgatoire formation (fig. 4). The term "Dakota" should not be used alone, because "Dakota" can refer to the Dakota group (the entire interval between the Graneros shale and the Morrison formation), to the Dakota formation (the upper part of the Dakota group), or to the Dakota sandstone (the lower member of the Dakota formation, according to usage by drillers in the Clayton area).

Dakota Formation. The Dakota formation is about 150 ft thick in the Clayton area. The upper member is generally the more variable, consisting of interbedded dark-brown to gray shaly sandstone, light- to dark-gray shale, and locally some thick yellow sandstones. The lower member is a fairly persistent massive light-colored sandstone which averages about 30 ft in thickness. This sandstone forms the cliffs of the mesas along the Dry Cimarron Valley. In places, the massive sandstone grades laterally into thin-bedded and shaly sandstone. The lower member may locally fill channels cut down into the Purgatoire sandstone, as suggested in Figure 4, but this condition is an interpretation which may apply in only a few areas.

Purgatoire Formation. The Purgatoire formation, 40-100 ft thick, generally consists of dark-gray shale in the upper half and light-colored sandstone in the lower half. In some parts of Union County, such as the area just west of Stead, the Purgatoire appears to be absent. In other areas, the sandstone member is absent and the

Purgatoire is represented by dark-gray somewhat sandy shale. In turn, the shale member may be cut out locally by channel sandstones of the overlying Dakota formation. Since 1947, wells in Baca County, Colorado (McLaughlin, 1954), have been producing as much as 1000 gpm from the sandstone member of the Purgatoire formation, with the overlying shale member confining water under artesian pressure. In the Clayton area, some of the high-yield wells may obtain water from the sandstone member of the Purgatoire formation, although as noted below, this sandstone may actually be in the Morrison formation.

Morrison Formation of Jurassic Age

The Morrison formation in the Clayton area consists of about 300 ft of green, light-greenish-gray, red-brown, and maroon sandy clay, with local lenses of white sandstone and minor thin limestone. The Morrison formation appears to be more than 500 ft thick in the Herndon Mock No. 1 oil test (27.36.25.111). The characteristic color of the Morrison is the faint green of raw cement. About 10 ft above the base of the Morrison formation there is a persistent layer of reddish-orange to light-bluish-gray "agate" nodules. This useful marker indicates that the Exeter sandstone is less than 80 ft below.

In the town of Clayton well No. 6, the sandstone below 310 ft underlies sandy clay and therefore is Morrison. This sandstone is evidently the main aquifer in this well. In general, however, the Morrison does not supply enough water even for stock wells.

"Wanakah Formation" of Jurassic Age

A sequence of 25-70 ft of thin-bedded light-brown siltstone with some interbedded light-colored sandstone and red-brown mudstone occurs at the base of the Morrison formation. This sequence is treated as part of the Morrison in some reports (Schoff and Stovall, 1943; McLaughlin, 1954), but in eastern Colfax County (Wood, Northrop, and Griggs, 1953) the unit is tentatively classified as the upper part of the Wanakah formation. Cooley (1955) showed that the brown silts intertongue with the underlying Exeter sandstone.

Exeter (Entrada) Sandstone of Jurassic Age

The Exeter sandstone was named by Lee (1902) for exposures "near Exeter post office"; this is evidently the old Valley post office which, before 1915, was located as shown in Figure 1 (31.33.8.243). The Exeter is 80 ft thick at its type section (Lee, 1902; Parker, 1933) near Wedding Cake Butte in the Dry Cimarron Valley, but it is generally much thinner and in parts of the county is absent. At the type section, the Exeter lies across tilted and eroded beds of the Dockum group. The Exeter is the Ocate sandstone of the Colfax County report (Wood, Northrop, and Griggs, 1953) and is correlated with the Entrada sandstone of the Colorado Plateau.

For most purposes the Exeter sandstone is too deep to warrant testing in the Clayton area, but in those parts of Union County where the Morrison is at the surface, it may be desirable to drill into the Exeter.

"Red Beds" - - - Dockum Group of Triassic Age

The Dockum group is more than 500 ft thick and includes red-brown silty mudstone, light-colored fine sandstone, silt-pebble conglomerate, and some green and red mudstone. In the Dry Cimarron Valley, Parker (1933) subdivided the Dockum into the Sheep Pen sandstone, the Sloan Canyon formation of green and red mudstone, and the underlying "red beds." A still lower unit, the "purple member," was recognized by R. W. Foster (1956), of the State Bureau of Mines, from well samples and was later recognized in exposures north of the junction of N. Mex. Highway 370 and N. Mex. Highway 325. The red-bed sequence forms the bulk of the Dockum group and in general directly underlies the Exeter sandstone. In the Dry Cimarron Valley, several stock wells obtain low yields of moderate to poor quality water from the red beds.

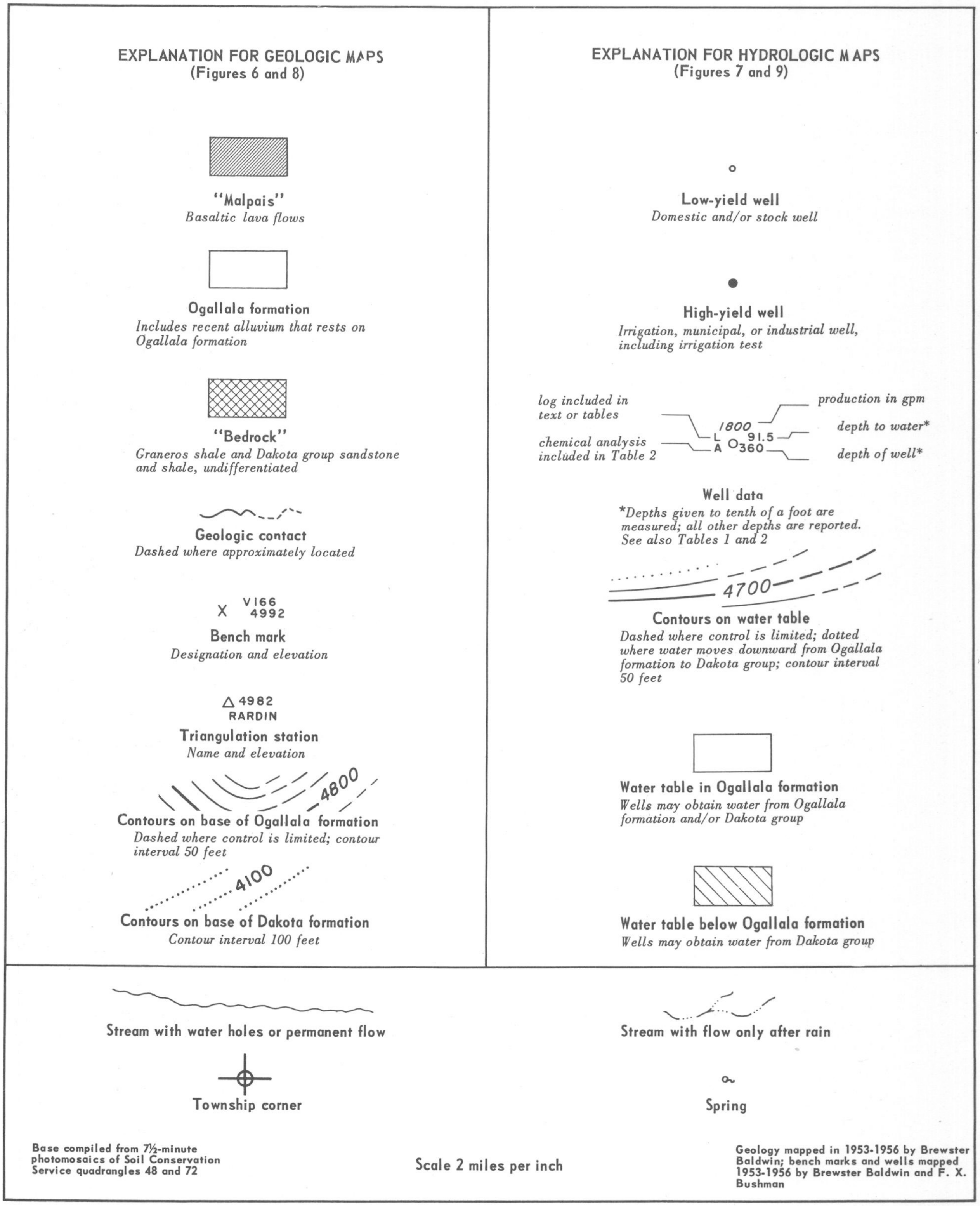


Figure 5. Explanation for maps (figs. 6, 7, 8, and 9)

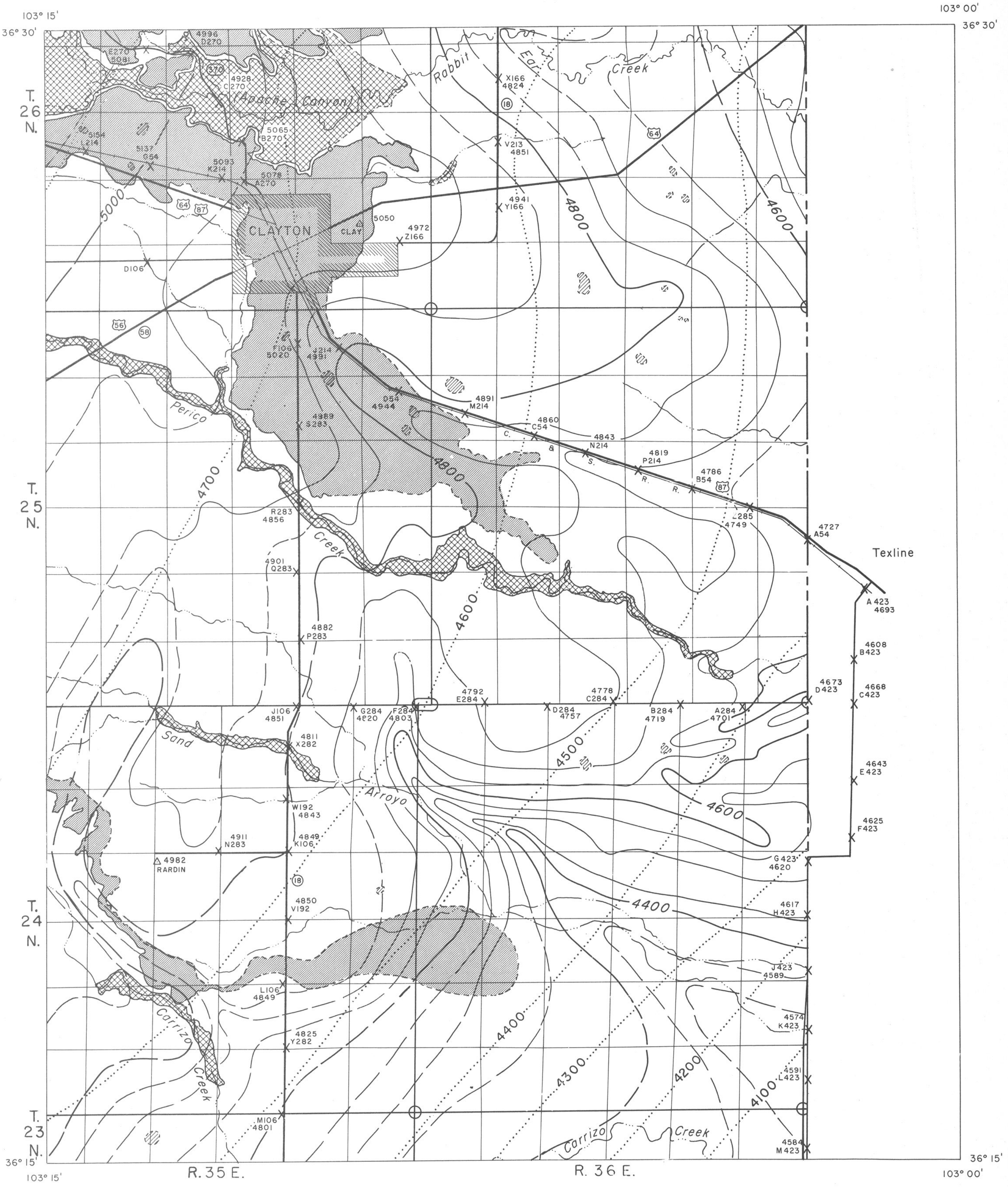


Figure 6. Geologic map of Clayton quadrangle

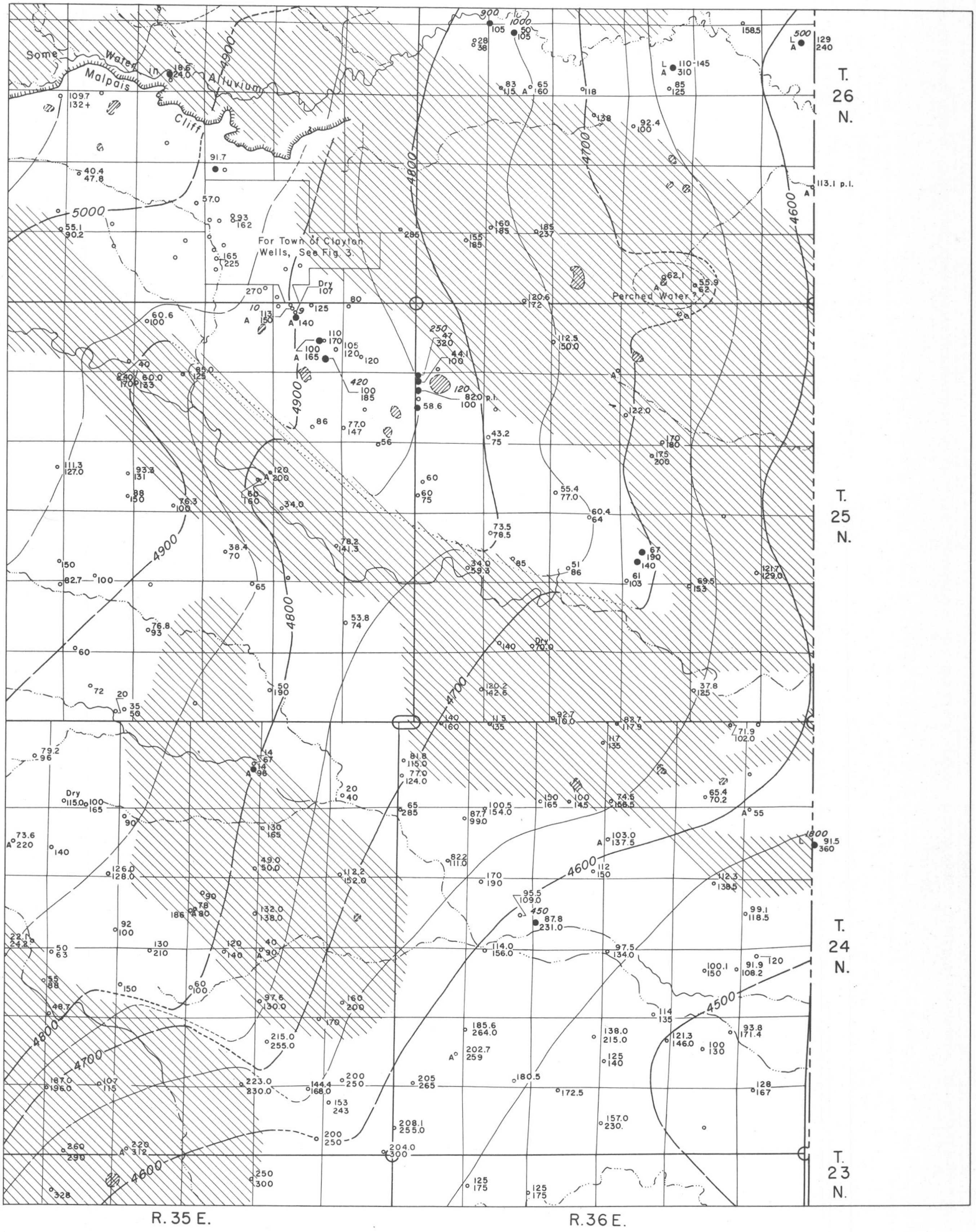


Figure 7. Hydrologic map of Clayton quadrangle

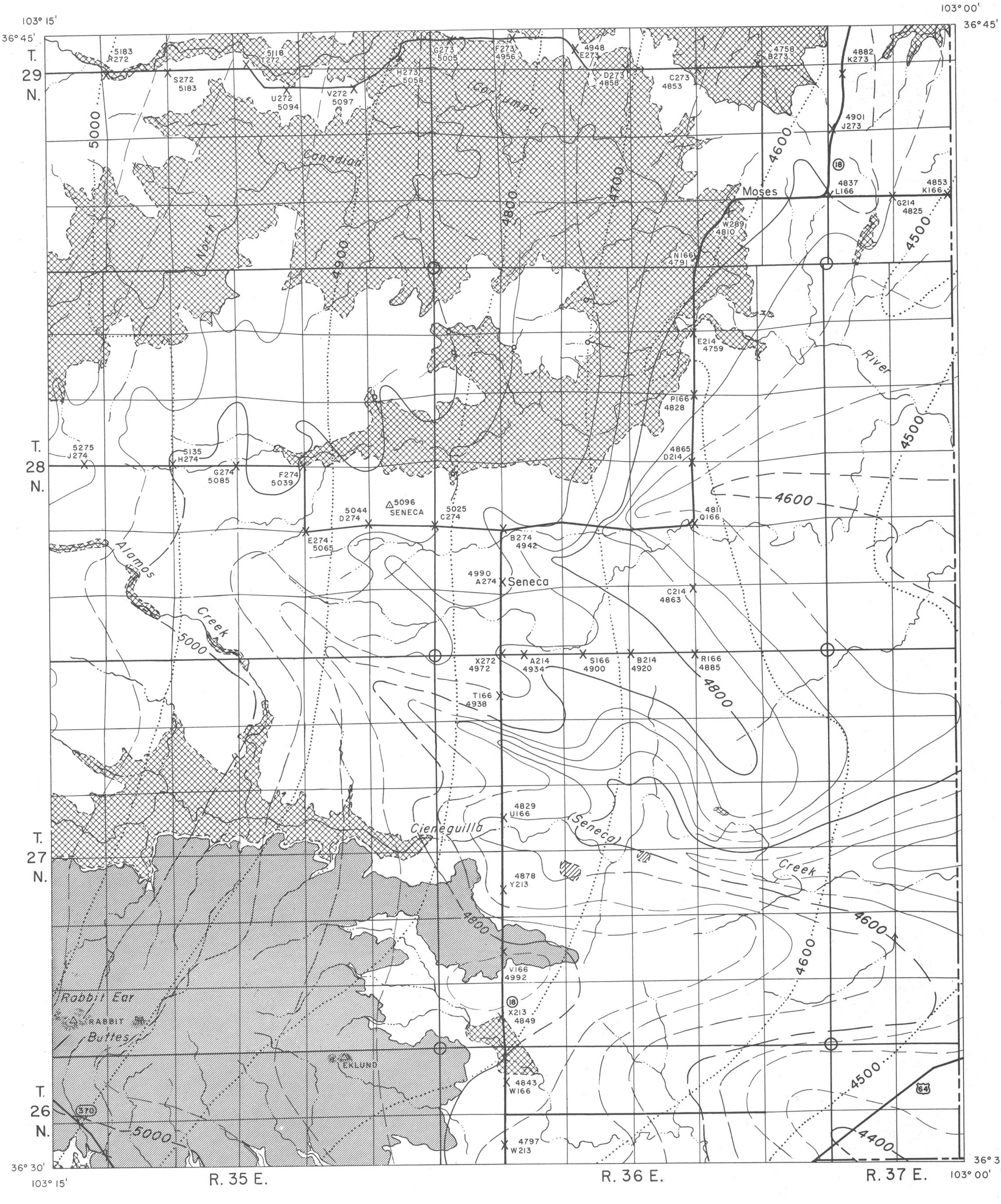


Figure 8. Geologic map of Seneca quadrangle

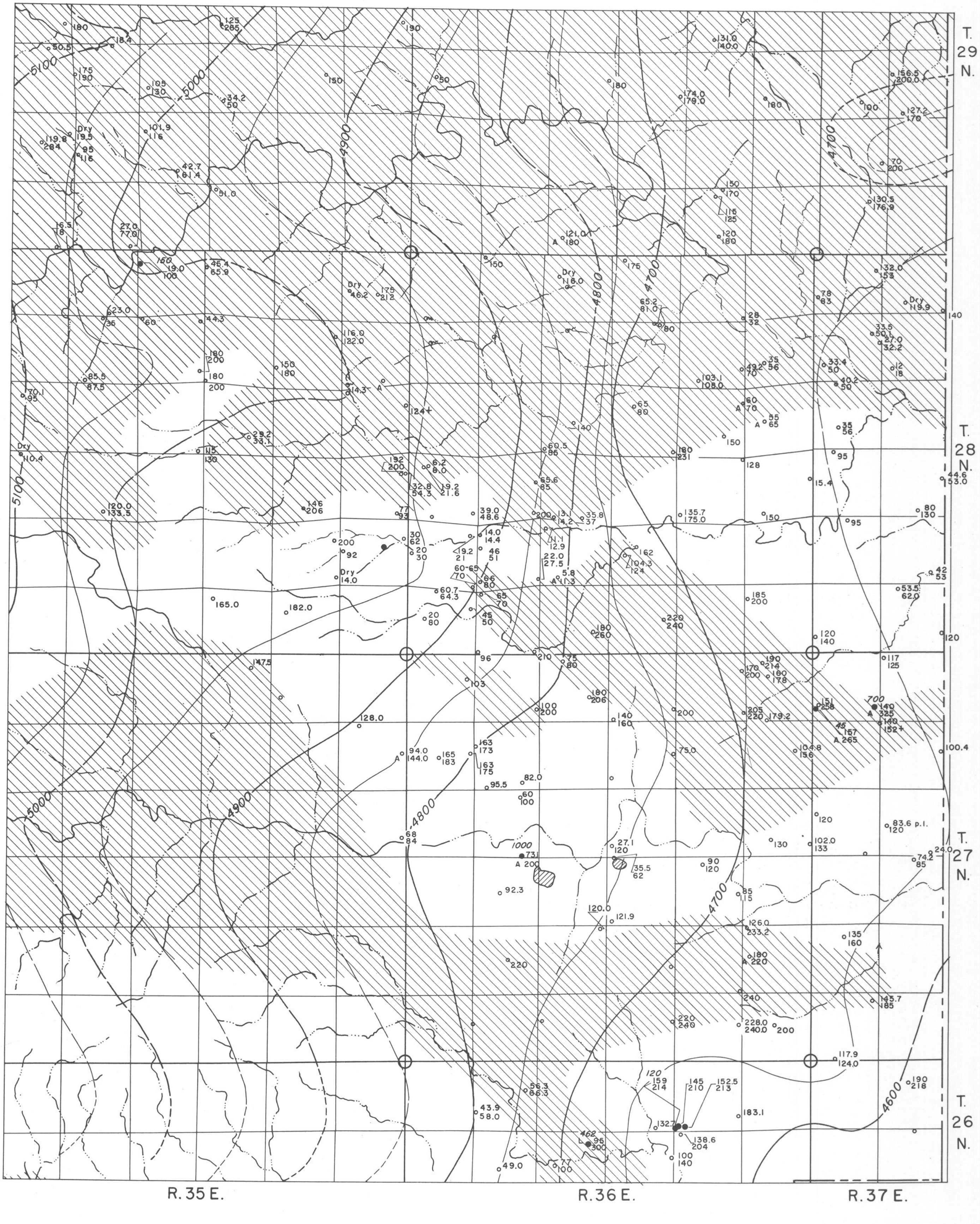


Figure 9. Hydrologic map of Seneca quadrangle

CONTOUR LINES

Three surfaces are shown by contour lines on the geologic and hydrologic maps. On the hydrologic maps, the water table is shown by solid, dashed, and dotted lines, with a contour interval of 50 ft. On the geologic maps, the base of the Ogallala formation is shown by solid and dashed lines with an interval of 50 ft, and the base of the Dakota formation is shown by dotted lines with an interval of 100 ft.

Each contour line connects points of equal altitude above sea level. Where lines are close together the contoured surface is steep, and where lines are far apart the surface is nearly level. Where contours bend in a U-shape, with the inner contours representing a lower elevation (for example, Ogallala contours in fig. 6, 24.35.1.400), the U outlines a valley. Where the inner contours represent a higher elevation (fig. 8, 27.36.1), the U outlines a ridge.

The water table was contoured by data from those wells in Table 1 for which surface elevations and measured depths of water are given; for each well, the depth to water is subtracted from the surface elevation to give the elevation of the water table at this point. Contours are drawn as smooth curves, according to the plotted points of elevation. For example, in well 28.36.23.333 the water table is at 4,681 ft above sea level, and in well 28.36.27.134 it is 4,726 ft. Therefore, the 4,700-ft contour is drawn between these wells. Contours are not adjusted to fit all those wells for which depths to water are only reported.

The base of the Ogallala formation is contoured largely from shothole data, supplemented by some points of elevation on wells with good logs, and on outcrops of the Ogallala-bedrock contact. The contours are drawn to show ancient topography, and so a single well that reached bedrock at a lower altitude than nearby wells is necessarily in a valley. The surface elevation of well 25.36.7.133 is 4,912 ft, and samples to 150 ft showed malpais and Ogallala. Therefore the base of the Ogallala here is below 4,762 ft. This is lower than in several nearby wells, and so the well must be in a buried valley. The valley is shown draining southeastward because shothole data within a few miles would not permit extending the valley in any other direction.

The base of the Dakota formation is contoured from shothole data in the north part of Seneca quadrangle, and from scattered well logs, shothole logs, and outcrops of the lower limestone of the Graneros. Only those holes or wells which were drilled into the Morrison could be used, and south of Seneca only a few holes went this deep. The contoured surface represents the regional warping of bedrock formations. Because so few control points are available, the contours are generalized.

The Ogallala rests on Purgatoire or Morrison in several places, according to comparison of the Ogallala and Dakota contours. One place is along the buried valley in the southeast part of Clayton quadrangle (fig. 6). Note that the 4,600-ft contours of both the Ogallala and Dakota cross in 24.35.1.200, the 4,500-ft contours cross in 24. 36. 8. 300 and the 4,400-ft contours cross in 24.36.15.330 and 24.36. 21.322. If 50-ft contours are sketched in for the Dakota, they will cross the corresponding contours of the Ogallala. By marking these points of intersection, it is possible to outline the area in which the Ogallala rests on the Purgatoire or Morrison. A similar situation exists in 26.36.1.400 (fig. 8), where the base of the Ogallala is about 50 ft below the base of the Dakota.

The water table is below the Ogallala formation in the shaded areas of Figures 7 and 9, according to comparison of Ogallala and water table contours. In 25.36.31.342 the 4,700-ft water-table contour crosses the 4,750-ft Ogallala contour, and so the water table is in bedrock 50 ft below the Ogallala. But in 24.35.1.444, where the 4, 700-ft water-table contour touches the tip of the 4,550 ft Ogallala contour, there is 150 ft of saturation in the Ogallala formation.

Thickness of saturation above the base of the Dakota group can be determined by comparing the water-table contours with the Dakota formation contours, adding about 50 ft for the underlying Purgatoire formation.

GROUND-WATER CONDITIONS

The description of ground-water conditions presented here will be concerned not so much with a technical approach to the concepts of ground-water hydrology, as with examples as they occur in Clayton and Seneca quadrangles. Many reference volumes are available to those who care to study any phase of ground water, or who desire merely to read a bit. Tolman (1937) brought out the first formal text on the comparatively new science of ground-water hydrology, and Bennison (1947) has written for the well driller and the well operator. Thomas (1951) gave "a survey of the present ground-water situation in the United States," which should be of special interest to readers in these semi-arid regions of the country.

Occurrence

The ground-water reservoir consists of the spaces between the grains and pebbles, and the cracks in the rocks, including large crevices or possibly small tunnels in some formations such as malpais. The upper surface of the zone of saturation, if it is open to atmospheric pressure, is known as the water table, and the formation is known as an aquifer if it will yield water to wells and springs. As ground water in an aquifer moves from the recharge area, an overlying impermeable bed, perhaps a shale bed, dipping at a slope greater than the water table, may cause the water to be confined under pressure. Under these conditions the water will rise in wells above the top of the aquifer, and the wells and aquifer are said to be "artesian." Although none of the wells in the Clayton-area flow at the surface, some of them are artesian wells.

The water table is the surface connecting water levels in wells in an unconfined aquifer; the piezometric surface is the imaginary plane connecting water levels in an artesian aquifer. In the area of this report, the two surfaces are nearly coincident and the "water-table" contours shown on the hydrologic maps (fig. 7, 9) indicate the altitude at which water will stand in wells in both unconfined and artesian aquifers.

Source and Recharge

The source of all ground water in the Ogallala formation and the Dakota group in the Clayton area was one of the forms of precipitation within the relatively recent past. Though most of the rainfall is either quickly evaporated or used by vegetation, some small part will percolate below the limits of evaporation and the root zone and may eventually reach the water table. Theis (1937) concluded that the average annual recharge to the ground water was less than one-half inch in the Southern High Plains of southeastern New Mexico. Theis' estimate was for an area in which conditions, including the average annual precipitation of 152 inches, are much like those in this part of Union County.

Ground water that moves eastward into these quadrangles was precipitation within Union County. The Sierra Grande arch, a structural ridge that trends north-northeast through Des Moines, acts as a barrier to ground-water movement from the Rocky Mountains. Moreover, in parts of Union County streams have cut through the Ogallala formation and the Dakota group, intercepting most of the ground water in those places. In the section on Estimates, it is shown that recharge by underflow may be 14,000 acre-ft per year from the area bounded on the north by the North Canadian River and its southern tributaries, on the west by Sierra Grande, and on the south by Carrizo Creek.

Though some water moves directly downward in areas of flat sandy terrain, or in usually dry lakes, or along cracks in malpais, the principal source of present-day recharge to the ground-water reservoir is that portion of the flood flow of the streams that percolates through the sandy bottoms of the arroyos and washes, particularly east of N. Mex. Highway 18.

Artificial recharge along the main sandy arroyos could supplement the natural recharge to the ground-water reservoir. Natural recharge is about 3 percent of the average annual precipitation. Much water runs past the recharge area during flood flows because the stream channels cannot absorb it. Flood-retention dams, with little or no permanent ponding of water, could be designed to permit water to seep into the channel fill and percolate downward into buried valleys. Probably not more than once a year would there be enough runoff to fill the reservoirs, and therefore the amount of this induced recharge might be limited to the capacity of the reservoirs. Artificial recharge will affect the area down-gradient from such retention dams. As irrigation wells are drilled, and decline of water levels occurs, the ultimate development of the area may require consideration of artificial recharge.

Movement

Generally, ground water in these two quadrangles is moving very slowly eastward, with a southeasterly trend in the southern part of Clayton quadrangle. In gravel, the velocity may be more than 20 ft a day; in sandstone and less permeable formations the velocity may be only a fraction of a foot a day. In response to gravity, the movement will be towards points of lower elevation of the water table perpendicular to the water-table contours shown on the hydrologic maps (fig. 7, 9).

In most places in the quadrangle, the near-coincidence of the water table and the piezometric surface indicates the formations act as a single hydrologic unit. The water-table contours, which cross geologic boundaries without deflection, also indicate this hydraulic interconnection. An exception is indicated in the area immediately north of, and parallel to, Perico Creek southeast of Clayton, where there is an abrupt break in the water table. The ground water north of this anomalous zone (shown by dots connecting the contours of equal elevation on either side of the zone, fig. 7) is held at an elevation about 75 ft higher than that south of the zone. One explanation is that a relatively effective subsurface dam might be caused by a landslide slope of shales or clays on the north side of a southeastward-trending Dakota group ridge. Less likely, though a possibility, is the presence of a fault. Adjacent water-level contours indicate that very little water moves downward across this zone from the Ogallala formation to the Dakota group except toward the eastern end, where the levels merge into a smooth water table.

Natural Discharge

The underflow into Texas and Oklahoma constitutes the greatest natural discharge from the area, and has been evaluated in the section on Estimates. Natural discharge from aquifers in this area, in addition to underflow, may be by evapo-transpiration, by discharge to surface bodies of water, and by leakage through less permeable underlying beds (called aquicludes), into deeper formations.

Ground-water discharge by evapo-transpiration from the main water table occurs only in two or three small areas where the water is within a few feet of the ground surface. Such areas will usually be distinguished by comparatively lush vegetation and large *trees,* as for example, the area near the center of Seneca quadrangle where highway construction crews obtained water from shallow pits.

The total discharge from aquifers to surface bodies of water, such as streams with perennial flow or permanent water holes, or springs such as Apache Spring (26.35.23.411) located below the malpais cliff north of Clayton, is estimated less than 50 acre-ft per year. No estimate of the quantity that might be lost by leakage through aquicludes into deeper formations is included.

Discharge by Wells

Artificial discharge by wells, which represents present development of ground-water resources, is estimated for the area of this report to be less than 6,000 acre-ft per year. Records of 410 wells are arranged in Table 1; location, water levels, and depths are given on the hydrologic maps (fig. 7, 9).

About 372 acre-ft was pumped from the town of Clayton wells in the fiscal year which ended June 1956. Though no pumpage was obtained for the Colorado Interstate Gas Company's pumping station, it is estimated between 100 and 200 acre-ft per year. The pumpage from stock and domestic wells is probably much less than 500 acre-ft per year.

In 1955, water from 13 irrigation wells equipped with pumps having capacities greater than 100 gpm (gallons per minute), was used to irrigate 1,900 acres of farm land. A duty of water of 22 ft (acre-ft per acre) was assumed for the irrigated acreage reported here, which acreage is believed to be high. Though these figures are only estimates, for duty will vary with crops, and some of the developed acreage may not have been irrigated, the indicated use is about 5,000 acre-ft per year.

The highest reported pumping rate was 1,800 gpm for the Kehoe well (24.36.12.244), producing from the Dakota formation and Purgatoire formation. The rate of pumping and acreage irrigated are not included in the above estimates because the location of the well is just across the State line in Texas, but the well data are mentioned here and included in Table 1 because of the unusually high reported yield and proximity to the area of this study.

Town of Clayton Wells

Currently, seven wells ranging in depth from 127 ft to 800 ft are operated by the town of Clayton to supply municipal water. Locations of these wells, two town wells not being pumped, and a number of private wells are shown in Figure 3. Pertinent data, mostly from municipal records, are given in the table below.

TOWN OF CLAYTON WELLS

Well no.	Location no.	Depth *(ft)*	Reported water level *(feet below ground surface)* Static	Pumping	Pump capa-city *(gpm)*	Analysis in Table 2	Deepest formation penetrated	Remarks
1	26.35.34.211a	127	96		60	x	Ogallala	
1a	34.211b	125	97				Ogallala	Observation well.
2	27.443	166	97		40	x	Ogallala	
3	34.212	750		432	125	x	Exeter	Leased from C&S Ry. Co.
4	34.243	705		432	125	x	Exeter (?)	Log on file.
4a	34.243a	976					Exeter	Bureau log no. W-212; plugged and abandoned.
5	34.422	800		575	325	x	Exeter	Log in this report.
6	36.143	374		345	135	x	Morrison	Log in this report.
7	35.313	497	189	420	292	x	Morrison	Log in this report.

The total annual pumpage from the town of Clayton wells is shown in Figure 10. On the basis of the production figures furnished by the City Manager, the per capita consumption dropped slightly from 88 gal per day in 1950, when the population was 3,515 (U. S. Census Bureau, 1952), to 84 gal a day in 1956, when the population was 3,951 (New Mexico Economic Development Commission, 1956). The total reported production of 121,240,000 gal in 1955-56 is equal to 372 acre-ft, or about enough water to irrigate 150 acres at a duty of 2½ ft.

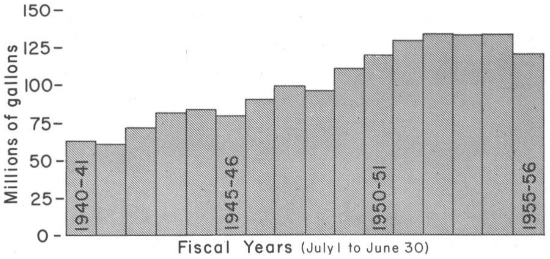


Figure 10. Pumpage, town of Clayton

Fluctuations of water level. Fluctuations of water level in well no. 1a are shown in Figure 11. The hydrograph was drawn from curves obtained with an automatic water-level recorder. The large declines of water level are caused by pumping of Clayton no. 1, 99 ft from no. 1a. The recovery curve during late 1953 and early 1954 was obtained when no. 1 was not operated for more than a few minutes at a time. During the period shown in the hydrograph, well no. 2 was not operated, but it can be shown that the effect of pumping no. 2, located some 400 ft from no. 1a, and pumping only half as much water, would be perhaps 1/32 the effect of well no. 1; that is, if the aquifer is continuous and constant in character.

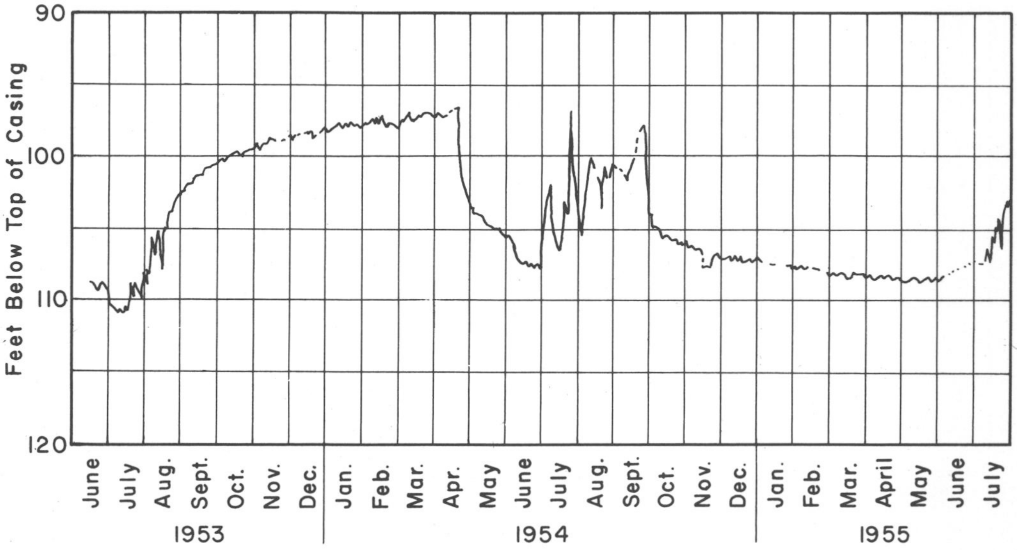


Figure 11. Hydrograph, town of Clayton well no. 1a

The small fluctuations are caused by changes in barometric pressure. These oscillations of the water surface, which may be as much as several tenths of a foot, correspond inversely to changes in atmospheric pressure. In simpler words, a high barometric pressure will "push" the water level in the well down just a little, and a low pressure will cause it to rise slightly.

A correlation between cumulative departures from normal precipitation (fig. 2) and water levels was observed from random measurements made by city personnel between 1927, when the well was drilled, and 1951. The plotted measurements made when neither well no. 1 nor well no. 2 had been operated for at least several weeks fit the curve of Figure 2. The water-level curve is not shown here.

Well Tests

Pumping tests commonly are made to determine characteristics of wells. The results of the tests can be used to aid in the selection of pumps designed to meet the performance of the wells. The results can be used also to compare the well tested with other wells in the area, or to compare present pump and well performance with previous test records of the same pump and well.

One way of comparing the performance of wells is on the basis of specific capacities, which ranged from 7 to 83 gpm per foot of drawdown in six irrigation wells. These wells were selected for comparison because nonpumping (static) water levels, pumping water levels, and rates of production were available, thus permitting the calculation of specific capacities. Except for those wells in which pumping water levels stabilize rapidly, the specific capacities normally should be referred to the length of time during which a well was pumped at a given rate of flow.

In marked contrast to the low specific capacities of less than one-half gpm per foot of drawdown for many stock wells, the Pachta irrigation well (29.28.18.323), near Capulin, produces 1,200 gpm from cinders, with only 1.2 ft of drawdown (maximum yield is much greater). This is an extraordinarily high specific capacity of 1, 000 gpm per foot of drawdown.

Although such factors as well construction, development, slots, and screens affect the specify capacity of a well, the ultimate yield will depend upon the permeability of the formation adjacent to the well.

Aquifer-Performance Tests

An aquifer-performance test (a well test made primarily to evaluate the hydraulic characteristics of the aquifer) was made in April 1954. Well no. 1 in the city hall annex was pumped, and observations of the water-level changes in well no. la were made with a specially equipped automatic water-level recorder. Analysis of the decline of water levels in no. la disclosed that the coefficient of transmissibility was about 7,000 gallons a day (per foot width of aquifer per unit hydraulic gradient), and that the coefficient of storage was about 0.005 (cu ft of water released from each vertical column with a cross-sectional area of one square foot for each foot of decline of head). Analysis of the test data also disclosed the presence of both a limiting boundary and a recharge boundary in the vicinity.

Near the wells, silty beds overlying the producing beds could be responsible for the semiartesian conditions indicated by the coefficient of storage of one-half of one percent. In unconfined aquifers where actual dewatering and subsequent slow draining take place, the coefficient of storage eventually should approach the value of porosity (more accurately, specific yield, which is the ratio of the quantity of water which will drain by gravity from a given volume of material in a specified time). In artesian aquifers the coefficient will be many times smaller, because no water is obtained by dewatering the formation, and initially the water must be released principally by compaction of the aquifer as a result of reduced internal pressure.

The set of values indicating the ability of the Ogallala formation in the vicinity of the city hall to permit the flow of water and to release water from storage can be used to calculate interference between present or proposed wells in that area. However, because the Ogallala formation consists of permeable channel deposits that are interwoven complexly with much less permeable floodplain deposits, tests should be made over a much wider area before long-term predictions of water levels are computed for various assumed pumping conditions. Aquifer-performance tests of the Dakota sandstone and the Purgatoire sandstone should be made, to provide data which can be analyzed to evaluate the respective hydrologic characteristics.

In an aquifer-performance test, the discharge rate should be maintained as constant as possible. Very careful measurements of water levels made at frequent intervals before, during, and after the pumping period in all available wells are an essential part of the test, without which the analysis of the test data will be unreliable for purposes of calculating interference between wells and future water levels in the aquifer.

Those who are interested in quantitative methods will find the various methods and theories adequately described by Ferris (1949).

Estimates of Available Quantities

This section is designed to demonstrate methods for obtaining estimates of the quantities of ground water available for irrigation. It is shown that the annual recharge from precipitation should supply sufficient ground water to irrigate 10,000 acres, and that an additional 18,000 acres might be irrigated if the recoverable portion of the water in storage is "mined" over a 40-year period.

These quantitative estimates, which are described in more detail later in this section, are based on assumed values for recharge rate, effective permeability, and proportion recoverable from storage, for which supporting data from this area were very scarce; the estimates, therefore, necessarily were based on reports of measurements made elsewhere. Accordingly, the quantities of water available from recharge and from storage must be regarded merely as estimates. Only through careful collection and preservation of all pertinent data will it be possible to obtain more reliable solutions for the examples shown here.

Under natural conditions over a long period of time, the recharge to the ground-water reservoir will be balanced by the discharge, together with changes in storage. When discharge by wells is introduced, water will be supplied from storage in the vicinity of the well or wells. The resulting decline in levels, known as a cone of depression, will spread until either new recharge is encountered or other discharge from the aquifer is reduced. Assuming, then, that the subsurface outflow from the area can be minimized by this method, it is apparent that any additional withdrawals must be entirely from storage and will be accompanied by continuingly declining water levels. In the following paragraphs attempts have been made to illustrate the recharge, storage, and discharge factors.

Recharge From Precipitation

Using one-half inch per year (Theis, 1937) as that part of the average annual precipitation which reaches the ground-water reservoir, the average annual recharge from precipitation is estimated to be 27,000 acre-ft. The recharge is assumed to occur within an area of 1,000 sq miles, limited on the north by the North Canadian River, on the west by Sierra Grande, on the south by Carrizo Creek, and on the east by the state line.

In this example, 15,000 acre-ft is recharged west of Clayton and Seneca quadrangles. Perhaps 1,000 acre-ft is intercepted by wells or springs and seeps, and the balance of the water will move eventually into the quadrangle as underflow. Discharge by wells and springs in the two quadrangles is estimated at less than 6,000 acre-ft.

The average section of land contributes only enough recharge to the ground-water supply to irrigate 10 acres, but with 1,000 sq miles of recharge area, 10,000 acres can be irrigated.

Storage

An additional supply of almost 2 million acre-feet of water may be recoverable from storage in the ground-water reservoir. In the New Mexico part of Clayton quadrangle, the volume of saturated rock, including clays and shales, from which water is available by slow drainage over a very long period of time, is 24,200,000 acre-ft, which is the product of the 200-sq-mile area times an average thickness of saturation of 190 ft above the base of the Dakota group. With an assumed average porosity of 20 percent, this saturated rock contains nearly 5 million acre-feet of water. Perhaps one-fifth, or 1 million acre-ft, may be recoverable by wells over many years. Similar calculations for the 240-square-mile area of Seneca quadrangle, with a saturation of 140 ft, give a recoverable estimate of 860,000 acre-ft.

The value of 20 percent used for effective porosity may be conservative; clays and shales may have porosities close to 50 percent, and sands and gravels usually have porosities close to 30 percent. The unlikelihood of constructing a well system by which most of the saturated material might be dewatered was considered when assuming the recoverable fraction.

In view of the quantity of water available from storage, it is reasonable to assume that optimum development of the area would not preclude use of water in storage, without which the irrigated acreage would be limited to a development based on the annual recharge. If the recoverable portion of the storage water is pumped during an arbitrarily chosen period of 40 years, 18,000 acres could be irrigated at the rate of 45,000 acre-ft a year. The "40 years" is used only as an example and is not meant to imply that this period is recommended. Once the recoverable water has been "mined" out, ground-water irrigation would have to be cut back to that acreage which would be sustained by annual recharge from precipitation. Long before this happened, better estimates of effective porosity, and especially of recoverable percentage, would have been obtained and the development planned and adjusted accordingly.

Subsurface Outflow

The quantity of water leaving the two quadrangles as subsurface outflow has been estimated to be 13,800 acre-ft per year, sufficient to irrigate 5,500 acres. This water moves out across the state line through a vertical section that is 35 miles long (from the north edge of Seneca quadrangle to the south edge of Clayton quadrangle), with an average saturation above the base of the Dakota group of 240 ft for the Clayton quadrangle and 160 ft for the Seneca quadrangle, or an average of 200 ft for the section. Water-table contours indicate an average hydraulic gradient of 35 ft per mile. The assumed effective coefficient of permeability of 50 gallons a day per square foot would be too high for fine-grained materials such as are found in much of the Dakota group, but is much too low for the coarse channel deposits in the Ogallala formation.

Instead of assuming effective values for the section as a whole, similar calculation may be made for the highly permeable parts of each of the saturated formations. Much higher values of the coefficient of permeability would be used for the buried valleys in the Ogallala and for the massive sandstones at the base of the Dakota group. The total effective area of the section would be smaller, but the result should be the same. Although such figures would not be more reliable than those demonstrated above, they would be more realistic, in that they would indicate that the buried valleys •undoubtedly carry considerably more water than the formations on either side.

As irrigation projects are developed, the decline in levels accompanying such development would reduce the gradient toward the east edge of the area, with a consequent reduction in the loss by underflow.

Chemical Quality of Ground Water

Chemical analyses of water from 36 wells indicate that the chemical quality of the water is satisfactory for ordinary uses. Because many publications on ground water discuss quality of water at great length, brief mention will be made only of those constituents of common interest. For those who are interested in irrigation quality, the United States Salinity Laboratory Staff (1954), Wilcox (1948), and Richards (1956) are listed as references.

Most of the wells yield water classified for irrigation use as "excellent to good" (Wilcox, 1948), with water from five wells classified as "good to permissible. The United States Salinity Laboratory Staff (1954) cross-classifies irrigation water in four classes, each according to salinity hazard and sodium (alkali) hazard, a total of 16 types. All analyses in Table 2 fall in C2-S1 or C3-S1 types. These classes are quoted below:

C2 MEDIUM-SALINITY WATER (C2) can be used if a moderate amount of leaching occurs. Plants with moderate salt tolerance can be grown in most cases without special practices for salinity control. (Specific conductance, 250-750 micromhos.)

C3 HIGH-SALINITY WATER (C3) cannot be used on soils with restricted drainage. Even with adequate drainage, special management for salinity control may be required and plants with good salt tolerance should be selected. (Specific conductance, 750-2250 micromhos.)

Si LOW-SODIUM WATER (S1) can be used for irrigation on almost all soils with little danger of the development of harmful levels of exchangeable sodium. However, sodium-sensitive crops such as stone-fruit trees and avocados may accumulate injurious concentrations of sodium. (Sodium adsorption ratio, 0-8.)

With the possible exception of *sulfates* concentration of 471 ppm (parts per million, by weight) in the water from well 26.36.17.434, which may impart a taste to the water, all the concentrations of the other minerals are low and may be disregarded for most purposes. The *hardness* is the property of water which most affects its use for cleansing purposes, being almost a direct measure of the soap requirements. Hardness of well water reported in Table 2 ranges from 159 ppm (hard) to over 700 ppm (extremely hard). Hard waters are softened readily for household use.

When present in concentrations of about 1 ppm, *fluorides* are reported to be responsible for a reduction in the number of dental caries in the teeth of growing children. Concentration much in excess of 1.5 ppm may cause some mottling of the enamel of the teeth. Two samples showed only 0.2 ppm, two contained over 2.0 ppm (2.2 and 2.4), and all others were between 0.6 and 2.0 ppm. Fluorides in the water from the various Clayton municipal wells ranged from 0.6 to 1.4 (well no. 1, which produces 60 gpm), with the average in the water delivered to the consumer estimated to be about 1 ppm.

Because the capacity to conduct an electric current is dependent upon the concentrations and solubilities of the different minerals in solution, the *specific conductance* is a relative indicator of the *total dissolved solids* in the water. The total dissolved solids (in ppm) is roughly two-thirds of the specific conductance in micromhos.

SUGGESTIONS FOR GROUND-WATER EXPLORATION

The data in this section are presented as guides to help owners and drillers who are faced with the questions: Where to drill? What formation to test? How deep to drill?

The elevations of bench marks (fig. 6, 8) and of wells, as recorded in Table 1, may help to indicate the surface elevation of a new well. Knowing the surface elevation, the approximate depths to water, base of Ogallala, and base of Dakota formation can be predicted.

Low-Yield Wells

Small supplies of water can be obtained from the Ogallala formation or the Dakota group anywhere in Clayton or Seneca quadrangles; therefore, domestic and stock wells should be located at points of most convenience to the owners.

Ordinarily, water in the finished well will stand at the elevation indicated by the water-table contours on the hydrologic maps. In a few places, perched water, which cannot be predicted from present information and surface features, may supply low-yield wells. Such saturated lenses of permeable materials may rest on beds of clay, shale, or silty sands above the water table. The unusually high water levels in several wells about 6 miles east of Clayton apparently represent perched water.

High-Yield Wells

High yields can be obtained only in limited areas in either the Ogallala formation or in the bedrock. The best places to test for irrigation supplies are in the Ogallala formation in the buried valleys. A similar simple guide cannot be given for choosing a location of high-yield wells in the bedrock, but brief descriptions of the availability from the different formations will be given, together with a few suggestions to follow in prospecting and development.

High Yields From Buried Valleys

All the buried valleys in the Ogallala formation are saturated. The valleys are shown by contour lines in Figures 6 and 8 and are in the unshaded areas on the hydrologic maps (fig. 7, 9). In those valleys where the Ogallala has 200 ft of saturation, it should be possible to construct irrigation wells from which several thousand gallons per minute can be pumped. For example, the measured yield of 420 gpm with less than 40 ft of drawdown gives a specific capacity of more than 10 gpm per foot of drawdown for the Winchester irrigation well (25.35.2.441).

The saturation at this location is only slightly over 80 ft, indicating that a probable maximum yield of more than 700 gpm might be obtained by increasing the drawdown to 70 ft.

A line of test wells across any buried valley, drilled to bedrock, should indicate not only the deepest part of the valley but also the beds of sand or gravel which would be most likely to yield the greatest quantity of water to an irrigation well. Geophysical exploration by electrical earth resistivity, induced polarization, and seismic methods should provide similar information.

Away from buried valleys the thickness of saturated Ogallala is not great, and therefore high-yield wells are not to be expected.

High Yields From "Bedrock"

In shaded areas on the hydrologic maps the water table is in bedrock below the base of the Ogallala formation. Anyone trying to develop maximum yield with the least possible drawdown must know what part of the geologic section is being drilled in order to decide whether or not all the economic possibilities have been exhausted. The availability of water in each of the bedrock formations is discussed below. This discussion should be considered in the light of the descriptions and thicknesses of the formations on pages 11-14.

High yields from the Dakota group can be obtained from the massive sandstone in the lower part of the Dakota formation or from thick sandstones in the Purgatoire formation. In order to assure that the Dakota group has been completely penetrated (in the past most wells have ended above the base of the group) and will be given a thorough test, all test holes should be drilled at least 10 feet into the green and red clays of the Morrison formation. Several of the irrigation wells along the state line obtain a part or all of the water from the bedrock; the highest reported production is 1,800 gpm for well 24.36.12.244, which yield, according to the log, is coming from sandstones in both the Dakota and Purgatoire formations.

Where a buried valley has been cut through the Dakota formation (see p. 20, 21) the potential for obtaining high-yield wells should be even greater. In such cases the Ogallala will act as a collection gallery, with the Dakota formation on the flanks of the valley feeding water into channel deposits of the Ogallala.

The Morrison Formation appears to be the principal aquifer in Clayton municipal well no. 6 (Airpark, 26.35.36.143), which reportedly yields 135 gpm from a pumping level of 325 ft. If adequate water has not been encountered in overlying formations, it is suggested that drilling be continued 30 feet below the top of the Morrison, as indicated by green and red mudstone. Below this it is unlikely that a sandstone capable of yielding adequate quantities will be found.

Little is known about the water-yielding character of the Exeter sandstone in this area . Town of Clayton wells no. 3, 4, and 5 penetrate the Exeter but are also open to other formations, and the proportions of the yield from the different formations has not been determined. The nearest known production from the Exeter is from several flowing artesian wells 5 miles southwest of Clapham, on Tramperos

Creek. The natural flow of these wells ranges from 2 gpm to 50 gpm, but it is reported that they can be pumped at 500 gpm or more. The waters are relatively high in dissolved solids and high in sodium hazard. For these reasons, if a well is drilled to test the Exeter, which is more than 700 ft below the surface at Clayton, and probably more than 500 ft deep throughout these two quadrangles, both yield and quality should be determined. Any test of the Exeter should be carried several feet into the underlying Triassic "red beds."

Drilling and Testing Wells

The well owner would be wise to have the driller lay out samples for every 5 or 10 ft of drilling, as is the habit of some local drillers. Instead of relying on memory, the driller should make his final log from these samples after the hole is finished. The log should include the color of clay, mudstone, and shale; grain size of sand or sandstone; and the driller's assignment of formation intervals.

Samples of the drill cuttings should be saved. (Sample cuttings may be bagged and sent to the State Bureau of Mines and Mineral Resources for permanent filing.) Information from individual wells taken alone may not be particularly useful, but when complete data are available for a large number of wells, including dry tests, the resulting correlations can be of great value. This is precisely how the buried valleys were outlined.

Samples of drill cuttings from a test well in sand or gravel should be collected with great care in order to assure that they are representative of the formation interval. Gravel packing, which theoretically is needed only for uncemented, very fine, uniform sands, should determine width of slots in screen or casing. Practically, because screens commonly are not used in this area, it is often necessary to bridge the gap from formation size to torch-cut casing slots with a gravel pack. Screened wells can be constructed and developed to yield a maximum quantity of water from any gradation of grain sizes.

It is not only desirable but reasonably simple to construct a well from which sand-free water can be pumped. During development work, sand should be removed from the material immediately adjacent to the well, either by surging-and-bailing or by pump-surging (rawhiding). Development is designed to leave only coarse material in contact with the slots, gradually grading to undisturbed formation. If the well is properly developed, the permanent pump installation should not cause more sand to be dislodged. The permanent pump should not be used for any part of the development work, because pumping sand will cause excessive wear, and power will be wasted as a result of the decreased efficiency.

Because doubling the diameter of a well will increase the yield only about 10 percent, the proper construction and development is much more important than drilling an unusually large hole. The proposed pump installation or the drilling equipment should determine the minimum diameter of a well.

More thorough discussions of construction and development of wells can be found in numerous periodicals and publications, the best of the general field for the well driller being the handbook by Bennison (1947).

If at all possible, well-test data should be recorded and filed for future reference. The minimum requirements of a well test are that the rate of flow be measured periodically, and that water levels in the pumped well be measured before, during, and after the test. All observations should be recorded, along with the time when they were made, as well as any remarks deemed pertinent. A well test should be made by starting at a low rate of production; when the water levels begin to stabilize or to approach equilibrium, the rate should be increased by steps until either the desired maximum rate or the capacity of the well has been reached. Water levels in nearby wells should be measured and recorded. Sometimes the value of such records is not immediately apparent, but they may prove of great benefit at some later date. The sections on well tests and aquifer-performance tests indicate how such results can be employed.

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LOGS OF WELLS

Logs of seven water wells are given below. Many other logs and partial logs are on file. However, the wells either did not go through the Dakota group into the Morrison formation, or the logs are incomplete and therefore difficult to interpret. Typed drillers' logs for two oil tests, Buffalo Oil Syndicate Odiorine #1 (24.36.3.400) and Herndon Mock #1 (27.36.25.111), and also for town of Clayton well no. 4a, are available from the State Bureau of Mines and Mineral Resources, Socorro, New Mexico. Samples from the Mock test are on file; as they are poor above 360 ft, at which depth the Morrison is present, a log of samples is not included here.

Formation assignments on the seven logs given below have been made by Baldwin, except as noted. Formation intervals are difficult to pick in some wells, even when samples are available.

Depth to bottom and Thickness (ft)		
		Kehoe irrigation well, 24.36.12.244, elevation 4,630 ft. Log by J. W. Lindsey, driller; formation assignments by D. H. Griswold, S. C. S.
		OGALLALA FORMATION (75 ft)
40	40	Surface -- caliche
50	10	Sand -- yellow
75	25	Gravel -- coarse
		GRANEROS SHALE (44 ft)
90	15	Clay -- blue
119	29	Shale -- bluish, coal
		DAKOTA FORMATION (181 ft)
142	23	Sand -- coarse
180	38	Shale -- bluish
220	40	Sand -- yellow, hard, white
300	80	Sand -- white, soft
		PURGATOIRE FORMATION (59 ft)
340	40	Shale -- bluish
359	19	Sand -- white
		MORRISON FORMATION (1 ft)
360	1	Shale -- red, bottom of hole

Town of Clayton well no. 5, 26.35.34.422, elevation 5,049 ft. Log by J. B. Leiser from samples; modifications and comments by B. Baldwin.

Depth to bottom and Thickness (ft)		
		MALPAIS (50 ft)
50	50	Volcanic lava flow rock
		OGALLALA FORMATION (50 ft)
55	5	Limestone -- sandy (caliche?)
60	5	Sandstone -- coarse, pebbly
63	3	Limestone -- sandy (caliche)
88	25	Sandstone -- medium-coarse to coarse, slightly limy but porous
100	12	Shale -- brown, soft, clayey, slightly sandy (sandy clay?)
		GRANEROS SHALE (70 ft)
108	8	Shale -- dark-gray to black, soft
130	22	No sample
170	40	Shale -- dark-gray to black, soft
		DAKOTA FORMATION (150 ft)
173	3	Shale -- gray, slightly sandy
175	2	Sand, whitish clay, trace of coal
180	5	Sandstone -- fine- to medium-grained, porous
185	5	Shaly sandstone -- fine- to very fine-grained, tight
200	15	Shale -- medium-dark-gray
210	10	Shaly sandstone -- gray-white, very fine-grained, tight
230	20	Sandstone -- coarse- to fine-grained, pyritic; grading downward to very fine-grained, only slightly porous
240	10	Shale -- medium-dark-gray, partly silty, gritty
250	10	Sandstone -- fine- to medium-grained, shaly at top and porous below
260	10	Shaly sandstone -- tight, no porosity
270	10	Sandstone -- white to gray, fine- to very fine-grained, porous
290	20	No sample
300	10	Sandstone -- fine to very fine-grained, dirty, slightly limy, slightly porous to porous
310	10	Shaly sandstone -- somewhat porous
320	10	Shaly sandstone -- very dirty, somewhat porous
		PURGATOIRE FORMATION (68 ft)
335	15	Shale -- dark-gray to black, slightly sandy at top
340	5	Sand in black shale -- fine- to coarse-grained, tight and pyritic, no porosity
350	10	No sample
360	10	Sand -- white, medium-coarse to very coarse-grained, loose
365	5	Sandstone -- fine- to medium-grained, hard, glassy
380	15	Sandstone -- as above, 360-365; in part iron-stained - pink, red, rusty
388	8	Sandstone with some chert

MORRISON FORMATION (345 ft)

392	4	Clay-shale -- deep-maroon and green
415	23	Sand -- fine- to coarse-grained, loose, porous
418	3	Shale -- dark-gray to black (caving from above?)
430	12	Clay-shale -- pale-greenish-white
440	10	Sandstone -- fine- to very fine-grained, partly shaly, somewhat tight and only slightly porous
480	40	Sand -- fine- to coarse-grained, loose, porous
490	10	Clay-shale -- pale-greenish-white, sandy
500	10	Shale -- deep-brownish-maroon, silty -- gritty
507	7	Shale -- deep-brownish-maroon, with imbedded fine to medium sand grains
510	3	Shaly sandstone -- greenish-white, extremely fine, tight
520	10	Shaly sandstone -- reddish-white, fine to medium-coarse, tight
525	5	Sandstone -- white to gray, fine- to medium-grained, tight, hard
540	15	Sandstone -- as above, 520-525, but part medium-coarse, glassy, slightly limy
548	8	Sandstone -- as above, 525-540, but iron-stained
560	12	No sample
570	10	Sandstone -- white, fine- to medium-coarse sandstone aggregates, with coarse grains associated; appears porous, with less porosity in lower part
580	10	Sandstone -- as above, 560-570, but with hard to glassy streaks
592	12	Sandstone -- similar to 560-570, buthard and glassy with some shale content
598	6	Limestone -- reddish-pink, very finely crystalline; shale partings
605	7	Shale and sandstone -- reddish-gray interbedded shale and hard, tight sandstone, broken or streaked
609	4	Shale -- greenish, clayey, hard, with imbedded fine-to medium-size sand grains
621	12	Sandstone -- fine-grained, tight, with few coarser grains and some red-maroon shale
626	5	Limestone -- light-gray, sandy, dense
632	6	Limy sandstone -- medium to coarse, tight
647	15	Shale -- pale-green, soft, with limestone pebble inclusions; quite sandy toward base
680	33	Sandstone -- medium to coarse, tight, slightly limy, some occasional iron pyrite
683	3	Sandy limestone -- buff to light-brown
686	3	Sandstone
692	6	Limestone -- gray-brown, dense to micro-crystalline
707	15	Sandstone -- medium to coarse, tight, slightly limy and slightly quartzitic; some ochreous color-staining
710	3	Limestone -- gray-buff, siliceous, with trace of interbedded gray shale
713	3	Sandy shale -- green
722	9	Sandstone and shale -- fine-grained, limy sandstone and pale-green sandy shale
733	11	Sandy shale and "agate bed" -- conglomeratic-type sediment; some granite wash mineral grains - feldspars; some red and white agate-like cherts, with maroon, finely sandy shale

		"WANAKAH FORMATION" (27 ft)
739	6	Sandstone and shale -- very fine limy and shaly sandstone with crystalline calcite and interbedded maroon shale
742	3	Limy sandstone -- fine- to medium-grained, very limy, tight, with included pink to red crystals
748	6	Limestone -- maroon, fine crystalline to shaly
750	2	Sandstone
760	10	Shale -- pale-green, black-speckled in top, with fine sandstone and siliceous pebbles toward base
		EXETER SANDSTONE (19 ft)
763	3	Sandstone -- buff, very fine, crumbly, friable
779	16	Sand -- coarse, frosted, free, with pebbles of dolomite, limestone, and quartz
		DOCKUM GROUP OR EXETER SANDSTONE (21 ft)
784	5	Shale -- olive-green to moss-green
785	1	Sandstone
788	3	Shale -- pale-green, with maroon and red pellets; soft to flaky
800	12	Sand -- fine-grained with some medium and coarse grains; friable to free

Depth to bottom
and
Thickness
(ft)

Town of Clayton well no. 6, 26.35.26.143, elevation 4,975 ft. Log by B. Baldwin from samples on file.

		OGALLALA FORMATION (70 ft)
10	10	Surface -- silt, sand, some caliche
70	60	Sand and gravel -- fine to coarse sand and pebbles to 1/2 inch; clean
		GRANEROS SHALE (20 ft)
72	2	Limestone -- light-brown, granular, tiny needles
90	18	Shale -- light-to medium-gray, silty, non-calcareous
		DAKOTA FORMATION (160 ft)
100	10	Siltstone -- light-gray, sandy
130	30	Shale -- medium-gray, silty
140	10	Sandstone -- light-gray, very fine-grained to silty, cemented
160	20	Sandstone -- fine- to medium-grained, poorly cemented
170	10	Sandstone -- light-gray, very fine-grained to silty, cemented
180	10	No sample
220	40	Shale and sandstone -- medium-gray to black silty shale, interbedded or laminated with light-gray fine-grained sandstone
250	30	Sandstone -- medium-gray, fine-grained to silty, subangular; minor dark-gray shale

		PURGATOIRE FORMATION(?) (20 ft)
260	10	No sample
270	10	Shale -- black, sandy to silty, with some light-gray cemented sandstone
		MORRISON FORMATION (104 ft)
300	30	Sandy clay -- light-gray (270-280), grayish-red (280-290), and light-greenish-gray (290-300)
310	10	Caving -- gravel typical of Ogallala formation
320	10	Sandstone -- fine- to medium-grained, uncemented; some chips of greenish-gray sandy mudstone
330	10	No sample
372	42	Sandstone -- fine- and medium-grained, rounded to subrounded, uncemented; finer above 350 ft
374	2	No sample below 370 -- reported that well entered red and green clay at 372

Depth to bottom
and
Thickness
(ft)

Town of Clayton well no. 7, 26.35.35.313, elevation 5,034 ft.
Log by B. Baldwin from samples on file.

		SURFACE (20 ft)
20	20	Caliche -- cream-white to grayish-orange; scattered quartz grains
		MALPAIS (20 ft)
40	20	Basaltic lava -- dark-gray, with some olivine phenocrysts, vesicles
		OGALLALA FORMATION (90 ft)
60	20	Sand and caliche -- grayish-orange
70	10	Gravel -- pebbles up to 1/2 inch
80	10	Sand -- medium-to coarse-grained; minor caliche and silt
90	10	No sample
130	40	Sand -- fine- to medium-grained; minor caliche and silt
		GRANEROS SHALE (65 ft)
135	5	Shale -- medium-gray silty clay; calcareous
145	10	Sandstone -- light-gray, fine-grained to silty, with carbonaceous laminae; noncalcareous; pieces of brown rock (concretions?)
175	30	Shale -- dark-gray, clayey (not gritty), fissile; brown fragments
177	2	Limestone -- medium-gray, fine grains of calcite and quartz; tiny needles
195	18	Shale -- as above, 145-175

DAKOTA FORMATION (165 ft)

200	5	Sandstone -- light-gray, fine-grained, well-cemented
230	30	Shale -- dark- to medium-gray, clayey; calcareous in upper 20 ft
240	10	No sample
270	30	Sandstone -- light-gray, fine-grained, subangular, clean, some mica flakes and carbonaceous streaks; uncemented in top 10 ft
280	10	Silty sandstone -- medium-gray
300	20	Sandstone -- light-gray, fine-grained, subangular, poorly cemented
310	10	Sandy mudstone -- light- to medium-gray
318	8	Sandstone -- light-gray, fine-grained, subrounded, uncemented
340	22	Shale -- medium-gray, sandy and silty
360	20	Sandstone -- light- to medium-gray, fine- to medium-grained, moderately cemented

PURGATOIRE FORMATION (10 ft?)

370	10	Shale -- dark-gray, sandy to silty

PURGATOIRE FORMATION OR MORRISON FORMATION (127 ft)

385	15	Sandy clay -- light-gray (similar to interval 270-280 of Clayton well #6)
480	95	Sandstone -- yellowish-gray to white, fine- and medium-grained, rounded to subrounded, uncemented; 463-465, water and minor black shale
497	17	No sample -- reported that well entered red and green clay

Depth to bottom
and
Thickness
(ft)

Dickens irrigation well, 26.36.13.231, elevation 4,725 ft.
Log by B. Baldwin from samples of interval 165-240, on file.

OGALLALA FORMATION (168 ft)

165	165	No samples
168	3	Sand -- medium-grained, subangular

DAKOTA FORMATION (72 ft)

170	2	Mudstone -- light-gray, clayey to fine sandy silt
200	30	Sandstone and siltstone -- light-gray, pale-yellow-brown, and grayish-brown; fine-grained; angular, clean sandstone, silty sandstone, and minor siltstone; soft
203	3	Shale -- dark-gray, silty clay
215	12	Caving -- gravel typical of Ogallala formation
219	4	Mudstone -- light-gray, silty
240	21	Sandstone -- fine-grained and angular in upper part, grading downward to fine- and medium-grained and subrounded in lower part; poorly cemented; minor light-gray soft siltstone

Depth to bottom and Thickness (ft)		
		Freeman irrigation test, 26.36.9.214, elevation 4,778 ft. Log by B. Baldwin from samples for interval 60-277 on file.
		OGALLALA FORMATION (60 ft)
60	60	No sample
		DAKOTA FORMATION (110 ft)
105	45	Sandstone -- yellowish-gray, pale-red-purple, some iron-stained red-brown and yellow-brown; very fine-grained; moderately cemented
135	30	Sandstone -- yellowish-gray, poorly cemented, mica flakes; minor light-gray silty shale
142	7	Coal and sandstone -- yellowish-gray, fine-grained sandstone, and medium-gray silty sandstone with streaks of coal and carbonaceous matter
155	13	Sandstone -- light-gray, fine- to medium-grained, subrounded, poorly cemented
165	10	Sandy shale -- medium-gray, some carbonaceous streaks
170	5	Sandstone -- as above, 142-155
		PURGATOIRE FORMATION (48 ft)
180	10	Shale and sandstone -- medium-gray, silty to sandy shale, and fine-grained, poorly cemented sandstone
215	35	Sandstone -- medium-gray, fine- to very fine-grained, minor clay cement; some dark-gray (chert?) grains; minor light- to medium-gray silty shale
218	3	Shale -- dark-gray, silty
		PURGATOIRE FORMATION (?) (82 ft)
277	59	Sandstone -- fine- to medium-grained, rounded to subrounded, uncemented; traces of white clay cement in bottom sample; traces of dark-gray silty shale in upper half
300	23	No sample -- test deepened to 300 in developing irrigation well

Depth to bottom and Thickness (ft)		
		Flesher irrigation well, 26.36.15.412, elevation 4,753 ft. Log by J. W. Lindsey, driller.
		OGALLALA FORMATION (120 ft)
20	20	Clay
25	5	Sand
30	5	Clay
40	10	Sand and gravel
60	20	Clay
70	10	Gravel
116	46	Sand lime -- soft
120	4	Sand and gravel -- hard
		DAKOTA FORMATION (156 ft)
121	1	Shale -- green
124	3	Sand lime -- soft
128	4	Rock -- hard
129	1	Shale -- brown
130	1	Sand -- soft
136	6	Rock -- hard
138	2	Shale -- green, sticky
140	2	Shale -- yellow
144	4	Rock -- malpai (boulder from Ogallala formation?)
170	26	Shale -- blue, hard
180	10	Gray and sandy
190	10	Coal -- sandy
200	10	Sand -- hard, white
205	5	Shale -- black
210	5	Shale -- hard
220	10	Shale -- black
229	9	Sand -- yellow
252	23	Shale -- yellow, sandy
253	2	Shale -- black
264	10	Sand -- yellow, lost circulation
265	1	Shale -- white
268	3	Sand -- yellow, soft, lost circulation
275	7	Sand, lime, coarse gravel
276	1	Sand -- coarse
		PURGATOIRE FORMATION (?) (35 ft)
311	35	Sand and lime shale black

Table 1. Record of wells in Clayton and Seneca quadrangles, Union County, New Mexico

Location number	Owner	Date completed	Altitude above sea level (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Water level: Below ground surface (feet)	Water level: Date of measurement	Meth. of lift	Pumping rate: GPM	Pumping rate: Date of measurement	Use	Remarks
23.35.3.242	Mrs. M. Bean	1908	4794	Dr	300	4½	250		W			D,S	
5.311	Mrs. Brane	1924	4868	Dr	328				W			D,S	Reported very good well
23.36.4.311	G. Burrow	1916	5643	Dr	175	4	125						No access
5.133	K. Butt	1950		Dr	175	6¼	125						No access
24.35.1.332	E. C. Winsor			Dr	40		20		W			S	
3.244a	Winsor (House, north well)			Dr	67		14		N			N	No windmill
3.244b*	Winsor (House, south well)	1932		Dr	75	8	14		W			D	
3.244c	Winsor	1934	4815	Dr	96	6	14		T			I	
5.334	Winsor			Dr	115.0	4			N			N	Dry, no windmill
5.433	Winsor			Dr	165		100						
6.241	Winsor		4953	Dr	96	6½	79.2	7-26-54	W			S	
7.144	Winsor	1950	4952	Dr	220	6½	73.6	7-26-54	W	1		S	Reported yield
7.333	Winsor			Du	13.4	48	11.1	7-26-54	W			S	
8.311	Mrs. B. Toney		4962	Dr	140				W			D,S	
8.443	Toney		4968	Dr	129.0		126.0	7-22-54	W			S	Pumping level
9.111	Toney	1948	4943	Dr	90				W			S	
10.444			4858		50.0		49.0	7-22-54	N			N	No windmill
11.131	U. S. Gov't			Dr	165		130		W			S	
12.334			4820		152.0		112.2	6-26-54	N			N	No windmill
15.133a	C. E. Roush		4899	Dr	80		78		W	1		D,S	Reported yield
15.133b	Roush	1949		Dr	186				E	13	7-22-54	D,S	

Explanation at end of table

* underscored well numbers -- analysis in Table 2

Table 1. Record of wells in Clayton and Seneca quadrangles, Union County, New Mexico (continued)

Location number	Owner	Date completed	Altitude above sea level (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Water level: Below ground surface (feet)	Water level: Date of measurement	Meth. of lift	Pumping rate: GPM	Pumping rate: Date of measurement	Use	Remarks
24.35.15.140	W. A. Rardin	1949		Dr	90	5½							
15.422			4859		138.0		132.0	7-22-54	W			S	
17.424	Mrs. B. Toney		4932	Dr	100		92					D,S	
18.443	C. E. Webster		4869		24.2		22.1	7-26-54	N			N	
19.244	Webster		4886	Dr	88	4	55		N			N	Filled to 28 ft.
20.111	Webster		4892	Dr	63		50					D,S	
20.333	L. Leighton				85	4	48.7	7-26-54	W			S	
21.122	O. Bates				210	5	130		W			S	
21.311	Toney		4935	Dr	150							N	Dry at 136 ft.
22.211	Bates		4859	Dr	140	4	120		W			S	
22.311	Bates		4771	Dr	100		60		E			D,S	
23.111	K. Butt			Dr	90	4	40			2	6-26-54	D	
23.331	K. Butt		4855	Dr	130.0	4½	97.6	6-26-54	N			N	No windmill
24.332	L. Butt			Dr	200	4½	160		W			S	
25.334	L. Butt	1914	4799	Dr	250		200					D,S	
26.132	K. Butt		4848		255.0	4	215.0	7-20-53	N			N	Measurement doubtful
26.222	K. Butt			Dr	170		170	6-25-54	N			N	Partly filled
27.443	U. S. Gov't		4832		230.0		223.0	7-24-54	W	½	7-24-54	S	Pumping level
29.443	D. W. Walker	1934	4881	Dr	115		107		E			D	Submersible pump
32.111	Walker		4891		196.0		187.0	4-30-54	W			S	
32.343	A. Wisdom		4876		290		260		W			D,S	
33.334	Wisdom	1952		Dr	312	6½	220		W			S	
35.221	K. Butt		4808	Dr	168.0	4½	144.4	6-25-54	N			N	
35.442	K. Butt	1921		Dr	250	4	200		W			S	

Explanation at end of table

Record of wells in Clayton and Seneca quadrangles, Union County, New Mexico (continued)

Location number	Owner	Date completed	Altitude above sea level (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Water level		Meth. of lift	Pumping rate		Use	Remarks
							Below ground surface (feet)	Date of measurement		GPM	Date of measurement		
24.35.36.113	K. Butt	1927		Dr	243		153					D	
36.444	K. Butt	1914	4771	Dr	300	4	204.0	6-25-54	W	1	6-25-54	S	Pumping level
24.36.1.112	W. Spark								E			D	
1.311	E. Schnitzer			Dr		5			W			D,S	
2.221	U. S. Gov't		4714	Dr	102.0	4	71.9	5-29-54					
2.344			4695	Dr	70.2		65.4	6-29-54					
3.112	U. S. Gov't		4747		117.9		82.7	6-29-54	N			N	No windmill
3.333			4726	Dr	156.5		74.5	8-12-53	W			N	
3.400			4687	Dr	2171								Bur. log no. 1087
4.242	H. Rhoton		4760	Dr	135		117					D,S	
4.333	H. A. Moore		4748	Dr	165		150						
4.344	J. N. McKay	1922	4731	Dr	145		100					D,S	
5.121	U. S. Gov't	1924	4791	Dr	135	4½	115		W			S	
6.131	U. S. Gov't		4789	Dr	115.0		81.8	6-30-54	N			N	
6.211	J. M. Hanson			Dr	160		140						
6.311	U. S. Gov't		4783	Dr	124.0		77.0	6-30-54	W			S	
7.111	U. S. Gov't		4753	Dr	285		65		W			S	
7.224	U. S. Gov't			Dr	99.0	4	87.7	6-29-54	N			N	
7.432	G. Burrow		4748	Dr	111.0		82.2	6-29-54	W			S	Pumping level
8.112	U. S. Gov't		4764	Dr	154.0	4	100.5	6-29-54	N			N	
9.443	M. H. Burrow	1907	4698	Dr	150		112					D,S	
10.133	McKay	1951		Dr	137.5		103.0	7-1-54	W	2½	7-1-54		Pumping level 108.6
12.111	R. E. Fry (Home place)			Dr			55					D,S	
12.244	Mrs. L. Kehoe		4630	Dr	360		91.5	8-12-53	T	1800		I	Log, 50' E. of N.M.-Texas state line, Reported yield
12.333	U. S. Gov't				100								

Explanation at end of table

Table 1. Record of wells in Clayton and Seneca quadrangles, Union County, New Mexico (continued)

Location number	Owner	Date completed	Altitude above sea level (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Water level		Meth. of lift	Pumping rate		Use	Remarks
							Below ground surface (feet)	Date of measurement		GPM	Date of measurement		
24.36.13.311	U. S. Gov't	1908	4629	Dr	118.5		99.1	8-12-53	N			N	No windmill
14.211	U. S. Gov't		4653		138.5	4	112.3	8-12-53	N			N	
16.311	G. Burrow	1949	4680	Dr	231.0	20	87.8	6-30-54	N	450		I	Original depth 296 ft.
17.112	Burrow				190		170		W			S	
17.421	Burrow (House well)			Dr	109.0		95.5	6-30-54	W			D,S	Pumping level
20.121	Burrow				156.0	6	114.0	6-30-54	W			S	
22.111	M. H. Burrow	1900	4657	Dr	134.0		97.5	8-12-53	W	1	8-12-53	S	Pumping level
22.443	E. Claborn		4621	Dr	135		114					D,S	
23.142	U. S. Gov't	1917		Dr	150	4	100.1	6-25-54	W	1	6-25-54	S	
23.242	U. S. Gov't		4615	Dr	108.2	4	91.9	7-1-54	N			N	No windmill
24.112	Baker			Dr	120	4						D,S	
26.144	E. Sheets	1952	4609	Dr	130	6½	100		W			S	
26.224	Sheets		4595	Dr	171.4	6	93.8	6-26-54	N			N	
27.242	Claborn		4617	Dr	146.0	4	121.3	6-25-54	N			N	
27.311	U. S. Gov't		4659	Dr	140	4	125						
28.242	U. S. Gov't		4658	Dr	215.0	4	138.0	6-25-54	N			N	
29.113	U. S. Gov't		4754	Dr	264.0	6	185.6	6-26-54	W			S	Pumping slowly
29.434	U. S. Gov't		4732	Dr		6½	180.5	6-25-54					
30.343	Meador		4777	Dr	265		205		E				
30.422	G. J. Dallas (House well)	1912	4757	Dr	259	5	202.7	6-26-54	W	2	6-26-54	D,S	Pumping slowly
31.311	L. Butt	1913	4776	Dr	255.0	4	208.1	6-25-54	N			N	
33.122	U. S. Gov't		4690	Dr	172.5	4			W			S	
34.311	U. S. Gov't		4671	Dr	230.0	4	157.0	6-25-54	N			N	

Explanation at end of table

Table 1. Record of wells in Clayton and Seneca quadrangles, Union County, New Mexico (continued)

Location number	Owner	Date completed	Altitude above sea level (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Water level		Meth. of lift	Pumping rate		Use	Remarks
							Below ground surface (feet)	Date of measurement		GPM	Date of measurement		
24.36.35.411	E. Claborn	1953		Dr									
36.112	T. Wilson	1914	4585	Dr	167	6	128		W			D,S	
25.35.1.111	C. Delinger			Dr		6	80						
1.332	E. C. Dysart			Dr	120								
2.121a	G. Coons	1947		Dr	150	6	113	9-23-47	E	10	8-24-54	D,I	
2.121b	C. Coons	1954		Dr								D,I	
2.123a	G. Coons	1946		Dr	140				E	9	8-24-54	D,I	
2.123b	G. Coons			Dr	107				N			N	Dry at 107
2.211	Mrs. R. Beasley	1930		Dr	125							D	
2.412a	C. F. Beasley	1952		Dr	170		110					D,I	Irrigation test
2.412b	Beasley	1952		Dr	165		100					I	
2.424	M. Matthews			Dr	120		105						
2.441	W. J. Winchester	1956	4984	Dr	185		100			420	5-16-56	I	Pumping level 142.0, near old abandoned well.
4.132	L. W. Gillespie		5010	Dr	100	5½	60.6	10-27-54	W				
5.442	Gillespie		4934						E	12	10-27-54	D,S	Hydraulic ram and electric pump. Developed spring
8.221a	E. Sheets		4950	Dr	40								
8.221b	Sheets			Dr	170	3	40						.221b is located southwest of .221a
9.113	Gillespie		4922	Dr	133	10	60.0	10-27-54	N			N	Drilled for Town of Clayton
9.212	Gillespie		4941	Dr	125		85.0	10-27-54	W			N	
11.431			4971		150		86						
12.331			4949		147		77.0	3-24-55					

Explanation at end of table

Table 1. Record of wells in Clayton and Seneca quadrangles, Union County, New Mexico (continued)

Location number	Owner	Date completed	Altitude above sea level (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Water level		Meth. of lift	Pumping rate		Use	Remarks
							Below ground surface (feet)	Date of measurement		GPM	Date of measurement		
25.35.12.321	J. Dehm			Dr									No data available
13.211	O. Johnson		4915	Dr		150	56.0	3-24-55	W	1½	3-24-55	S	Pumping level
14.334	McDade		4859	Dr		100	68.1	3-24-55	W	1	3-24-55	S	Pumping level
15.244	R. Leighton (House well)		4905	Dr	200	6	120		E	5	10-30-54	D,S	
15.421	Leighton			Dr	160		60		W			S	
16.433		1955	4980	Dr	100	5	76.3	8-12-55	W	2	8-12-55	S	Pumping level
17.244	E. Sheets		5029	Dr	131	4	93.3	10-26-54					
17.442	J. B. Callahan	1952	5011	Dr	150	6¼	88						
18.244	Sheets		5049	Dr	127.0	4	111.3	10-26-54	W	3	10-26-54	S	Pumping level
19.424	L. H. Haisten		5026	Dr	150								
20.344	D. Wight		4995	Dr	100				W			S	
22.321	Leighton	1952	4928	Dr	70	6 5/8	38.4	10-28-54	W			S	
23.244	McDade		4853		141.3		78.2	3-25-55					
23.334			4878										No access
25.341	U. S. Gov't			Dr	74		53.8	6-29-54	N			N	
27.212	Winsor		4914	Dr	65								
28.121	N. McDade		4970	Dr					W			D,S	
28.314	McDade			Dr	93		76.8	10-28-54				S	Pumping slowly
29.334	J. R. Morgan			Dr	60	6						S	
30.222	Morgan		5002	Dr		5 7/8	82.7	7-27-54				S	
32.322	Rema Leighton	1952	4923	Dr	72	6 5/8							
32.442	Leighton	1934	4898	Dr	50		35		W			D,S	
32.443	Leighton		4886	Dr		6	20		W			S	

Explanation at end of table

Table 1. Record of wells in Clayton and Seneca quadrangles, Union County, New Mexico (continued)

Location number	Owner	Date completed	Altitude above sea level (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Water level: Below ground surface (feet)	Water level: Date of measurement	Meth. of lift	Pumping rate: GPM	Pumping rate: Date of measurement	Use	Remarks
25.35.33.423			4928										
34.422	E. C. Winsor		4862	Dr	190		50		W			S	
25.36.4.311			4873	Dr	150.0		112.5	8-16-54	W			S	
4.444	U. S. Gov't			Dr		4							
6.343	Kitts		4896	Dr									
7.111a	B. B. Altman	1952	4907	Dr	320		47		N	250		N,I	Caved, dry at 47, 7-2-54 Reported original test yield
7.111b	Altman		4905	Dr	100	16	44.1	7-2-54	T			I	
7.113	Altman		4902	Dr	100		82.0	7-2-54		120	7-2-54	I	Pumping level
7.131	Altman			Dr		4			W			D,S	
7.133	J. L. McDade	1955	4912	Dr			58.6	7-2-54				I	Irrigation test Drilling at 150' on 7-2-54
8.312	J. A. Boyd			Dr									
8.333	McDade	1951		Dr	75	7	43.2	7-2-54					Pumping level
10.311	U. S. Gov't		4832				122.0	8-16-54	N			N	No windmill
10.433	U. S. Gov't			Dr	180		170		W			S	
15.124	T. A. Bolinger			Dr	200		175		W			D,S	
16.313	McDade	1950	4829	Dr	77.0	6	55.4	7-2-54	W	3.5	7-2-54	S	Pumping level
18.311	McDade		4903				60		W			D,S	North well
18.331	McDade	1952		Dr	75		60		W			D,S	South well
19.441	McDade			Dr	59.3	6½	34.0	7-2-54	W			S	
20.132	McDade		4878	Dr	78.5	4	73.5	7-2-54	N			N	
20.324	B. Bates (House well)			Dr	85							D,S	

Explanation at end of table

Table 1. Record of wells in Clayton and Seneca quadrangles, Union County, New Mexico (continued)

Location number	Owner	Date completed	Altitude above sea level (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Water level: Below ground surface (feet)	Water level: Date of measurement	Meth. of lift	Pumping rate: GPM	Pumping rate: Date of measurement	Use	Remarks
25.36.21.211	J. L. McDade		4821	Du	64.0	24	60.4	7-1-54	N			N	
21.341	B. Bates	1953		Dr	86	6½	51		W	2½	7-1-54	S	
22.314	Bates	1953		Dr	190	6	67		N				Irrigation test #2
22.321	Bates	1953		Dr	140				N				Irrigation test #1
22.333	Bates	1952		Dr	103	6¼	61			3½	7-1-54		
23.122				Dr					W			S	No access
23.442			4730	Dr	129.0	4	121.7	7-1-54	N			N	
25.444	C. D. Ranch			Dr					W	8½	7-1-54	S	No access
27.222	Mrs. H. I. Pool			Dr	153		69.5	7-1-54	W			S	
29.343	U. S. Gov't			Dr	140	5			W			S	
29.434	U. S. Gov't			Dr	70.0			6-29-54	N			N	Probably caved, dry at 70
31.422	Hanson		4804	Dr	142.6	6	120.2	6-29-54	N			N	No windmill
33.333	U. S. Gov't		4765	Dr	110.0	4	92.7	6-29-54	W	1½	6-29-54	S	
35.311	U. S. Gov't		4690	Dr	125	6	37.8	6-29-54	W			S	
26.35.16.431a	Steed		4937	Dr					W			S	300 ft. south of dug well
16.431b	Steed		4935	Du	24.0		18.6	10-12-54				I	Centrifugal pump
19.224	O. Giles		5160	Dr	132	4	109.7	10-12-54	N			N	
25.443	Zeigh & Elliot			Dr	285	4½			W			D,S	Deepened in 1954
27.112	C. Wall		5083	Dr		8	91.7	10-12-54	T			I	
27.343a	Convalescent Home	1948	5056	Dr	162	7½	93		W			D	
27.443	Town of Clayton No. 2	1935	5052	Dr	170		97		T	40		P	Reported yield
28.421	Fort Jordan, Inc.	1955	5052	Dr			57.0	4-21-55	E			D,S	Not completed, 4-21-55
29.114			5052	Dr	47.8		40.4	10-29-54	W			S	

Explanation at end of table

Table 1. Record of wells in Clayton and Seneca quadrangles, Union County, New Mexico (continued)

Location number	Owner	Date completed	Altitude above sea level (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Water level: Below ground surface (feet)	Water level: Date of measurement	Meth. of lift	Pumping rate: GPM	Pumping rate: Date of measurement	Use	Remarks
26.35.30.444			5046	Dr	90.2		55.1	3-25-55	N			N	
34.134	J. Johnson	1950	4990	Dr	225		165		W			S	
34.212	Town of Clayton No. 3	1900	5057	Dr	750				T	150	7-8-54	P	Leased from Colorado and Southern RR, Reported yiel
34.211a	Town of Clayton No. 1	1908	5052	Dr	125				T	61	4-23-54	P	
34.211b	Town of Clayton Test (Behind City Hall)	1927	5051	Dr	175				N			N	
34.243	Town of Clayton No. 4	1916	5055	Dr	705				T	120	7-8-54	P	Reported yield
34.422	Town of Clayton No. 5	1943	5049	Dr	800				T	290	7- -52	P	Reported yield, Log
34.441	B. Sink		5044	Dr	270				E			D,S	
35.313	Town of Clayton No. 7	1954	5034	Dr	497		189.0	-53	T	275	-53	P	Reported yield, Log
36.143	Town of Clayton No. 6	1954	4975	Dr	374		243	-54	T	135	-53	P	Reported yield, Log
26.36.2.333a	Colorado Interstate Gas Company No. 2		4762	Dr	214		159		T	120		G	
2.333b	Colo. Int. Gas Co. No. 3		4763	Dr	210		145		T			G	
2.334	Colo. Int. Gas Co. No. 4		4766	Dr	213		152.5	6- -40	T			G,D	
2.442			4789	Dr		4	183.1	8-17-54	N			N	No windmill
3.434			4753	Dr		4½	132.7	8-17-54	N			N	No windmill
5.243	C. Lawrence		4825	Dr	66.3	4	56.3	8-17-54	W	1½	8-17-54	S	Pumping level
5.313	Lawrence		4844	Dr	58.0	4	43.9	8-3-54	N			N	No windmill
8.322	Adams		4790	Du			49.0	8-18-54	W	4	8-18-54	S	

Explanation at end of table

Table 1. Record of wells in Clayton and Seneca quadrangles, Union County, New Mexico (continued)

Location number	Owner	Date completed	Altitude above sea level (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Water level		Meth. of lift	Pumping rate		Use	Remarks
							Below ground surface (feet)	Date of measurement		GPM	Date of measurement		
26.36.8.333	D. Paddock	1941	4793	Dr	105	18			T	900		I	
9.214	F. Freeman	1953	4778	Dr	300		95		T	462	6-26-54	I	Log, pumping level 160
9.421	Freeman			Dr	100		77						
10.244	E. Wilson	1900		Dr	140		100						
11.111	Colo. Int. Gas Co. #1		4759	Dr	204		138.6	8-11-54	N			N	Not in use at present
11.434	U. S. Gov't			Dr	158.5	5½			W			S	
13.231	J. Dickens	1953	4725	Dr	240	20	129			500	7-3-54	I	Log, pumping level 141.5
15.412	E. S. Flesher	1950	4753	Dr	310	18	145			1140	1-6-54	I	Log, pumping level 220
15.434	Flesher			Dr	125		85					D,S	
16.343	C. J. Cox	1942		Dr	118							D,S	Old well 20 ft. north
17.124	W. A. Raines	1941	4777	Dr	105	24	50			1000		I	Reported yield
17.334	Raines	1939	4851	Dr	115	5	83					D,S	
17.434	L. A. McElfresh		4831	Dr	160		65					D	
18.223	Zeigh & Elliot		4805	Dr	38		28		W			S	Two wells, same depth
21.213	Cox			Dr	138								
22.133	Flesher		4779	Dr	100		92.4	7-6-54	W			S	
25.242				Dr			113.1	7-5-54		4	7-5-54	S	Pumping level
29.333	Zeigh & Elliot			Dr	185		160		G				
29.434	J. H. Teague			Dr	237		185						
31.212	Zeigh & Elliot			Dr	185		155		W			D,S	
32.433	Kitts			Dr	172	4	120.6	8-16-54	W	3	8-16-54	S	Pumping level
34.413			4850	Dr		7	62.1	5-29-54	W			S	Pump is broken down
35.313			4838	Dr	62	4	55.9	5-29-54	N			S	No windmill

Explanation at end of table

Table 1. Record of wells in Clayton and Seneca quadrangles, Union County, New Mexico (continued)

Location number	Owner	Date completed	Altitude above sea level (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Water level		Meth. of lift	Pumping rate		Use	Remarks
							Below ground surface (feet)	Date of measurement		GPM	Date of measurement		
26.37.5.142	F. K. Petro	1948	4769	Dr	218		190						
8.211	Mrs. Brandon												No access
27.35.2.312	U. S. Gov't		5104	Dr		4			W			S	
3.214	U. S. Gov't		5095	Dr			147.5	8-3-54	W			S	
6.111	C. J. Voth		5180		100		40						
6.313	W. R. Wiggins	1915	5173	Dr	100		35						Reported very good well
7.331	C. J. Harder		5131	Dr	93.2	8	79.2	6-22-55					No windmill
12.121	U. S. Gov't		5012	Dr			128.0	8-3-54					No windmill
12.244	U. S. Gov't		4984	Dr	144.0		94.0	8-3-54					
13.424	I. W. Walker			Dr	84		68						
27.36.1.114	C. H. Kennann		4823	Dr	214		190		W			S	Reported very good well
1.141	Kennann	1901		Dr	178		160		W		10-19-54	S	
1.334			4848			4	179.2	8-18-54	N			N	
2.242	Kennann	1950	4834	Dr	200	$6\frac{1}{4}$	170						
2.444	D. H. Mock		4865	Dr	220		205		W			S	
3.333	J. A. Barton	1912	4880	Dr	160	$5\frac{1}{2}$	140		W			S	
3.442	Mock		4882	Dr	200								
4.121	Barton		4905	Dr	80		75		W			D,S	
4.414	Barton	1907	4905	Dr	206	$5\frac{1}{2}$	180						
5.442	W. E. Oldham		4905	Dr	200	4	100		W			S	
6.244	Walker	1920	4960	Dr	103							D,S	
7.244	Oldham		4895	Dr	175	6	163		W			D,S	
7.322	W. E. Oldham	1949	4935	Dr	183	5	165		W	30		S	Reported yield
8.131	Oldham		4896	Dr	173	6	163		W			S	

Explanation at end of table

Table 1. Record of wells in Clayton and Seneca quadrangles, Union County, New Mexico (continued)

Location number	Owner	Date completed	Altitude above sea level (feet)	Type of well	Type of well (feet)	Diameter of well (inches)	Water level: Below ground surface (feet)	Water level: Date of measurement	Meth. of lift	Pumping rate: GPM	Pumping rate: Date of measurement	Use	Remarks
27.36.8.334	Mrs. Morris		4865	Dr		4	95.5	8-4-54	N			N	No windmill
8.434	Morris		4851	Dr		4½	82.0	8-4-54					
10.244			4820	Dr		4½	75.0	8-18-54	N			N	
10.331	O. M. Kennann			Dr									No information
12.234	C. H. Kennann		4798	Dr	156	6½	104.8	8-18-54		4	8-18-54		
13.342	Mrs. B. Mock	1922	4767	Dr	130				W			S	
13.442	C. H. Kennann	1951		Dr	133	6¼	102.0	8-18-54		1.5	8-18-54		Pumping level
15.331	Kennann			Dr	120	6	27.1	8-18-54					No windmill
17.212	F. Carter		4843	Dr	100		60					D,S	Not visited
17.434	Carter		4837	Dr	200	16	73.1	7-7-54	T	1000	7-7-54	I	
20.322	U. S. Gov't		4858	Dr			92.3	8-3-54	W	1	8-3-54	S	Pumping level
22.111	Kennann		4791	Dr	62	6¼	35.5	8-18-54					
22.333	Kennann		4851	Dr			121.9	8-18-54					
23.122	Kennann			Dr	120	4	90						
23.422	Kennann		4751	Dr	115		85						
25.111a	Mock		4796	Dr	233.2	8	126.0	8-17-54	N			N	
25.111b	Mock		4794	Dr		10 3/4			N			N	Oil test, Bur. log no. 4705
25.133	Mock	1910	4805	Dr	220	6	180			2.5	8-17-54		
26.444	Mock	1916		Dr	240	4			N			N	No access
27.422	E. Hasting		4864	Dr									No data obtained
28.222			4877	Dr		3	120.0	8-17-54	N			N	No windmill
29.411	C. W. Lawrence	1952	4974	Dr	220	6							
32.113	Lawrence		4859	Dr									
33.133	Lawrence					4							Sealed

Explanation at end of table

Table 1. Record of wells in Clayton and Seneca quadrangles, Union County, New Mexico (continued)

Location number	Owner	Date com- pleted	Altitude above sea level (feet)	Type of well	Type of well (feet)	Diameter of well (inches)	Water level		Meth. of lift	Pumping rate		Use	Remarks
							Below ground surface (feet)	Date of measure- ment		GPM	Date of measure- ment		
27.36.34.244	Mrs. B. Mock		4854	Dr	240		220						
35.244				Dr	240.0		228.0	8-17-54					
36.144	Mrs. B. Mock	1925		Dr	200	4							
27.37.5.111	E. Fones	1910	4754	Dr	125	4½	117					S	
6.331a	J. E. Fones	1915	4811	Dr	258		151			4			
6.331b	J. E. Fones (West Irrigation well)	1943.	4812	Dr	265	8	157		T	45	7-7-54	I	
6.442	J. E. Fones (East Irr. well)	1953	4789	Dr	325	18 -	140		T	700		I	Reported yield
7.222	Fones	1900	4795	Dr	152	4½	140		W	41.5		S	Reported yield
8.244	B. Mock		4749	Dr		3½	100.4	8-18-54	W			S	
17.311	Mock	1940	4745	Dr	120	6	83.6	8-18-54	W			S	Pumping level
17.443	R. Mock		4713	Dr			24.0	8-18-54					
18.133	B. Mock	1909		Dr	120								
18.443	R. C. Gregory		4754	Dr									No data available
20.122	D. Mock		4726	Dr	85		74.2	8-18-54	W			S	
30.124	D. Mock		4707	Dr	160		135						
31.222	Mock	1944	4760	Dr	185		145.7	8-18-54					
31.343			4799	Dr	124.0	4	117.9	7-16-54					No windmill
28.35.1.311			5040	Dr	46.2								Dry 9-30-53
1.413	W. & O. Harris	1950	5023	Dr	212	5½	175						
3.113		1931	5061	Dr	65.9		45.4						
4.113	P. Miller	1953	5008	Dr	100	14	19.0	7-7-54		150		I	Reported yield
5.434	H. Belew		5053	Du			23.0	8-4-54					
8.211	Belew		5048	Dr	35								

Explanation at end of table

Table 1. Record of wells in Clayton and Seneca quadrangles, Union County, New Mexico (continued)

Location number	Owner	Date completed	Altitude above sea level (feet)	Type of well	Type of well (feet)	Diameter of well (inches)	Water level		Meth. of lift	Pumping rate		Use	Remarks
							Below ground surface (feet)	Date of measurement		GPM	Date of measurement		
28.35.8.343	H. Belew		5150	Dr	87.5	4½	85.5	8-4-54	W				
9.111	U. S. Gov't		5056	Dr	60	6							Weak well
9.224	U. S. Gov't		5089	Dr		6	44.3	8-5-54	N			N	Weak well
9.442	W. Keener		5135	Dr	200	6	180		W			S	
10.333	J. Miller		5128	Dr	200		180		W			S	
11.242	M. Baker		5085	Dr	122.0	4	116.0	10-11-54	W	1	10-11-54	S	Pumping level
11.313	U. S. Gov't		5120	Dr	180		150		W			S	
12.433			5065	Dr					W	1½	7-7-54	S	No access
13.111			5020	Du			14.3						
13.242			5020	Dr		4			W			S	Measuring tape to 124' only
15.414			5044	Dr	33.1	6	29.2	8-4-54	N			N	
16.444	W. Keener	1940	5084	Dr	130	6	115		W				
18.123			5170	Dr	95		70.1	9-30-53					
19.121			5240	Dr	110.4								Dry at 110.4 on 9-30-53
20.431			5124	Dr	133.5		120.0	10-30-53					
23.342	J. Miller	1910	5053	Dr	206		146		W			D,S	
24.242a	O. Nece		5013	Dr	54.3	4	32.8	10-11-54	W			N	
24.242b	Nece		5015	Dr	200	4	192		W			S	200 ft. west of .242a
24.443	L. Oldham	1949	5043	Dr	93	5	77			3½		S	Reported yield
25.133	L. Oldham (House well)		5021	Dr	92	6				3½			Reported yield
25.234	O. T. Campbell	1954		Dr									Irrigation test, not completed 10-11-54
25.242	O. T. Campbell	1952	4982		62	6½	30		W			D,S	

Explanation at end of table

Table 1. Record of wells in Clayton and Seneca quadrangles, Union County, New Mexico (continued)

							Water level			Pumping rate			
Location number	Owner	Date completed	Altitude above sea level (feet)	Type of well	Type of well (feet)	Diameter of well (inches)	Below ground surface (feet)	Date of measurement	Meth. of lift	GPM	Date of measurement	Use	Remarks
28.35.26.242	O. T. Campbell		5018	Dr	200	6			W			N	
26.442	U. S. Gov't		5077	Dr	14.0				N			N	Dry at 14' on 8-4-54
34.114	U. S. Gov't		5129	Dr	165.0				W			S	Attempts to measure water level unsuccessful
35.134	U. S. Gov't		5090	Dr			182.0	8-3-54	N			N	No windmill
28.36.2.444	R. Mock	1938	4701	Dr	32		28		W				
3.112	J. Harris		4823	Dr	175	5			W			S	
4.141	Harris			Dr	116.0				N			N	Dry at 116' on 8-27-54
5.111	Harris			Dr	150	4			W			S	
10.212a	Harris			Dr	80				E			D,S	
10.212b	Harris		4759	Dr	81.0	6	65.2	8-22-54	W			S	
11.343	Harris			Dr	108.0	4½	103.1	8-27-54	W			S	
11.424	C. Kennann	1950		Dr	70	6½	49.2	8-27-54	W	1	8-26-54	S	Pumping level
12.323	L. C. Allen		4718	Dr	56		35		W			D,S	
13.143	J. Kennann (House well)		4721	Dr	65	5	55		W			D,S	
14.224	Kennann (½ mi. N.W. of house)			Dr	70		60		W			D,S	
14.414	R. Walker	1924		Dr	150								No access
15.141	U. S. Gov't	1914		Dr	80		65		W			S	
15.444	W. L. Scroggs	1918	4869	Dr	231		180		W				
16.333	R. Rinker		4910	Dr	85		60.5	8-19-54	N			N	No tower
16.411	Rinker		4898	Dr	140								
19.114			4956	Du	21.6	48	19.2	10-11-54					
19.123			4942	Du	8.0	6	6.2	10-11-54					
19.343	O. Campbell		5005	Dr		4							

Explanation at end of table

Table 1. Record of wells in Clayton and Seneca quadrangles, Union County, New Mexico (continued)

Location number	Owner	Date completed	Altitude above sea level (feet)	Type of well	Type of well (feet)	Diameter of well (inches)	Water level		Meth. of lift	Pumping rate		Use	Remarks
							Below ground surface (feet)	Date of measurement		GPM	Date of measurement		
28.36.19.442			4963	Dr	48.6		39.0	9-30-53					Tower, no windmill
20.244	R. Rinker			Dr	85	4	65.6	8-19-54					
20.444	Rinker		4913	Dr	200								No information
21.334	J. Freeburg		4876	Du	14.2		13.1	8-26-54	W			D,S	
21.433	Freeburg		4769	Dr	37		35.8	8-26-54					No windmill
23.222	Baker		4769	Dr	128								
23.333	R. Walker		4817	Dr	175.0	5	135.7	8-19-54					
24.244					15.4	4							
24.343	Baker (House well)			Dr	150								No access
27.134	Rinker		4830	Dr	124		104.3	8-19-54					
27.142	U. S. Gov't		4825	Dr	161								
28.113	Freeburg		4893	Du	12.9	24	11.1	9-25-54	W				
28.341	Harris		4905	Du	11.3		5.8	8-25-54	W	3½	8-25-54		
29.113	C. A. Twombly	1951	4942	Du	14.4		14.0	8-26-54	W			S	
29.131	Twombly	1950	4967	Dr	51	6	46		E	4		D,S	Reported yield
29.331	G. E. Blackwell (House well)		4984	Dr	80	5	66			4		D,S	Deepened in 1953, reported yield
29.444	U. S. Gov't	1920	4948	Du	27.5	6	22.0	8-25-54	W			S	
30.224	Twombly	1951	4948	Dr	21	6	19.2	8-26-54	W			S	
30.311	Blackwell		4985	Du	30		20		N			N	
30.444	Blackwell	1922	4988	Dr	70		65						
31.122	A. Shellenberg		5005	Dr	64.3	5	60.7	10-11-54	W			S	
31.134	Shellenberg		5000	Dr	80		20		W			S	
31.242	Shellenberg (House well)		4960	Dr	50		45		W			D,S	Weak well

Explanation at end of table

Table 1. Record of wells in Clayton and Seneca quadrangles, Union County, New Mexico (continued)

Location number	Owner	Date completed	Altitude above sea level (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Water level		Meth. of lift	Pumping rate		Use	Remarks
							Below ground surface (feet)	Date of measurement		GPM	Date of measurement		
28.36.32.111	School Dist. No. 36		4965	Dr	70		65						
32.333	C. Williams	1918	4975	Dr	96							S	Weak
32.444	C. A. Twombly		4905	Dr	210								
33.423	J. Myers			Dr	260		180		E			D,S	
34.421	C. Kennann		4873	Dr	240		220		W			S	
36.113	Kennann			Dr	200		185		W	10		S	Reported yield
28.37.5.343	R. Mock			Dr	119.9	4			N			N	Dry at 119.9' on 8-25-54
5.444	Mock		4772	Dr	140								Tape to 79' only
6.242	Mock	1950		Dr	153	6	132.0	8-26-54	W			S	
6.331	Mock	1950		Dr	83	6	78		W			S	
7.241	Mock		4697	Dr	50.1	7	33.5	8-25-54					
7.244	Mock		4661	Dr	32.2	4	27.0	8-25-54	W			S	
7.332	L. Allen			Dr	50		33.4	8-26-54	W			S	
8.332	Mrs. W. Smith	1890	4646	Du	18		12					D,S	
18.121	R. Walker		4687	Dr	50		40.2	8-26-54	W			S	
18.323	J. Kennann	1951		Dr	56	6	35		W			S	
19.121	W. Baker			Dr	95				W			S	
20.244	Baker		4675	Dr	53.0	6	44.6	8-26-54	W			S	Pumping level
20.433	S. Freeburg	1917	4715	Dr	130		80		W			D,S	
29.432	Freeburg	1952		Dr	53	6¼	42		W			S	
30.122	W. Baker			Dr	95								
31.331	C. Kennann		4778	Dr	140	2	120		W			S	
32.112			4699	Dr	62.0		53.5	8-26-54	N			N	
32.424	McLain		4751	Dr	120				W			D,S	

Explanation at end of table

Table 1. Record of wells in Clayton and Seneca quadrangles, Union County, New Mexico (continued)

							Water level			Pumping rate			
Location number	Owner	Date completed	Altitude above sea level (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Below ground surface (feet)	Date of measurement	Meth. of lift	GPM	Date of measurement	Use	Remarks
29.35.13.424	A. Witt	1948	5000	Dr	190				W			S	No access
15.332	Witt	1948	5076	Dr	265		125		W			S	
18.424	J. Weiland	1951	5197	Dr	180	5½			W			S	
19.212	W. Behm		5197	Dr		4	50.5	8-5-54	N			N	No windmill tower
20.133	Behm		5239	Dr	190		175						
20.211			5166				18.4	6-27-55					
21.314	T. Irons	1912	5131	Dr	130		105						Hot water at 113 feet reported
22.332	Witt		5008	Dr	50	9	34.2	10-9-54	W			S	
23.234	Witt	1948	5095	Dr	150				W			S	No access
28.131	H. Belew		5103	Dr	116.0	4	101.9	8-5-54	W			S	Tower
28.431	Belew		5025	Dr	61.4	4	42.7	8-5-54	W			N	Tower, but no windmill
29.311	W. Behm	1912	5147	Dr	116		95		W			D,S	
30.233	M. Belew	1951	5190	Dr	284	7¼	119.8	8-5-54	W			S	
30.242	Belew		5176	Du	19.5				N			N	Dry, 19.5' on 8-5-54, Well drilled to 390' at this site in 1951 was dry hole
31.443	Belew		5059	Du	18		16.5		W			D,S	
32.443	Belew		5017	Dr	77.0	4	27.0	8-5-54	N			N	No windmill
34.111	J. Beasly			Dr	51.0								
29.36.14.342	Mrs. I. Martinez		4800	Dr	140.0	3½	131.0	8-27-54	W			D,S	
15.122	J. T. Harris			Dr	162.0	4½	158.0	8-27-54	W			S	
19.143	A. Witt (House well)	1939		Dr	50				W			D,S	
21.243	Harris		4827	Dr	180	8			W			S	
22.424	Harris		4864	Dr	179.0		174.0	8-27-54	W			S	
24.314	Harris			Dr	180				W			S	

Explanation at end of table

Table 1. Record of wells in Clayton and Seneca quadrangles, Union County, New Mexico (continued)

Location number	Owner	Date completed	Altitude above sea level (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Water level		Meth. of lift	Pumping rate		Use	Remarks
							Below ground surface (feet)	Date of measurement		GPM	Date of measurement		
29.36.33.314	Harris			Dr	180	4	121.0	8-27-54	W			S	
35.122	D. Mock		4810	Dr	125		115		W			S	
35.211	Mrs. I. Martinez	1943	4833	Dr	170		150		W			D,S	
35.413	Mock		4768	Dr	180		120		W			S	
29.37.19.431	Mrs. W. Smith		4874	Dr	100				W			S	No access
20.133			4850	Dr	200.0		156.5	8-26-54	N			N	Not operating
20.334	J. Harris		4872	Dr	170		127.2	8-26-54	W			S	
30.424	R. Mock	1942	4851	Dr	200	6	85.4	8-26-54	W	1½	8-26-54	S	Pumping level
31.232	Mock (House well)	1902	4807	Dr	176.9	6	130.5	8-26-54	W			D,S	

Explanation:

Location number underscored indicates an analysis of water from the well is listed in Table 2
Altitude above sea level: determined with surveying altimeter
Type of Well: Dr, drilled; Du, dug
Depth of well and Water level: When shown to nearest foot are reported, when given to nearest 0.1 foot are measured.
Method of Lift: W, windmill; G, gasoline engine and pump jack; H, hand pump; N, no pump; T, deep well turbine pump; E, electric motor on small pump
Use: S, stock; D, domestic; I, irrigation; N, none; P, public supply; G, industrial (gas pumping plant)

Table 2. Water analyses

Well number	Analysis number	Date of collection	Silica (SiO_2) ppm	Sodium(Na) Potassium (K) ppm	Carbonate (CO_3) ppm	Bicarbonate (HCO_3) ppm	Sulfate (SO_4) ppm	Chloride (Cl) ppm	Fluoride (F) ppm	Nitrate (NO_3) ppm	Hardness as $CaCO_3$		Specific Conductance (Micromhos at 25°C)	Percent sodium	Sodium Adsorption Ratio
											Total ppm	Non-carbonate ppm			
24.35.3.244b	27123	7-27-54	21	22	0	238	31	10	0.6	4.9	199	4	459	19	.7
7.144	27124	7-27-54	19	21	0	206	21	7.5	0.6	1.2	159	0	367	22	.7
7.333	27125	7-26-54	19	58	0	312	129	47	0.8	1.7	334	78	839	27	1.4
15.133b	27126	7-22-54	38	40	0	216	46	60	0.8	15	236	59	574	27	1.1
23.111	26654	6-26-54	33	30	0	221	37	10	1.2	4.9	176	0	434	27	1.0
33.334	27127	7-26-54	17	44	0	224	34	25	0.8	1.0	161	0	482	37	1.5
24.36.10.133	26641	7-1-54	21	30	0	244	45	24	1.6	7.7	226	26	535	22	.9
12.333	23407	8-12-53	17	29	0	260	38	8	1.0	1.0	204	0	492	24	
30.422	26655	6-26-54	35	17	0	212	35	16	0.6	11	206	32	459	15	.5
25.35.2.121a	27892	8-24-54			0	216					266	89	586		
2.123a	27893	8-24-53	33	50	0	220	67	32	2.2	29	280	100	597	8	.3
2.441	33187	5-16-56	36	12	0	242	29	14	1.0	8.4	232	34	483	10	.3
15.244	27899	10-30-54	12	37	0	304	183	19	1.2	.0	390	141	830	17	.8
25.36.4.444	33188	5-16-56	13	16	0	260	39	10	1.0	2.7	237	24	503	13	.5
26.35.27.443 Clayton No. 2		11-29-56									240		600		
34.212 Clayton No. 3	26714	7-8-54	28	15	0	242	23	8	0.6	4.1	206	8	445	14	.5
34.221a Clayton No. 1	26715	7-8-54	37	25	0	248	45	64	1.4	60	338	135	768	14	.6
	29093	3-30-55	37	11	0	242	65	88	1.4	89	442	244	934	5	.2
34.243 Clayton No. 4	26716	7-8-54			0	238		8					426		
	33221	5-23-56	23	27	0	252	34	12	1.0	3.8	206	0	490	22	.8

Analyses by United States Geological Survey Quality of Water Laboratory, Albuquerque.
ppm - parts per million

Table 2. Water analyses (continued)

Well number	Analysis number	Date of collection	Silica (SiO_2) ppm	Sodium(Na) Potassium (K) ppm	Carbonate (CO_3) ppm	Bicarbonate (HCO_3) ppm	Sulfate (SO_4) ppm	Chloride (Cl) ppm	Fluoride (F) ppm	Nitrate (NO_3) ppm	Hardness as $CaCO_3$ Total ppm	Non-carbonate ppm	Specific Conductance (Micromhos at 25°C)	Percent sodium	Sodium Adsorption Ratio
26.35.34.422 Clayton No. 5	26717 33222	7-8-54 5-23-56	19 19	54 44	0 0	285 269	29 28	7 8.0	1.0 1.0	2.0 2.4	160 169	0 0	499 491	42 36	1.9 1.5
35.313 Clayton No. 7	23848 33228	-53 5-21-56	20 13	30 35	0 0	246 275	42 35	12 12	1.0 1.0	3.0 .4	201 205	0 0	492 506	25 27	 1.1
36.143 Clayton No. 6	33223	5-22-56	28	17	0	226	18	9.0	.8	5.1	184	0	414	17	.6
26.36.13.231	26644	7-3-54	29	14	0	240	16	6.5	0.8	6.0	198	2	408	14	.4
15.412	26646	7-6-54	26	23	9	201	47	34	0.8	7.4	234	54	530	18	.7
17.434	*512155	6-12-54		69.0	0	410.0	471.4	20.6	1.6	0.0	708.3				
25.242	26718	7-5-54	50	14	0	241	21	13	2.4	11	224	26	476	12	.4
34.413	33224	5-16-56	31	1.8	0	216	5.4	10	.4	18	208	31	405	2	.1
27.35.12.244	27130	8-3-54	30	17	0	226	18	9	0.8	1.2	181	0	436	17	.6
27.36.17.434	26719	7-7-54	23	3.9	0	194	26	8	0.2	23	208	49	416	4	.1
25.133	27147	8-17-54	21	23	0	248	27	9	0.8	4.1	200	0	451	20	.7
27.37.6.331b	26638	7-6-54	29	17	0	178	33	14	0.8	4.9	170	24	379	17	.6
6.442	26639	7-6-54	41	15	0	236	34	14	1.0	5.4	222	28	471	13	.5
28.35.12.433	26643	7-7-54	50	45	0	230	95	46	2.0	13	270	82	696	27	1.2
28.36.13.143	27896	8-28-54	38	38	0	184	209	210	0.6	76	645	494	1,410	11	.6
14.224	27898	8-28-54	32	17	0	220	12	3	0.2	9.3	168	0	377	18	.6
28.341	27905	8-25-54			0	264				5.6	310	94	672		
29.36.33.314	27908	8-27-54	22	79	0	340	153	28	1.4	7.7	315	36	866	35	1.9

*Analysis by New Mexico State Public Health Laboratory
Analyses by United States Geological Survey Quality of Water Laboratory, Albuquerque.
ppm - parts per million