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GEOLOGY AND GROUND-WATER RESOURCES OF THE PORTALES VALLEY AREA, ROOSEVELT AND CURRY COUNTIES, NEW MEXICO

By

Sherman E. Galloway

A Thesis

Submitted in Partial Fulfillment of the

Requirements for the Degree of

Master of Science in Geology

The University of New Mexico

1956

This thesis, directed and approved by the candidate's committee, has been accepted by the Graduate Committee of the University of New Mexico in partial fulfillment of the requirements for the degree of

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GEOLOGY AND GROUND-WATER RESOURCES OF THE PORTALES VALLEY AREA, ROOSEVELT AND CURRY COUNTIES, NEW MEXICO

By

Sherman E. Galloway

ABSTRACT

The Portales Valley is located on the Llano Estacado of eastern New Mexico and western Texas and represents a sediment-filled erosional trough that is incised through a mantle of Tertiary sediment into the underlying rocks of Triassic and Cretaceous age. The valley is a part of an early Pleistocene drainage system that appears to have included the headwater of the present Pecos River and extended across the plains to the approximate position of the present Brazos River drainage near Lubbock, Texas. The valley fill present in this trough includes sediment of both fluviatile and aeolian origin.

The detailed mapping of the top of the Triassic "red beds" at the base of the valley fill reveals no depression of this surface in the vicinity of three of the larger surface depressions in the area, which discounts, to some extent, the generally accepted theory that the surface depressions of the Llano Estacado are the result of collapse, due to the removal of some of the more soluble parts of the underlying strata by solution.

The ground-water reservoir occurring in the valley-fill sediment extends from the top of the underlying Triassic "red beds" to the water table and is limited on either side by definite hydraulic boundaries which reflect the geological and hydrological conditions encountered in these areas. Recharge to this reservoir is derived entirely from precipitation that falls on the valley and the adjacent areas. Most of the precipitation comes during the growing season,

when evaporation and transpiration are at a maximum, therefore the amount of the precipitation reaching the water table is probably very small.

Since 1910, and particularly since the closing years of World War II, considerable development of the ground water occurring in the valley fill has been made for irrigation purposes. This increase in development has resulted in a progressive decline of the water levels in this area. The results of this study indicate that the water occurring in the valley fill is the only water of good chemical quality occurring in the Portales Valley that can be obtained in quantities that are sufficient for normal irrigation, municipal, industrial, stock, and domestic uses, and that if the present rate of ground-water withdrawal is continued, under the conditions presently existent in the valley, this source will ultimately be depleted.

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INTRODUCTION

Water levels in shallow-water wells in the Portales Valley area of New Mexico that derive water from the Quaternary valley fill present in this locality have shown a general decline since the initiation of irrigation development near the turn of the century. This trend has been greatly accelerated by the impetus of irrigation development that followed World War II, and has resulted in an increasing concern for the future of the irrigation water supply of this area, both among the water users and the state officials responsible for the administration of this vital resource.

The results of investigations by previous workers have shown the general principles of the occurrence of ground water in this area, and the continued collection of data since 1931 has resulted in the accumulation of a vast store of information relative to the hydrology of the shallow ground-water reservoir in the Portales Valley. To date, however, no comprehensive compilation or integration of these data has been presented, upon which an estimate of the ground water available to pumpage or the possible determination of the future of the water supply of this area could be based.

Early in 1953 it became apparent that a comprehensive quantitative survey of the ground-water resources of this area was imperative for the determination of the future availability of ground water. In 1954, the writer, at the request of the New Mexico State Engineer, began a quantitative study of the ground-water resources of this valley. The material included in this report represents only a part of the results of this more comprehensive study.

PURPOSE AND SCOPE

The study of the Portales Valley was made primarily to determine the present extent of the ground-water reservoir in the valley fill of Pleistocene to Recent age which overlies the Triassic "red beds" in order to provide a more accurate basis for the determination of the present and future conditions of water use. The objectives of this study have been to determine the lithologic characteristics and vertical and lateral extent of the various geologic units underlying the valley, and their relation to the occurrence of ground water; to prepare maps showing the configuration of the land surface, water table, and base of the ground-water reservoir; to determine the general relationship of the various climatic factors which relate to the general occurrence of ground water in the valley; to review briefly, the history and effects of ground-water development in the area; and to determine, in a general way, the chemical quality of the ground water occurring in the region.

Although the discussion in this report has been limited largely to the Portales Valley, from the standpoint of geology and hydrology the area studied is only a part of a much larger hydrologic region comprising most of southeastern New Mexico and western Texas. This has necessitated the expansion of some parts of the study beyond the borders of the area included in this report, especially to include regional stratigraphy, structure, climatology, and quality of water data.

LOCATION AND SIZE OF AREA

The Portales Valley is located in north-central Roosevelt County and southwestern Curry County, New Mexico, and occupies a part of the west-central Llano Estacado or "Staked Plains" area of eastern New Mexico and western Texas. It extends from Krider, New Mexico, at the western

edge of the Llano Estacado, in an east to southeastward direction through Portales, the county seat of Roosevelt County, to Big Salt Lake, near the New Mexico-Texas state line (Fig. 1).

An area of approximately 850 square miles of underground drainage is tributary to the Portales Valley (Theis, 1932, p. 143). A major part of this area is included in the Portales Underground Water Basin as declared and extended by order of the New Mexico State Engineer, and is subject to his administrative jurisdiction. An area of about 621 square miles is included in the declared underground water basin. The area covered during the investigation is shown in Figure 1.

GENERAL DESCRIPTION OF AREA

The Portales Valley, as it exists today, is a remnant of a Pleistocene drainage system, which appears to have followed the present course of the upper Pecos River southeastward to the vicinity of Fort Sumner, De Baca County, New Mexico, and then continued its course eastward across the plains through northern Roosevelt and southern Curry Counties, New Mexico, to the vicinity of the valley of the Double Mountain Fork of the Brazos River, northeast of the city of Lubbock, Lubbock County, Texas. The river which flowed in this channel was probably beheaded by the headward erosion of the Pecos River in early Pleistocene time (Baker, 1915, p. 54) (Fiedler and Nye, 1933, p. 99). At the present time there are no streams flowing in this valley and no well-developed stream channels of any length.

Geologically, the valley contains a well-developed buried stream channel that was incised through the mantle of Tertiary sediment which covers the region and any remnants of Cretaceous sediment that might have existed in the area prior to the erosion of the valley. This

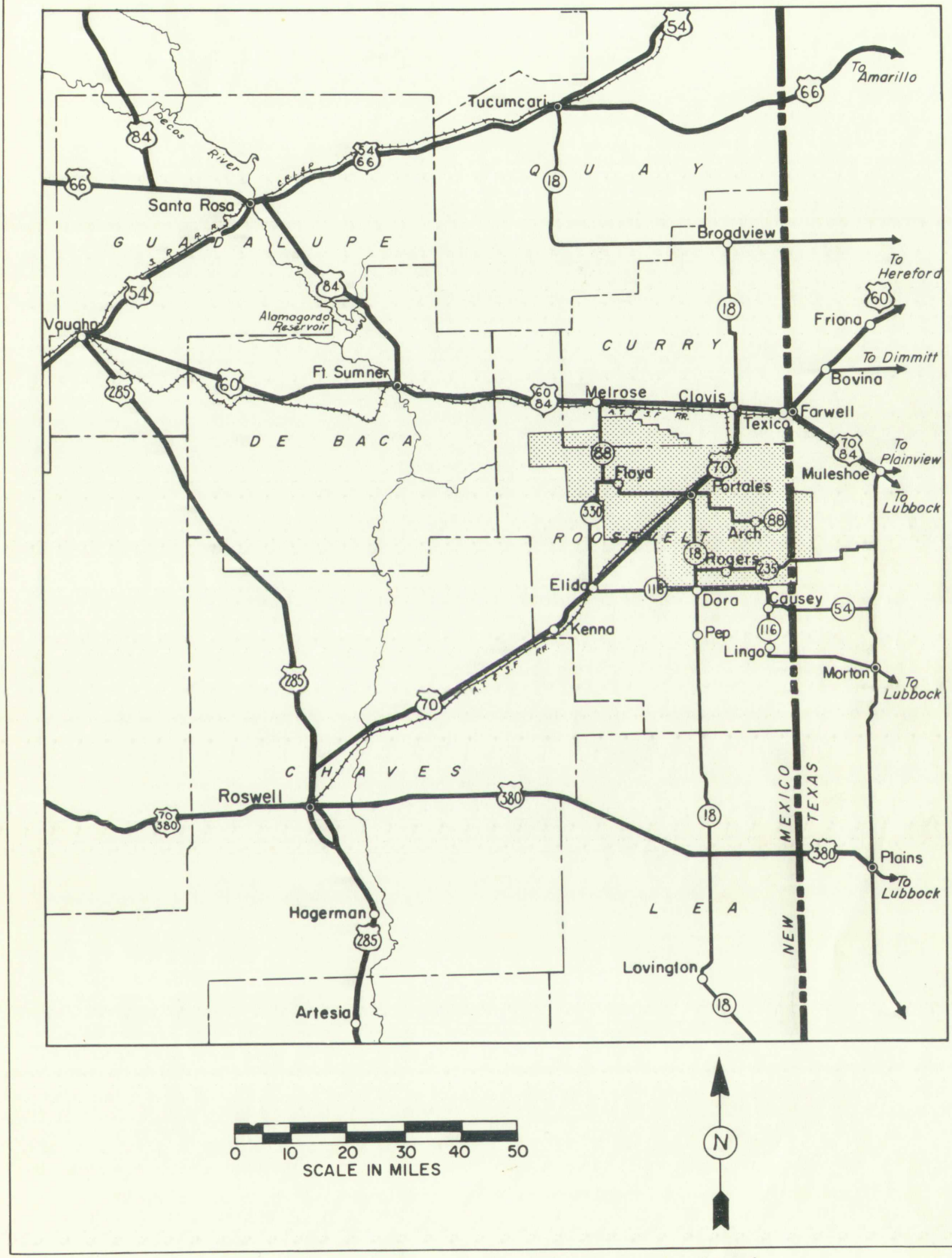

Figure 1. Index map of area studied

erosion surface extends into the "red beds" of the underlying Dockum group in most of the valley proper. The valley was subsequently filled with as much as 20 feet of fluvatile sand and gravel at the base of the deposit, and up to 135 feet of an overlying deposit of aeolian material. The total valley fill ranges from 50 to 150 feet in thickness in most of the valley area.

The surface of the major part of the area is remarkably smooth, with surface slopes ranging from 15 to 150 feet per mile at right angles to the axis of the valley and from 5 to 15 feet per mile along the valley floor. Surface depressions and playas occur throughout the area. Some of these depressions, which extend below the water table, contain water throughout most of the year; the majority, however, are dry except for short periods that follow excessive precipitation. A belt of sand dunes as much as 5 miles wide and 50 feet high bisects the entire length of the valley, separating the principal area studied from Blackwater Draw which lies to the north and east. Another somewhat smaller belt lies north of Blackwater Draw.

Climatologically, the Portales area is classed as semiarid. Native vegetation consists of prairie grasses, mesquite, yucca, cacti, plum brush, greasewood, and other plants.

Most of the land is devoted to ranching and farming and at the present time the valley is classed as one of the principal agricultural areas of New Mexico. Roosevelt County ranks first in New Mexico in dairying, and in addition to the dairy products the valley produces large numbers of poultry, sheep, cattle, and hogs, many of which are fattened on locally grown grain and alfalfa. Approximately 50,000 acres are under irrigation, from which is produced a diversity of

crops that include peanuts, sweet potatoes, grain sorghum, alfalfa, cotton, and vegetables. Considerable acreage is also devoted to the production of grain sorghum and broomcorn by dry-farming methods, which are usually successful in years of normal or above normal precipitation.

Portales has a population of about 9,000 which is devoted, for the most part, to providing services to the surrounding agricultural area. The industries of this city are almost entirely dependent on agriculture for their existence and include peanut processing, poultry processing, feed manufacturing, cotton ginning, processing of dairy products, meat packing, canning, broom manufacturing and the manufacturing of agricultural machinery. The city is also the home of Eastern New Mexico University. The city is located on U. S. Highway 70 and the Clovis, New Mexico — Pecos, Texas branch of the Atchison, Topeka, and Santa Fe Railway. Access may be had to all the valley area from this city via farm to market, section-line and ranch roads.

Other communities in the area include Floyd and Arch which are located 16 miles west-northwest and 16 miles east-southeast, respectively, from Portales.

PREVIOUS REPORTS

Although a number of the early reports on the High Plains area of eastern New Mexico and western Texas (Hill, 1893; Johnson, 1901, 1902; et al.) set forth the general geology and the occurrence of underground water in this region, the earliest investigation that dealt specifically with the Portales Valley was by O. E. Meinzer, assistant geologist of the U. S. Geological Survey, who spent a short time in the valley in 1909. This study resulted in two reports, (Meinzer, 1909a, 1909b) wherein he outlined the sand-dunes area of the valley and the belt in which ground

water occurred within 25 feet of the surface. He also pointed out that the Portales Valley was an abandoned stream channel, cut off by capture by the Pecos River. In 1914, a rather comprehensive study of the entire northern Llano Estacado, including the Portales Valley, was made by C. L. Baker and his published report (1915) includes many valuable data.

The most comprehensive investigation of ground water in the area under discussion was made by C. V. Theis in 1931. The investigation covers both Roosevelt and Curry Counties, but the majority of the data presented in his published report (1932) pertains to the Portales Valley. Additional data of a continuing nature, collected since the completion of this report, are given in progress reports by Theis in 1934 and 1939, and Conover and Akin in 1942.

In 1938, a discussion of ground-water recharge in the southern High Plains area was published by Theis, and a recharge estimate for the Portales Valley was included.

To date, the most comprehensive study of the geology of the Portales valley fill is that made by H. W. Robbins. This study was made in the period of 1939 to 1941, and the resulting report (1941) contains a wealth of information relative to the development of the valley and the dating of the sediment in the Portales area.

Water-level measurements, annual pumpage, and other pertinent ground-water data for the valley have been collected by the U. S. Geological Survey since 1931. These data are given in the annual water-level and artesian-pressure reports of this federal agency.

In addition to these cited works, there are a number of reports, both published and unpublished, by various investigators, that deal with the region in which the area is located. These deal, for the most part,

with the regional stratigraphy and geologic structure of the subsurface Paleozoic and Mesozoic strata, extremely detailed geology at sites of archeological interest, climatology, and farm economics. The more important of these are listed in the selected supplemental bibliography.

WELL-NUMBERING SYSTEM

The system used for numbering wells in this report corresponds to the system used by the U. S. Geological Survey for numbering wells in New Mexico and is based on the common system of subdivision of public lands into sections. By means of this system, the well number, in addition to designating the well, locates its position to the nearest 10-acre tract in the land net. The well number is divided by periods into four segments. The first segment denotes the township north or south of the New Mexico base line; the second denotes the range east or west of the New Mexico principal meridian; and the third denotes the section. In the Portales Valley area, where wells are both north and south of the base line, an N is added to the first segment of the well number if the well is north of the base line and, similarly, an S is added to the first segment of the well number if the well is south of the base line. The fourth segment of the number, which consists of three digits, denotes the particular 10-acre tract in which the well is situated. For this purpose, the section is divided into four quarters, numbered 1, 2, 3, and 4, in the normal reading order, for the northwest, northeast, southwest and southeast quarters, respectively. The first digit of the fourth segment gives the quarter section. Similarly, the quarter section is divided into four 40-acre tracts numbered in the same manner, and the second digit denotes the 40-acre tract. Finally, the 40-acre tract is divided into four 10-acre tracts, and the third digit denotes

the 10-acre tract. Thus, well 1S.34.19.123 is the SW¼ NE¼ NW¼ Sec. 19, T. 1 S., R. 34 E. If a well cannot be located within a 40-acre tract, zeros are used for both the second and third digits. If a well cannot be located more closely than the section, the fourth segment of the well number is omitted. When it becomes possible to locate more accurately a well in whose number zeros have been used, the proper digit or digits are substituted for the zeros. Letters a, b, c, ... are added to the last segment to designate the second, third, fourth and succeeding wells in the same 10-acre tract.

The method of numbering sections within a township and tracts within a section is shown in Figure 2.

ACKNOWLEDGMENTS

The determination of the extent of the valley-fill ground-water reservoir of the Portales Valley area was possible only with the cooperation of many persons and organizations who have assisted in the collection of pertinent data and who have made records available to the writer.

The writer is especially indebted to the New Mexico State Engineer, in whose employ this study was initiated, for making available the majority of data presented in this report. The study was begun in June 1954, under J. R. Erickson, then New Mexico State Engineer, and was carried on and completed during the successive administrations of J. H. Bliss and S. E. Reynolds, respectively. Special acknowledgment is given to J. C. Yates, for numerous suggestions and consultations relative to the investigation; to J. I. Wright, for many suggestions and aid in the collection of ground-water data; and to R. L. Borton and other employees of the Office of the New Mexico State Engineer

a. Method of numbering sections within a township.

6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

6 miles

b. Method of numbering tracts within a section.

111	112	121	122	211	212	221	222
(110)		(120)		(210)		(220)	
113	114	123	124	213	214	223	224
[100]				[200]			
131	132	141	142	231	232	241	242
(130)		(140)		(230)		(240)	
133	134	143	144	233	234	243	244
311	312	321	322	411	412	421	422
(310)		(320)		(410)		(420)	
313	314	323	324	413	414	423	424
[300]				[400]			
331	332	341	342	431	432	441	442
(330)		(340)		(430)		(440)	
333	334	343	344	433	434	443	444

1 mile

Figure 2. Well-numbering system.

who have freely contributed to the investigation from their personal knowledge of the valley and the data available to them.

Personnel of the U. S. Geological Survey, especially C. S. Conover and W. E. Hale, Ground-water Branch, and J. R. Averett, Quality of Water Branch, Water Resources Division, have kindly furnished pertinent ground-water data, and chemical analyses of ground water in the area. T. F. Stipp, Oil Conservation Branch, Geologic Division, furnished information relative to deep oil tests that have been drilled in the area.

The Atlantic Refining Company contributed many data relative to the elevation of points on the land surface and the depths at which the Triassic formations were encountered in several hundred seismic shot holes that have been drilled in the area. Without these data, it would have been virtually impossible to have shown the configuration of the Triassic "red beds" outside the heavily populated area in which irrigation has taken place.

The Magnolia Petroleum Company contributed numerous logs of deep oil tests drilled in Curry and Roosevelt Counties. Information relative to the Gulf-Stevenson No. 1, drilled near Elida, was furnished by the Gulf Oil Corporation.

Many data for wells that have been drilled for stock water south and west of the Portales Valley have been contributed by J. A. Greathouse and Foy Jones of Floyd, New Mexico. The results of chemical analyses of irrigation water in the area, made by the New Mexico College of Agriculture and Mechanic Arts, have been furnished by the Agricultural Experiment Station.

Grateful acknowledgment is also made to the drilling contractors

of the area who have kindly furnished drill samples for a great number of recent water wells drilled in the valley; to the private land owners who have permitted investigation of their wells; and to a large number of individuals who have contributed information of many kinds.

S. A. Wengerd, Associate Professor of Geology, University of New Mexico, under whose direction the study was made, has given freely of his time and counsel. The cost of reproducing the illustrations and the typing of the manuscript has been borne by the New Mexico Geological Society in a grant-in-aid to the writer. For both of these the writer is truly grateful.

STRATIGRAPHY

The surface formation of the Portales Valley area consists largely of sand, gravel and clay of Pleistocene to Recent age that rest unconformably on Triassic, Cretaceous, and Tertiary rocks. These in turn are underlain by Paleozoic strata that range from Pennsylvanian to Permian in age, which rest upon a Precambrian crystalline complex. A generalized stratigraphic column of these rocks and sediments for the area studied is given in Figure 3.

The principal exposures of the Permian, Triassic, and Tertiary rocks underlying the area are located below the cap rock of the Llano Estacado, which lies some distance to the north, west, and southeast of the Portales Valley. Rocks of the Pennsylvanian system and the Precambrian complex occurring in the area are known only from the records of deep wells that have been drilled in the region.

Known outcrops in the area studied are few in number and are limited to poor and meager exposures of rocks and sediments of the Triassic, Cretaceous, Tertiary, and Quaternary systems.

PRECAMBRIAN ROCKS

The oldest rocks underlying the Portales Valley area are those of the Precambrian basement complex which consist wholly, so far as is known, of igneous rocks. These rocks may be expected at depths that range from about 8,000 to more than 8,500 feet below the land surface in the general region of the area of study. The general characteristics of these rocks have been described by Flawn (1954, p. 116) as follows:

> "In central Chaves county, northern Lea and southern Roosevelt counties, and parts of Curry and Quay counties the basement rocks are volcanic rocks, mostly undeformed and unmetamorphosed rhyolite flows and tuffs.

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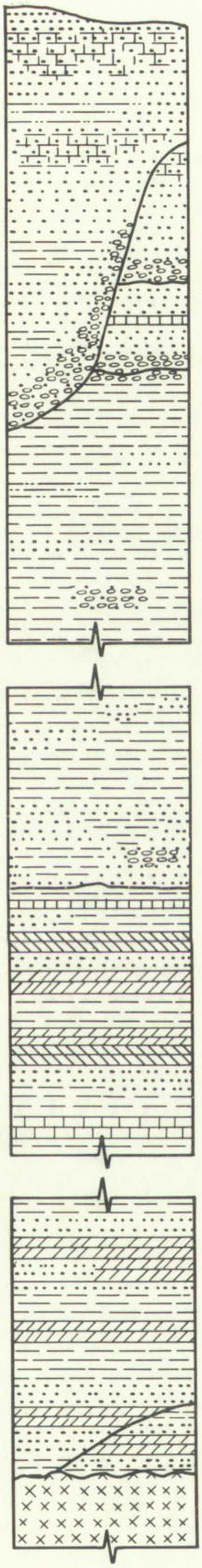
> "In central Chaves county, northern Lea and southern Roosevelt counties, and parts of Curry and Quay counties the basement rocks are volcanic rocks, mostly underformed and unmetamorphosed rhyolite flows and tuffs.



Valley fill (Pleistocene–Recent): vari-colored gravel; light tan to red sand; light tan to red silt; light gray caliche.

Ogallala formation (Miocene (?)—Pliocene): vari-colored gravel; light tan to brown sand; light tan to brown silt; light gray caliche.

Kiamichi–Duck Creek shale equivalent (Comanchean): vari-colored conglomerate; light gray calcareous sandstone; light gray limestone.

Dockum group (Upper (?) Triassic): conglomerate; sandstone and red shale with minor quantities of chemical sediments.

Permian system: sandstone; red, gray, brown, and black shale; dolomite; dolomitic limestone; anhydrite; salt.

Pennsylvanian system: arkosic sandstone; gray and red shale; limestone; dolomite.

Basement complex (Precambrian): rhyolitic flows and tuffs; gabbro; diabase.

Figure 3. Generalized stratigraphic column, Portales Valley area, Roosevelt and Curry Counties, New Mexico.

These rocks are much more extensively developed to the east in the Texas Panhandle, and hence the name Panhandle volcanic terrane has been adopted. Petrographic study shows this terrane to be composed mainly of rhyolitic extrusive and pyroclastic rocks with subordinate trachytic and andesitic types and shallow intrusions of rhyolitic and granitic rocks. The rocks of the Panhandle volcanic terrane appear to have been extruded and deposited as a relatively thin mantle on the surface of the older craton which presumably extends beneath the volcanic rocks.

In Roosevelt and southern Curry counties, and extending eastward into Texas, basement rocks are composed largely of gabbro and diabase. Again this terrane is more extensively developed in the southern Texas Panhandle—poor well control makes it difficult to define its limits in New Mexico. The gabbroic rocks appear to be younger than the volcanic rocks of the Panhandle volcanic terrane for gabbro and diabase sills intrude the volcanic section. The gabbroic terrane proper seems to be a great lopolith or stratiform body occupying a major basement sag or syncline, floored by the Panhandle volcanic terrane, which in part coincides with the structural low of the Plainview or Palo Duro basin. The lack of a gravity maximum over these dense gabbroic rocks supports the concept of a relatively thin rootless stratiform body probably originating through a complex of sheet-like intrusions."

PALEOZOIC ROCKS

The Paleozoic rocks underlying the Portales Valley area rest unconformably on the Precambrian basement complex and include the Pennsylvanian and Permian systems. These rocks lie at relatively great depths within the area studied, and therefore are largely beyond the scope of this investigation. No outcrops of these rocks are known within the regional limits of the Llano Estacado.

Pennsylvanian System

To the writer's knowledge, no deep oil tests have been drilled within the general limits of the area of study in which rocks of definite Pennsylvanian age have been encountered; consequently, information on the distribution and character of any Pennsylvanian rocks which may be present

These rocks are much more extensively developed to the east in the Taxpa Foldbelt, and very little Tertiary volcanic terrane has been mapped. Petrographic study shows this terrane to be composed mainly of tuffaceous and pyroclastic rocks with subordinate andesitic and rhyolitic types and shallow intrusions of rhyolitic and granitic rocks. The rocks of the Tertiary volcanic terrane appear to have been extruded and deposited as a relatively thin mantle on the surface of the older craton which presumably extends beneath the volcanic rocks.

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To the writer's knowledge, no deep oil tests have been drilled within the general limits of the area of study in which rocks of Pennsylvanian age have been encountered; consequently, information on the distribution and character of any Pennsylvanian rocks which may be present

in this area is lacking. Stratigraphic evidence from adjacent areas, however, indicate that there is the possibility that these rocks may extend into parts of the area covered by this investigation. The available data suggest that these strata, if present, are composed largely of interbedded limestone, dolomite, gray shale, red shale, and arkosic sandstone.

Permian System

Rocks of the Permian series, which include the Abo formation, Yeso formation, Glorieta sandstone member of the San Andres formation, San Andres formation, and the Chalk Bluff formation (Whitehorse), attain a total thickness of more than 5,000 feet and underlie all the area studied (Dobrovolny, et al., 1946). The rocks are composed primarily of red, gray, brown, and black shale, anhydrite, salt, dolomite, dolomitic limestone, and sandstone. In the neighborhood of Roswell, 100 miles southwest of Portales, two-thirds of the upper 1,500 feet of Permian beds consists of limestone, salt, gypsum, and anhydrite (Darton, 1928, p. 22-23). The clastic sediment of the upper part of this series is relatively homogeneous, with the sandstone commonly consisting of clear, well-rounded, frosted, quartz grains in a matrix of very fine grained sandstone (Adams, 1929, p. 1052). The upper shale is usually well-lithified, which, in combination with the lithology of the sand, and the presence of anhydrite and salt, serves to distinguish these strata from those of the overlying Triassic system.

Previous workers in the area have postulated that the presence of the soluble beds in this series is instrumental in the development of the sink-hole topography of the southern High Plains, which is generally believed to be of considerable importance in the recharge of the shallow

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ground-water supply of this region. It has been supposed that the removal of parts of the soluble beds caused collapse of the overlying beds, thus forming the "dry lakes" and playas on the present surface of the plains (Theis, 1932, p. 106) (Price, 1944, p. 403). This theory, however, has been largely discounted by data collected during this investigation, as will be shown in a subsequent section of this report.

MESOZOIC ROCKS

The Mesozoic rocks occurring in the Portales Valley area include representatives of both the Triassic and Cretaceous systems.

Triassic System

The oldest rocks exposed in the Portales Valley area are a series of "red beds" which are late (?) Triassic in age and have been assigned to the Dockum group (Darton, 1928, p. 32). These rocks rest unconformably on Permian strata and underlie all the southern High Plains area of eastern New Mexico and western Texas. These rocks are exposed in the escarpment of the Llano Estacado, particularly along the western side, and in the valley of the Canadian River, which lies beyond the escarpment to the north and northwest of the area studied. Limited exposures also occur along the margins of some of the deeper playa basins within the interior of the southern High Plains region where the post-Triassic sediments have been removed by erosion.

The Triassic rocks are composed largely of clastic sediment --- shale, heterogeneous sandstone, and conglomerate. Minor lenses of chemical and organic sediment occur within these clastic rocks. The sandstone ranges from very fine to very coarse grained. Sorting is generally poor and the coarser grains may grade upward into fine gravel.

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The sand becomes progressively finer toward the west away from the source of its supply, but in no place is the sand as fine as that of the underlying Permian series (Adams, 1929, p. 1047). The color of this sediment is generally red and ranges through white, yellow, red, and blue. The generally red hue is due to the presence of red interstitial clay rather than to the color of the separate grains (Adams, 1929, p. 1048). The sand is composed largely of quartz with minor amounts of feldspar and mica, and a high concentration of heavy minerals. These rocks are poorly lithified and this characteristic in combination with the heterogeneous character of the sand, the presence of gravel and mica, and the lack of thin uniform bedding, serves to differentiate these strata from the underlying Permian beds (Adams, 1929, p. 1053-1054).

Although these rocks underlie all the Portales Valley area, specific data relative to the characteristics of these rocks within this area are limited largely to the lithologies observed in two incomplete sections exposed about 4 miles south of Little Salt Lake, in the vicinity of Sec. 30, T. 3 S., R. 36 E., and on the northwest side of Lewiston Lake in Sec. 3, T. 3 S., R. 31 E., and to the stratigraphic sequence indicated by drill samples that were obtained between the depths of 105 and 405 feet in well 1S.33.10.321. This well was drilled in an attempt to obtain irrigation water from this formation. The general lithologic characteristics of these rocks are shown in the following descriptions of the Lewiston Lake exposure and these drill samples. A description of the units exposed about 4 miles south of Little Salt Lake is given on page 28.

on page 28.

Stratigraphic Section on Northwest Side of Lewiston Lake
NW 1/4, Sec. 3, T. 3 S., R. 31 E.

Two units are exposed at this locality. The bottom of the lower unit and the top of the upper unit are indeterminable. The strike of the strata exposed here is N. 10° E. and the dip is 6° NW. The section was measured by the writer and chip samples were examined with the aid of a binocular microscope.

No.	Description	Thickness (feet)
	Top of outcrop:	
	Triassic (?):	
1.	SANDSTONE: very light tan to olive; 20 per cent feldspar and 80 per cent quartz; 98 per cent fine-grained, subangular to subrounded, well sorted sand with traces of clay and silt; micaceous, with some hornblende; friable; tan, $CaCO_3$ cement; flaggy beds, 1/8 inch to 1 inch; good porosity; no fossils.....	2+
	Total:	2+
	Triassic:	
1.	CLAYSTONE: light maroon; 99 per cent clay with traces of silt and very fine grained sand; micaceous; some greenish streaks; no porosity; no fossils.....	2+
	Bottom of outcrop:	
	Total:	2+

Sample Log - Well 1S.33.10.321
Owner: Monroe Mitchell Total depth: 1,000 feet

It should be noted here that certain samples in the following drill-sample descriptions, and all subsequent drill-sample descriptions, may represent a mixture of one or more individual units; i. e., a silty sand may actually represent an interbedding of units composed largely of sand with units composed largely of silt. These samples and all subsequent drill samples were examined with the aid of a binocular microscope.

Stratigraphic Section on Northwest Side of Division Butte
NW 1/4, Sec. 29, T. 3 S., R. 1 E.

Two units are exposed at this locality. The bottom of the lower unit and the top of the upper unit are inaccessible. The strata exposed here lie N. 15° E. and dip 15° W. The section was measured by the writer and chip samples were examined with the aid of a binocular microscope.

No.	Description	Thickness
	Top of outcrop:	
	Triassic (?):	
1.	SANDSTONE: very light tan to olive; 70 per cent feldspar and 30 per cent quartz; fine-grained, subangular to subrounded; well sorted sand with traces of clay and silt; micaceous with some hornblende; friable; thin, 0.2' to 0.4' clayey beds, 1/8 inch to 1 inch; good porosity; no fossils	25'
	Total:	25'
	Triassic:	
1.	CLAYSTONE: light maroon; 80 per cent clay with traces of silt and very fine grained sand; micaceous; some greenish streaks; no fossils	7'
	Bottom of outcrop:	
	Total:	32'

Sample Log -- Well 18.12.10.321
Owner: Monroe Mitchell Total depth: 1,000 feet

It should be noted here that certain differences in the following sample descriptions, and well subsequent drill sample descriptions, may represent a mixture of one or more individual units; i.e., a well may actually represent the penetrating of units composed largely of a certain unit with units composed largely of silt. These samples and all subsequent drill samples were examined with the aid of a binocular microscope.

Interval (feet)	Description
	Quaternary valley fill:
0-100	No samples.
100-105	SAND: light brown; 50 per cent very fine grained, sub-angular to subrounded, well sorted, quartz sand with 50 per cent silt and a trace of clay; poorly indurated.
	Triassic:
105-120	SAND: gray-brown; 60 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 40 per cent silt and a trace of clay; micaceous; poorly indurated.
120-135	SILT: red-brown; 75 per cent silt with 15 per cent very fine grained, subangular to subrounded, well sorted, quartz sand, 10 per cent clay and a trace of very fine gravel; fair induration.
135-150	SILT: gray-brown; 75 per cent silt with 20 per cent very fine grained, subangular to subrounded, well sorted, quartz sand, and 5 per cent clay; micaceous; fair induration.
150-180	SAND: gray; 75 per cent very fine to fine-grained, sub-angular to subrounded, well sorted, quartz sand, with 25 per cent silt and a trace of clay; micaceous; fair induration.
180-195	SILT: gray-brown; 50 per cent silt with 40 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand and 10 per cent clay; micaceous; fair induration.
195-225	SILT: red-brown; 80 per cent silt with 20 per cent clay and a trace of very fine to fine-grained, subangular to subrounded, well sorted, quartz sand; micaceous; fair induration.
225-240	SILT: red-brown; 90 per cent silt with 10 per cent clay and a trace of very fine to fine-grained, sub-angular to subrounded, well sorted, quartz sand; micaceous; fair induration.
240-255	SILT: red-brown; 80 per cent silt with 20 per cent clay and a trace of very fine to fine-grained, subangular to subrounded, well sorted, quartz sand; micaceous; fair induration.
255-270	SAND: gray-brown; 75 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 25 per cent silt and a trace of clay; micaceous; fair induration.
270-285	SAND: gray; 50 per cent very fine grained, subangular to subrounded, well sorted, quartz sand with 50 per cent silt and a trace of clay; micaceous; fair induration.
285-300	SAND: light gray; 50 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand, with 45 per cent silt, a trace of clay and 5 per cent subbituminous coal; micaceous; poorly indurated.

300-315	SAND: light gray to brown; 50 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 45 per cent silt and 5 per cent clay; micaceous; fair induration.
315-330	SILT: red-brown to light gray; 80 per cent silt and 20 per cent clay and a trace of very fine to fine-grained, subangular to subrounded, well sorted, quartz sand; micaceous; fair induration.
330-345	SAND: red-brown; 70 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand, with 25 per cent silt and 5 per cent clay; micaceous; fair induration.
345-360	SAND: red-brown to light gray; 55 per cent very fine grained, subangular to subrounded, well sorted, quartz sand with 40 per cent silt and 5 per cent clay; fair induration.
360-375	SILT: red-brown; 85 per cent silt with 10 per cent clay and 5 per cent very fine grained, subangular to subrounded, well sorted, quartz sand; fair induration.
375-390	SAND: light gray to brown; 55 per cent very fine grained, subangular to subrounded, well sorted, quartz sand with 40 per cent silt and 5 per cent clay; fair induration.
390-405	SILT: light brown; 55 per cent silt with 40 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand and 5 per cent clay; fair induration.
405-1,000	No samples.
	Total depth.

The stratigraphic equivalents of these strata were first described by Cummins (1890, p. 189-190) as the "Dockum beds" from the type locality at Dockum, Dickens County, Texas, and were later subdivided by Drake (1892, p. 229-231) into three members. Gould (1907, p. 21-29) subdivided this group into two formations, the Tecovas and the Trujillo, which consist of a basal shale and an upper sandstone, respectively. Hoots (1925, p. 86-92) believed the Dockum group of the southern Llano Estacado to be divisible into two formations: a lower unit, which is characterized by red clay and numerous beds of massive, gray, cross-bedded sandstone; and an upper unit, which consists largely of red clay. A division, similar to that of Hoots, has been used by Adams (1929) in a study of the

Triassic sediment of the southern Llano Estacado, which was based largely on the study of drill samples obtained from a great number of oil tests drilled in this region.

According to Adams (1929, p. 1052), a two-fold subsurface division, based on lithologic characteristics, may be made of the Dockum group in southeastern New Mexico. The lower formation consists of a sandstone and shale sequence, which averages 350 feet in thickness and attains a total thickness of 600 feet or more. The sandstone is fairly persistent geographically and the unit has been correlated with the Santa Rosa sandstone of north-central New Mexico. The upper formation, separated from the lower formation by a somewhat indefinite contact, is composed largely of shale with discontinuous lenses of sandstone, limestone, and conglomerate, which appear to be more extensive in eastern New Mexico than in Texas. This unit occupies the same stratigraphic position as the Chinle formation of north-central New Mexico and attains a maximum thickness of about 1,200 feet. To the south and east this formation has been removed by erosion, with the result that the Santa Rosa sandstone is the only unit present on the eastern and southern margins of the Triassic area in western Texas. The Dockum group attains its greatest thickness in central Lea County, New Mexico, and the adjoining area in Texas.

The surface and near-surface Triassic rocks of the Portales Valley area, described in this report, are considered to be a part of the upper formational unit described by Adams.

The general lithologic characteristics of the Dockum group indicate that the sediment was derived, for the most part, from the erosion products of the Paleozoic rocks exposed in Llanoria to the east, with a possible

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supplemental source existing in the highlands of northern New Mexico and southern Colorado. According to Sidwell (1945, p. 54) the sediment of the Tecovas, or the basal Dockum group, was derived largely from reworked Permian strata, while the Santa Rosa and Chinle formations received sediment which appears to have been derived from igneous and metamorphic rocks. A supplemental source, consisting of volcanic clastics, is also postulated during Chinle time (Sidwell, 1945, p. 54).

The character of these rocks also indicates that the sediment accumulated as a floodplain deposit in a warm region of moderate rainfall. Considerable humidity is indicated by the common occurrence of fossil plants, and non-marine vertebrate and invertebrate fossils. It appears that a large amount of water was necessary to transport these alluvial materials to form such a thick and extensive deposit. Much of this water may have been supplied by streams emerging from the mountains to the east, but some undoubtedly fell as rain on the plains. Although there is evidence of folding and erosion elsewhere, both before and after the period of deposition, as will be shown in subsequent sections of this report, the period of deposition was apparently one of relative quiescence accompanied only by slow subsidence in the Permian basin. This would account for the greater thickness of Triassic sediment present in this area.

Cretaceous System

The Cretaceous rocks present in the southern High Plains area of eastern New Mexico and western Texas occur only as discontinuous erosional remnants that rest unconformably on the underlying Dockum group. The rocks are exposed in the escarpment of the Llano Estacado, particularly along the northwest, southeast and southern sides, and along the margins of some

of the deeper playa basins within the interior of this region, where the overlying Tertiary and Quaternary sediment has been removed by erosion. The rocks consist largely of limestone, sandstone, and shale in most of the High Plains region and usually occur as remnant caps on the divides separating the valleys of a pre-Miocene(?)-Pliocene erosion surface. Early Cretaceous fossils have been identified in these rocks in many localities throughout the southern High Plains area (Brand, 1953, p. 27-54).

One of the more extensive remnants of Cretaceous strata known to be present in the southern High Plains region occurs in the area south of the Portales Valley and trends from the general vicinity of the townsite of Dora to the New Mexico-Texas state line. These strata crop out high on the southern flank of the Portales Valley about 4 miles south-southeast of Little Salt Lake and have been encountered in seismic shot holes beneath a mantle of younger sediment in an area of more than 100 square miles, south of this outcrop. The extent of these strata, so far as is known from the available data, is shown on Figure 4.

Cretaceous strata have been tentatively identified between the depths of 95 and 165 feet in a well in Sec. 1, T. 2 S., R. 31 E.

Data available relative to the presence of Cretaceous rocks in the Portales Valley are limited largely to the lithology observed in the single outcrop that is known in Roosevelt and Curry Counties, and to the extent of the Triassic-Cretaceous unconformity south of the valley as determined by the Atlantic Refining Company during a seismic survey of this area. Data are not available from this seismic survey relative to the thickness of the Cretaceous formations or the stratigraphic sequence encountered in the shot holes; consequently, the discussion of the stratigraphic sequence is limited to the sequence of rocks exposed in the outcrop

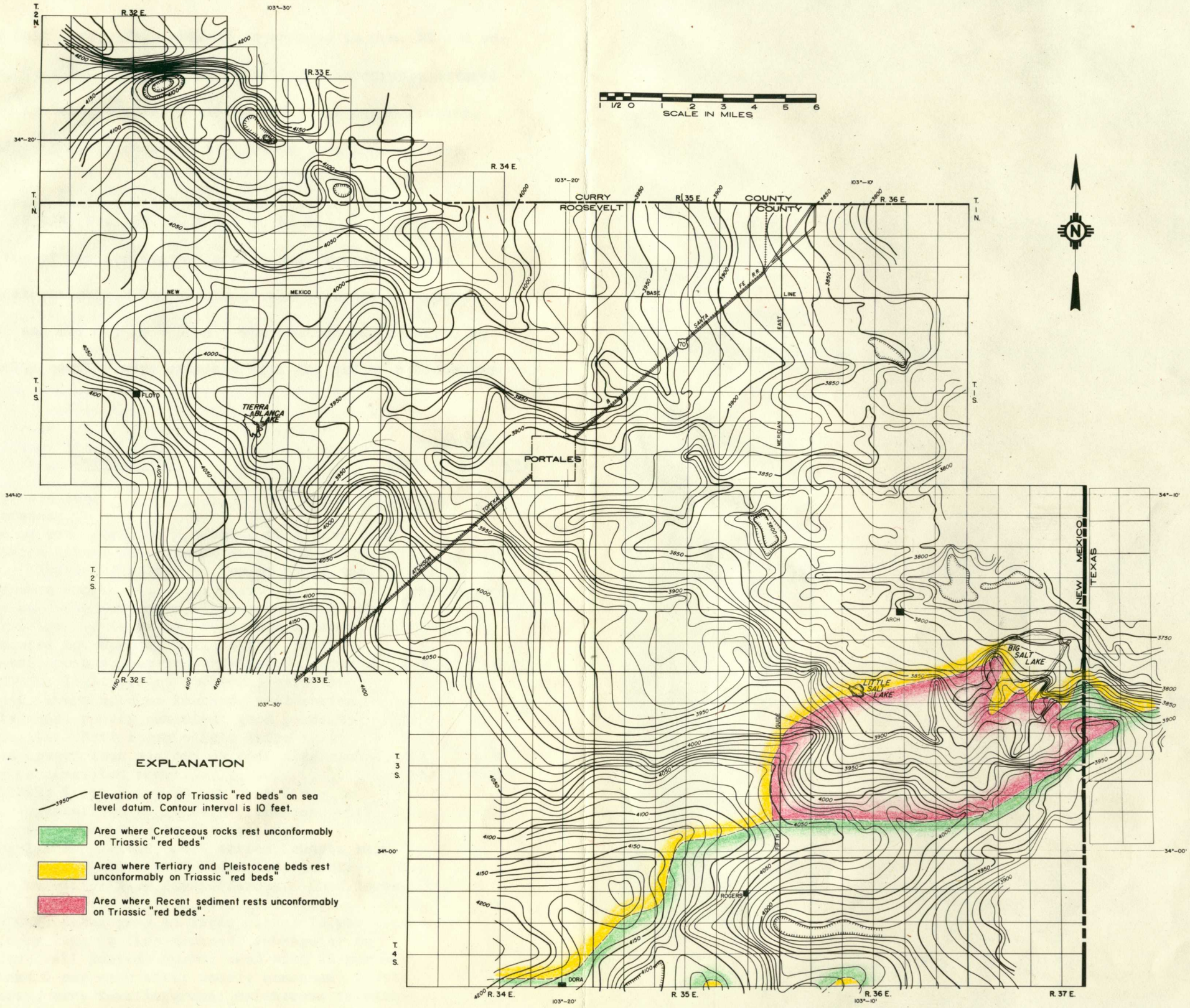

Figure 4. Configuration of top of Triassic "red beds", Portales Valley area, Roosevelt and Curry Counties, New Mexico.

south of Little Salt Lake. This outcrop is exposed in Sec. 30 and adjacent sections, T. 3 S., R. 36 E., and exhibits considerable lateral gradation in the lithologic characteristics of the exposed section. The following stratigraphic sequence is exposed in this locality:

Stratigraphic Section 3 1/2 Miles Northeast of Rogers
SW 1/4, Sec. 30, T. 3 S., R. 36 E.

The bottom and top of the stratigraphic sequence exposed at this locality are indeterminable. The strike of these strata is approximately east-west and the dip is $\pm$ 3° S. The section was measured by the writer and chip samples were examined with the aid of a binocular microscope.

No.	Description	Thickness (feet)	Thickness (inches)
	Top of section:		
	Cretaceous:		
14.	Slope on concealed rocks covered with very fine to coarse gravel of variable color and composition. Vertical distance to top of slope was not determined.....	--	--
13.	Slope on concealed rocks with numerous blocks of light yellow to brown, very fine grained, subrounded to rounded, well sorted, poorly cemented, porous, quartz sandstone on surface..	9	0
12.	SANDSTONE: light yellow to brown; very fine grained, subrounded to rounded, well sorted, quartz sand; poorly cemented; good porosity; no fossils. Unit forms slight ledge that grades upward into a slope on concealed rocks..	1	4
11.	Slope on concealed rocks.....	5	0
10.	LIMESTONE: light gray; 70 per cent fine- to medium-crystalline to granular limestone with 30 per cent very fine to fine-grained, subangular to rounded, well sorted, quartz sand and a trace of silt; well indurated; nodular; little porosity; very fossiliferous. Unit forms slight ledge.....	0	5
9.	SANDSTONE: light gray to light olive; 70 per cent very fine to fine-grained, subangular to rounded, well sorted, quartz sand with 25 per cent clay and 5 per cent silt; poorly cemented; little porosity; very fossiliferous; calcareous in vicinity of fossil fragments. Unit forms recess in ledge.....	0	5

8.	LIMESTONE: light gray; 90 per cent fine- to medium-crystalline to granular limestone with 10 per cent very fine to fine-grained, subangular to rounded, well sorted, quartz sand; well indurated; little porosity; very fossiliferous. Unit forms ledge.....	0	7
7.	SANDSTONE: light gray to light olive; 70 per cent very fine to fine-grained, subangular to rounded, well sorted, quartz sand with 10 per cent clay, 20 per cent silt and a trace of very fine gravel; poorly cemented; little porosity; very fossiliferous; calcareous in vicinity of fossil fragments. Unit forms recess in ledge....	1	9
	Ledge was traced along outcrop and measurement of section was continued 120 feet to the northeast.		
6.	SANDSTONE: light gray; 60 per cent fine- to coarse-grained, subangular to rounded, fair sorted, quartz sand with 40 per cent limestone and traces of silt and very fine gravel; well cemented; little porosity; very fossiliferous. Unit forms ledge.....	0	7
5.	SANDSTONE: light gray to light olive; 70 per cent very fine to fine-grained, subangular to rounded, well sorted, quartz sand with 25 per cent clay, 5 per cent silt and a trace of very fine gravel; poorly cemented; little porosity; fossiliferous; calcareous in vicinity of fossil fragments. Unit forms recess in ledge.....	0	11
4.	SANDSTONE: light gray; 60 per cent fine- to coarse-grained, subangular to rounded, fair sorted, quartz sand with 40 per cent limestone and traces of silt and very fine gravel; well cemented; little porosity; very fossiliferous. Unit forms ledge.....	0	3
3.	SANDSTONE: light gray to light olive; 70 per cent very fine to fine-grained, subangular to rounded, well sorted, quartz sand with 25 per cent clay, 5 per cent silt and a trace of very fine gravel; poorly cemented; little porosity; fossiliferous; calcareous in vicinity of fossil fragments. Unit forms recess in ledge.....	0	3 1/2
2.	SANDSTONE: light gray; 60 per cent fine- to coarse-grained, subangular to rounded, fair sorted, quartz sand with 40 per cent limestone and traces of silt and very fine gravel; well cemented; little porosity; very fossiliferous. Unit forms ledge.....	0	4

1.	CONGLOMERATE: vari-colored; 50 per cent very fine to large, angular to rounded, quartz gravel with 50 per cent very fine grained to granule sized, angular to subrounded, poorly sorted, quartz sand and a trace of silt; some femags and basic rock fragments; well cemented with white to tan, $CaCO_3$ cement; little porosity; some fossil fragments. Unit forms ledge.....	0	3
	Total measured :	21	1 1/2
2.	Triassic (?): CONGLOMERATE: vari-colored; 80 per cent very fine grained to granule sized, angular to subrounded, poorly sorted, quartz sand with 20 per cent fine, angular to rounded, quartz gravel and a trace of silt; some femags and basic rock fragments; friable; white to tan, $CaCO_3$ cement; excellent porosity; cross-bedded. Unit forms ledge. Bottom of unit is indeterminable.	1	4
1.	Slope on concealed rocks; surface covered with fossil fragments, sand, and gravel from the overlying units. Soil characteristics indicate that the underlying rock may be similar to lower unit exposed at Lewiston Lake.....	--	--
	Bottom of section:		
	Total measured:	1	4

The Cretaceous strata cropping out at this locality are tentatively considered to be stratigraphically equivalent to the Tucumcari shale described by Dobrovolny, et al., (1946). The name "Tucumcari beds" was originally used by Cummins in 1892 and Cragin in 1895 for the exposures of this unit and the overlying Mesa Rica sandstone at Tucumcari Mountain, Quay County, New Mexico, where the zone of Graphaea tucumcari was originally discovered by Jules Marcou (Wilmarth, 1938, p. 2190-2191). They may also be equivalent to the Kiamichi-Duck Creek shale unit of the Llano Estacado of Texas, which was first described by Hill (1891, p. 504, 515-516) and named, respectively, for the Kiamichi River in Choctaw County, Oklahoma and Duck Creek in Grayson County, Texas.

Robbins (1941, p. 7) has identified a typical Kiamichi (Comanchean) fauna from the calcareous and argillaceous sandstone in the lower part

of the outcrop at this locality that includes Gryphaea corrugata Say, Gryphaea navia Hall, Exogyra texana Roemer, Alectryonia quadriplicata Shummard, Neithia subalpinus Böse, Trigonia emoryi Conrad, Protocardia texana Conrad, Turritella sp., and Oxytropidoceras of. belknapi. These forms, and the lithologic characteristics of these units compare quite well with the fauna and lithologies given for the Kiamichi shale by Brand (1953) from his study of the Cretaceous formations of the Llano Estacado in Texas east and southeast of the Portales Valley area. The fauna is also comparable to the Kiamichi-Duck Creek fauna identified by Dobrovolny, et al. (1946) in the Tucumcari shale member of the Purgatoire formation in northwestern Quay County. No fossils were noted in the upper sandstone of the measured section; however, the lithology of this upper lentil is comparable to the lithology of the upper part of the Tucumcari shale.

On the basis of the observed lithologic characteristics and the faunal evidence available to the writer it appears that the Cretaceous strata present in the Portales Valley area represent a facies intermediate between the carbonate and calcareous shale units of the Llano Estacado of Texas and the clastic units of northwestern Quay County. The lower part of the Portales section is considered to be equivalent to the lower shale beds of the Tucumcari shale and to the Kiamichi shale member in the Fredricksburg group of the Llano Estacado of Texas. The upper part of the Portales section is believed to be correlative with the sandstone that is present in the upper part of the Tucumcari shale and may be the equivalent of the Duck Creek shale member in the Washita group of the western Texas section.

The limited extent of the Cretaceous exposures in this area precludes the development of definite conclusions relative to the conditions of

of the outcrop at this locality that includes Gryphaea corrugata Say, Gryphaea navia Hall, Exogyra texana Roemer, Alectryonia quadriplicata Shumard, Nettia subiplana Böse, Trigonia emoryi Conrad, Pterocardia texana Conrad, Turritella sp., and Cryptoplocosrea sp. belongs. These forms, and the lithologic characteristics of these units compare quite well with the fauna and lithologies given for the Kiamichi shale by Brand (1953) from his study of the Cretaceous formations of the Llano Estacado in Texas east and southeast of the Portales Valley area. The fauna is also comparable to the Kiamichi-Duck Creek fauna identified by Dobrovolny, et al. (1946) in the Tecumseh shale member of the Purgatoire formation in northwestern Quay County. No fossils were noted in the upper sandstone of the measured section; however, the lithology of this upper limit is comparable to the lithology of the upper part of the Tecumseh shale.

On the basis of the observed lithologic characteristics and the faunal evidence available to the writer it appears that the Cretaceous strata present in the Portales Valley area represent a facies intermediate between the carbonate and calcareous shale units of the Llano Estacado of Texas and the clastic units of northwestern Quay County. The lower part of the Portales section is considered to be equivalent to the lower shale beds of the Tecumseh shale and to the Kiamichi shale member in the Fredrickshurg group of the Llano Estacado of Texas. The upper part of the Portales section is believed to be correlative with the sandstone that is present in the upper part of the Tecumseh shale and may be the equivalent of the Duck Creek shale member in the Washita group of the western Texas section.

The limited extent of the Cretaceous exposures in this area precludes the development of definite conclusions relative to the conditions of

deposition of this sediment; however, the presence of calcareous, conglomeratic sandstone containing a profusion of thick-shelled pelecypods, would appear to indicate that deposition occurred in shallow water, under near-shore conditions. Brand (1953, p. 17 18) from his regional study of the Cretaceous rocks in Texas, has concluded that:

> "Kiamichi time began by marine expansion and an influx of mud from the adjacent Triassic landmass. Angular quartz grains and unabraded crystals of tourmaline, zircon, and magnetite suggest short transportation and slight abrasional wear. The absence of feldspar indicates either that the Triassic provenance was free of these minerals or that weathering was dominantly decomposition during Cretaceous time. The mud that entered the Cretaceous sea during Kiamichi and Duck Creek time probably reflects more humid climates than during the preceding time intervals. That the Kiamichi sea was shallow is indicated by a profusion of massive, thick-shelled pelecypods (Gryphaea and Exogyra), ripple-marked and cross-bedded sandstone, and conglomeratic limestone. The paucity of fossils and thinly laminated dark gray and black shales of the upper Kiamichi indicate slow deposition in a reducing environment.
>
> Washita time began by another marine expansion and increased circulation in the sea. Although the Duck Creek shales are mineralogically similar to those of the Kiamichi, the colors differ because of the change from a reducing environment in the Kiamichi to an oxidizing environment in the Duck Creek. The new faunal elements of the Duck Creek formation likewise reflect distinct changes from the conditions existing during upper Kiamichi time."

Although the lack of a definite age determination for the upper part of the Cretaceous rocks exposed in the Portales Valley prevents the positive application of this interpretation to all the stratigraphic section exposed in this outcrop, the lithology and other evidences noted at this locality, particularly in the lower units, appear to essentially substantiate these conclusions. The upper part of the exposed section is believed to represent either aeolian or beach-type deposition.

CENOZOIC ROCKS

Cenozoic rocks occurring in the Portales Valley area include representatives of Tertiary and Quaternary age.

Tertiary Strata

The oldest Cenozoic strata occurring in the Portales Valley area are complex clastic beds of Miocene-Pliocene age (Darton, 1928, p. 58) that rest unconformably on the rocks of the Triassic and Cretaceous systems. These beds constitute the surface formation over most of the southern High Plains area of eastern New Mexico and western Texas and are well exposed at many localities along the escarpment of the southern Llano Estacado. These rocks are largely absent from the Portales Valley proper, however, having been removed by erosion in early Pleistocene time.

The occurrence of Tertiary rocks in the Portales Valley area is limited, so far as is known, to the adjacent areas on both the north and south sides of the valley, beyond the general limits of the area of study. In these areas the rocks consist largely of poorly consolidated, lenticular beds of silt, sand, and fine gravel, with the coarse-grained sand and fine gravel commonly occurring near the base. Caliche commonly occurs throughout the sediment, particularly near the land surface, and ranges from irregular zones of calcareous cementation, that exhibit varying degrees of consolidation of the clastic sediment, to almost pure calcium carbonate. The sand lenses predominate in the section and are usually composed of light tan to brown, subangular to subrounded, quartz sand. The gravel commonly consists of well rounded quartzose pebbles that range from about 1/8 inch to nearly 2 inches in their largest dimension. The sediment ranges from a few feet to more than 400 feet in thickness, depending on the paleotopographic relief that was developed on the underlying rocks prior to its deposition, and the degree of erosion to which

it has been subjected since early Pleistocene time.

In northeastern Roosevelt and southern Curry Counties these Tertiary beds rest directly on the "red beds" of the Dockum group and grade southward into the younger valley fill of the Portales Valley. The Tertiary valley-fill contact is imperceptible on both the land surface and in the subsurface and can only be inferred from the general relation of the present topographic surface to the unconformable contact of the valley-fill sediment with the Dockum group in the Portales Valley proper (Fig. 5). South of the Portales Valley these beds rest on the rocks of both the Triassic and Cretaceous systems and are largely separated from the valley-fill sediment by intervening surface exposures and near-surface occurrences of these older rocks that are overlain by Recent sediment.

The heterogeneity of the material which constitutes these rocks makes it impossible to subdivide these deposits into stratigraphic units on any basis or criterion other than paleontology, and owing to the general scarcity of fossils it is considered to be impractical to attempt any subdivision as a part of this investigation. The beds, however, are considered to be correlative with the Ogallala formation of Kansas and Nebraska and are believed to be almost wholly of Pliocene age (Darton, 1928, p. 58).

The formation is believed to be composed largely of stream deposits which had their beginning as a series of alluvial fans at the mouths of streams which emerged from the mountains to the west in late Tertiary time. The deposit subsequently spread over an area which is believed to have extended from the mountains to the west, to the area some distance beyond the eastern escarpment of the present Llano Estacado. The extensive development of caliche, in various zones throughout the

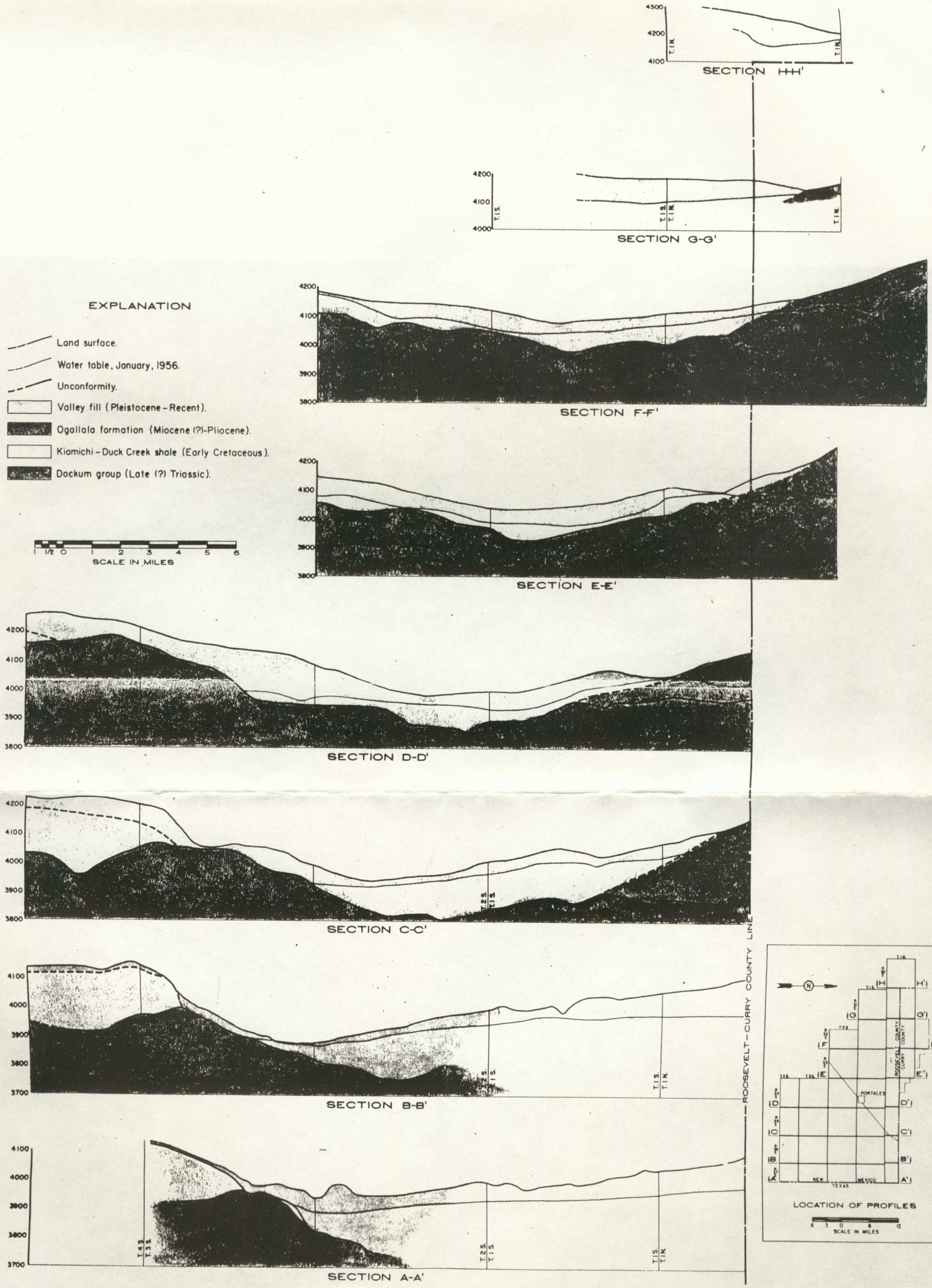

Figure 5. North–south profiles of the Portales Valley area, Roosevelt and Curry Counties, New Mexico.

formation, is indicative of deposition under arid or semiarid conditions. Physiographic relations, the caliche profile, and other features indicate that the caliches were developed by soil-forming processes from parent materials consisting largely of limestone gravels (Bretz and Horberg, 1949, p. 491).

Quaternary Sediment

Quaternary sediment of the southern High Plains area of eastern New Mexico and western Texas includes material of both Pleistocene and Recent age and is composed of clay, silt, sand and gravel, with interbedded zones of caliche, that rest unconformably on rocks of Triassic, Cretaceous, and Tertiary age. The Recent sediment is commonly present throughout the area of the southern Llano Estacado as a relatively thin veneer of aeolian and lacustrine deposits, while the Pleistocene sediment is limited largely to some of the deeper depressions and valley troughs that developed in early Pleistocene time. The latter deposits include sediment of fluviatile, lacustrine and aeolian origin. Numerous occurrences of both vertebrate and invertebrate fossils and human artifacts have been noted in these deposits by previous works throughout the southern High Plains region.

The area covered by this investigation comprises one of the most extensive areas of Pleistocene deposition that is known within the general limits of the southern Llano Estacado and consists primarily of an early Pleistocene erosional trough that was subsequently filled with sediment of aeolian, lacustrine, and fluviatile origin. The sediment consists largely of poorly consolidated clay, silt, sand, and gravel, with one or more zones of interbedded caliche. The deposit is characterized by lenticular bedding and exhibits considerable lateral gradation from place to place. The deposit is poorly exposed at the surface.

Coarse clastic sediment is usually found in the lower part of the deposit, and with few exceptions, the gravel when present is confined to a bed that ranges from less than a foot to more than 10 feet in thickness at the very base of the sequence. The gravel ranges in size from 4 inches downward, and commonly consists of fragments of various crystalline rocks with a lesser amount of rounded caliche fragments. Several logs of early wells drilled in the valley, published by Baker (1915), mention gravel in the upper part of the valley fill, but Theis (1932, p. 110), on the basis of data available to him during his investigation, concluded that these logs were largely in error. Data collected during this investigation essentially substantiate the conclusion of Theis.

The upper part of the valley fill consists largely of fine- to medium-grained sand and silt and is massive and structureless (Theis, 1932, p. 110). Various grade sizes grade into one another without a distinct boundary. The boundary between the upper and lower parts of the valley fill is indistinguishable on the logs of wells drilled in the area.

The samples retained during the drilling of well 2S.34.18.141 and the general hydraulic characteristics of wells drilled on the south side of the valley suggest that the sediment of the valley fill in this area is generally finer than the equivalent sediment on the north side of the valley.

Recent deposits in the area include both lake beds and sand dunes. The lake beds are found particularly in the vicinity of Big and Little Salt Lakes and consist of interbedded clay, silt, and sand. Evaporite deposits, typical of arid lakes, are also present in these localities.

The upper part of the valley fill consists largely of fine- to medium-grained sand and silt and is massive and structureless (Theis, 1932, p. 110). Various grade sizes grade into one another without a distinct boundary. The boundary between the upper and lower parts of the valley fill is indistinguishable on the logs of wells drilled in the area.

The samples retained during the drilling of well 29.34.18.141 and the general hydraulic characteristics of wells drilled on the south side of the valley suggest that the sediment of the valley fill in this area is generally finer than the equivalent sediment on the north side of the valley.

Recent deposits in the area include both lake beds and sand dunes. The lake beds are found particularly in the vicinity of Big and Little Salt Lakes and consist of interbedded clay, silt, and sand. Evaporite deposits, typical of arid lakes, are also present in these localities.

Sand dunes occur locally throughout the area studied and attain their greatest development along the north-northeast margin of the irrigated area between the Portales Valley proper and Blackwater Draw, where they consist primarily of fine- to medium-grained, subrounded quartz sand. The dunes exhibit small-scale, aeolian cross-bedding, with the individual beds ranging from less than a foot to slightly more than 2 feet in thickness. A similar line of dunes is present on the north side of Blackwater Draw.

The Pleistocene and Recent deposits can be differentiated only with great difficulty and are considered as a single stratigraphic unit for the purposes of this report. The general character of these deposits is indicated by the following lithologic descriptions of samples retained during the drilling of selected irrigation wells in the area. Supplemental descriptions are given in Appendix A. The locations of the wells for which samples were retained and examined are shown on Figure 6.

Sample Log - Well 1S.32.14.421
Owner: Robert Morrison Total depth: 114 feet

Interval (feet)	Description
	Quaternary valley fill:
0-1	No sample.
1-10	SAND: light tan; 60 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 40 per cent silt and a trace of clay; poorly cemented by light gray, $CaCO_3$ cement.
10-20	SAND: tan; 60 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 40 per cent silt and a trace of clay; poorly indurated.
20-40	SAND: light brown; 60 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 40 per cent silt and a trace of clay; poorly indurated.
40-60	SAND: light brown; 90 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 10 per cent silt; poorly indurated.

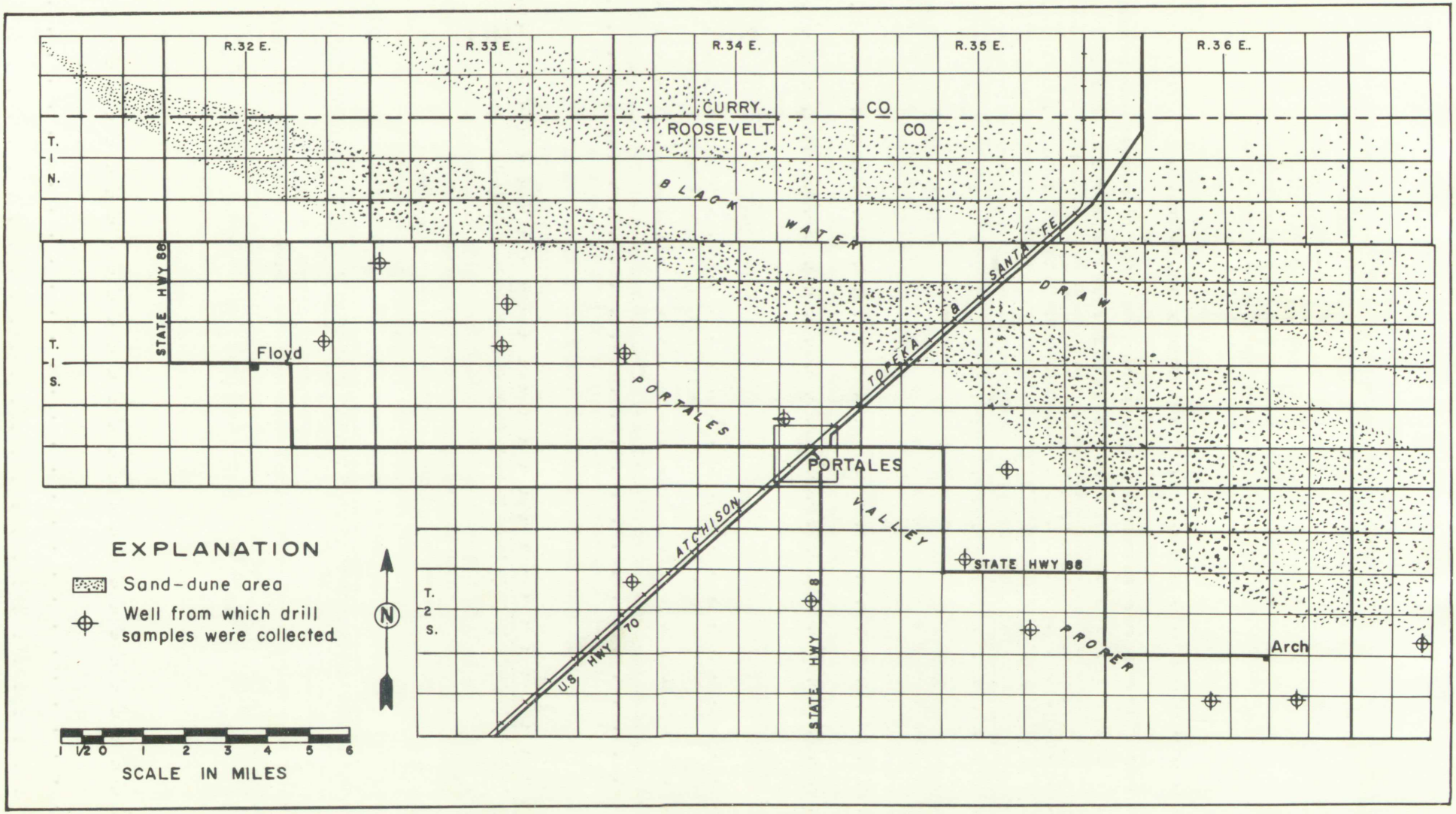

Figure 6. Location of wells from which drill samples were collected and examined.

60-70	SILT: light tan; 70 per cent silt with 25 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand and 5 per cent clay; poorly indurated.
70-80	SAND: brown; 75 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 25 per cent silt and a trace of clay; poorly indurated.
80-90	SAND: brown; 95 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 5 per cent silt; poorly indurated.
90-100	SAND: brown; 90 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 10 per cent silt and a trace of very fine gravel; poorly indurated.
100-110	SAND: brown; 85 per cent very fine to medium-grained, subangular to subrounded, fair sorted, quartz sand with 10 per cent silt and 5 per cent very fine gravel; poorly indurated.
110-114	No sample.
	Total depth.

Sample Log - Well 2S.34.14.441

Owner: N. R. Blackard Total depth: 155 feet

Interval (feet)	Description
	Quaternary valley fill:
0-9	No sample.
9-30	SAND: light gray to tan; 90 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 10 per cent silt and a trace of clay; poorly cemented by light gray to light tan, $CaCO_3$ cement.
30-70	SAND: tan; 90 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 10 per cent silt; poorly indurated.
70-90	SAND: brown; 99 per cent fine- to medium-grained, subangular to subrounded, well sorted, quartz sand; clean samples; no cement.
90-100	SAND: brown; 90 per cent very fine to coarse-grained, subangular to subrounded, poorly sorted, quartz sand with 10 per cent very fine to fine gravel and a trace of silt; poorly indurated.
100-110	SAND: brown; 97 per cent fine- to medium-grained, subangular to subrounded, well sorted, quartz sand with 2 per cent very fine gravel; clean sample; no cement.

Interval (feet)	Description
	Quaternary valley fill:
0-9	No sample.
9-30	SAND: light gray to tan; 90 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 10 per cent silt and a trace of clay; poorly cemented by light gray to light tan, $CaCO_3$ cement.
30-70	SAND: tan; 90 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 10 per cent silt; poorly indurated.
70-90	SAND: brown; 95 per cent fine- to medium-grained, subangular to subrounded, well sorted, quartz sand; clean samples; no cement.
90-100	SAND: brown; 90 per cent very fine to coarse-grained, subangular to subrounded, poorly sorted, quartz sand with 10 per cent very fine to fine gravel and a trace of silt; poorly indurated.
100-110	SAND: brown; 97 per cent fine- to medium-grained, subangular to subrounded, well sorted, quartz sand with 3 per cent very fine gravel; clean samples; no cement.

110-120	SAND: brown; 93 per cent very fine to medium-grained, subangular to subrounded, fair sorted, quartz sand with 5 per cent silt and 2 per cent very fine gravel; poorly indurated.
120-130	SAND: brown; 90 per cent very fine to medium-grained, subangular to subrounded, fair sorted, quartz sand with 10 per cent silt; poorly indurated.
130-140	SAND: brown; 95 per cent very fine to medium-grained, subangular to subrounded, fair sorted, quartz sand with 5 per cent silt; poorly indurated.
140-150	SAND: gray to brown; 70 per cent very fine to coarse-grained, subangular to subrounded, poorly sorted, quartz sand with 20 per cent very fine gravel and 10 per cent silt; poorly indurated.
150-155	No sample.
	Total depth.

Sample Log - Well 2S.37.20.400

Owner: B. R. Tate Total depth: 144 feet

Interval (feet)	Description
	Quaternary valley fill:
0-1	No sample.
1-20	SAND: light tan; 99 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand; samples very clean; no cement.
20-50	SAND: light tan; 99 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with some caliche fragments; poorly cemented by light gray, $CaCO_3$ cement.
50-90	SAND: light tan; 99 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand; poorly cemented by light gray, $CaCO_3$ cement.
90-100	SAND: light tan; 95 per cent very fine to fine-grained subangular to subrounded, well sorted, quartz sand with 5 per cent silt; poorly indurated.
100-120	SAND: brown; 90 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 10 per cent silt and a trace of clay; poorly indurated.
120-130	SAND: brown; 90 per cent very fine to coarse-grained, subangular to subrounded, poorly sorted, quartz sand with 10 per cent silt and traces of clay and very fine gravel; poorly indurated.
130-140	SAND: brown; 90 per cent fine- to coarse-grained, subangular to rounded, poorly sorted, quartz sand with 5 per cent silt and 5 per very fine gravel; poorly indurated.

140-144 No sample.
Total depth.

Theis, (1932, p. 110) reports the presence of fossil pelecypods, at scattered localities, in the upper part of these deposits, and on the basis of these finds has attributed at least some parts of this unit to lacustrine-type deposition. It is his belief, however, that the upper unit of the valley fill is probably an aeolian deposit which grades downward into the underlying sediment of fluviatile origin. Robbins (1941, pl. 2) has recognized eight periods of erosion and deposition in the area that range from Nebraskan to Recent in age, which he has correlated with the developmental sequence postulated for the Pecos Valley by Fiedler and Nye (1933, p. 112). The lower part of his section consists largely of cross-bedded sand, gravel, cobbles, and clay balls, to which he has assigned a Nebraskan age. This unit is overlain by seven successive units that consist primarily of aeolian sand and loess that are separated by postulated periods of erosion which include several periods of caliche development. The recognition of these latter units, however, is largely beyond the scope of this investigation, which has recognized only the general subdivision of the valley fill into a lower fluviatile deposit and an overlying unit that consists primarily of aeolian sand and loess.

The lithologic character of the lower part of the valley fill indicates that this fluviatile deposit was derived from both the mountains to the north and west and the rocks that were exposed in the adjacent areas on both the north and south sides of the valley during early Pleistocene time. The upper part of the valley fill is considered to be chiefly an aeolian deposit that includes localized lacustrine deposits.

The sediment of the upper part is considered to have been derived primarily from the Triassic, Cretaceous, and Tertiary formations that are present on both the north and south sides of the valley.

The caliche zones, like those of the Ogallala formation, are believed to have developed by soil-forming processes from parent materials consisting largely of limestone gravel and older caliche fragments.

STRUCTURE

GENERAL STATEMENT

The geologic structure of the Portales Valley area is characterized by a gentle east-to-southeastward regional dip. This regional dip is interrupted only by gentle folds that are limited, so far as is known, to the Triassic and older rocks. The location and structure of these gentle folds can only be determined by a detailed study of well logs or by geophysical methods. The details of these structures have little, if any, bearing upon the problems connected with this investigation; consequently, no detailed study has been devoted to them.

The only structural features studied in any detail are those that have developed since the close of deposition in late Triassic time. These are limited largely to the lenticular bedding of the post-Cretaceous sediments, which have been discussed previously, and to the erosional unconformities that have developed since late Triassic time.

POST-TRIASSIC UNCONFORMITIES

Although a number of major unconformities have been recognized in deep wells which penetrate the thick stratigraphic sequence that underlies the Portales Valley, the subsurface data available to the writer are generally insufficient to permit the detailed mapping of most of these surfaces within the area studied. Drilling activity in the area has been limited largely to water wells and to relatively shallow holes drilled during seismic prospecting. These are usually drilled to the top of the Dockum group, but seldom penetrate beyond; consequently, only those unconformities that have developed since Triassic time can be studied in any detail. In fact, only the unconformities

that have developed during the periods of erosion since Cretaceous time are of importance to the evaluation of the ground-water supply of the Portales Valley area.

Since late Triassic time the Portales Valley area has undergone at least three periods of extensive erosion that have been followed by periods of deposition. Each of these successive periods of erosion has modified to some extent the final surface developed by the period of erosion immediately preceding it, and in each period the erosion has extended into the underlying "red beds" of Dockum group. As a result, each period of erosion and the succeeding period of deposition within the area studied are represented by an erosional surface on the "red beds" upon which the sediment of the succeeding period of deposition rests unconformably. The "red beds" of the Dockum group are overlain by the Kiamichi-Duck Creek shale unit of Cretaceous age south of the valley, by the Ogallala formation of Miocene (?)-Pliocene age in the area north of the valley, in northeastern Roosevelt and southern Curry Counties, and by valley fill of Pleistocene-Recent age in the Portales Valley proper. On this basis, it is evident that periods of erosion occurred in this area during post-Triassic-pre-Cretaceous time, post-Cretaceous-pre-Miocene (?) time and in early Pleistocene time.

It is unfortunate that data are not presently available that would permit the mapping of the remnants of each of these erosional surfaces in all of the area studied, particularly in those areas on the north and south sides of the valley where the successively younger unconformities transcend the sediment and rocks occurring above and below the older unconformities; however, the top of the Dockum group, which represents a composite erosional surface that is the end result of all these periods of erosion, has been mapped in considerable detail, and it is

believed that a description of this surface within the limits of a given overlying sediment will reveal in a general way the character of the erosion surface that existed prior to the deposition of that sediment.

The configuration of the top of the Dockum group is shown on Figure 4. North-south profiles of this surface within the general limits of the area of study are shown on Figure 5.

Post-Triassic-Pre-Cretaceous Unconformity

The only remnant of the post-Triassic-pre-Cretaceous erosional surface known to exist in the Portales Valley area occurs south of the valley proper in T. 4 S., R. 34, 35, 36 and 37 E. (Fig. 4), where rocks of Cretaceous age occupy an erosional trough incised into the underlying Dockum group. Subsurface data available for this area have enabled the writer to trace this trough northeastward from the vicinity of Dora to the vicinity of Rogers and thence eastward to the New Mexico-Texas state line. The trough has an average width of about 5 miles and exhibits local relief that ranges from approximately 80 feet to slightly more than 150 feet.

Within the limits of the area mapped, the profile along the axis of this trough is steplike and exhibits three relatively abrupt changes in gradient that are separated by relatively flat surfaces. These changes in gradient occur in the areas southeast of Dora, south of Rogers, and in the vicinity of the east line of R. 36 E. near the eastern limit of the available subsurface data. South and east of Dora depressions have been encountered on the surface of the unconformity, and as a result of these, the floor of the trough tends to be somewhat irregular in this area. South and east of Rogers, however, the floor of the trough tends to flatten along the axis and the trough assumes a broad assymetrical,

believed that a description of this surface within the limits of a given overlying sediment will reveal in a general way the character of the erosion surface that existed prior to the deposition of that sediment.

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Post-Triassic-Pre-Cretaceous Unconformity

The only remnant of the post-Triassic-pre-Cretaceous erosional surface known to exist in the Portales Valley area occurs south of the valley proper in T. 4 S., R. 34, 35, 36 and 37 E. (Fig. 4), where rocks of Cretaceous age occupy an erosional trough incised into the underlying Dockum group. Subsurface data available for this area have enabled the writer to trace this trough northeastward from the vicinity of Dora to the vicinity of Rogers and thence eastward to the New Mexico-Texas state line. The trough has an average width of about 3 miles and exhibits local relief that ranges from approximately 80 feet to slightly more than 150 feet.

Within the limits of the area mapped, the profile along the axis of this trough is steplike and exhibits three relatively abrupt changes in gradient that are separated by relatively flat surfaces. These changes in gradient occur in the area southeast of Dora, south of Rogers, and in the vicinity of the east line of R. 36 E. near the eastern limit of the available subsurface data. South and east of Dora depressions have been encountered on the surface of the unconformity, and as a result of these, the floor of the trough tends to be somewhat irregular in this area. South and east of Rogers, however, the floor of the trough tends to flatten along the axis and the trough assumes a broad asymmetrical,

U-shaped cross section which persists to the approximate center of Sec. 14, T. 4 S., R. 36 E. East of this point the trough widens as it continues across the New Mexico-Texas state line.

Although the limited extent of this remnant erosional surface precludes the drawing of definite conclusions relative to the regional geomorphology of post-Triassic-pre-Cretaceous time, it is believed that the unconformity in this area is indicative of a surface of low-to-moderate relief on which the drainage pattern in any given area had developed in consequence to the lithology and structure of the Dockum group then present at that locality. Although other substantiating data are not available, the presence of the depressions on the floor of the trough south and east of Dora and the general irregularity of the top of the Dockum group in this area suggest that solution of the underlying Permian rocks was active prior to or during the period of development of this surface. On this basis it is believed that the drainage pattern developed on this surface may have been related, to some extent, to zones of weakness produced by the removal of the more soluble parts of the underlying Permian rocks and the subsequent subsidence of the overlying Dockum group. The steplike profile along the axis of the trough is believed to be due largely to the differential resistance to erosion of the various lithologic units present in the Dockum group in this area.

Post-Cretaceous-Pre-Miocene(?) Unconformity

A remnant surface of the post-Cretaceous-pre-Miocene(?) unconformity in the Portales Valley area occurs in northeastern Roosevelt and southern Curry Counties, where rocks of Miocene(?)-Pliocene age rest unconformably on the underlying Dockum group. Data available to the writer suggests that this unconformity extends northward from the northern

U-shaped cross section which persists to the approximate center of Sec. 14, T. 4 S., R. 36 E. East of this point the trough widens as it continues across the New Mexico-Texas state line.

Although the limited extent of this remnant structural surface precludes the drawing of definite conclusions relative to the regional geomorphology of post-Triassic-pre-Cretaceous time, it is believed that the unconformity in this area is indicative of a surface of low-to-moderate relief on which the drainage pattern in any given area had developed in consequence to the lithology and structure of the Dockum group then present at that locality. Although other substantiating data are not available, the presence of the depressions on the floor of the trough south and east of Bora and the general irregularity of the top of the Dockum group in this area suggest that solution of the underlying Permian rocks was active prior to, or during the period of development of this surface. On this basis it is believed that the drainage pattern developed on this surface may have been related, to some extent, to zones of weakness produced by the removal of the more soluble parts of the underlying Permian rocks and the subsequent subsidence of the overlying Dockum group. The steplike profile along the axis of the trough is believed to be due largely to the differential resistance to erosion of the various lithologic units present in the Dockum group in this area.

Post-Cretaceous-Pre-Miocene(?) Unconformity

A remnant surface of the post-Cretaceous-pre-Miocene(?) unconformity in the Portales Valley area occurs in northeastern Roosevelt and southern Curry Counties, where rocks of Miocene(?) Pliocene age rest unconformably on the underlying Dockum group. Data available to the writer suggests that this unconformity extends north and from the northern

margin of the Portales Valley proper and is present throughout most of Curry County. The rocks of the Dockum group that occur below this unconformity form an effective barrier to the downward percolation of the shallow ground water occurring in the Ogallala formation in this area. The similarity of the sediment of the valley fill and the Ogallala formation along the northern margin of the Portales Valley precludes an accurate determination of the southern limit of this unconformity; however, a comparison of the profile of the land surface with a northward extrapolation of the profile of the Triassic-early Pleistocene unconformity in the Portales Valley proper, along a given north-south line (Fig. 5), suggests that the southern limit of this unconformity is roughly coincident with a low southeast-trending "red bed" ridge with 20 or more feet of local relief. This ridge is somewhat curvilinear from the vicinity of Sec. 33, T. 1 S., R. 36 E. to Sec. 30, T. 2 N., R. 33 E.

The post-Cretaceous-pre-Miocene(?) unconformity in the previously described area is a gently undulating surface, much like the present surface of the Llano Estacado, that slopes gently eastward at an average gradient of about 18 feet per mile. The local relief in this locality, as indicated by north-south profiles, is about 20 feet. The maximum north-south relief is slightly more than 50 feet.

A comparison of the general elevation of the top of the Dockum group in this area, with the present general elevation of the top of the Cretaceous system on the south side of the Portales Valley, suggests a pre-Miocene(?)-Pliocene topographic surface of moderate local relief, upon which was developed a southeast-trending, consequent drainage system. This drainage system is believed to have consisted largely of broad, shallow valleys which were separated by low southeast-trending

ridges, many of which were capped by rocks of Cretaceous age. These ridges, on the basis of data collected during this investigation, appear to have risen 200 to 300 feet or more above the general level of the valley floors. The presence of depressions on this unconformity, particularly in the vicinity of the southeast corner of T. 2 S., R. 33 E. and in Sec. 10, T. 1 S., R. 36 E., suggests that solution may also have been active in the underlying rocks prior to or during the period of development of this surface.

Early Pleistocene Unconformity

As noted previously in this report, the Pleistocene-Recent sediment present in the area covered by this investigation rests directly on rocks of the Triassic, Cretaceous and Tertiary systems. This contact is an erosional unconformity that is believed to extend from the area immediately north of the previously described "red bed" ridge on the north side of the Portales Valley proper, to approximately the northern margin of the post-Triassic-pre-Cretaceous unconformity on the south side of the valley. Within the general area of ground water development, the Cretaceous and Tertiary sediment is absent and the valley fill of Pleistocene-Recent age rests directly on the "red beds" of the underlying Dockum group. The contact of these rocks in this area is particularly important because the latter rocks form an effective barrier to the downward percolation of water from the overlying valley fill.

The Triassic-early Pleistocene unconformity in the Portales Valley area consists primarily of a relatively broad, shallow, generally U-shaped, erosion trough that is incised into the beds of the Dockum group. The axis of this trough trends in a generally east-to-south-

eastward direction from the vicinity of Sec. 5, T. 1 S., R. 32 E, to a point approximately 3 miles southeast of Portales, and from this point continues in a generally eastward direction to the New Mexico-Texas state line. The average gradient along the axis is about 10 feet per mile, and the total relief on the "red beds", as indicated by north-south profiles across the valley (Fig. 5), is slightly more than 320 feet. Valleys tributary to this trough have been mapped in several localities, particularly in the vicinity of the south line of T. 1 S., R. 33 E., and the SW 1/4 of T. 2 S., R. 35 E.

The principal irregularities of this erosion surface, in the area covered by this investigation, consist primarily of local steepenings in the trough gradient and the occurrence of depressions in several localized areas on the trough floor. The general profiles along the axes of the principal trough and its tributaries (Fig. 4), are steplike and exhibit several relatively abrupt changes in gradient that are separated by relatively flat stretches. A similar configuration may also be seen (Fig. 5) in the cross profile taken along the east line of R. 34 E. Notable depressions occur on the approximate axis of the principal trough in the vicinity of Sec. 12, T. 2 S., R. 35 E. and Sec. 24, T. 2 S., R. 36 E.

A comparison of the general elevation of the principal trough axis near the New Mexico-Texas state line, with the present elevation of the top of the Cretaceous rocks on the south side of the valley, suggests a local relief of more than 400 feet in the Portales Valley area during early Pleistocene time. The steplike configuration of the trough surface is attributed largely to the presence of resistant strata within the generally poorly indurated rocks of the Dockum group in this area. The presence of depressions near the axis of the trough suggests

collapse of the near-surface Triassic rocks as the result of active solution in the underlying Permian rocks prior to or during the period of development of this surface.

collapse of the near-surface Triassic rocks as the result of active solution in the underlying Permian rocks, prior to, or during the period of development of this surface.

PHYSIOGRAPHY

The Portales Valley area is a part of the Llano Estacado or "Staked Plains" which in turn is a part of the High Plains section of the Great Plains Province (Fenneman, 1931, pl. 1). The area here considered lies in the west-central part of the Llano Estacado.

The Llano Estacado is typically a grassy, treeless plateau of low relief that occupies a large part of eastern New Mexico and western Texas. The New Mexico part of this plateau is broken by bold, erosion escarpments which face the Canadian River to the north and the Pecos River to the west. The surface in this region slopes southeastward at a gradient of 5 to 15 feet per mile and is one of remarkable smoothness, being interrupted only by numerous dry lakes and playas, a small number of low mesas or cuestas,localized areas of sand dunes, and a few relatively broad, shallow valleys that traverse the area. The Portales Valley is the longest and best developed of these valleys (Theis, 1932, p. 103).

The Portales Valley extends from the vicinity of Krider, at the western edge of the Llano Estacado, in a southeastward direction through Portales to Big Salt Lake at the approximate meridian of the New Mexico-Texas state line. The valley attains a total width of about 30 miles and exhibits a total north-south relief of about 250 feet. Elevations on the floor of the valley in the area studied range from about 4,200 feet in the vicinity of Sec. 31, T. 2 N., R. 31 E., to less than 3,880 feet in the vicinity of Big Salt Lake. The maximum elevation in this area is attained in Sec. 8, T. 1 N., R. 30 E., where an elevation of slightly more than 4,340 feet is reached. The average gradient along

the axis of the valley is about 8 feet per mile. A belt of sand dunes as much as 5 miles wide and 50 feet high lies northeast of the axis of the valley in the area covered by this investigation and divides the valley into two draws which have been previously referred to in this report as Blackwater Draw and the Portales Valley proper. Blackwater Draw is the higher of these draws and constitutes a relatively minor physiographic feature in comparison with the Portales Valley proper, which lies on the southwest side of these dunes.

The floor and side slopes of the Portales Valley proper are characteristically smooth with the gentle gradients being interrupted only by localized areas of minor sand dune development and numerous surface depressions, playas, salt lakes and salt-grass flats. This part of the valley has a closed drainage system and the surface runoff that occurs from precipitation falling in the area drains primarily into these depressions where it is lost by evaporation, transpiration, and seepage. The larger of these depressions include Big Salt Lake, Little Salt Lake, Tierra Blanca Lake, and an unnamed major depression that is present about 2 miles northwest of the townsite of Floyd.

The dunes separating the Portales Valley proper from Blackwater Draw appear to be relatively well stabilized and are largely covered with mesquite, yucca, and other vegetation characteristic of stabilized dune areas in semiarid climates. Similar dunes, merging in places with the north slope of the valley, occur on the northeast side of Blackwater Draw at the approximate northern limit of the area covered by this investigation. Active dunes of moderate extent occur in some areas on the south side of the valley and in extremely localized areas

within the area studied. Aeolian deposits are particularly prominent features on the east and southeastern sides of the lakes and dry depressions in the area and have been described by Theis (1932, p. 105) as follows:

> "A very noteworthy feature of all the large lakes consists of deposits of fine silt on the eastern and southeastern edges of the lake beds. This material is massive and structureless and is evidently of eolian origin.....
>
> On the easterly sides of the lakes and dry depressions in Portales Valley there are deposits of clayey silt, which are doubtless of eolian origin. The material is massive in structure, in contrast to the laminated beds found on the westerly sides of the basins. Gastropods only are contained in these deposits, whereas the laminated beds to the west contain also small pelecypods in abundance.
>
> The size of these silt deposits is dependent upon the size of the playas or lakes near which they lie. Thus the deposits at Lake Tierra Blanca rise some 30 feet above the playa level and then deposits at Big Salt Lake, the largest of the water bodies, attain a height of about 100 feet above the lake."

The general physiographic characteristics of Blackwater Draw are similar to those of the Portales Valley proper.

The configuration of the land surface in the area studied is shown on Figure 7. North-south profiles of the land surface, taken on the New Mexico-Texas state line and the successive range lines to the west, are shown on Figure 5. It should be noted here that the surface configuration shown on these figures for the line of sand dunes that separate the Portales Valley proper from Blackwater Draw, although based on actual elevation determinations, is somewhat generalized, and should not be construed to represent the exact configuration of the land surface in this area. These figures, which do not show the many smaller natural irregularities of this area, are based largely on elevations obtained

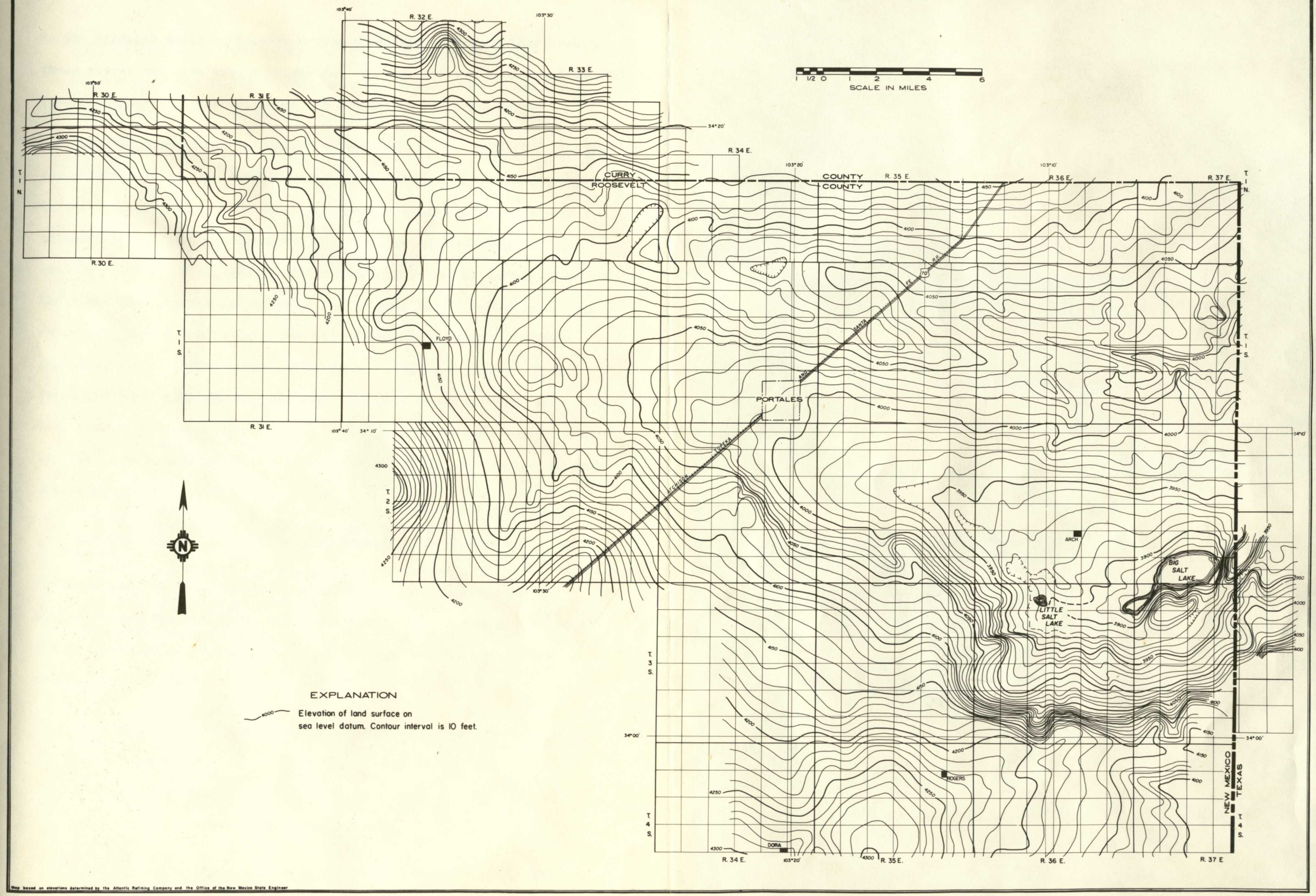

Figure 7. Topography of the Portales Valley area, Roosevelt and Curry Counties, New Mexico.

by the Atlantic Refining Company during a seismic survey of this area. These elevations have been supplemented, to some extent, by an instrumental leveling program of the Office of the New Mexico State Engineer.

ORIGIN OF THE PORTALES VALLEY AND THE SURFACE DEPRESSIONS

A review of the geologic literature relative to the southern Llano Estacado of eastern New Mexico and western Texas reveals a general agreement between previous workers in the area (Baker, 1915; Theis, 1932; Price, 1944; et al.) in attributing the surface depressions occurring on the land surface in this area to the removal of some of the more soluble beds of the underlying Permian rocks by solution and the subsequent subsidence of the relatively incompetent overlying rocks. Similarly, there has been general agreement in the recognition of the Portales Valley as an abandoned stream channel cut off by capture by the Pecos River (Meinzer, 1909a, 1909b; Baker, 1915; Theis, 1932; and Robbins, 1941). Price (1944, p. 401), however, has not conceded to the latter interpretation and has concluded that the development of both the Portales Valley and the surface depressions is due to surface collapse. He has further concluded (p. 404) that:

> "the conception of a Brazos river flowing through the Portales trough in a wide valley, seems to have no secure basis."

It is believed that the following observations, drawn from both the literature and the field data collected during this investigation, may aid in establishing the validity of the earlier conclusions for the Portales Valley area.

1. A comparison of the surface topography and the paleotopography of the Dockum group in the vicinity of some of the larger depressions reveals no depression of the "red-bed" surface in the vicinity of these surface depressions.

2. Although both Baker (1915, p. 47) and Theis (1932, p. 115)

have presented positive evidence of slumping, particularly in the vicinity of Yellow and Illusion Lakes in Bailey County, Texas, and in the vicinity of Red Lake, which lies south of the Portales Valley, no evidence has been noted during this investigation that would indicate collapse in the area studied. The dip of the Triassic and Cretaceous beds exposed on the south side of the Portales Valley is to the south, and not to the north as would be expected had the valley developed as a collapse trough. Similarly, the dip of the Triassic beds exposed on the northwest side of Lewiston Lake is to the west, and not to the east as would be expected had this lake developed as a collapse basin.

3. The aeolian deposits noted by Theis (1932, p. 105) on the lee side of Big Salt Lake and Tierra Blanca Lake appear to be of sufficient size to largely account for the volume of material necessary to refill the depressions (Fig. 7). If these depressions are due to aeolian erosion, some of the material removed by the wind has undoubtedly been carried some distance beyond the leeward extent of the present aeolian deposits.

4. The character of the deposits of the basal valley fill is indicative of fluviatile deposition. The presence of the extensive gravel deposit in the basal valley fill can only be explained by assuming a gravel-producing provenance in the mountainous areas to the north and west of the area studied. There are no formations within the present limits of the Llano Estacado that could produce gravel as an erosion product, to

the extent necessary to produce the deposit now present in this valley.

5. The general spatial relations of the post-Triassic unconformities are indicative of extensive erosion in the Portales Valley during early Pleistocene time.

Although it must be conceded that some of the depressions occurring on the surface of the southern Llano Estacado may be the result of subsidence of the near-surface sediment due to the removal of some of the more soluble parts of the underlying Permian strata by solution, on the basis of the foregoing observations made both by previous workers and the writer it is concluded that there is no evidence to substantiate the theory of solution and subsidence in either the development of the Portales Valley or the major post-Pleistocene surface depressions that occur in this area. The evidence, however, largely substantiates the generally accepted theory which attributes the initial development of the Portales Valley trough to early Pleistocene erosion. The presence of the major surface depressions in the area is tentatively attributed to aeolian erosion.

GEOLOGIC HISTORY

The geologic record reflected in the rocks underlying the Portales Valley indicates that the area covered by this investigation comprised a shelf area of the Permian basin, which occupied a large part of southeastern New Mexico and western Texas during Permian time. The character of the sediment indicates that the water was largely shallow and that much of the deposition took place in partially or completely landlocked basins. During the depositional periods, intervals of chemical precipitation alternated with intervals of clastic sediment influx from the adjacent land masses. Deposition was accompanied by a slow subsidence of the basin which maintained shallow water conditions and at the same time allowed a considerable thickness of sediment to accumulate in this area. The retreat of the Permian sea was followed by a period of mild erosion and local folding (Adams, 1929, p. 1049) that apparently continued in the region until late Triassic time.

The deposition of the Dockum group was initiated by considerable uplift and erosion of Llanoria to the east in late Triassic time, which spread sediment to the west on a west- to northwest-sloping post-Permian terrain (Adams, 1929, p. 1047). During the early part of this period, particularly in the region along the eastern margin of the Llano Estacado, the streams emerging from Llanoria deposited coarse-grained, clastic sediment in alluvial fans. As erosion continued, these fans coalesced as a broad, uniform, terrestrial floodplain, on which overloaded meandering streams deposited progressively finer-grained sediment of the Santa Rosa sandstone as they continued westward. By Chinle time, the continued reduction of Llanoria by erosion and the resulting decrease in stream gradients allowed only the finer sediment to be transported. The fine sediment gave rise to the extensive shale beds

GEOLOGIC HISTORY

of the upper Dockum group. Sediment apparently was also being contributed to these deposits from the highlands of southern Colorado and northern New Mexico.

The interval of time between the close of Triassic deposition and the beginning of early Cretaceous time was apparently a period of local deformation in which extensive erosion was predominant over deposition. The latter is indicated by the general absence of Jurassic sediment from the High Plains area and the almost complete removal of the upper beds of the Dockum group from the eastern margin of Triassic deposition. Robbins (1941, p. 5) has noted localized, small-scale faulting and folding in Triassic exposures in the escarpment of the Llano Estacado, which, apparently, took place during this interval.

The advent of Cretaceous time was accompanied by a slow subsidence of the area and a spasmodic advance of a shallow Comanchean sea from the southeast. Progressively younger beds were deposited on the underlying Dockum group as the sea transgressed to the north and west, and the Portales Valley apparently represents the approximate western margin of the sea during Fredricksburg and Washita time in the High Plains area. Although all evidence of late Cretaceous sedimentation has been removed from the geologic record in the area studied, deposition apparently continued throughout this region until the initiation of the Laramide orogeny, and the subsequent withdrawal of the late Cretaceous sea.

Following the withdrawal of the Cretaceous sea most of the Cretaceous and part of the Triassic deposits of the area were removed by early and middle Tertiary erosion. In late Tertiary time, however, considerable rejuvenation of the area to the west resulted in the spread of an extensive blanket of clastic sediment over the area, which

of the upper Dockum group. Sediment apparently was also being contributed to these deposits from the highlands of southern Colorado and northern New Mexico.

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continued until early Pleistocene time. The sediment deposited during this interval gave rise to the Ogallala formation now present on the High Plains. The Ogallala formation apparently represents alluvial deposits which in time coalesced and allowed the sediment-carrying streams to meander and assume the braided pattern characteristic of overloaded streams in an arid region. In this manner a lensing deposit of clastic material ranging in grade size from silt to gravel was built up to a nearly uniform surface. Alternating periods of deposition and non-deposition, under generally arid conditions, allowed the formation of caliche during various intervals of this period.

In early Pleistocene time, as the result of a general increase in precipitation and the melting of glaciers in the mountains to the northwest, a stream having a course similar to the Pecos River above Fort Sumner crossed the plains to the vicinity of the Brazos River, near Lubbock, Texas, and began incising itself in what is now the Portales Valley. The ensuing erosion resulted in the removal of all the Tertiary sediment and part of the Triassic and Cretaceous rocks from the valley floor. As this stream became graded, downcutting gave way to lateral gradation which eventually resulted in the stream becoming incompetent to the point that it could no longer transport the coarse material which it received from its mountain tributaries. This condition resulted in the deposition of the fluviatile sand and gravel in the lower part of the valley fill of the Portales Valley.

During the period of erosion and the subsequent period of fluviatile deposition in the Portales Valley, the general increase in precipitation in the region also resulted in a general extension of the Pecos River by headward erosion, to a close proximity of the Brazos drainage system passing through the Portales Valley. As the headward

erosion of the Pecos River continued, its upper reaches eventually captured the upper Brazos drainage system through stream piracy. According to Robbins (1941, p. 11) this capture occurred late in the Nebraskan stage of early Pleistocene time.

Subsequent to the loss of its contributory drainage, the geologic history of the Portales Valley has been limited largely to a slow filling of the trough with aeolian silt and sand, lake beds, and minor fluviatile deposits, and the development of the sand dunes and surface depressions. At the present time the area is undergoing little modification from agencies other than the wind and the "sheet wash" that usually occurs during short periods of intense precipitation.

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CLIMATOLOGY

The climate of the Portales Valley area is characterized by sunny days, low relative humidity, relatively low rainfall and a high evaporation rate; consequently, the area can be classed as semiarid. The winters are relatively cool, summers are warm, and light breezes prevail throughout most of the year.

The climate of this area, like most of the southern High Plains, is well suited to the pursuance of certain types of agriculture when sufficient soil moisture is available. During years of normal and above-normal precipitation, grain sorghum, broomcorn, and wheat may be produced by dry-farming methods. Irrigation, however, is normally necessary for the successful production of the majority of crops produced in the valley.

Climatological records have been collected for a number of years at several localities in the general area of this study, and include data relative to precipitation, temperature, evaporation, and wind movement. Eight stations have been maintained by the U. S. Weather Bureau in, and immediately adjacent to, the Portales Valley. The data contained in the subsequent paragraphs of this report have been computed from the records of these stations that have been drawn from data compiled by the New Mexico Interstate Stream Commission and the annual Climatological Summaries of the U. S. Weather Bureau. The stations for which data are presented, and the latitude, longitude, elevation, and period of record available for each, are given in Table 1. The location of these stations is shown on Figure 8.

Computed mean monthly values, mean annual values, and the period of record for the records obtained at these eight stations are given in

The climate of the Portales Valley area is characterized by many days, low relative humidity, relatively low rainfall and a high evaporation rate; consequently, the area can be classed as semiarid. The winters are relatively cool, summers are warm, and light breezes prevail throughout most of the year.

The climate of this area, like most of the south Great Plains, is well suited to the production of certain types of agriculture where sufficient soil moisture is available. Narrow rows of normal and above normal precipitation, grain sorghums, broomcorn, and wheat may be produced by dry-farming methods. Irrigation, however, is usually necessary for the successful production of the majority of crops produced in the valley.

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Computed mean monthly values, mean annual values, and the period of record for the records obtained at these eight stations are given in

Table 1

Weather Stations - Portales Valley Area

Station	Record*	Latitude	Longitude	Elevation	Period of Record
Melrose	P	34° 26'	103°38'	4599	1908-1954
	T				1908-1910; 1926-1927; 1941-1954
Clovis	P	34°24'	103°12'	4280	1911-1954
	T				1911-1954
Floyd	P	34°13'	103°33'	4300[a]	1929-1954
Portales 7WNW	P	34°14'	103°26'	4200[b]	1934-1954
	T				1934-1954
	E				1934-1954
	W				1934-1954
Portales	P	34°10'	103°21'	4004	1905-1907; 1911-1954
	T				1905-1906; 1912-1954
Arch	P	34°07'	103°11'	4000[c]	1909-1911; 1929-1931; 1939-1954
Elida	P	33°57'	103°39'	4345	1913-1954
	T				1941-1954
Pep	P	33°50'	103°20'	4506	1913-1946; 1948-1953
	T				1913-1946; 1948-1953

* P - Precipitation, T - Temperature, E - Evaporation, W - Wind.
[a] Elevation should be revised to approximately 4150 feet.
[b] Elevation should be revised to approximately 4080 feet.
[c] Elevation should be revised to approximately 3920 feet.

Table 2

Weather Data Made Available by Observers

Station	Record*	Latitude	Longitude	Elevation (Feet)	Period of Record
Melrose	P	34° 26'	103° 39'	4890	1908-1960
	T				1908-1910
					1912-1924
					1926-1960
Clovis	P	34° 24'	103° 12'	4200	1911-1960
	T				1911-1924
					1926-1960
Floyd	P	34° 13'	103° 33'	4300	1939-1960
Portales NWR	P	34° 14'	103° 24'	4270	1934-1960
	T				1934-1960
	S				1934-1960
	W				1934-1960
Portales	P	34° 10'	103° 21'	4090	1902-1960
	T				1910-1924
					1926-1960
Arch	P	34° 07'	103° 11'	4000	1939-1960
					1939-1941
					1943-1960
Elida	P	33° 57'	103° 39'	4090	1923-1960
	T				1941-1954
					1956-1960
Pep	P	33° 50'	103° 20'	4300	1918-1960
	T				1918-1923
					1925-1960

* P - Precipitation, T - Temperature, E - Evaporation, S - Snow.
[a] Elevation should be revised on topographic quadrangle.
[b] Elevation should be verified by observer in 1959 Event.
[c] Elevation should be revised by approximately 2500 ft.

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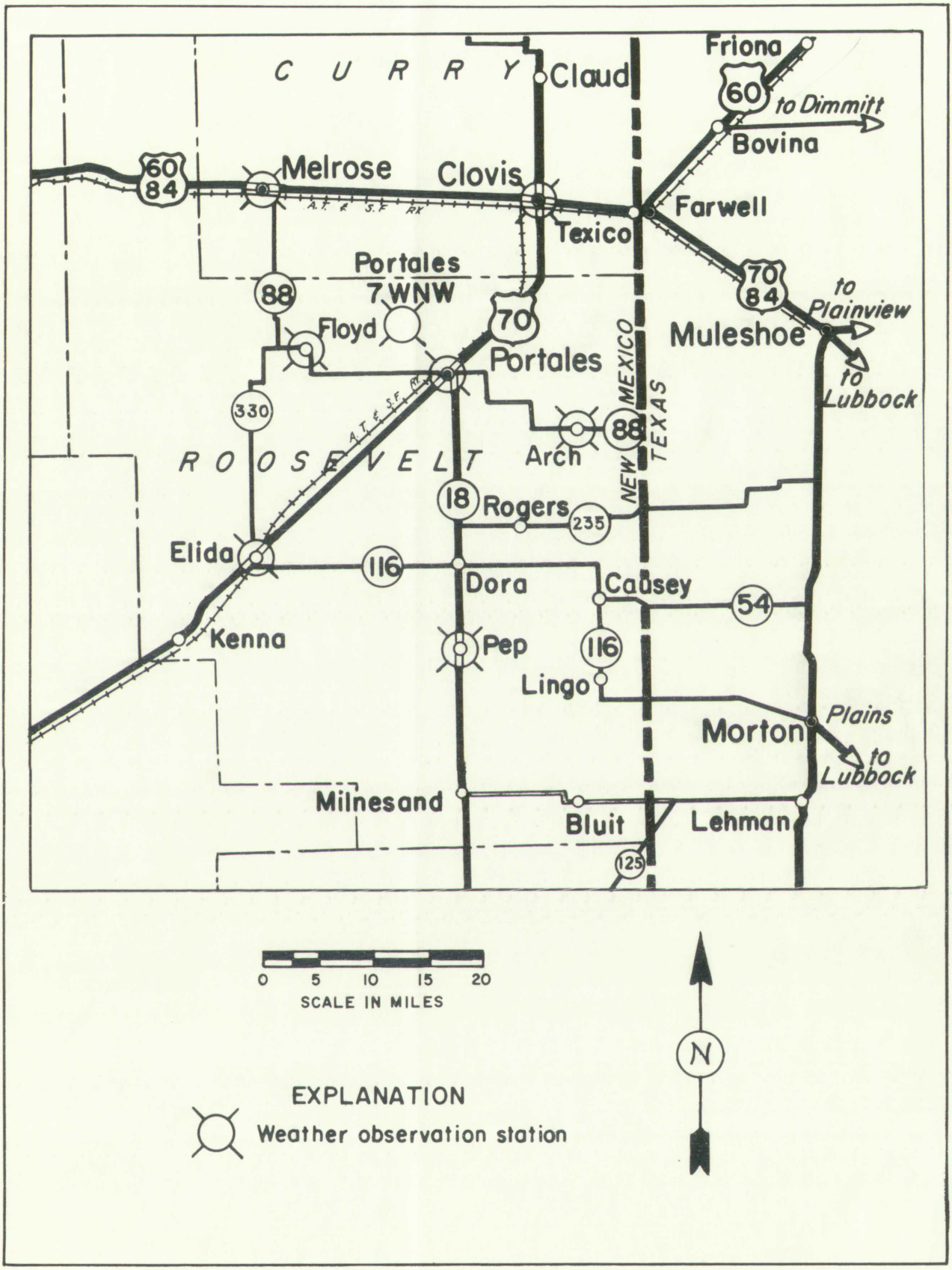

Figure 8. Location of weather observation stations, Portales Valley area, Roosevelt and Curry Counties, New Mexico

Tables 2 through 6. Appropriate plots of these data are given on Figures 9, 10 and 15. All mean values given in these tables, the graphic presentations of these data and the paragraphs of this report that follow are computed means, based on the summation of actual records and the actual number of years for which these records are available. Values so computed vary somewhat from the normals computed for any given station by the U. S. Weather Bureau. All records have been computed from the initial year of record through 1954.

PRECIPITATION

Mean annual precipitation in the Portales Valley area, like the mean annual precipitation in the remainder of the southern High Plains area of New Mexico, increases generally from southwest to northeast and ranges from 13.99 inches for 26 years of record and 14.92 inches for 36 years of record at Pep and Elida, respectively, in southern Roosevelt County, through 17.34 inches for 33 years of record at Portales, to 17.79 inches for 41 years of record at Clovis in Curry County.

Some precipitation falls on the area as snow during the winter, but the principal precipitation comes during the growing season. The precipitation usually comes in the form of scattered thundershowers of varying intensities, which occur in an irregular fashion over the area. In many instances the storms are localized to the extent that one section of land may be drenched by a moderate-to-heavy rain, whereas the adjacent sections receive no precipitation.

TEMPERATURE

Mean annual temperatures vary only slightly among the six stations for which temperature records are available in the Portales Valley area,

Table 2

Precipitation - Portales Valley Area

Melrose, Curry County

Record	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Years of Record	42	41	41	42	40	41	43	41	41	41	41	40	35
Mean in Inches	0.36	0.37	0.66	1.16	2.00	1.93	2.36	2.83	1.77	1.37	0.53	0.63	15.38

Clovis, Curry County

Record	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Years of Record	43	43	43	43	42	44	44	44	44	42	44	44	41
Mean in Inches	0.41	0.40	0.57	1.28	2.29	2.51	2.43	2.90	2.07	1.85	0.49	0.56	17.79

Floyd, Roosevelt County

Record	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Years of Record	24	25	25	24	25	26	25	26	26	26	25	26	21
Mean in Inches	0.40	0.22	0.42	0.67	2.27	1.73	2.24	2.09	1.73	1.51	0.41	0.56	14.78

Portales 7 WNW, Roosevelt County

Record	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Years of Record	21	20	21	21	21	21	20	21	21	21	21	21	19
Mean in Inches	0.38	0.26	0.46	0.74	2.68	2.12	2.75	2.20	2.13	1.73	0.50	0.64	16.56

Table 8

Precipitation - Portales Valley Area

Meltrose, Curry County

Record	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Years of Record	42	41	42	42	40	41	42	41	41	41	41	40	39
Mean in Inches	0.37	0.56	1.10	2.00	1.83	2.38	2.85	1.77	1.37	0.58	0.53	0.39	15.38

Clovis, Curry County

Record	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Years of Record	42	42	42	42	42	42	42	42	42	42	42	42	42
Mean in Inches	0.40	0.57	1.04	2.00	3.03	3.01	2.85	2.09	1.85	0.90	0.53	0.43	18.45

Portales, Roosevelt County

Record	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Years of Record	34	34	34	34	34	34	34	34	34	34	34	34	34
Mean in Inches	0.40	0.58	1.07	1.90	3.27	3.09	2.69	2.09	1.70	0.87	0.58	0.46	18.45

Table 2 (cont'd.)

Portales, Roosevelt County

Record	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Years of Record	45	45	44	43	41	42	42	44	44	44	42	43	33
Mean in Inches	0.37	0.41	0.72	1.15	2.42	2.49	2.71	2.88	2.12	1.40	0.53	0.64	17.34

Arch, Roosevelt County

Record	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Years of Record	19	17	19	18	19	19	17	17	18	19	18	16	10
Mean in Inches	0.25	0.33	0.42	1.07	2.23	1.74	2.38	2.03	1.80	1.43	0.40	0.59	15.23

Elida, Roosevelt County

Record	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Years of Record	39	39	39	39	40	41	39	41	41	41	40	39	36
Mean in Inches	0.33	0.29	0.52	0.86	1.82	1.98	2.39	2.53	2.21	1.33	0.36	0.50	14.92

Pep, Roosevelt County

Record	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Years of Record	34	34	33	35	36	36	38	37	36	36	33	34	26
Mean in Inches	0.32	0.25	0.58	0.88	1.73	1.91	2.34	2.05	2.15	1.39	0.49	0.43	13.99

Table 3 (cont'd.)

Portales, Roosevelt County

and all computed mean values fall within the range of 1.1° F. between the lower extreme of 57.3° F. for 33 years of record at Portales and the upper extreme of 58.4° F. for 11 years of record at Elida.

The hottest weather of the year may be expected in July and the coldest weather in January. Mean values for the month of July range from 76.4° F. for 36 years of record at Pep to a high of 78.6° F. for 43 years of record at Clovis. Mean temperatures for the month of January range from the low of 36.7° F. for 42 years of record at Portales to 38.7° F. for 15 and 32 years of record at Melrose and Pep, respectively.

The average frost-free period, or period when temperatures do not drop below 32° F., as computed from the average records for the period of record of all the stations, is 193 days and ranges from a minimum mean value of 182 days at Portales to a maximum mean value of 201 days at Elida. The latest mean date for frost to occur in the area in the spring is April 21 at Portales. The earliest mean date for frost to occur in the area in the fall is October 20 at this same station. The average frost-free period for Elida extends from April 13 to October 21.

WIND MOVEMENT

Light-to-moderate breezes prevail in the Portales Valley throughout most of the year. Records collected by the U. S. Weather Bureau at the Portales Evaporation Station (Portales 7 WNW) show a total average wind movement of nearly 35,000 miles per year for the 14 years of record available at this station.

Wind movement tends to increase slowly from the month of September through the month of February. There is a sharp increase in velocity

Table 3

Temperature - Portales Valley Area

Melrose, Curry County

Record	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Years of Record	16	15	15	17	16	17	15	16	15	16	14	15	12
Mean in °F.	38.7	42.1	48.0	57.3	64.9	75.0	77.1	76.9	69.6	58.9	46.6	38.9	57.9

Clovis, Curry County

Record	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Years of Record	42	42	41	41	41	43	43	43	44	40	42	44	35
Mean in °F.	37.3	41.6	47.1	57.0	65.7	75.1	78.6	77.2	69.9	58.8	46.3	38.0	58.1

Portales 7 WNW, Roosevelt County

Record	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Years of Record	20	19	19	20	21	21	20	21	21	21	19	20	16
Mean in °F.	36.8	41.9	48.1	57.3	65.0	73.9	76.7	75.7	67.6	58.0	45.0	38.8	57.4

Portales, Roosevelt County

Record	Jan	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Years of Record	42	44	42	42	41	41	41	44	44	41	39	41	31
Mean in °F.	36.7	41.4	47.7	56.8	65.5	74.2	77.2	76.1	69.1	58.6	45.9	38.1	57.3

Table 3

Temperature - Fortaleza, Ceará

Meteorological Station, Ceará

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Mean maximum	31.0	30.6	30.4	30.1	29.6	29.2	29.1	29.6	30.2	30.8	31.1	31.2	30.3
Mean minimum	24.6	24.5	24.4	24.1	23.6	23.1	22.6	22.5	22.7	23.1	23.5	24.0	23.6
Absolute maximum	34.0	33.0	33.0	32.0	31.0	31.0	31.0	32.0	33.0	34.0	34.0	34.0	34.0
Absolute minimum	22.0	22.0	22.0	21.0	20.0	20.0	19.0	19.0	19.0	20.0	20.0	21.0	19.0
Mean	27.8	27.6	27.4	27.1	26.6	26.2	25.9	26.1	26.5	27.0	27.3	27.6	26.9
Mean daily range	6.4	6.1	6.0	6.0	6.0	6.1	6.5	7.1	7.5	7.7	7.6	7.2	6.7
Absolute range	12.0	11.0	11.0	11.0	11.0	11.0	12.0	13.0	14.0	14.0	14.0	13.0	15.0

Source: Meteorological Station, Ceará

Table 3 (cont'd.)

Elida, Roosevelt County

Record	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Years of Record	13	14	14	14	14	13	14	14	14	14	14	13	11
Mean in °F.	38.3	43.0	47.6	57.3	65.5	75.1	77.2	76.9	69.8	60.1	47.3	39.7	58.4

Pep, Roosevelt County

Record	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Years of Record	32	32	32	35	36	35	36	36	35	36	31	33	26
Mean in °F.	38.7	42.0	48.1	56.6	64.7	73.7	76.4	75.4	69.0	59.0	47.6	39.3	57.5

Table 4

Frost-free Period* - Portales Valley Area

Station	Mean Dates		Extreme Dates		Average Frost-free Period (days)
	Last in Spring	First in Fall	Last in Spring	First in Fall	
Melrose	April 14	October 31	May 14, 1953	September 16,1951	200
Clovis	April 14	October 30	May 14, 1953	October 7, 1948	199
Portales 7WNW	April 20	October 21	May 18, 1952	September 20,1942	184
Portales	April 21	October 20	May 19, 1952	September 27,1942	182
Elida	April 13	October 31	April 26, 1945	October 6, 1952	201
Pep	April 16	October 25	May 14, 1953	September 28,1924	192

*Temperature of 32° F. or lower.

Table 3 (cont'd.)

Ellis, Roosevelt County

Record	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Years of Record	19	19	19	19	19	19	19	19	19	19	19	19	19
Mean in °F	38.2	40.6	47.6	57.0	65.8	75.1	79.2	77.2	69.8	59.0	47.1	39.7	58.4
Record Highest Temp.	80	82	90	96	98	106	108	104	102	96	86	82	108
Year of Occurrence	1949	1954	1954	1954	1954	1954	1954	1954	1954	1954	1954	1954	1954
Record Lowest Temp.	-16	-12	-2	20	32	46	56	52	36	22	6	-10	-16
Year of Occurrence	1951	1951	1951	1951	1951	1951	1951	1951	1951	1951	1951	1951	1951
Mean Precipitation (Inches)	0.4	0.5	1.0	1.7	2.7	3.4	2.8	3.0	2.1	1.4	0.6	0.5	20.1

Depth of Frost Penetration

Data not available

Heating Degree Days

Mean Degree Days

Precipitation

Mean Number of Days with Precipitation of .01 Inch or More

Mean Number of Days with Precipitation of 1.0 Inch or More

Mean Number of Days with Thunderstorms

Mean Number of Days with Snowfall

Mean Number of Days with Fog

Mean Number of Days with Sunrise to Sunset

Mean Number of Days with Sunrise to Sunset*

Mean Number of Days with Sunrise to Sunset*

Mean Number of Days with Sunrise to Sunset*

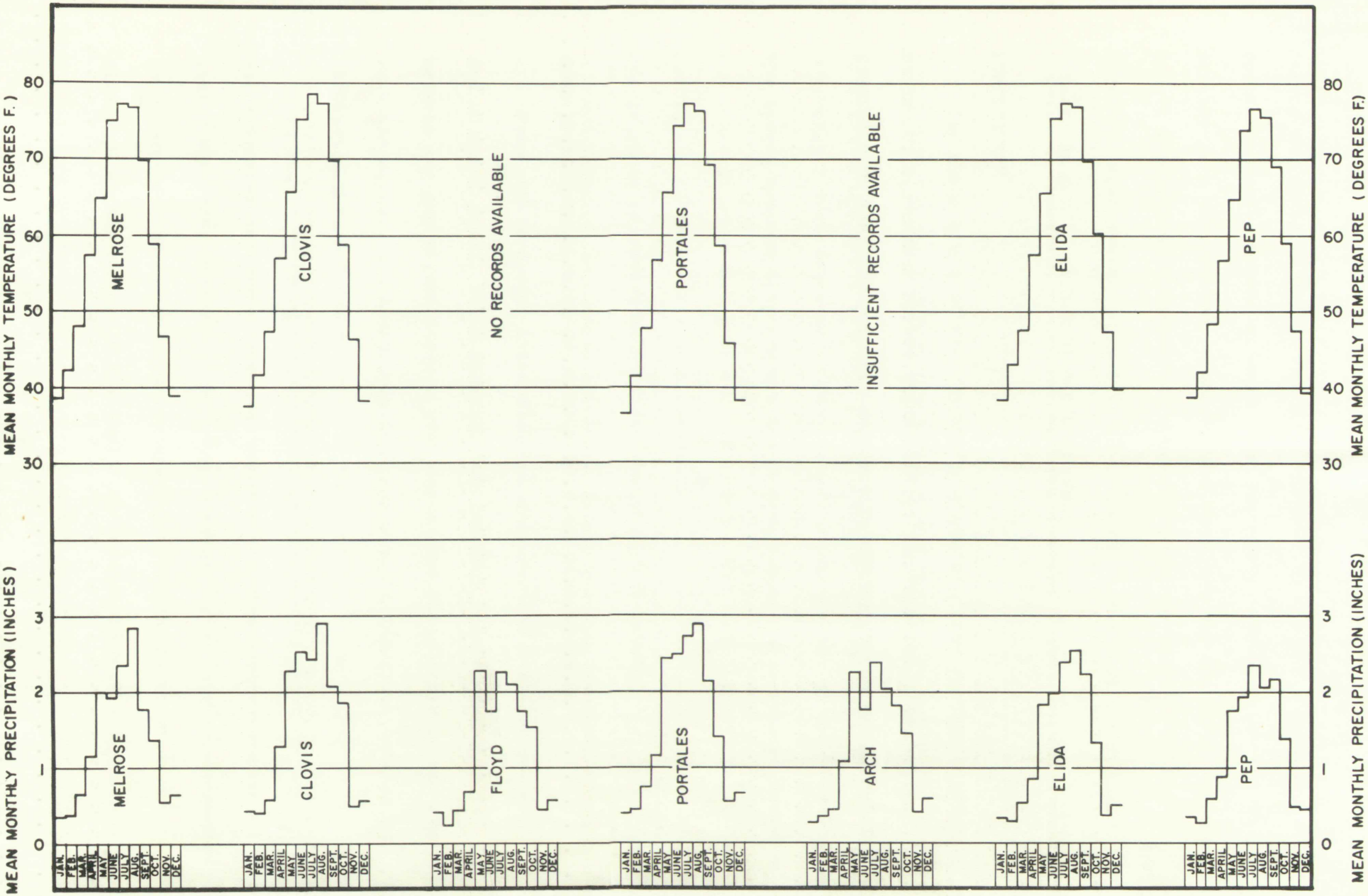

Figure 9. Relation of mean monthly temperature and precipitation, Portales Valley area, Roosevelt and Curry Counties, New Mexico

during the month of March, which is followed by a general decline that continues to the months of August and September, during which the mean monthly lows are reached. Computations based on the available records show a mean monthly movement of 4,099 miles for 20 years of record in March and mean monthly movements of 1,823 and 1,814 miles, respectively, during the months of August and September.

EVAPORATION

The computation of mean monthly evaporation from records collected by the U. S. Weather Bureau since 1934 at the Portales Evaporation Station show that the greatest evaporation occurs during the month of June when a mean value of 12.563 inches is reached for 21 years of record. The lowest mean monthly evaporation occurs during the months of December and January, when mean lows of 3.032 inches and 3.035 inches are reached for 14 and 17 years of record, respectively. The mean annual evaporation for 10 years of record at this station is 90.788 inches.

SOME EFFECTS OF CLIMATE ON WATER SUPPLY AND SOIL MOISTURE

From the foregoing climatological data for the Portales Valley and adjacent areas, it is apparent that certain relationships exist between the individual factors that enter into the climate of the region as a whole, and that these relationships have an important bearing on the agriculture and water supply of this valley.

It should be noted particularly that the greater part of the precipitation falling on the area comes during the summer growing season when temperatures are high and consumptive use and transpiration by vegetation and crops is at a maximum. Although there is little wind during this season of the year, the prevailing high temperature

Table 5

Wind Movement - Portales Valley Area

Portales 7 WNW, Roosevelt County

Record	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Years of Record	18	18	20	21	21	21	18	21	21	20	20	20	14
Mean in Miles	3103	3257	4099	3731	3354	2942	2166	1823	1814	2086	2220	2508	34,937

Table 6

Evaporation - Portales Valley Area

Portales 7 WNW, Roosevelt County

Record	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Years of Record	14	16	20	21	21	21	20	21	21	21	19	17	10
Mean in Inches	3.032	4.073	7.544	9.108	10.728	12.563	11.851	10.714	8.341	6.214	4.297	3.035	90.788

Table 5

Wind Movement - Portales Valley Area

Portales 7 NW, Roosevelt County

Record	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Years of Record	18	18	21	20	21	18	18	18	18	18	20	18	18
Mean Hrly Miles	8308	9227	9809	9781	8951	8048	7185	7385	7805	8088	8280	8296	8254

Portales 7 NW, Roosevelt County

Table 6

Temperature and Precipitation Data

and the change to hot sunny weather that usually occurs after a storm produces very dry air which absorbs moisture quite readily; consequently, the evaporation rate is quite high. This evaporation in combination with the high consumption of water by plants before it can move downward through the soil beyond the reach of their root zone, allows very little of this precipitation to reach the water table.

Although favorable for agriculture, these climatic factors are not favorable for ground-water recharge; consequently, from this consideration alone, the annual contribution of precipitation to the ground-water reservoir would appear to be very small in this valley.

It should also be noted that the greatest wind movement occurs in the period of the year when precipitation is at a minimum; consequently, the land is subject to considerable deflation by the wind. Dust storms are common throughout the winter and spring seasons, particularly in March, and lands that have been broken and laid bare by the harvest of crops, especially peanuts and sweet potatoes, are particularly vulnerable to this onslaught of the elements. Although the evaporation and transpiration rate is at a low during this season of the year, when coupled with low precipitation these factors result in the loss of considerable winter moisture from the soil. This condition necessitates the practice of pre-irrigation prior to the planting of crops at the beginning of the normal growing season.

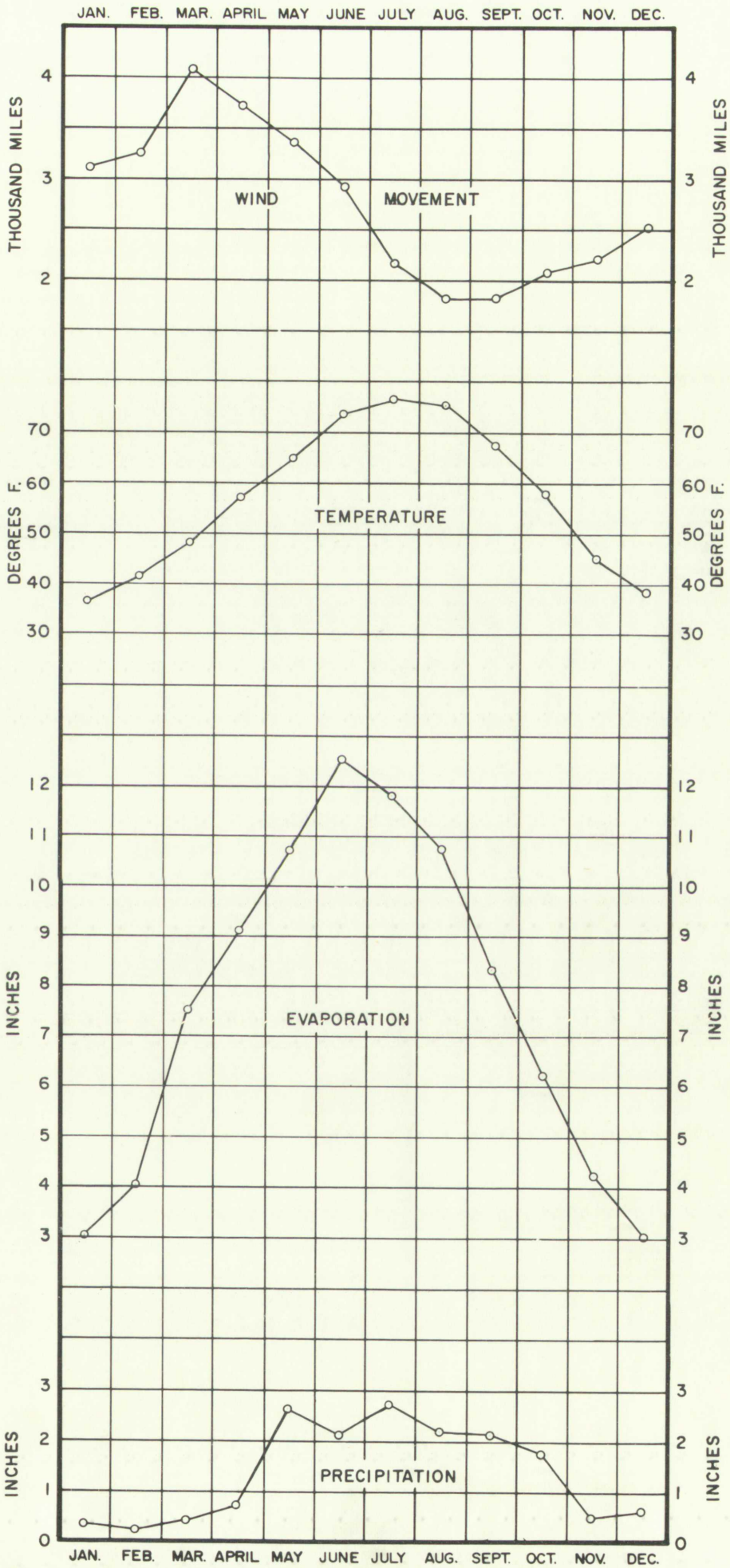

Figure 10. Comparative curves of climate, Portales 7 W N W

GROUND WATER

Although ground water is a pervasive constituent of all the sedimentary formations underlying the Portales Valley, there are marked differences in the chemical characteristics and the quantities of water that are available from each of these formations. These differences can be attributed largely to the interrelationship of lithology, and to the source and availability of recharge to each of these units.

For the purposes of this report, the occurrence of ground water in the Portales Valley may be conveniently divided into four categories; (1) the water in the Permian strata, which has only been encountered in the deep oil tests drilled in the region; (2) the water in the Mesozoic strata, which is utilized for stock and domestic purposes in an extensive area southwest and west of Portales; (3) water in the Ogallala formation, which is the principal source of ground water in the Clovis area to the north and the region some distance south of the Portales Valley; and (4) water in the Quaternary valley fill, which is the most important water-bearing formation in the Portales Valley proper.

PERMIAN STRATA

Records of oil tests available to the writer indicate that although ground water may be encountered in any of the diverse lithologic units which constitute the Permian formations in the Portales Valley, the water occurring in these units is mineralized to the extent that it is unfit for stock, domestic, or irrigation uses. The water is believed to be composed largely of connate water that has been present in the interstices of these rocks since the period of their deposition.

The water in the Permian strata is found in both clastic and carbonate rocks, and usually exhibits considerable artesian pressure when the containing formation is tapped by the drill. Pressures sufficient to cause the well to flow at the surface have been reported in some localities. Some recharge to these formations occurs to the north and west in the area of their outcrop; consequently, it may be expected that the general movement of ground water is toward the southeast in the general direction of the regional dip.

The composition of residual connate water remaining in the formations, the general composition of the strata containing the water, the distance of movement, the low rate of natural discharge and the resulting slow movement of the water, precludes the occurrence of fresh water in the Permian formations in the area studied. The electric log of an oil test near Elida (Gulf-Stevenson No. 1) indicates that no fresh water was encountered in the interval between the top of the Permian rocks at 1,560 feet and the top of the Precambrian crystalline complex at 7,050 feet. An analysis of water obtained in a drill-stem test of the San Andres limestone (the water-producing formation in the Roswell artesian basin), indicated that this water contained more than 250,000 parts per million total dissolved solids. A deflection in the spontaneous-potential curve at 6,500 feet (Abo formation) indicates that the fluid in this formation contains an equivalent of about 190,000 parts per million sodium chloride.

MESOZOIC STRATA

Field observations made by the writer in Curry and Roosevelt Counties and the available records, both published and unpublished,

The water in the Permian strata is found in both clastic and carbonate rocks, and usually exhibits considerable artesian pressure when the containing formation is tapped by the drill. Pressures sufficient to cause the well to flow at the surface have been reported in some localities. Some recharge to these formations occurs to the north and west in the area of their outcrop; consequently, it may be expected that the general movement of ground water is toward the south east in the general direction of the regional dip.

The composition of residual connate water remaining in the formations, the general composition of the strata containing the water, the distance of movement, the low rate of natural discharge and the resulting slow movement of the water, precludes the occurrence of fresh water in the Permian formations in the area studied. The electric log of an oil test near Hope (Unit-Stevenson No. 1) indicates that no fresh water was encountered in the interval between the top of the Permian rocks at 1,380 feet and the top of the Precambrian crystalline complex at 7,050 feet. An analysis of water obtained in a drill-stem test of the San Andres limestone (the water producing formation in the Roswell artesian basin), indicated that this water contained more than 280,000 parts per million total dissolved solids. A deflection in the spontaneous-potential curve at 6,300 feet (the formation) indicates that the fluid in this formation contains an equivalent of about 190,000 parts per million sodium chloride.

MESOZOIC STRATA

Field observations made by the writer in Curry and Roosevelt Counties and the available records, both published and unpublished,

indicate that ground water occurs in various lenses throughout the Mesozoic rocks. Unlike the water from the Permian rocks, which is highly mineralized in this area, this water ranges from that which is highly mineralized to water that is definitely fresh. The production from wells tapping this source of water is usually small.

Mesozoic strata occur at or near the surface, above the general elevation of the water table in an extensive area south of the Portales Valley, particularly south and west of the townsite of Floyd. As a result of this "red bed" high, the zone of saturation above the "red beds" is ordinarily too thin to provide sufficient water for either normal stock or domestic use; consequently, water for these purposes is usually obtained from the more porous sand and gravel lenses that occur within the generally impermeable clays of the Triassic rocks.

The ground water occurring in the Mesozoic strata in this area has a spotted distribution. Residents report that only about one in every four wells drilled encounters water in sufficient quantity to supply even the smallest windmill pumps. It is common to find localities in which the discharge of two or more wells is combined, or in which wells have been drilled in clusters and subsequently "shot together" in an effort to obtain water in sufficient quantity to meet the needs of stock and domestic uses. Much of the water is mineralized to the extent that it is unfit for use, particularly for domestic purposes.

The ground water occurring in these lenses is usually under some artesian pressure and ordinarily rises in the well when the aquifer is struck by the drill. Instances are reported where wells penetrating these formations have encountered sufficient artesian pressure to cause the well to flow at the land surface. Long-time residents of the Portales Valley, as well as Theis (1932, p. 119),

report that two wells of unknown depth, drilled on the site of the present Roosevelt County courthouse near the turn of the century, flowed weakly at the surface for a short period immediately after being cleaned. Theis (1932, p. 119) reported an artesian well of very weak flow in Sec. 32, T. 1 S., R. 34 E., in the lower part of the Portales Valley. Practically all of the water utilized from these strata is pumped by windmills and is obtained from relatively shallow wells with depths of less than 200 feet.

The occurrence of underground water in the Mesozoic strata at depths of more than 200 feet within the general region of the area studied has been noted in the following deep water-well and oil-well records available to the writer.

Frio Oil Co.-Saunders No. 2, Sec. 11, T. 5 N., R. 35 E.: 495'-506', sand, water; 860'-995', sand, salt water; 1,000'-1,165', sand, hole full of salt water.

Clovis Oil and Gas Co.-Hoskins No. 1, Sec. 21, T. 3 N., R. 36 E.: 570'-595', gray sand, fresh water; 615'-625', gray sand, fresh water; 1,025'-1,050', "light" sand, salt water; 1,060'-1,065', "light" sand, water; 1,125'-1,165', red shale, water; 1,605'-1,627', gray sandy shale, water.

A. G. Trout-Hart No. 1, Sec. 24, T. 2 N., R. 31 E.: 600'-625", salt-water sand.

Atchison, Topeka and Santa Fe Railway well, St. Vrain, New Mexico: 452'-465', gray sand, water.

Atchison, Topeka and Santa Fe Railway, No. 1, Clovis, New Mexico: 476'-509', fine gray sand, water rose to 285'; 575'-587', gray sandrock, salt water.

Capitan Oil Company-Vera Mae No. 1, Sec. 4, T. 1 S., R. 30 E.: 693'-730', hard gray sand, 2 BWPH; 730'-773', soft red shale, salt water; 1,240'-1,295', soft red sand, 1 BWPH; 1,295'-1,300', hard gray sand, salt water.

Clovis Development Co.-Sheely and Smith No. 1, Sec. 17, T. 2 S., R. 30 E.: 1,352'-1,380', water sand; 1,410'-1,425', sand and salt, salt water.

Claudell Development Co.-Wilmes No. 1, Sec. 21, T. 2 S., T. 30 E.: 290'-295', sand, water; 439'-465',red sand, water; 675'-718', sand, 5 BWPH; 1,215'-1,229' (?), gray sand, fresh water; 1,255'-1,265', coarse sand, salt water.

Flank M. Hill-Claudell "X" No. 1, Sec. 22, T. 2 S., R. 30 E.: 1,285'-1,295', white water sand; 1,403'-1,410', red and white water sand; 1,460'-1,470', white sand, salt water.

Sloan and Smith-Lovern No. 1, Sec. 4, T. 3 S., R. 35 E.: 220'-225', gray sand, little water; 410'-425', gray sand, water; 550'-580', blue sandy shale, 2 bailers of water per hour; 705'-745', sand, hole full of fresh water; 1,000'-1,045', sand,hole full of water; 1,185'-1,190', sand, 7 BWPH; 1,575'-1,627', gray sand, salt water; 1,645'-1,660', sand, water.

New Mex-Wilcox No. 1, Sec. 4, T. 3 S., R. 35 E.: 280'-310', sand, water; 396'-426', sand, water and slight showing of oil; 715'-735', quicksand, water; 742'-750', gravel, water.

Gulf-Stevenson No. 1, Sec. 22, T. 4 S., R. 31 E.: tool pusher reports that no addition to the drilling fluid was noted during the drilling of the well and that water was added to the drilling mud during the entire period of drilling.

In each of these cited occurrences of underground water in the deep Mesozoic strata, the water-producing formation is relatively thin. In each of the records where data relative to the production of water are given, the production is usually small in quantity and of very poor chemical quality.

On the basis of data available to the writer, it is believed that the major part of the water derived from the Mesozoic formations by the wells south of the Portales Valley originated from water occurring in the zone of saturation of the overlying Pleistocene and Recent sediment, and has since been transferred as recharge to the "subcrops" of the permeable zones of these Mesozoic strata. Some recharge undoubtedly enters these rocks in the area of their outcrop on the western escarpment and within the areal limits of the Llano Estacado, and although definite

conclusions cannot be reached from available data, there is also the possibility that some relatively fresh connate water has remained in the strata since the period of their deposition. It is believed, however, that this latter origin of water is of minor importance in the area studied. Quantitatively, ground water from all these sources is relatively unimportant in most of the area, and this in combination with the general characteristics of these rocks and the relative thinness of the porous zones precludes the possibility of obtaining any substantial quantity of water from these strata.

It is recognized that there is the remote possibility that extremely localized areas exist in which geologic structure, lithology, permeability, and thickness of strata are combined in a manner favorable to the accumulation and transmission of ground water from the overlying Pleistocene and Recent sediment, and it is believed such a combination is the controlling factor in a reported occurrence of artesian water in Triassic rocks in the vicinity of Hereford, Deaf Smith County, Texas (Galloway, 1955, p. 11). Unfortunately, there are insufficient geologic data to allow the prediction of localities in which an occurrence of ground water of this type might be expected; consequently, the Mesozoic formations are not recommended as a potential source of ground water that is of suitable chemical quality and in sufficient quantities to meet the needs of irrigation and other related uses within the Portales Valley.

OGALLALA FORMATION

In the area north and south of the Portales Valley beyond the limits of the valley fill, moderate to large yields of ground water

are obtained from the Ogallala formation of Tertiary age. The water is of fairly good chemical quality and is usually obtained from wells drilled through the formation to the top of the "red beds" at depths of less than 500 feet. The water pumped from this formation is usually obtained from the gravel and coarse sand commonly found near its base.

The occurrence of ground water in the Ogallala formation is of little importance in the Portales Valley because of the absence of the Ogallala formation in the valley proper. The only wells considered to be deriving ground water from the Ogallala formation in the general area of study are those wells located in northeastern Roosevelt and southern Curry Counties northeast of the general vicinity of Blackwater Draw.

The water in the Ogallala formation occurs under water-table conditions and moves in a generally southeastward direction with an apparent gradient of 10 to 15 feet per mile (Howard, 1954, p. 7). The depth to water, in the area immediately adjacent to the Portales Valley, ranges from about 80 feet in the vicinity of Melrose to about 130 feet in the southeastern part of Curry County. The saturated thickness of the Ogallala formation is about 45 feet and 200 feet, in these respective areas.

VALLEY FILL

Occurrence

The principal source of ground water in the Portales Valley is the ground-water reservoir that occurs within the valley fill of Pleistocene and Recent age, which occupies an erosional trough incised through the Tertiary and Cretaceous rocks into the Triassic "red beds". For practical purposes, the reservoir may be considered as occupying the interval that extends from the erosional unconformity

at the top of the Triassic "red beds" to the water table. Hydraulic boundaries, which reflect the geological and hydrological conditions encountered on the sides of the valley, separate the reservoir from adjacent areas to the north and south where ground water is obtained from sources other than the valley fill. The ground water in the valley fill occurs under water-table conditions and is of fairly good chemical quality.

Toward the north and northeast, the availability of substantial ground-water recharge from the linear area of sand hills that is present in the vicinity of Blackwater Draw and the presence of a low northwest-trending "red bed" ridge which is roughly coincident with, and parallel to the sand-hill area, gives rise to a water-table divide which is the northern boundary of the valley-fill reservoir. The water table slopes both northeastward and southwestward away from this divide toward Clovis and the Portales Valley, respectively. The northeastward slope of the water table toward the Clovis area, in combination with a gentle increase of the elevation of the land surface in this direction, results in depths to water that are greatly in excess of those usually encountered in the Portales Valley.

Although it cannot be stated with certainty, it is also believed that a gradual transition from the sediment of the valley fill to sediment of the Ogallala formation begins in the approximate position of this hydraulic boundary as the valley fill thins toward the northeast away from the valley trough. For this reason, only those wells which have been drilled to the south and southwest of the ground-water divide are considered to be deriving their water supply from the valley fill.

On the south, southwest, and southeast sides of the reservoir, there

is a gradual increase in the elevation of the top of the Triassic "red beds" that exceeds the increase in elevation of the water table toward the south side of the valley. As a result of this condition, a line exists south of the Portales Valley at which the water table very nearly intersects the "red beds". The line of this intersection is the southern boundary of the ground-water reservoir. Water in quantities sufficient for domestic and stock use is usually obtained only with great difficulty in the area immediately south of this boundary. The hydraulic limit of the valley-fill reservoir on the south side of the Portales Valley is shown on Figure 11.

The ground water in the valley fill occurs in the interstices of the sand and gravel that is present in this deposit. The water is usually encountered at relatively shallow depths in sufficient quantities and of suitable chemical quality to meet the requirements of stock, domestic and irrigation uses. The highest yields are normally obtained from the gravel and coarse sand of fluviatile origin at the base of the valley fill.

It is estimated that the valley fill is the source of more than 95 per cent of the ground water pumped in the Portales Valley; consequently, it is within the approximate limits of the valley fill that the study outlined in this report has been concentrated.

History of Development

Irrigation farming is not a new development in the Portales Valley. Prior to 1910, many farmers irrigated small tracts with water pumped by windmills, and in a few cases centrifugal pumps powered by gasoline engines had been installed, but it was not until 1910 that large-

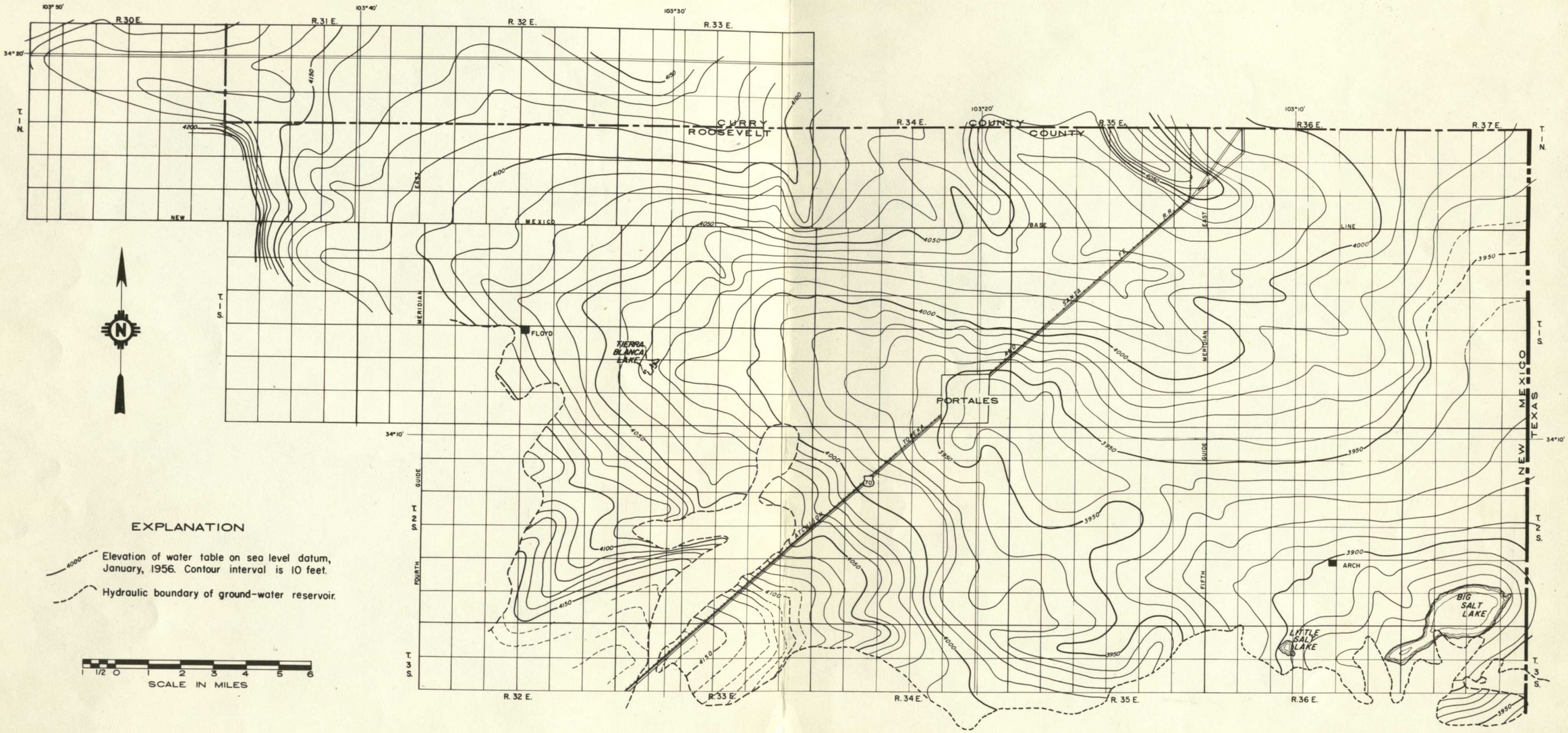

Figure 11. Configuration of water table in January, 1956, in the Portales Valley area, Roosevelt and Curry Counties, New Mexico.

scale irrigation was begun. In 1910, the Portales Irrigation Company was organized by local irrigators who financed the project with mortgages on their irrigated land. A power plant was constructed at Portales and 69 individual pumping plants were served in the present irrigated area. The power plant was able to produce sufficient electric power to pump 30,000 acre-feet during the growing season and 10,000 acres were included in the project, but the capacity of the plant was never reached and the planned acreage was never irrigated (Theis, 1932, p. 124). It is reported that an average of 4,000 acre-feet of water a year was pumped in the four years from 1910 to 1914 (Baker, 1915, p. 90).

As the result of lack of irrigation experience on the part of the people involved in the project, the experiment was unsuccessful. Attempts were made to irrigate too much land with one well, suitable crops were not ascertained, no markets were readily available for the produce, and a great deal of dissatisfaction developed among the irrigators because of the restrictions that were imposed to distribute the load on the central power plant. As the result of these and other factors the project failed and the electric plant was dismantled and sold during World War I.

In 1919, the pumping plants were too few to be reported separately by the U. S. Census and it was not until 1925 that irrigation began to increase in the area. Irrigation increased slowly and by 1929 the U. S. Census reported that 166 pumping plants were in operation and 4,823 acres were irrigated. About 300 irrigation wells were in use in 1931 and about 8,850 acres were under irrigation (Theis, 1932, p. 124). Approximately 19,000 acre-feet were pumped during the 1931 irrigation season.

The growth of irrigation in the Portales Valley since 1931 is shown on Figure 12, which is based on data collected by the U. S. Geological Survey and other agencies.

Physical Limits of Reservoir

Water Table:--In pervious granular material the water table is the upper surface of the body of free water which completely fills all openings in the material sufficiently pervious to permit percolation (Tolman, 1937, p. 565) and is for all practical purposes the upper limit of ground water available to pumpage. The ground water present in the Portales Valley is considered to occur under water-table conditions; therefore, the water table in this valley is considered to be the upper limit of the valley-fill ground-water reservoir. The configuration of the water table in the Portales Valley is shown on Figure 11, which is based on approximately 365 water-level measurements made during January, 1956.

In general, the water table in the Portales Valley is a slightly southeastward-sloping surface that corresponds approximately to the slope of the land surface. The water table, in general, has less relief than the land surface and is a subdued replica of the surface topography of the valley. The many irregularities in the configuration of this surface are caused largely by differences in the permeability of the water-bearing sediment, and by the unequal additions of water to, or removal from, the ground-water reservoir. Where the recharge to the reservoir is exceptionally high the water table forms a mound or ridge from which the ground water spreads out slowly to the adjacent areas. Where the withdrawal of water from the reservoir is excessive, the spread of pumping effects results in a general depression of the

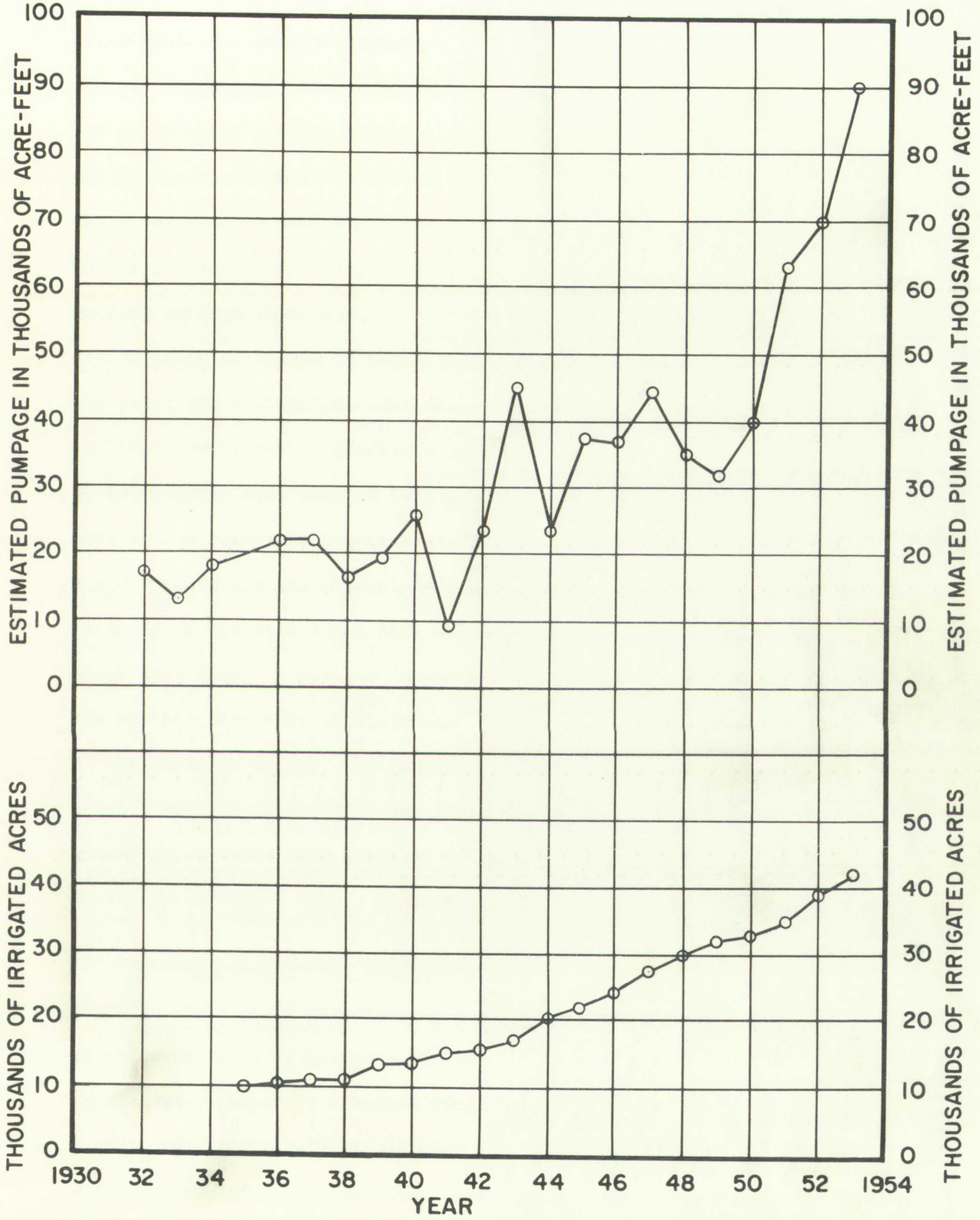

Figure 12. Growth of irrigation development, Portales Valley, Roosevelt County, New Mexico.

water table. A similar depression occurs in the vicinity of areas of natural discharge from the ground-water reservoir. Both the mounds and depressions develop largely in consequence to the slow movement of ground water, which results from the resistance to flow encountered in the water-bearing sediment. The direction of ground-water movement in any particular locality is at right angles to the water-table contour passing through that area.

A study of Figure 11 shows that the average hydraulic gradient of the water table along the axis of the valley is about 8 feet per mile and that the hydraulic gradients on the side slopes range from less than 10 to slightly more than 60 feet per mile. Particular note should be made of the general depression of the water table in the vicinity of Big Salt Lake and the general "mounding" of the water table in the vicinity of the sand dunes that separate the Portales Valley proper from Blackwater Draw. A similar "mounding" occurs in the sand-dune area on the northeastern side of Blackwater Draw near the northeastern margin of the Portales Valley. It should also be noted that excessive pumping in the vicinity of Portales has resulted in a complete reversal of the generally southeastward gradient of water table in the vicinity of Sections 9 and 10, T. 2 S., R. 35 E.

Triassic-Pleistocene Unconformity:--The configuration of the Triassic-Pleistocene unconformity relates significantly to the study of the occurrence of ground water in this area, for the greater part of the water pumped is obtained from the overlying Tertiary and Pleistocene rocks. Below this bedrock surface, ground water is obtained only with great difficulty, and when water is encountered, it is usually small

in quantity and of extremely poor chemical quality.

Within the general areal limits of the valley-fill deposit the Cretaceous and Tertiary rocks are absent and the Pleistocene and Recent valley-fill deposit rests directly on rocks of Triassic age. The top of these latter rocks, which are commonly referred to as the "red beds" by the drillers and local residents of the valley, is the lower limit of geologic strata in which ground water of suitable chemical quality may be expected in quantities that are sufficient for normal stock, domestic and irrigational purposes.

The configuration of the Triassic-Pleistocene unconformity in the Portales Valley is shown on Figure 4.

Source of Recharge

There are no perennial streams on the Llano Estacado and no contributing drainage, hence all the water supply of the Portales Valley must be derived from precipitation that falls on the region.

The general configuration of the water table and its general response to periods of precipitation indicate that recharge to the shallow ground-water reservoir is derived largely from precipitation that falls on the valley and parts of the adjacent areas, and that ground water moves into the area from both the upper reaches of the valley and the adjacent areas immediately north and south of the Portales Valley. The general "mounding" of the water table in the vicinity of the line of dunes that separates the Portales Valley proper from Blackwater Draw indicates that these dunes are a particularly important source of recharge to the valley-fill ground-water reservoir. This is further indicated by the distribution of water of similar

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conductance and chloride concentration as is shown on Figures 13 and 14. According to Theis (1932, p. 143-144; 1938, p. 565) the underground drainage basin tributary to the Portales Valley covers an area of about 850 square miles and the annual recharge is on the order of 24,000 acre-feet or about 0.5 inch per year.

Any theories set forth regarding a possible recharge of the shallow ground-water reservoir by artesian circulation through the Permian and Triassic strata which underlie the area are largely discounted on the basis of comparative water analyses (see subsequent section on quality of water and Appendix C) and the relatively impervious character of the latter sediment. As has been shown previously, the water obtained from these rocks is usually small in quantity and of very poor chemical quality. Admittedly, some recharge may be contributed to the valley fill from this source in some localized areas, but the quantity is not large.

Effects of Ground-Water Development

Seasonal Water-Level Fluctuations:--Seasonal water-level fluctuations occur largely in consequence of the effect of the withdrawal of large volumes of water for irrigational purposes during the growing season and are usually initiated by a general water-level decline during the months of March and April. The seasonal lows are generally reached in September toward the end of the growing season. The close of the irrigation season is followed by a general movement of water from the outlying parts of the ground-water reservoir into the cone of depression created by the withdrawal of water during the irrigation season. This results in a general recovery of water levels in the wells throughout the irrigated part of the basin. The maximum

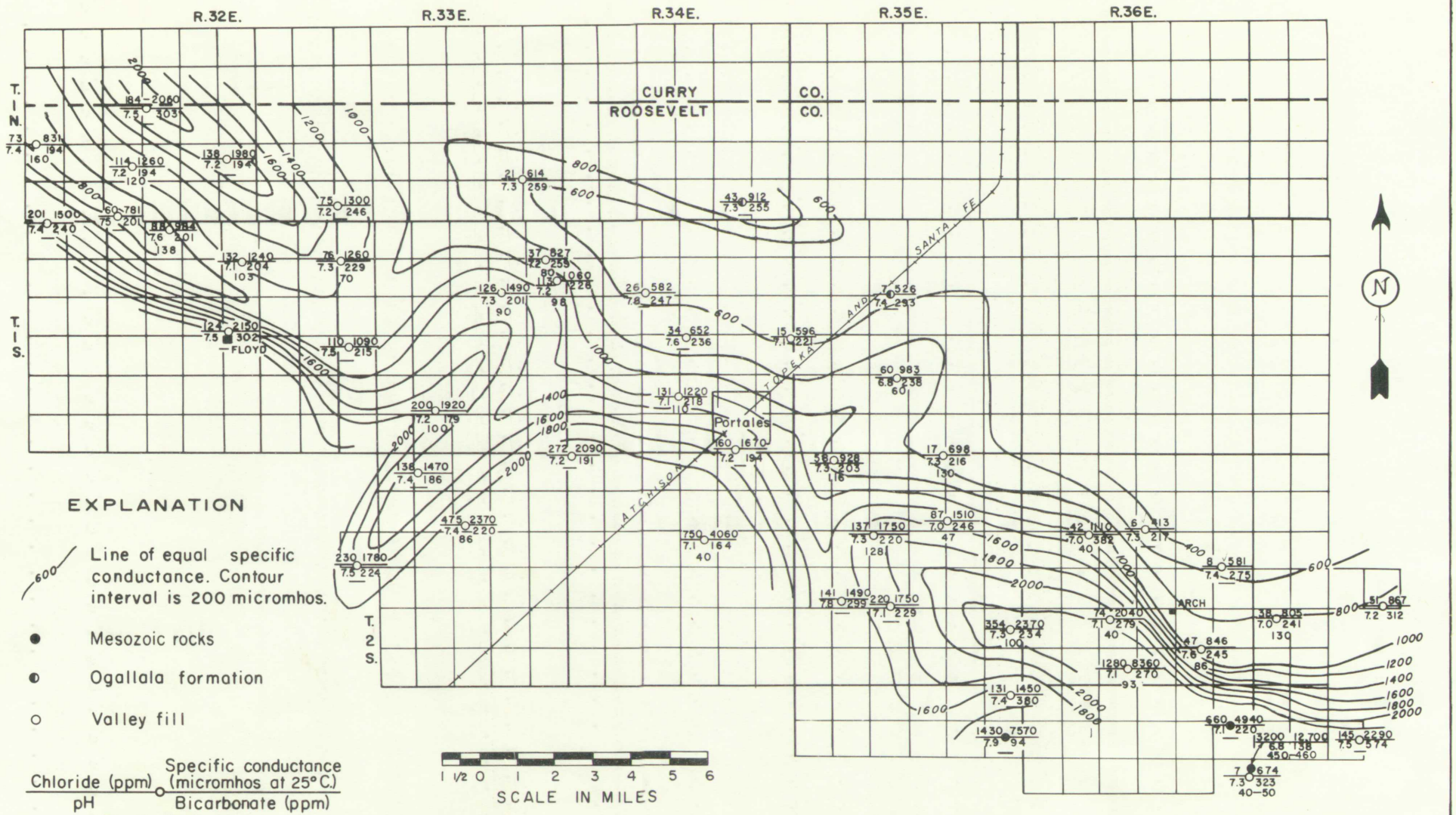

Figure 13. Distribution of water of equal specific conductance in the Portales Valley area, Roosevelt County, New Mexico, in October, 1955.

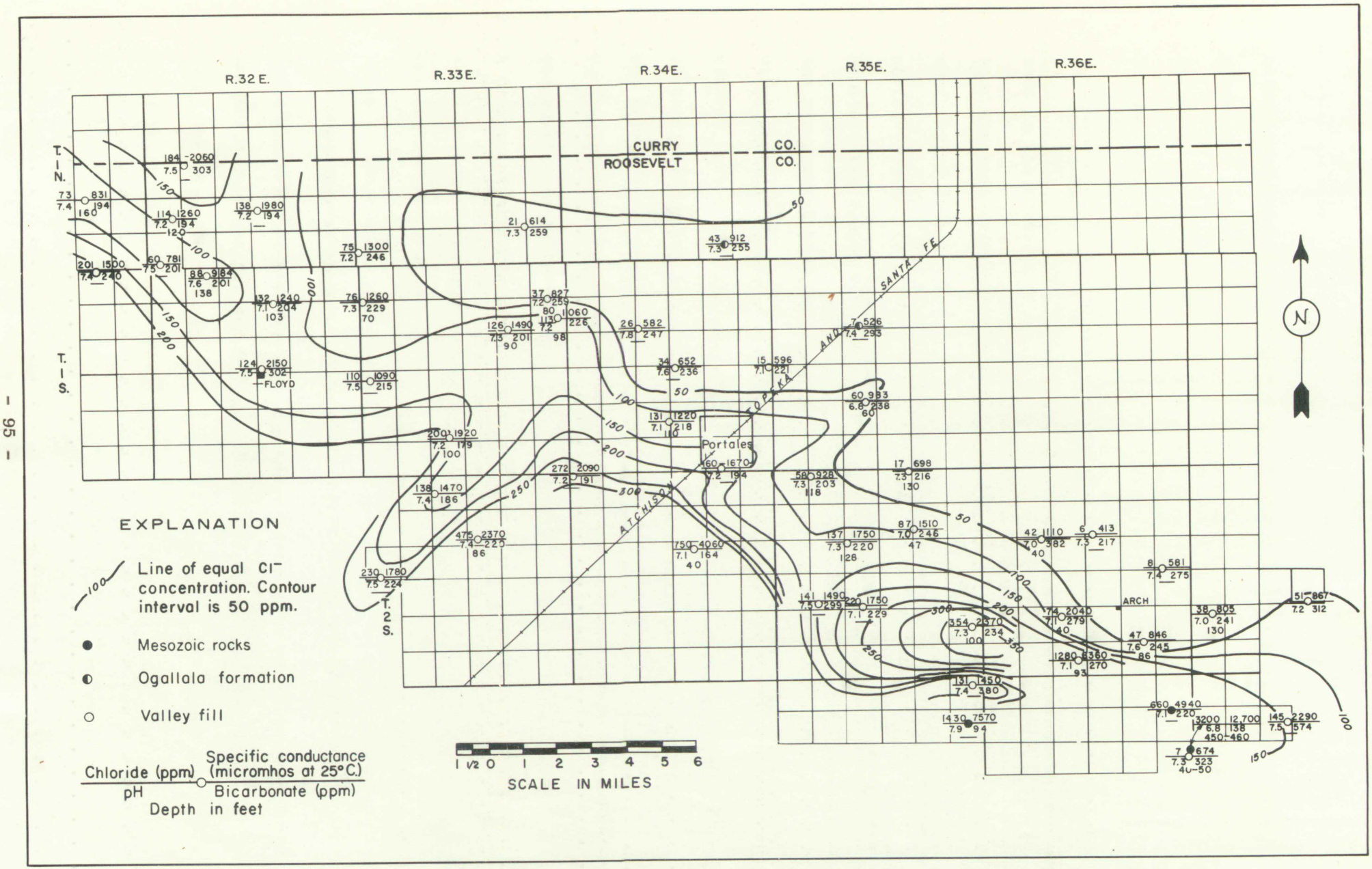

Figure 14. Distribution of water containing equal concentrations of Cl^- in the Portales Valley area, Roosevelt County, New Mexico, in October, 1955.

water-level recovery usually occurs during the months of February and March just prior to the beginning of the irrigation season. The seasonal water-level fluctuations in three selected observation wells in the Portales Valley are shown on Figure 15.

Water-Table Decline:--Since the initiation of irrigation development in the Portales Valley water levels have shown a progressive decline that has been interrupted only by the heavy precipitation received in the area during 1941. The abnormal precipitation received during this period resulted in a recovery of water levels throughout the valley; however, the growth of irrigation development during World War II and the years which have followed have largely obliterated this general water-level recovery. Water levels declined more than 34 feet in the central part of the valley during the period from January, 1932, to January, 1955, with about 18 feet of this decline occurring during the period from January, 1950, to January, 1955. Records collected in January, 1956, indicate that the water levels in the majority of observation wells in the Portales Valley have reached all-time lows. A decline of slightly more than 7 feet occurred in two observation wells during the period from January, 1955, to January, 1956. During the latter period declines of 3 feet or more were common in observation wells in the heavily pumped area.

Maps showing changes in ground-water levels for the periods from January, 1932, to January, 1955, January, 1950, to January, 1955, and the annual changes for the period from January, 1946, to January, 1956, are given in Appendix B. Water-level changes in three selected wells for the period from January, 1934, to January, 1955, are shown on Figure 15.

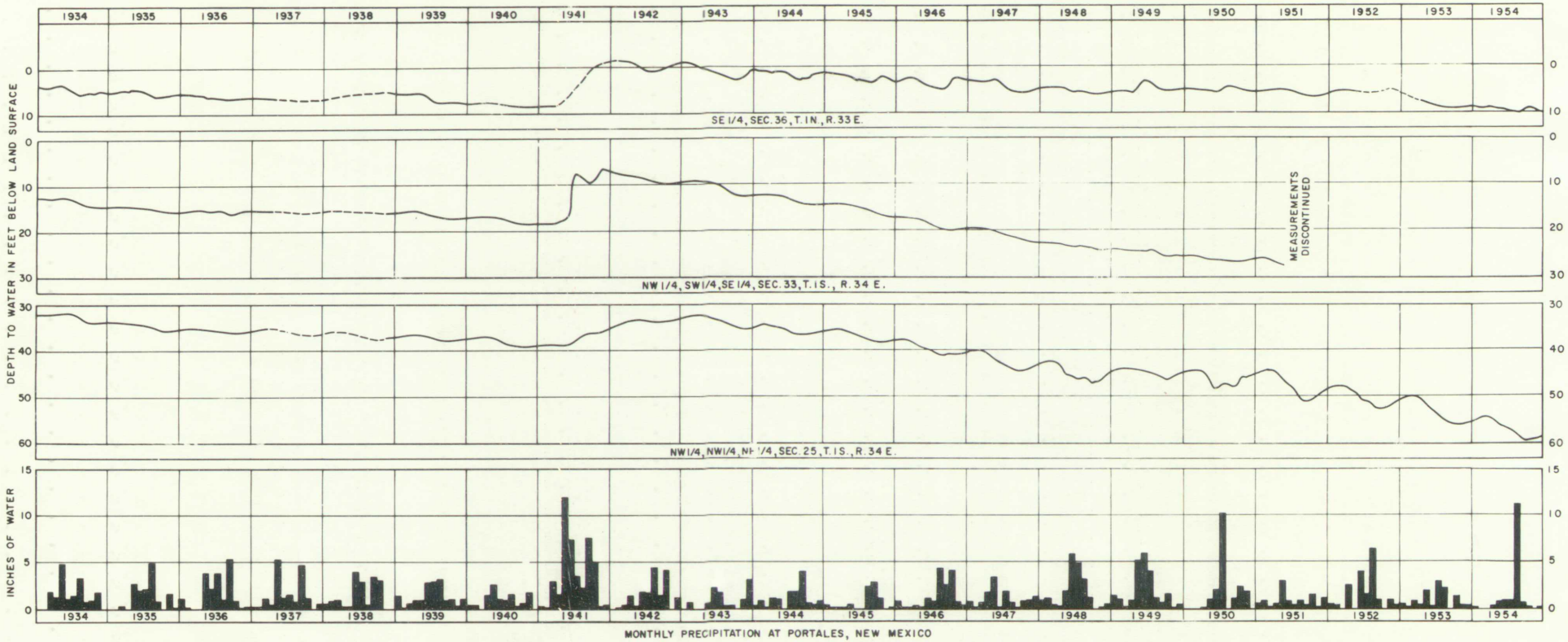

Figure 15. Fluctuations of water levels in three wells, and precipitation in the Portales Valley, Roosevelt County, New Mexico

THEORY OF PUMPING EFFECTS

In any area where unconfined ground water is held in storage under hydrologic and geologic conditions imposed by nature, it is assumed the water table remains essentially static except for fluctuations induced by climatic conditions, and that the natural discharge is equal to recharge; i. e., the aquifer is essentially in a state of equilibrium. From our present knowledge of ground-water hydrology, it is also believed that the aquifer will continue in this state until such time as a change in recharge or discharge is imposed upon the aquifer, either through natural means or the works of man. As can be readily seen, any extraneous influence upon the aquifer must of necessity be followed by a readjustment of the water in storage in that aquifer.

If it is assumed that all other factors remain constant and that the only change in the aquifer system is the introduction of a withdrawal rate in excess of that usually lost by natural means, the equilibrium of the system may be re-established by one or both of the following: (1) an increase in recharge equal to the amount of withdrawal, or (2) a decrease in natural discharge equal to the amount of withdrawal. If the state of the aquifer is such that equilibrium cannot be re-established by either of the above means, it follows that the additional draft upon the system will be derived by storage depletion with a resulting water-level decline. If the additional draft on the system is continued, ultimate depletion of the aquifer will result.

In the Portales Valley, the conditions are such that the additional draft on the aquifer by pumping cannot be equalized by an increase in recharge. The valley is presently absorbing all the natural recharge available from its contributory sources. The natural movement

of ground water is along the axis of the valley; consequently, a volume of water approximating the volume of the average natural recharge in New Mexico moves across the state line into Texas each year. As noted previously, it only remains that the water can be withdrawn from transient storage with a subsequent water-level decline. This is the case in the Portales Valley and the fact is verified by the progressive decline in water levels noted in the records.

QUALITY OF WATER

All natural water contains mineral matter dissolved from the rocks and soils with which the water has come in contact. The quantity and type of these dissolved minerals differs widely and depends primarily on the type of rock or soil through which the water has passed, the length of the time of contact, and the conditions of temperature and pressure encountered by the water. Human activities, such as irrigation and sewage disposal may further modify the chemical characteristics of natural water. A knowledge of these chemical characteristics is of the utmost importance in determining the suitability of a given water for various purposes.

The chemical characteristics of water are determined by chemical analyses, which, in addition to indicating the suitability of water for various uses, may also provide valuable information regarding the source, movement, and natural discharge of the water, and the character of the containing rocks.

CHEMICAL CHARACTER OF GROUND WATER

The chemical character of the ground water in the Portales Valley area is indicated by chemical analyses of 122 water samples collected from 110 wells, and 3 points in the Portales municipal water-supply system, which are tabulated in Appendices C and D. Appendix C contains the results of 89 chemical analyses of untreated well water, made by the U. S. Geological Survey in the period from October 1931 through November 1955 and includes the analyses of 51 water samples collected during the course of this investigation. Appendix D contains the results of 33 chemical analyses of well water made by the Cooperative Soils Laboratory of the New Mexico College of Agriculture and Mechanic Arts.

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The wells represented by these chemical analyses are scattered widely over the area studied and are therefore believed to represent very nearly the full range in chemical quality that may be expected in this area. The tabulations include analyses of ground water derived from Mesozoic rocks, from the Ogallala formation, and from the Quaternary valley fill. The majority of the analyses, however, pertain to water derived from the latter source.

The mineral constituents and physical properties of ground water having a practical bearing on the value of water for most purposes include silica, iron, calcium, magnesium, sodium, potassium, carbonate, bicarbonate, sulfate, chloride, fluoride, nitrate, total dissolved solids, hardness, hydrogen ion concentration, specific conductance, per cent soluble sodium, and sodium adsorption ratio. The discussion of these constituents in subsequent paragraphs has been limited to the analyses presented in Appendix C because of the inability of the writer to secure specific data for the wells represented by the analyses made by the New Mexico College of Agriculture and Mechanic Arts.

Effects of each of these constituents and their recommended tolerances have been appraised largely from similar discussions presented by Barclay and Burton (1953, p. 22-27) and others. In the following paragraphs 1 ppm equals 1 part by weight of the constituent, per 1 million parts by weight of the water, and is read as 1 part per million. An equivalent per million (epm) is defined as 1 equivalent weight of an element, ion or salt in a million weights of solution. An equivalent weight is the weight in grams of an element or compound that will react with 8 grams of oxygen (O) or its equivalent. A millequivalent per liter (meq./l.) is 0.001 of the equivalent weight of a cation or anion per liter of solution. For practical purposes, a millequivalent

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per liter is equal to an equivalent per million.

Silica

Silica is essentially inert as far as soils and plants are concerned. It contributes to the formation of hard scale in high-pressure boilers when its concentration exceeds 10 to 15 ppm in concentrated salines of low alkalinity and should be under 3 to 5 ppm in high-pressure boiler salines to avoid turbine deposits.

The following concentrations of silica have been noted in the ground water of the Portales Valley area: valley fill, 26 samples, 32 to 78 ppm; Ogallala formation, 2 samples, 37 to 49 ppm; Mesozoic rocks, 7 samples, 9.2 to 38 ppm.

Iron

Iron is present in most ground water, but generally in only comparatively small amounts in most of the ground water occurring in this area. Water containing more than a few tenths of a part per million iron is objectionable because of its reddish appearance after exposure to the air and because iron stains clothing and fixtures. Such water usually requires treatment. Excessive iron may interfere with the efficient operation of exchange-silicate water softeners. For general use the concentration of iron should not exceed 0.3 ppm.

The following concentrations of iron have been noted in the ground water of the Portales Valley area: valley fill, 7 samples, 0 to 0.01 ppm; Ogallala formation, no samples; Mesozoic rocks, 2 samples, 0.12 to 4.21 ppm.

Calcium and Magnesium

Calcium and magnesium are essential plant nutrients and are

per liter is equal to an equivalent per million.

Silica

Silica is essentially inert as far as soils and plants are concerned. It contributes to the formation of hard scale in high-pressure boilers when its concentration exceeds 10 to 15 ppm in concentrated salines of low alkalinity and should be under 2 to 3 ppm in high-pressure boiler salines to avoid turbine deposits.

The following concentrations of silica have been noted in the ground water of the Portales Valley area: valley fill, 28 samples, 32 to 78 ppm; Ogallala formation, 2 samples, 37 to 42 ppm; Mesozoic rocks, 7 samples, 8.2 to 28 ppm.

Iron

Iron is present in most ground water, but generally in only comparatively small amounts in most of the ground water occurring in this area. Water containing more than a few tenths of a part per million iron is objectionable because of its reddish appearance after exposure to the air and because iron stains clothing and fixtures. Such water usually requires treatment. Excessive iron may interfere with the efficient operation of exchange-silicate water softeners. For general use the concentration of iron should not exceed 0.3 ppm.

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Calcium and Magnesium

Calcium and magnesium are essential plant nutrients and are

commonly present in all ground water as the result of the common occurrence of these elements in practically all rocks. The presence of these metals in solution causes most of the hardness in ordinary water and is largely responsible for the formation of boiler scale. The effects and recommended tolerances for hardness will be discussed in a subsequent paragraph. Magnesium should not exceed 125 ppm in water used for drinking purposes.

The following concentrations of calcium have been noted in the ground water of the Portales Valley area: valley fill, 27 samples, 35 to 574 ppm; Ogallala formation, 2 samples, 33 to 75 ppm; Mesozoic rocks, 8 samples, 14 to 338 ppm. Concentrations of magnesium noted are: valley fill, 27 samples, 13 to 1,150 ppm; Ogallala formation, 2 samples, 30 to 48 ppm; Mesozoic rocks, 8 samples, 9 to 545 ppm.

Sodium and Potassium

Moderate quantities of sodium and potassium have little effect on the suitability of water for most industrial or domestic uses and concentrations of less than 50 ppm generally do not affect the usefulness of water for most purposes. More than 50 ppm of the two, however, may cause foaming in boilers. Generally, if the equivalents per million of sodium exceed the sum of the equivalents per million of calcium and magnesium in water used for irrigation, there is some danger of damage to the soil (see per cent sodium). Sodium is the cation commonly found in irrigation water which is most injurious to plants.

The following concentrations of sodium plus potassium have been noted in the ground water of the Portales Valley area: valley fill, 27 samples, 41 to 2,700 ppm; Ogallala formation, 2 samples, 32 to 43 ppm; Mesozoic rocks, 8 samples, 302 to 2,900 ppm.

commonly present in all ground water as the result of the common occurrence of these elements in practically all rocks. The presence of these metals in solution or suspension in drinking water is objectionable and is largely responsible for the formation of boiler scale. The silicate and recommended tolerances for bicarbonate will be discussed in a subsequent paragraph. Temperature should not exceed 125 ppm in water used for drinking purposes.

The following concentrations of calcium have been noted in the ground water of the Fortaleza Valley area: valley fill, 87 samples, 35 to 574 ppm; Ogallala formation, 7 samples, 33 to 73 ppm; Mesozoic rocks, 8 samples, 14 to 338 ppm. Concentrations of magnesium noted are: valley fill, 37 samples, 13 to 1,150 ppm; Ogallala formation, 2 samples, 30 to 58 ppm. Mesozoic rocks, 8 samples, 0 to 215 ppm.

Sodium and Potassium

Moderate quantities of sodium and potassium have little effect on the suitability of water for most industrial or domestic uses. Concentrations of less than 50 ppm generally do not affect the usefulness of water for most purposes. More than 50 ppm of the two, however, may cause foaming in boilers. Generally, if the equivalents per million of sodium exceed the sum of the equivalents per million of calcium and magnesium in water used for irrigation, there is some danger of damage to the soil (see per cent sodium). Sodium is the cation commonly found in irrigation water which is most injurious to plants.

The following concentrations of sodium plus potassium have been noted in the ground water of the Fortaleza Valley area: valley fill, 27 samples, 31 to 2,700 ppm; Ogallala formation, 7 samples, 32 to 62 ppm; Mesozoic rocks, 8 samples, 382 to 2,904 ppm.

Carbonate and Bicarbonate

Carbonate and bicarbonate affect the usability of water mainly when present with certain other constituents. Bicarbonate is the principal dissolved constituent in most natural water, expecially those derived from limestone, dolomite, and rocks whose principal cementing material is calcium carbonate. The presence of carbon dioxide in water passing through these rocks enables it to dissolve the carbonates of calcium and magnesium and to produce bicarbonates of these two metals which are responsible for the so-called "temporary hardness" encountered in some water. A high concentration of sodium bicarbonate will cause foaming in boilers and may be objectionable in water used for irrigation. The effects and recommended tolerances for carbonate hardness will be discussed in a subsequent paragraph.

The following concentrations of carbonate have been noted in the ground water of the Portales Valley area: valley fill, 35 samples, no carbonate; Ogallala formation, 5 samples, no carbonate; Mesozoic rocks, 8 samples, 0 to 7.9 ppm. Concentrations of bicarbonate noted are: valley fill, 70 samples, 164 to 574 ppm; Ogallala formation, 6 samples, 208 to 292 ppm; Mesozoic rocks, 10 samples, 94 to 450 ppm.

Sulfate

Sulfate may be dissolved by water which passes through gypsum, gypsiferous sediment, or rocks containing disseminated sodium sulfate. It may also be formed by the oxidation of the sulfides of lead, zinc, and iron. When combined with calcium and magnesium, sulfate contributes to noncarbonate hardness or the so-called "permanent hardness" and hence to boiler scale and to equipment-maintenance costs as well as to the cost of softening water. Sulfate should not exceed 250 ppm in water

used for domestic purposes. This ion has no special harmful effect on soils or plants except that it increases the salinity of the soil solution.

The following concentrations of sulfate have been noted in the ground water of the Portales Valley area: valley fill, 30 samples, 90 to 7,530 ppm; Ogallala formation, 2 samples, 38 to 179 ppm; Mesozoic rocks, 8 samples, 281 to 3,350 ppm.

Chloride

Chloride combined with sodium is common salt and both generally are present in ground water. Chloride in small amounts has little effect on the usefulness of water, but in concentrations of several hundred parts per million it gives water a salty taste. Chloride therefore is undesirable in water used for domestic purposes. Heavy concentrations of chloride may impart corrosiveness to water, requiring frequent replacement of water pipe, or corrective measures to prevent corrosion such as the lining of pipe with a protective coating.

Chloride, like sulfate contributes to "permanent hardness" of water that contains large amounts of calcium or magnesium. Waters containing chloride concentrations of 250 or more ppm are above the suggested upper limit of chloride for satisfactory drinking water. The ion has a directly toxic effect on some plants and greatly effects the salinity of the soil solution.

The following concentrations of chloride have been noted in the ground water of the Portales Valley area: valley fill, 68 samples, 6 to 2,760 ppm; Ogallala formation, 7 samples, 7 to 293 ppm; Mesozoic rocks, 10 samples, 121 to 3,290 ppm.

used for domestic purposes. This ion has no special harmful effect on soils or plants except that it increases the salinity of the soil solution.

The following concentrations of sulfate have been noted in the ground water of the Portales Valley area: valley fill, 30 samples, 20 to 7,330 ppm; Ogallala formation, 2 samples, 38 to 178 ppm; Mesozoic rocks, 8 samples, 381 to 3,330 ppm.

Chloride

Chloride combined with sodium is common salt and both generally are present in ground water. Chloride in small amounts has little effect on the usefulness of water, but in concentrations of several hundred parts per million it gives water a salty taste. Chloride therefore is undesirable in water used for domestic purposes. Heavy concentrations of chloride may impart corrosiveness to water, requiring frequent replacement of water pipes or corrective measures to prevent corrosion such as the lining of pipe with a protective coating.

Chloride, like sulfate contributes to "permanent hardness" of water that contains large amounts of calcium or magnesium. Waters containing chloride concentrations of 250 or more ppm are above the suggested upper limit of chloride for satisfactory drinking water. The ion has a directly toxic effect on some plants and greatly affects the salinity of the soil solution.

The following concentrations of chloride have been noted in the ground water of the Portales Valley area: valley fill, 88 samples, 6 to 2,730 ppm; Ogallala formation, 7 samples, 7 to 203 ppm; Mesozoic rocks, 10 samples, 121 to 3,290 ppm.

The distribution of the chloride and the relation of chloride concentration to specific conductance in the ground water occurring in the Portales Valley area are shown on Figures 14 and 16, respectively.

Fluoride

The principal effect of fluoride in water is on the dental health of children, and it is beneficial or detrimental according to the concentration. In concentrations up to about 1.5 ppm, fluoride is believed by many health authorities to lessen tooth decay, but in higher concentrations it may contribute to a permanent dental defect known as mottled enamel, which appears to teeth in the formative stage -- that is, in the teeth of children up to about 12 years of age.

The following concentrations of fluoride have been noted in the ground water of the Portales Valley area: valley fill, 20 samples, 0.6 to 7.9 ppm; Ogallala formation, 2 samples, 2 to 5.6 ppm; Mesozoic rocks, 4 samples, 0.5 to 12 ppm.

Nitrate

Nitrate in water is considered a final oxidation product of nitrogenous material and in some instances may indicate previous contamination by sewage or other organic matter. It has been reported that as little as 2 ppm of nitrate in boiler water tends to decrease intercrystalline cracking of boiler steel.

Water containing an excessive amount of nitrate has been suspected of causing a form of cyanosis ("blue baby") when used in the preparation of formulas for feeding infants (Waring, 1949, p. 147). The New Mexico State Department of Public Health now considers water containing less than 10 ppm nitrate (as N; approximately 44 ppm when

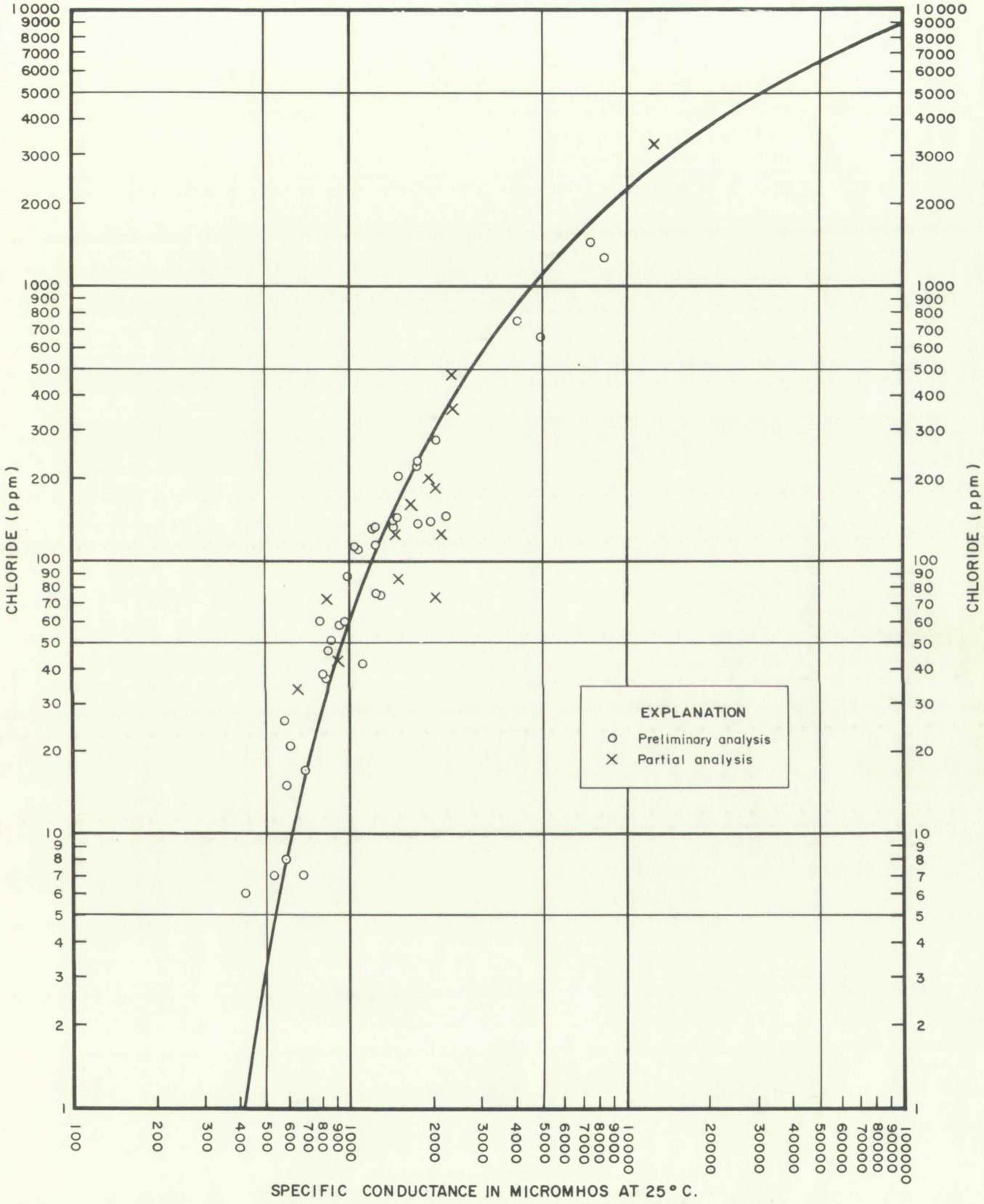

Figure 16. Relation of chloride concentration to specific conductance in water occurring in the Portales Valley area, Roosevelt County, New Mexico, in October, 1955

reported as NO_3) as safe for use.

The following concentrations of nitrate have been noted in the ground water of the Portales Valley area: valley fill, 27 samples, 0.94 to 28 ppm; Ogallala formation, 2 samples, 6.2 to 9.4 ppm; Mesozoic rocks, 6 samples, 0.25 to 46 ppm.

Total Dissolved Solids

The total quantity of dissolved mineral matter as determined by evaporating a measured quantity of clear water and weighing the residue after it has been dried at 180° C. for 1 hour is reported as total dissolved solids in ppm or in tons per acre-foot. Parts per million multiplied by 0.00136 gives the tons per acre-foot.

According to standards adopted by the U. S. Public Health Service, drinking water should contain not more than 1,000 ppm, and preferably not more than 500 ppm, total dissolved solids. Water containing several thousand ppm dissolved solids, however, is commonly used for irrigation and stock watering purposes.

The following concentrations of dissolved solids have been noted in the ground water of the Portales Valley area: valley fill, 8 samples, 397 to 1,245 ppm; Ogallala formation, no samples; Mesozoic rocks, 4 samples, 884 to 1,696 ppm.

Hardness

Hardness is the characteristic of water that receives the most attention with reference to industrial and domestic use. Hardness is the calcium carbonate ($CaCO_3$) equivalent of calcium and magnesium, and of all other individually determined cations having soap-consuming and encrusting properties. Hard water is objectionable because it forms

a lather with difficulty. It also causes a scale in boilers, water heaters, radiators and pipes, thereby decreasing the rate of heat transfer and creating the possibility of boiler failure and loss of flow. Hardness is caused almost entirely by compounds of calcium and magnesium. Other constituents such as iron, manganese, aluminum, barium, strontium, and free acid also cause hardness, but they are not usually found in appreciable quantities in most natural water.

Carbonate hardness caused by calcium and magnesium bicarbonate can be removed almost entirely by boiling and is commonly referred to as "temporary hardness". Noncarbonate hardness, caused mainly by the sulfates or chlorides of calcium and magnesium cannot be removed by boiling and is commonly referred to as "permanent hardness". Both types of hardness produce the same effect with respect to the use of soap in water.

Water having a hardness of less than about 50 ppm is generally rated as soft, and does not require softening except for special use. A hardness of 50 to 150 ppm does not seriously interfere with the use of water for most purposes, but slightly increases the consumption of soap. Its removal by a softening process is profitable for laundries or other industries using large quantities of soap. Water having a hardness in the upper part of this range will cause considerable scale in steam boilers. Hardness above 150 ppm is easily detectable, and in areas where it is above 300 ppm it is common practice to soften water for household use or to install cisterns for storing soft rain water. Where municipal supplies are softened, an attempt is generally made to reduce the hardness to less than 100 ppm.

The following hardnesses as $CaCO_3$ have been noted in the ground water of the Portales Valley area: valley fill, 25 samples, 225 to

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2,740 ppm; Ogallala formation, 3 samples, 206 to 386 ppm; Mesozoic rocks, 8 samples, 72 to 3,080 ppm. Noncarbonate hardnesses noted are: valley fill, 20 samples, 48 to 2,600 ppm; Ogallala formation, 2 samples, 15 to 176 ppm; Mesozoic rocks, 4 samples, 282 to 2,840 ppm.

Hydrogen-Ion Concentration

The degree of acidity or alkalinity of water is determined by the hydrogen-ion concentration and is expressed as the pH. A pH of 7.0 indicates that the water is neutral, being neither acid or alkaline. Values below 7.0 indicate acidity whereas those above 7.0 indicate alkalinity.

The pH of a water indicates in a general way its corrosive activity toward metal surfaces, and should be known so that proper treatment, if necessary, may be made. Acid waters are very corrosive and often contain excessive amounts of other objectionable constituents such as iron. The pH of water used for drinking purposes should not exceed 10.6 at 25° C.

The following values of pH have been noted in the ground water of the Portales Valley area: valley fill, 48 samples, 6.8 to 8.0; Ogallala formation, 4 samples, 7.2 to 7.5; Mesozoic rocks, 3 samples, 6.8 to 7.9.

Specific Conductance

The specific conductance of a water is the reciprocal of its resistance to an electric current under definite conditions. This property is ordinarily measured at 25° C. and is expressed in reciprocal ohms (mhos). In reports of analyses the conductivity is expressed as $Kx10^6$, or micromhos, instead of mhos, to avoid the use of decimals in expressing this property. In the irrigated West, according to

Dregne and Maker (1954, p. 7), the relation between electrical conductivity and plant response to salty water is closer than any other means of determining saltiness.

Dregne and Maker (1954, p. 10,12) have divided the ground water occurring in the Portales Valley into three classes based on this property. Class 1 includes water whose conductance ranges from 0 to 1,500 micromhos. Such water is suitable for use for most crops under most conditions. Class 2 includes water whose conductance ranges from 1,500 to 4,500 micromhos. This class of water can be used satisfactorily for most crops if care is taken to prevent the accumulation of soluble salt or sodium in the soil. Class 3 water has a conductance of more than 4,500 micromhos and is generally unsatisfactory for crop production. The less salty water in Class 3 may be used as a supplemental source of water if the regular water is of better quality.

The following values for specific conductance have been noted in the ground water of the Portales Valley area: valley fill, 63 samples, 582 to 16,400 micromhos; Ogallala formation, 6 samples, 526 to 912 micromhos; Mesozoic rocks, 7 samples, 1,430 to 12,700 micromhos.

The distribution of water of equal specific conductance and the relation of specific conductance to chloride concentration for 51 recent water samples collected in the Portales Valley are shown on Figures 13 and 16, respectively.

Per Cent Soluble Sodium

Per cent soluble sodium is the ratio of the equivalents per million of sodium to the sum of the equivalents per million of calcium, magnesium, sodium and potassium in a water.

The per cent soluble sodium is particularly important in classifying water for irrigation. A soluble sodium percentage of less than 60 in irrigation water usually will not cause a deterioration of soil structure. Water having a higher percentage of soluble sodium may so react with the soil that the soil becomes increasingly less permeable, particularly if other salts are present in large quantities and drainage is poor.

The following soluble sodium percentages have been noted in the ground water of the Portales Valley area: valley fill, 20 samples, 15 to 62 per cent; Ogallala formation, 2 samples, 20 to 25 per cent; Mesozoic rocks, 4 samples, 42 to 94 per cent.

Sodium Adsorption Ratio

The sodium adsorption ratio has been developed as a useful index for designating the sodium or alkali hazard of water used for irrigation. The sodium adsorption ratio is the ratio of Na to $\sqrt{\frac{Ca + Mg}{2}}$, where Na, Ca, and Mg represent the concentration in milliequivalents per liter of the respective ions. Water having a sodium adsorption ratio of less than 10 can be used for irrigation on almost all soil with little chance of soil deterioration. Water having a sodium adsorption ratio of 10 to 18 will present an appreciable sodium hazard in fine textured soils having high cation-exchange capacity, especially under conditions of relatively little leaching by fresh water unless gypsum is present in the soil. Such water may be used on coarse-textured or organic soil of good permeability. Water having a sodium adsorption ratio between 18 and 26 may produce harmful levels of exchangeable sodium in most soil and requires special soil management, except in gypsiferous soil. Water having a sodium adsorption ratio greater than 26 is generally unsatisfactory

The per cent soluble sodium is particularly important in determining water for irrigation. A soluble sodium percentage of more than 60 in irrigation water usually will cause deterioration of soil structure. Water having a higher percentage of soluble sodium may react with the soil that the soil becomes increasingly impervious, particularly if calcium salts are present in large quantities and drainage is poor.

The following soluble sodium percentages have been noted in the ground water of the Portales Valley area: valley fill, 20 samples, 0 to 62 per cent; Ogallala formation, 3 samples, 20 to 25 per cent; Chapola rocks, 4 samples, 42 to 65 per cent.

Sodium Absorption Ratio

The sodium absorption ratio has been developed as a useful index for designating the sodium or alkali hazard of water used for irrigation. The sodium absorption ratio is the ratio of Na to $\sqrt{\frac{Ca + Mg}{2}}$, where Na, Ca, and Mg represent the concentration in milliequivalents per liter of the respective ions. Water having a sodium absorption ratio of less than 10 can be used for irrigation on almost all soil with little change of soil deterioration. Water having a sodium absorption ratio of 10 to 18 will present an appreciable sodium hazard in fine textured soils having high cation-exchange capacity, especially under conditions of relatively little leaching by fresh water unless gypsum is present in the soil. Such water may be used on coarse-textured or organic soil of good permeability. Water having a sodium absorption ratio between 18 and 26 may produce harmful levels of exchangeable sodium in most soil and require special soil management, except in open-textured soil. Water having a sodium absorption ratio greater than 26 is generally unsuitable for

for irrigation except at low and perhaps medium salinity. The addition of gypsum may make the use of this water feasible (Wilcox, 1955, p. 14).

The following sodium adsorption ratios have been noted in the ground water of the Portales Valley area: valley fill, 11 samples, 1.2 to 6.9; Ogallala formation, 1 sample, 1.0; Mesozoic rocks, 1 sample, 63.

SUITABILITY OF WATER FOR IRRIGATIONAL PURPOSES

Whether water is satisfactory for irrigation depends on several factors in addition to the mineral content of the water, among them the amount of water applied to the soil. The total amount of dissolved mineral matter and the percentage of soluble sodium are the principal factors in evaluating an analysis of water for irrigational purposes.

Figure 17 from Wilcox (1948, p. 6), gives a classification of water for irrigational purposes based on the general relationship of these factors. The plot of the water samples represented in Appendix C for which these factors have been determined indicates that of the 28 water samples represented, 15 fall into the suitable area, 8 fall into the doubtful to unsuitable area, and 5 fall into the unsuitable area. Of the 13 water samples falling into the doubtful to unsuitable, or unsuitable area, 8 represent water from the valley fill, 4 represent water derived from the Mesozoic rocks, and 1 sample is of unknown origin. The 28 water samples represented include 20 samples obtained from the valley fill, 2 samples obtained from the Ogallala formation, 4 samples derived from the Mesozoic rocks, and 2 samples of unknown origin. Four Triassic samples and 1 valley-fill sample fall beyond the limits of Figure 17.

On the basis of the classification proposed by Dregne and Maker

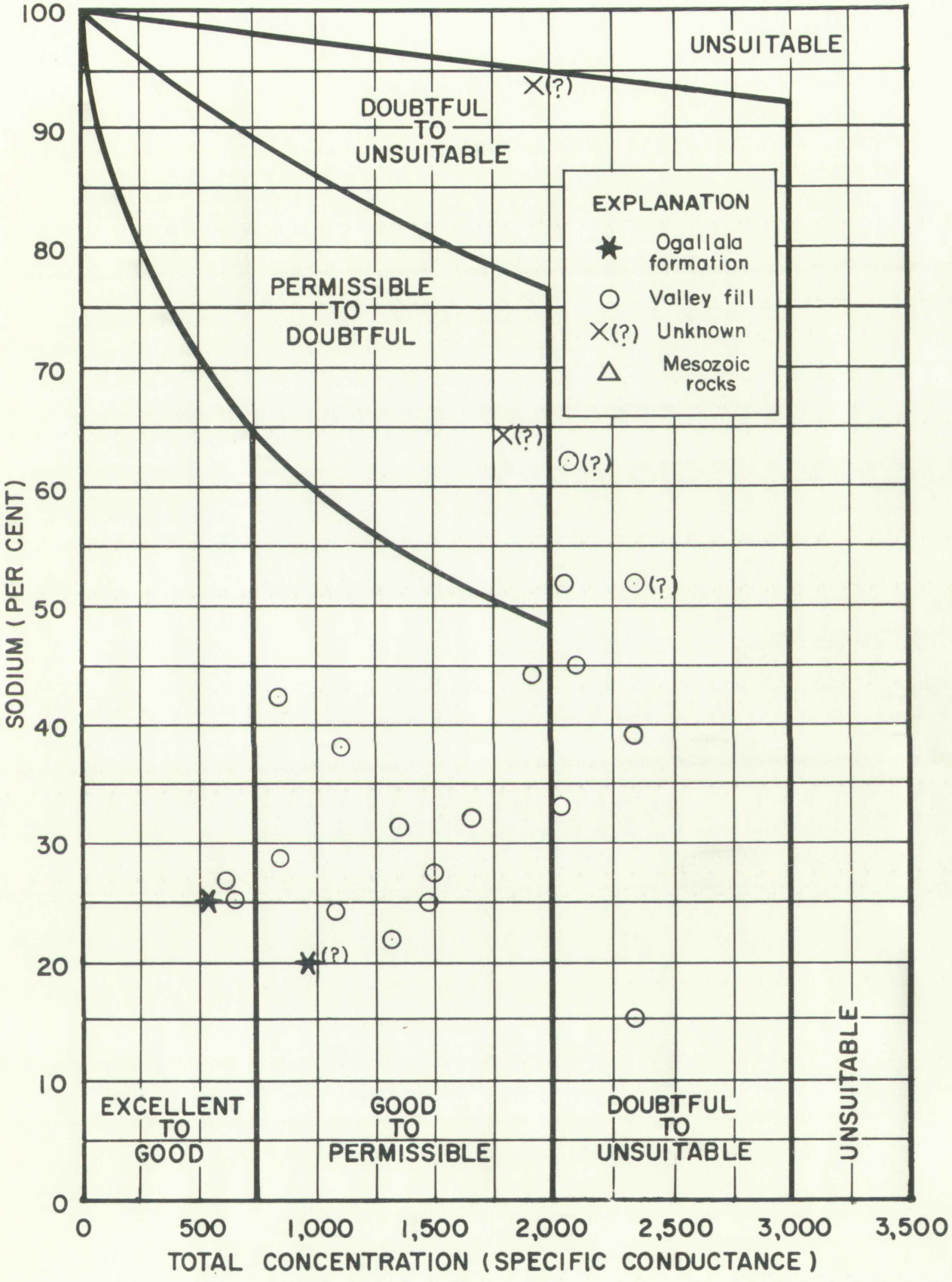

Figure 17. Classification of water for irrigation use (from Wilcox, 1948, page 6).

(1954, p. 10,12) 45 water samples fall in Class 1, 24 water samples fall in Class 2, and 7 water samples fall in Class 3. Of the Class 3 water samples, 3 represent water obtained from the valley fill and 4 represent water derived from Mesozoic rocks. The classification of the 76 water samples for which the specific conductance has been determined is given in Table 7.

Table 7

Classification of Irrigation Water - Portales Valley Area

Source of Water	Total Samples	Number of samples		
		Class 1	Class 2	Class 3
Valley fill	63	38	22	3
Ogallala formation	6	6	0	0
Mesozoic rocks	7	1	2	4
Totals	76	45	24	7

SUITABILITY OF WATER FOR DRINKING PURPOSES

Standards by which to judge the suitability of water for drinking purposes have been established by the U. S. Public Health Service (1946, p. 382-383). These standards indicate the maximum concentration of certain constituents, in ppm, that is acceptable for drinking and culinary water used on interstate carriers. These standards have been adopted by most of the state health departments. Among the constituents included in these standards, six are considered significant and the maximum limits for them are given on the page which follows.

Constituent	Parts per million
Magnesium (Mg)	125
Chloride (Cl)	250
Sulfate (SO_4)	250
Fluoride (F)	1.5
Dissolved solids	500 (1,000 acceptable)
Iron and Manganese together	0.3

A comparison of the water analyses in Appendix C with these standards shows a wide variation in the acceptability of water for drinking purposes, depending on the location of the well and the formation from which the water is derived. The reader is invited to compare specific analyses with these standards to ascertain the suitability of the water for drinking purposes.

CONCLUSIONS

The following general conclusions, relative to the occurrence of ground water in the Portales Valley area, have been drawn in the preceding pages of this report:

1. The Portales Valley shallow ground-water basin consists primarily of an early Pleistocene valley that has subsequently been filled with valley fill of both fluviatile and aeolian origin.

2. Within the limits of the principal irrigated part of the valley, the valley fill is the only source from which ground water can be obtained that is of suitable chemical quality and in sufficient quantities to meet the needs of agricultural, municipal, industrial, stock, and domestic uses.

3. Hydraulic boundaries, which reflect the geological and hydrological conditions encountered on the flanks of the valley, separate the valley-fill ground-water reservoir from the adjacent areas to the north and south, where ground water is obtained from sources other than the valley fill.

4. Recharge to the valley-fill ground-water reservoir is limited almost entirely to water derived from precipitation which falls on the area.

5. The greater part of the precipitation falling on the area comes during the summer growing season when temperatures are high and evaporation, consumptive use, and transpiration by

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2. Within the limits of the principal irrigated part of the valley, the valley fill is the only source from which ground water can be obtained that is of suitable chemical quality and in sufficient quantities to meet the needs of agricultural, municipal, industrial, stock, and domestic uses.

3. Hydraulic boundaries, which affect the geologic and hydrologic conditions encountered in the flanks of the valley, separate the valley-fill ground-water reservoir from the adjacent areas to the north and south, where ground water is obtained from sources other than the valley fill.

4. Recharge to the valley-fill ground-water reservoir is limited almost entirely to water derived from precipitation which falls on the area.

5. The greater part of the precipitation falling on the area comes during the summer growing season when temperatures are high and evaporation, consumptive use, and transpiration by

vegetation and crops are at a maximum.

6. The high evaporation rate in combination with the consumption of water by plants before it can move downward in the soil beyond the reach of their roots allows very little of the precipitation falling on the area to reach the water table.

7. The progressive water-level declines noted in the water-level records for this area are indicative that the annual ground-water withdrawal is far in excess of the annual recharge that is normally contributed to the reservoir.

8. The top of the Triassic "red beds" that occurs beneath the Portales Valley is, for all practical purposes, the lower limit of water-bearing sediment from which a ground-water supply may be expected that is of suitable chemical quality and in sufficient quantities to meet the normal needs of agricultural, municipal, industrial, stock and domestic uses.

9. When the water table declines to the top of the Triassic "red beds" the ground-water supply of the valley, for all practical purposes, will be exhausted.

10. If present rate of ground water withdrawal is continued, under the conditions that now prevail in the area, the ground-water supply of the Portales Valley will ultimately be depleted.

11. There is no evidence within the area studied to substantiate the generally accepted theory that the major surface depressions of the Llano Estacado are the result of subsidence of the near-surface strata due to the removal of some of the more soluble parts of the underlying strata by solution.

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APPENDIX A

Lithologic description of drill samples, Portales Valley area, Roosevelt County, New Mexico

Sample Log - Well 1S.33.6.311
Owner: Fred Taylor Total depth: 98 feet

Interval (feet)	Description
	Quaternary valley fill:
0-20	SAND: white to light;gray 50 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand, with 50 per cent light gray,$CaCO_3$ cement and a trace of silt; poorly cemented.
20-30	SAND: light tan; 80 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 20 per cent silt and a trace of clay; poorly cemented with light gray, $CaCO_3$ cement.
30-50	SAND: tan; 80 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 20 per cent silt and a trace of clay; poorly indurated.
50-60	SAND: tan; 90 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 10 per cent silt; poorly indurated.
60-80	SAND: light tan to tan; 80 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 20 per cent silt and a trace of clay; poorly indurated.
80-90	SAND: brown; 90 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 10 per cent silt; poorly indurated.
90-98	SAND: brown; 80 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 20 per cent silt; poorly indurated.
	Total depth.

Sample Log - Well 15.33.6.311

Owner: Fred Taylor Total depth: 98 feet

Interval (feet)	Description
	Quaternary valley fill:
0-20	SAND: white to light gray; 80 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand, with 30 per cent light gray, $CaCO_3$ cement and a trace of silt; poorly cemented.
20-30	SAND: light tan; 80 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 20 per cent silt and a trace of clay; poorly cemented with light gray, $CaCO_3$ cement.
30-50	SAND: tan; 80 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 20 per cent silt and a trace of clay; poorly indurated.
50-60	SAND: tan; 90 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 10 per cent silt; poorly indurated.
60-80	SAND: light tan to tan; 80 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 20 per cent silt and a trace of clay; poorly indurated.
80-90	SAND: brown; 90 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 10 per cent silt; poorly indurated.
90-98	SAND: brown; 80 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 20 per cent silt; poorly indurated. Total depth.

Sample Log - Well 1S.33.15.311
Owner: B. F. Miller Total depth: 105 feet

Interval (feet)	Description
	Quaternary valley fill:
0-1	No sample.
1-20	CALICHE: light gray; 75 per cent $CaCO_3$ with 25 per cent very fine to medium-grained, subangular to subrounded, fair sorted, quartz sand and a trace of silt; poorly cemented.
20-30	SAND: very light tan; 75 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 25 per cent silt; poorly cemented with light gray, $CaCO_3$ cement.
30-50	SILT: red-brown; 75 per cent silt with 25 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand and a trace of clay; fair induration.
50-60	SAND: red-brown; 90 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 10 per cent silt and a trace of clay; poorly indurated.
60-80	SAND: brown; 99 per cent fine- to medium-grained, subangular to subrounded, well sorted, quartz sand with a trace of silt; sample very clean; no cement.
80-90	SAND: brown; 85 per cent fine- to medium-grained, subangular to subrounded, well sorted, quartz sand with 15 per cent silt; poorly indurated.
90-100	SAND: brown; 90 per cent fine- to medium-grained, subangular to subrounded, well sorted, quartz sand with 10 per cent silt and a trace of very fine gravel; poorly indurated.
100-105	SAND: brown; 90 per cent fine- to medium-grained, subangular to subrounded, well sorted, quartz sand with 5 per cent silt and 5 per cent very fine gravel; poorly indurated.
	Total depth.

Sample Log - Well 1S.33.18.311

Owner: B. F. Miller Total depth: 105 feet

Interval (feet)	Description
	Quaternary valley fill:
0-1	No sample.
1-20	CALICHE: light gray; 75 per cent $CaCO_3$ with 25 per cent very fine to medium-grained, subangular to subrounded, fair sorted, quartz sand and a trace of silt; poorly cemented.
20-30	SAND: very light tan; 75 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 25 per cent silt; poorly cemented with light gray $CaCO_3$ cement.
30-50	SILT: red-brown; 75 per cent silt with 25 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand and a trace of clay; fair induration.
50-60	SAND: red-brown; 90 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 10 per cent silt and a trace of clay; poorly indurated.
60-80	SAND: brown; 99 per cent fine- to medium-grained, subangular to subrounded, well sorted, quartz sand with a trace of silt; sample very clean; no cement.
80-90	SAND: brown; 85 per cent fine- to medium-grained, subangular to subrounded, well sorted, quartz sand with 15 per cent silt; poorly indurated.
90-100	SAND: brown; 90 per cent fine- to medium-grained, subangular to subrounded, well sorted, quartz sand with 10 per cent silt and a trace of very fine gravel; poorly indurated.
100-105	SAND: brown; 90 per cent fine- to medium-grained, subangular to subrounded, well sorted, quartz sand with 5 per cent silt and 5 per cent very fine gravel; poorly indurated. Total depth.

Sample Log - Well 1S.34.18.331
Owner: Joe Terry Total depth: 127 feet

Interval (feet)	Description
	Quaternary valley fill:
0-10	SAND: light gray; 98 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with trace of silt; poorly cemented with light gray, $CaCO_3$ cement.
10-30	SAND: light tan; 95 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 5 per cent silt; poorly cemented with light gray, $CaCO_3$ cement.
30-40	SILT: brown; 90 per cent silt with 10 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand and a trace of clay; poorly indurated.
40-50	SAND: brown; 60 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 40 per cent silt and a trace of clay; poorly indurated.
50-60	SAND: tan; 70 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 30 per cent silt; poorly indurated.
60-70	SAND: tan; 80 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 20 per cent silt; fair cementation with light gray, $CaCO_3$ cement.
70-80	SAND: tan; 80 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 20 per cent silt; poorly indurated.
80-90	LIMESTONE (caliche): gray to red-brown; 75 per cent $CaCO_3$ with 15 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand and 10 per cent silt; well indurated.
90-100	SILT: red-brown; 70 per cent silt with 10 per cent very fine grained, subangular to subrounded, well sorted, quartz sand, 10 per cent clay and 10 per cent very fine gravel; fair induration.
100-110	SILT: red-brown to green; 80 per cent silt with 10 per cent clay, 5 per cent very fine gravel and 5 per cent very fine grained, subangular to subrounded, well sorted, quartz sand; well indurated.
110-120	SILT: red-brown; 90 per cent silt with 10 per cent clay; well indurated.
120-127	SILT: red-brown; 70 per cent silt with 10 per cent clay, 10 per cent very fine gravel and 10 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand; fair to poor induration.
	Total depth.

Sample Log - Well 18.34.18.331

Owner: Joe Terry Total depth: 127 feet

Interval (feet)	Description
	Quaternary valley fill:
0-10	SAND: light gray; 95 per cent very fine to fine-grained, subangular to subrounded, well sorted quartz sand with trace of silt; poorly cemented with light gray, $CaCO_3$ cement.
10-30	SAND: light tan; 95 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 5 per cent silt; poorly cemented with light gray, $CaCO_3$ cement.
30-40	SILT: brown; 90 per cent silt with 10 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand and a trace of clay; poorly indurated.
40-50	SAND: brown; 80 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 20 per cent silt and a trace of clay; poorly indurated.
50-60	SAND: tan; 70 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 30 per cent silt; poorly indurated.
60-70	SAND: tan; 80 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 20 per cent silt; fair cementation with light gray, $CaCO_3$ cement.
70-80	SAND: tan; 80 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 20 per cent silt; poorly indurated.
80-90	LIMESTONE (caliche): gray to red-brown; 75 per cent $CaCO_3$ with 15 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand and 10 per cent silt; well indurated.
90-100	SILT: red-brown; 70 per cent silt with 10 per cent very fine grained, subangular to subrounded, well sorted, quartz sand, 10 per cent clay and 10 per cent very fine gravel; fair induration.
100-110	SILT: red-brown to green; 80 per cent silt with 10 per cent clay, 5 per cent very fine gravel and 5 per cent very fine grained, subangular to subrounded, well sorted, quartz sand; well indurated.
110-120	SILT: red-brown; 90 per cent silt with 10 per cent clay; well indurated.
120-127	SILT: red-brown; 70 per cent silt with 10 per cent clay, 10 per cent very fine gravel and 10 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand; fair to poor induration. Total depth.

Sample Log - Well 18.34.26.131
Owner: J. I. Bacon Total depth: 115 feet

Interval (feet)	Description
	Quaternary valley fill:
0-10	SAND: gray; 60 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 25 per cent silt, 15 per cent caliche and a trace of clay; poorly cemented with gray, $CaCO_3$ cement.
10-20	SAND: white to light gray; 65 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 25 per cent silt, 10 per cent caliche and a trace of clay; poorly cemented with gray, $CaCO_3$ cement.
20-65	SAND: tan; 60 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 40 per cent silt and a trace of clay; fair induration.
65-75	SAND: tan; 70 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 30 per cent silt and a trace of clay; fair induration.
75-115	SAND: tan; 90 per cent fine- to medium-grained, subangular to subrounded, well sorted, quartz sand with 10 per cent very fine gravel; samples very clean; no cement.
	Total depth.

Sample Log - Well 18.34.26.131

Owner: J. I. Bacon Total depth: 115 feet

Interval (feet)	Description
	Quaternary valley fill:
0-10	SAND: gray; 80 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 25 per cent silt, 15 per cent caliche and a trace of clay; poorly cemented with gray, $CaCO_3$ cement.
10-20	SAND: white to light gray; 85 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 25 per cent silt, 10 per cent caliche and a trace of clay; poorly cemented with gray, $CaCO_3$ cement.
20-65	SAND: tan; 80 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 10 per cent silt and a trace of clay; fair induration.
65-75	SAND: tan; 70 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 30 per cent silt and a trace of clay; fair induration.
75-115	SAND: tan; 90 per cent fine- to medium-grained, subangular to subrounded, well sorted, quartz sand with 10 per cent very fine gravel; samples very clean; no cement. Total depth.

Sample Log - Well 1S.35.34.411
Owner: W. C. Harriman Total depth: 130 feet

Interval (feet)	Description
	Quaternary valley fill:
0-10	SAND: light tan; 90 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 10 per cent silt; poorly cemented with light gray, $CaCO_3$ cement.
10-20	SAND: light gray to tan; 95 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 5 per cent silt; poorly cemented with light gray, $CaCO_3$ cement.
20-50	SAND: tan; 99 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with a trace of silt; samples fairly clean; no cement.
50-60	No sample.
60-100	SAND: tan; 99 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand; samples very clean; no cement.
100-110	SAND: light gray to white; 99 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand; poorly cemented with white to light gray, $CaCO_3$ cement.
110-120	SAND: tan; 99 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand; sample fairly clean; no cement.
120-130	SAND: tan; 90 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 10 per cent silt; poorly indurated.
	Total depth.

Sample log - Well 18.35.34.411

Owner: W. C. Herriman Total depth: 130 feet

Interval (feet)	Description
	Quaternary valley fill:
0-10	SAND: light tan; 90 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 10 per cent silt; poorly cemented with light gray $CaCO_3$ cement.
10-20	SAND: light gray to tan; 95 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 5 per cent silt; poorly cemented with light gray $CaCO_3$ cement.
20-50	SAND: tan; 99 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with a trace of silt; samples fairly clean; no cement.
50-60	No sample.
60-100	SAND: tan; 99 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand; samples very clean; no cement.
100-110	SAND: light gray to white; 95 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand; poorly cemented with white to light gray $CaCO_3$ cement.
110-120	SAND: tan; 99 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand; sample fairly clean; no cement.
120-130	SAND: tan; 90 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 10 per cent silt; poorly indurated.
	Total depth.

Sample Log - Well 2S.34.18.141
Owner: A. M. McGowan Total depth: 217 feet

Interval (feet)	Description
	Quaternary valley fill:
0-10	SAND: very light tan to gray; 85 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 10 per cent silt, 5 per cent caliche and a trace of clay; poorly cemented with light gray, $CaCO_3$ cement.
10-30	SAND: very light tan to gray; 90 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 10 per cent silt; poorly cemented by light gray, $CaCO_3$ cement.
30-40	SAND: light tan; 80 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 20 per cent silt and a trace of clay; poorly indurated.
40-60	SAND: light brown; 99 per cent fine- to medium-grained, subangular to subrounded, well sorted, quartz sand; clean sample; no cement.
60-70	SILT: very light tan to gray; 60 per cent silt with 35 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand and 5 per cent clay; poorly indurated.
70-80	SILT: very light tan to gray; 70 per cent silt with 25 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand and 5 per cent clay; poorly indurated.
80-90	SILT: red-brown; 75 per cent silt with 20 per cent clay and 5 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand; fair induration.
90-120	SILT: red-brown; 80 per cent silt with 20 per cent clay and a trace of very fine to fine-grained, subangular to subrounded, well sorted, quartz sand; fair induration.
120-130	SILT: red-brown; 70 per cent silt with 20 per cent clay and 10 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand; fair induration.
130-160	SILT; red-brown; 80 per cent silt with 20 per cent clay and a trace of very fine to fine-grained, subangular to subrounded, well sorted, quartz sand; fair induration.
160-170	SILT: red-brown; 80 per cent silt with 20 per cent clay, a trace of very fine to fine-grained, subangular to subrounded, well sorted, quartz sand and a trace of very fine gravel; fair induration.

Sample log - Well 28.34.18.141

Owner: A. M. McGowan Total depth: 217 feet

Interval (feet)	Description
	Quaternary valley fill:
0-10	SAND: very light tan to gray; 85 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 10 per cent silt, 5 per cent calcite and a trace of clay; poorly cemented with light gray $CaCO_3$ cement.
10-30	SAND: very light tan to gray; 90 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 10 per cent silt; poorly cemented by light gray $CaCO_3$ cement.
30-40	SAND: light tan; 80 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 20 per cent silt and a trace of clay; poorly indurated.
40-60	SAND: light brown; 80 per cent fine- to medium-grained, subangular to subrounded, well sorted, quartz sand; clean sample; no cement.
60-70	SILT: very light tan to gray; 60 per cent silt with 35 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand and 5 per cent clay; poorly indurated.
70-80	SILT: very light tan to gray; 70 per cent silt with 25 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand and 5 per cent clay; poorly indurated.
80-90	SILT: red-brown; 75 per cent silt with 20 per cent clay and 5 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand; fair induration.
90-120	SILT: red-brown; 80 per cent silt with 20 per cent clay and a trace of very fine to fine-grained, subangular to subrounded, well sorted, quartz sand; fair induration.
120-130	SILT: red-brown; 70 per cent silt with 20 per cent clay and 10 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand; fair induration.
130-160	SILT: red-brown; 80 per cent silt with 20 per cent clay and a trace of very fine to fine-grained, subangular to subrounded, well sorted, quartz sand; fair induration.
160-170	SILT: red-brown; 80 per cent silt with 20 per cent clay, a trace of very fine to fine-grained, subangular to subrounded, well sorted, quartz sand and a trace of very fine gravel; fair induration.

170-180	SILT: red-brown; 80 per cent silt with 20 per cent clay and a trace of very fine to fine-grained, subangular to subrounded, well sorted, quartz sand; fair induration.
180-190	SILT: red-brown; 75 per cent silt with 15 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand and 10 per cent clay; fair induration.
190-200	SILT: red-brown; 50 per cent silt with 40 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand and 10 per cent clay; poorly indurated.
200-210	SILT: red-brown; 50 per cent silt with 45 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand and 5 per cent clay; poorly indurated.
210-212	GRAVEL: gray to brown; 90 per cent very fine, well rounded gravel with 10 per cent very fine to coarse-grained, subangular to subrounded, poorly sorted, quartz sand; clean sample; no cement.
	Triassic:
212-214	SILTSTONE: light gray to brown mottled; 75 per cent silt with 20 per cent clay, 5 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand and a trace of very fine gravel; well indurated.
214-217	No sample. Total depth.

170-180 SILT: red-brown; 80 per cent silt with 20 per cent clay and a trace of very fine to fine-grained, subangular to subrounded, well sorted, quartz sand; fair induration.

180-190 SILT: red-brown; 75 per cent silt with 15 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand and 10 per cent clay; fair induration.

190-200 SILT: red-brown; 80 per cent silt with 20 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand and 10 per cent clay; fair induration.

200-210 SILT: red-brown; 80 per cent silt with 20 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand and 5 per cent clay; poor induration.

210-212 GRAVEL: gray to brown; 80 per cent very fine, well rounded gravel with 10 per cent very fine to coarse-grained, subangular to subrounded, poorly sorted, quartz sand; clean sample; no fines.

Triassic:

212-214 SILTSTONE: light gray to brown mottled; 75 per cent silt with 20 per cent clay, 5 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand and a trace of very fine gravel; well indurated.

214-217 No sample.
Total depth.

Sample Log - Well 2S.35.9.431
Owner: A. L. Everette Total depth: 136 feet

Interval (feet)	Description
	Quaternary valley fill:
0-5	No sample.
5-15	CALICHE: white to light gray; 75 per cent $CaCO_3$ with 25 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand and traces of silt and clay; poorly indurated.
15-25	CALICHE: white to light gray; 50 per cent $CaCO_3$ with 50 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand and traces of silt and clay; poorly indurated.
25-75	SAND: tan; 60 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 40 per cent silt and a trace of clay; poorly indurated.
75-85	SAND: red-brown; 75 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 25 per cent silt and a trace of clay; poorly indurated.
85-95	SILT: red-brown; 60 per cent silt with 40 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand and a trace of clay; fair induration.
95-105	SAND: red-brown; 70 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 20 per cent silt and 10 per cent very fine gravel; poorly indurated.
105-117	SAND: brown; 99 per cent fine- to medium-grained, subangular to subrounded, well sorted, quartz sand; clean sample; no cement.
117-121	SAND: brown; 65 per cent fine- to coarse-grained, subangular to subrounded, fair sorted, quartz sand with 25 per cent very fine gravel and 10 per cent silt; poorly indurated.
	Triassic:
121-136	SILT: red to tan; 60 per cent silt with 40 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand and a trace of clay; poorly indurated.
	Total depth.

Sample log -- Well 28.35.9.431

Owner: A. L. Everette Total depth: 136 feet

Interval (feet)	Description
	Quaternary valley fill:
0-5	No sample.
5-15	GRAVEL: white to light gray; 75 per cent $CaCO_3$ with 25 per cent very fine to fine grained, subangular to subrounded, well sorted, quartz sand and traces of silt and clay; poorly indurated.
15-25	GRAVEL: white to light gray; 50 per cent $CaCO_3$ with 50 per cent very fine to fine grained, subangular to subrounded, well sorted, quartz sand and traces of silt and clay; poorly indurated.
25-75	SAND: tan; 90 per cent very fine to fine grained, subangular to subrounded, well sorted, quartz sand with 10 per cent silt and a trace of clay; poorly indurated.
75-85	SAND: red-brown; 75 per cent very fine to fine grained, subangular to subrounded, well sorted, quartz sand with 25 per cent silt and a trace of clay; poorly indurated.
85-95	SILT: red-brown; 80 per cent silt with 20 per cent very fine to fine grained, subangular to subrounded, well sorted, quartz sand and a trace of clay; fairly indurated.
95-105	SAND: red-brown; 70 per cent very fine to fine grained, subangular to subrounded, well sorted, quartz sand with 20 per cent silt and 10 per cent very fine gravel; poorly indurated.
105-117	SAND: brown; 95 per cent very fine to fine grained, subangular to subrounded, well sorted, quartz sand; clean sample, no cement.
117-121	SAND: brown; 75 per cent very fine to coarse grained, subangular to subrounded, fair sorted, quartz sand with 25 per cent very fine gravel and 10 per cent silt; poorly indurated.
	Triassic:
121-136	SILT: red to tan; 80 per cent silt with 20 per cent very fine to fine grained, subangular to subrounded, well sorted, quartz sand and a trace of clay; poorly indurated.
	Total depth.

Sample Log - Well 2S.35.23.133
Owner: W. J. Crump Total depth: 100 feet

Interval (feet)	Description
	Quaternary valley fill:
0-10	SAND: light gray to brown; 90 per cent very fine to medium-grained, subangular to subrounded, fair sorted, quartz sand with 10 per cent caliche and a trace of silt; poorly cemented with light gray, $CaCO_3$ cement.
10-30	SAND: light tan; 90 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 10 per cent silt; poorly indurated.
30-53	SAND: brown; 90 per cent fine- to medium-grained, subangular to subrounded, well sorted, quartz sand with 10 per cent silt; poorly indurated.
53-60	SAND: light gray to tan; 80 per cent very fine to medium-grained, subangular to subrounded, fair sorted, quartz sand with 10 per cent silt and 10 per cent caliche; poorly cemented with light gray, $CaCO_3$ cement.
60-90	SILT: red-brown; 95 per cent silt with 5 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand and a trace of clay; fair induration.
90-100	SAND: red-brown; 50 per cent very fine to medium-grained, subangular to subrounded, fair sorted, quartz sand with 50 per cent silt; fair to poor induration. Total depth.

Sample log - Well 2S.3S.23.133

Owner: W. J. Crump Total depth: 100 feet

Interval (feet)	Description
	Quaternary valley fill:
0-10	SAND: light gray to brown; 90 per cent very fine to medium-grained, subangular to subrounded, fair sorted, quartz sand with 10 per cent caliche and a trace of silt; poorly cemented with light gray, $CaCO_3$ cement.
10-30	SAND: light tan; 90 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 10 per cent silt; poorly indurated.
30-53	SAND: brown; 90 per cent fine- to medium-grained, subangular to subrounded, well sorted, quartz sand with 10 per cent silt; poorly indurated.
53-60	SAND: light gray to tan; 80 per cent very fine to medium-grained, subangular to subrounded, fair sorted, quartz sand with 10 per cent silt and 10 per cent caliche; poorly cemented with light gray, $CaCO_3$ cement.
60-90	SILT: red-brown; 95 per cent silt with 5 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand and a trace of clay; fair induration.
90-100	SAND: red-brown; 50 per cent very fine to medium-grained, subangular to subrounded, fair sorted, quartz sand with 50 per cent silt; fair to poor induration. Total depth.

Sample Log - Well 2S.36.33.211
Owner: John Plummer Total depth: 98 feet

Interval (feet)	Description
	Quaternary valley fill:
0-10	SAND: light gray to very light tan; 50 per cent very fine to coarse-grained, subangular to subrounded, fair sorted, quartz sand with 50 per cent caliche and a trace of silt; poorly cemented with white to tan, $CaCO_3$ cement.
10-20	SAND: very light tan; 75 per cent very fine to coarse-grained, subangular to subrounded, fair sorted, quartz sand with 25 per cent caliche and a trace of silt; poorly cemented with white to tan, $CaCO_3$ cement.
20-30	SAND: light gray to very light tan; 50 per cent very fine to coarse-grained, subangular to rounded, fair sorted, quartz sand with 50 per cent caliche and a trace of silt; poorly cemented with white to tan, $CaCO_3$ cement.
30-40	SAND: light gray to very light tan; 90 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 10 per cent caliche and a trace of silt; poorly cemented with white to tan, $CaCO_3$ cement.
40-60	SILT: red-brown; 75 per cent silt with 25 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand and a trace of clay; fair induration.
60-70	SAND: light tan; 99 per cent fine- to medium-grained, subangular to subrounded, well sorted, quartz sand; clean sample; no cement.
70-80	SAND: light brown; 98 per cent fine- to medium-grained, subangular to subrounded, well sorted, quartz sand with 2 per cent very fine gravel; clean sample; no cement.
80-90	SAND: light brown; 96 per cent fine- to medium-grained, subangular to subrounded, well sorted, quartz sand with 4 per cent very fine gravel; clean sample; no cement.
90-98	SILT: tan; 85 per cent silt with 13 per cent fine- to medium-grained, subangular to subrounded, well sorted, quartz sand, 2 per cent very fine gravel and a trace of clay; poorly indurated.
	Total depth.

Sample Log - Well 2S.36.35.212
Owner: L. B. Harrison Total depth: 86 feet

Interval (feet)	Description
	Quaternary valley fill:
0-1	No sample.
1-10	CALICHE: light gray to white; 75 per cent $CaCO_3$ with 25 per cent fine- to medium-grained, subangular to subrounded, well sorted, quartz sand, and traces of silt and clay; poorly cemented.
10-20	SAND: light gray to white; 50 per cent very fine to medium-grained, subangular to subrounded, fair sorted, quartz sand with 50 per cent caliche and a trace of silt; poorly cemented with white, $CaCO_3$ cement.
20-30	SAND: light gray; 60 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 40 per cent caliche and a trace of silt; poorly cemented with white, $CaCO_3$ cement.
30-40	SAND: light tan; 70 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 30 per cent silt; poorly indurated.
40-50	SAND: light tan; 99 per cent fine- to medium-grained, subangular to subrounded, well sorted, quartz sand with a trace of silt; clean sample; no cement.
50-60	SAND: red-brown; 90 per cent fine- to medium-grained, subangular to subrounded, well sorted, quartz sand with 10 per cent silt; poorly indurated.
60-70	SAND: red-brown; 99 per cent fine- to medium-grained, subangular to subrounded, well sorted, quartz sand with a trace of silt; clean sample; no cement.
70-80	SAND: red-brown; 98 per cent fine- to medium-grained, subangular to subrounded, well sorted, quartz sand with 1 per cent very fine gravel and a trace of silt; clean sample; no cement.
80-86	No sample.
	Total depth.

Sample Log - Well 28.38.35.212

Owner: I. S. Harrison Total depth: 86 feet

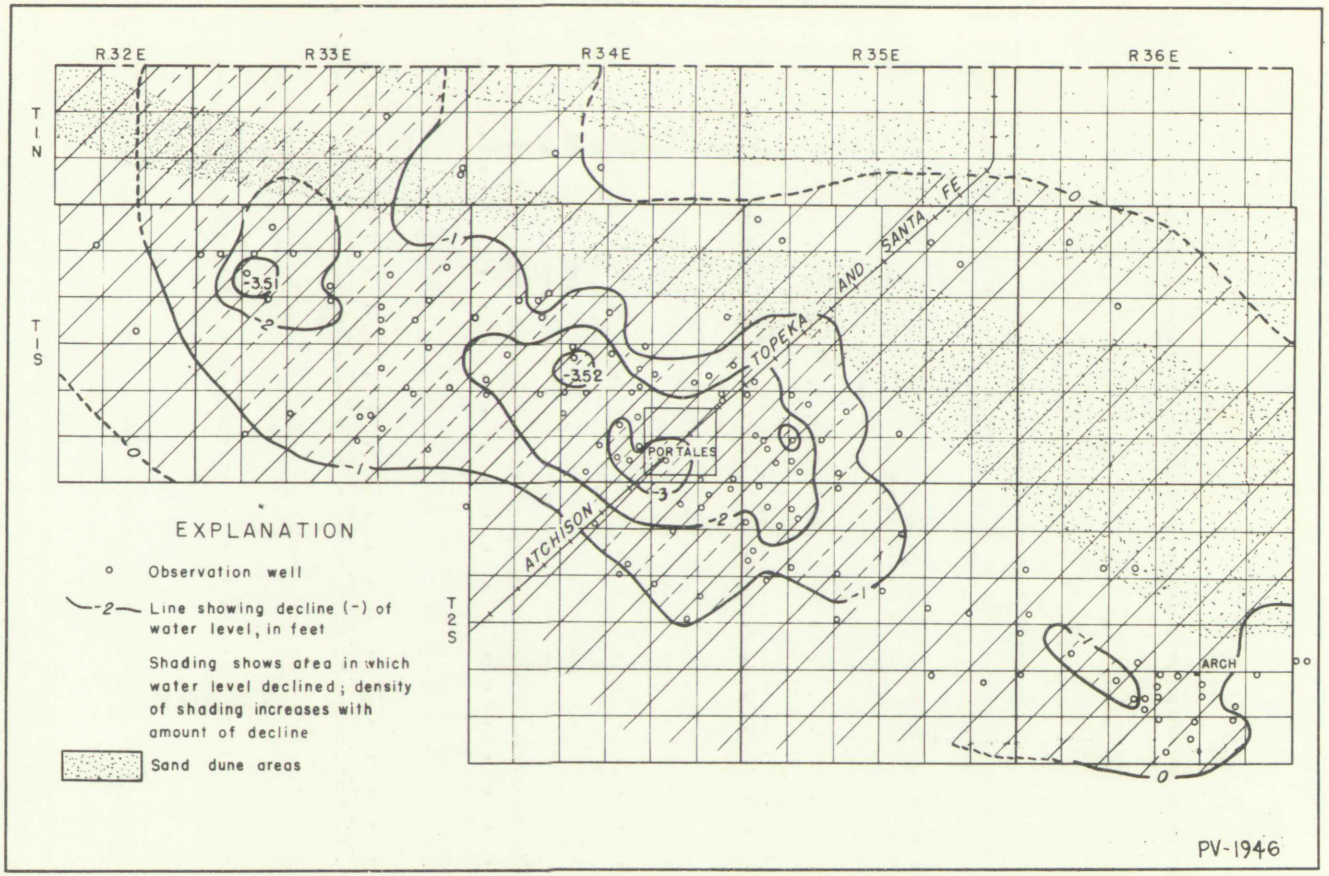
Interval (feet)	Description
	Quaternary valley fill:
0-1	No sample.
1-10	CALICHE: light gray to white; 75 per cent $CaCO_3$ with 25 per cent fine- to medium-grained, subangular to subrounded, well sorted, quartz sand, and traces of silt and clay; poorly cemented.
10-20	SAND: light gray to white; 80 per cent very fine to medium-grained, subangular to subrounded, fair sorted, quartz sand with 80 per cent caliche and a trace of silt; poorly cemented with white, $CaCO_3$ cement.
20-30	SAND: light gray; 60 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 40 per cent caliche and a trace of silt; poorly cemented with white, $CaCO_3$ cement.
30-40	SAND: light tan; 70 per cent very fine to fine-grained, subangular to subrounded, well sorted, quartz sand with 30 per cent silt; poorly indurated.
40-50	SAND: light tan; 99 per cent fine- to medium-grained, subangular to subrounded, well sorted, quartz sand with a trace of silt; clean sample; no cement.
50-60	SAND: red brown; 90 per cent fine- to medium-grained, subangular to subrounded, well sorted, quartz sand with 10 per cent silt; poorly indurated.
60-70	SAND: red-brown; 99 per cent fine- to medium-grained, subangular to subrounded, well sorted, quartz sand with a trace of silt; clean sample; no cement.
70-80	SAND: red brown; 98 per cent fine- to medium-grained, subangular to subrounded, well sorted, quartz sand with 1 per cent very fine gravel and a trace of silt; clean sample; no cement.
80-86	No sample.
	Total depth.

APPENDIX B

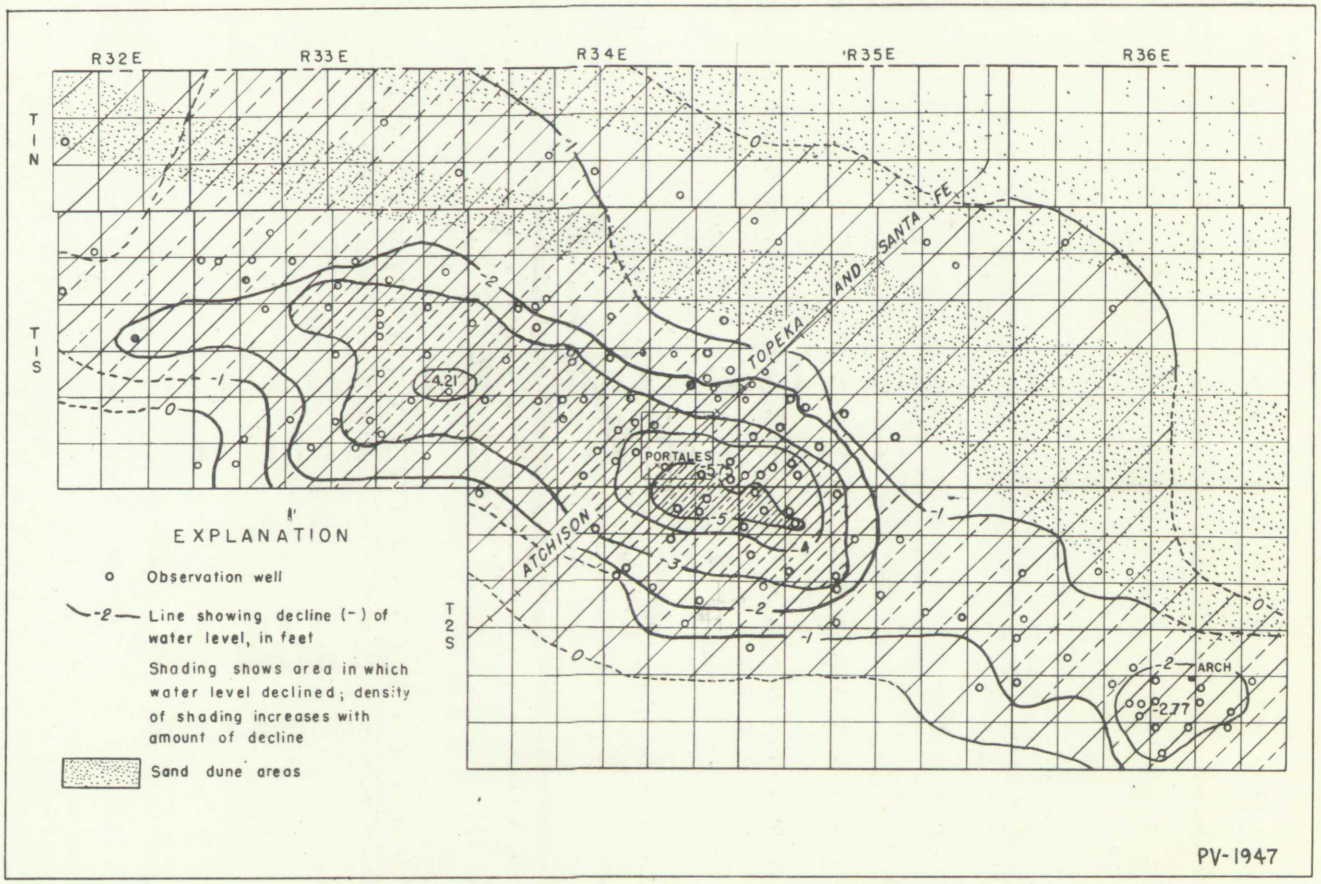
Changes in ground-water levels,
Portales Valley area, Roosevelt and Curry Counties,
New Mexico

APPENDIX B

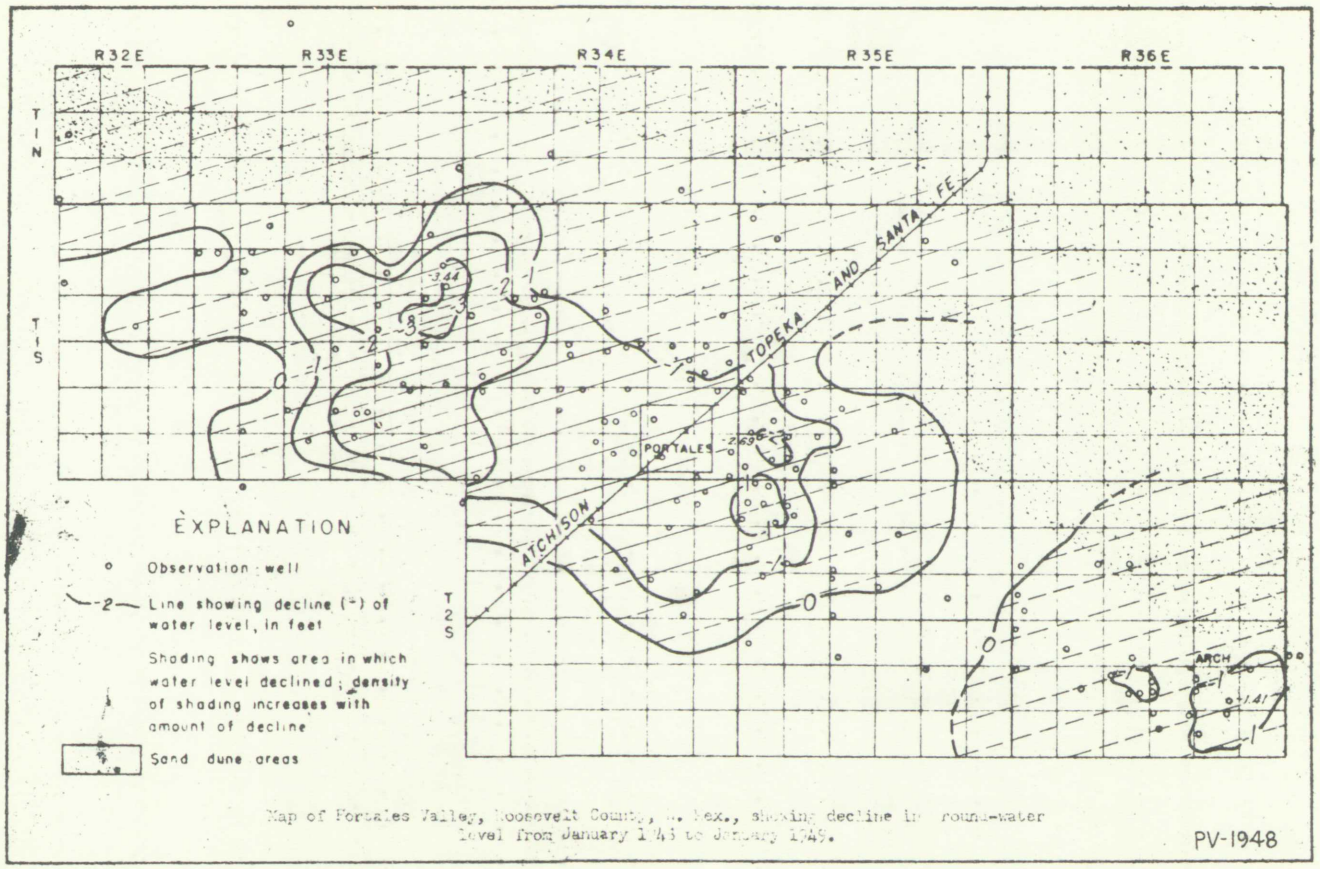
Changes in ground-water levels, Portales Valley area, Roosevelt and Curry Counties, New Mexico



Portales Valley, Roosevelt County, N. Mex., showing change in ground-water level from January 1946 to January 1947



Portales Valley, Roosevelt County, N. Mex., showing change in ground-water level from January 1947 to January 1948



Map of Portales Valley, Roosevelt County, N. Mex., showing decline in ground-water level from January 1 '43 to January 1 '49.

PV-1948

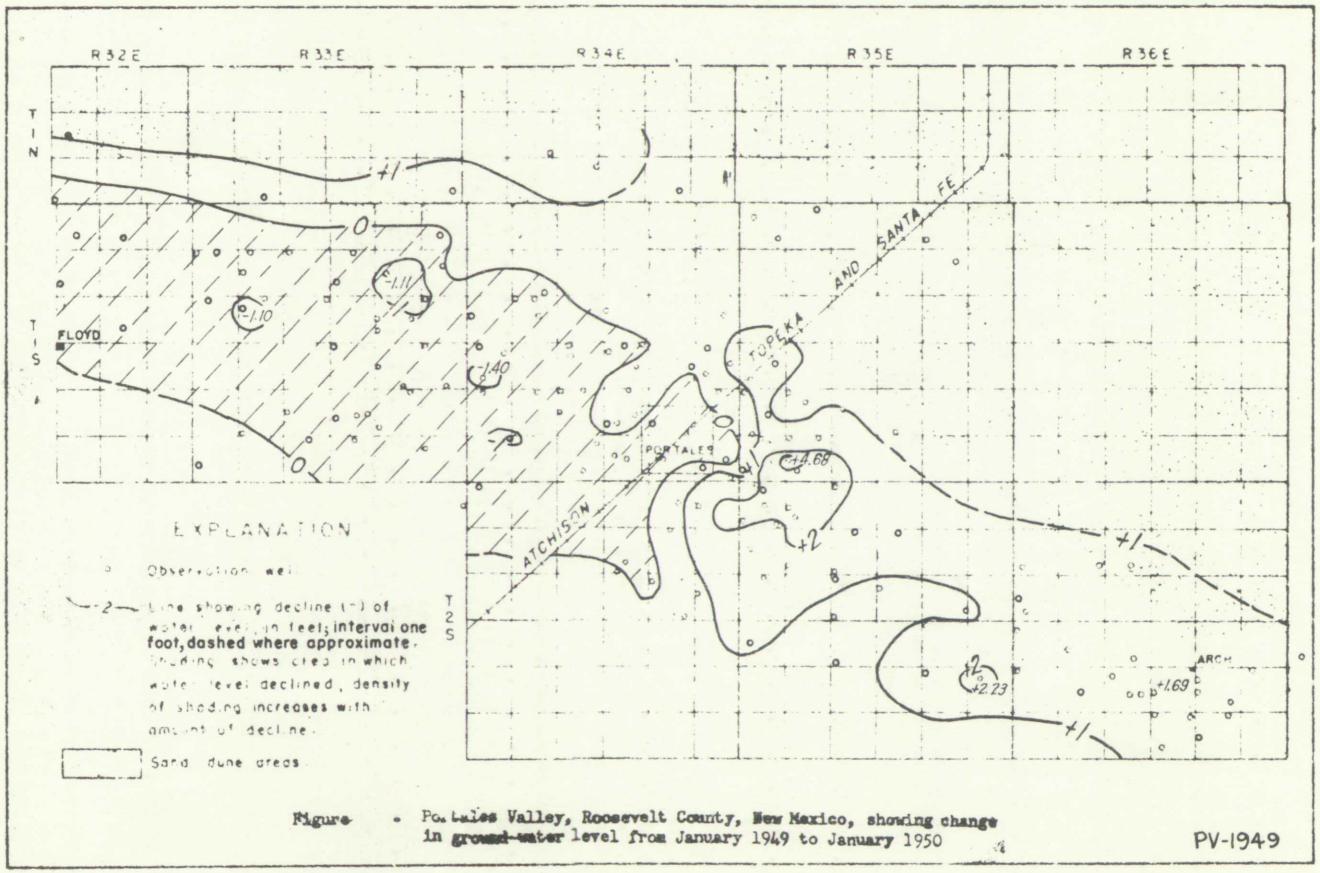
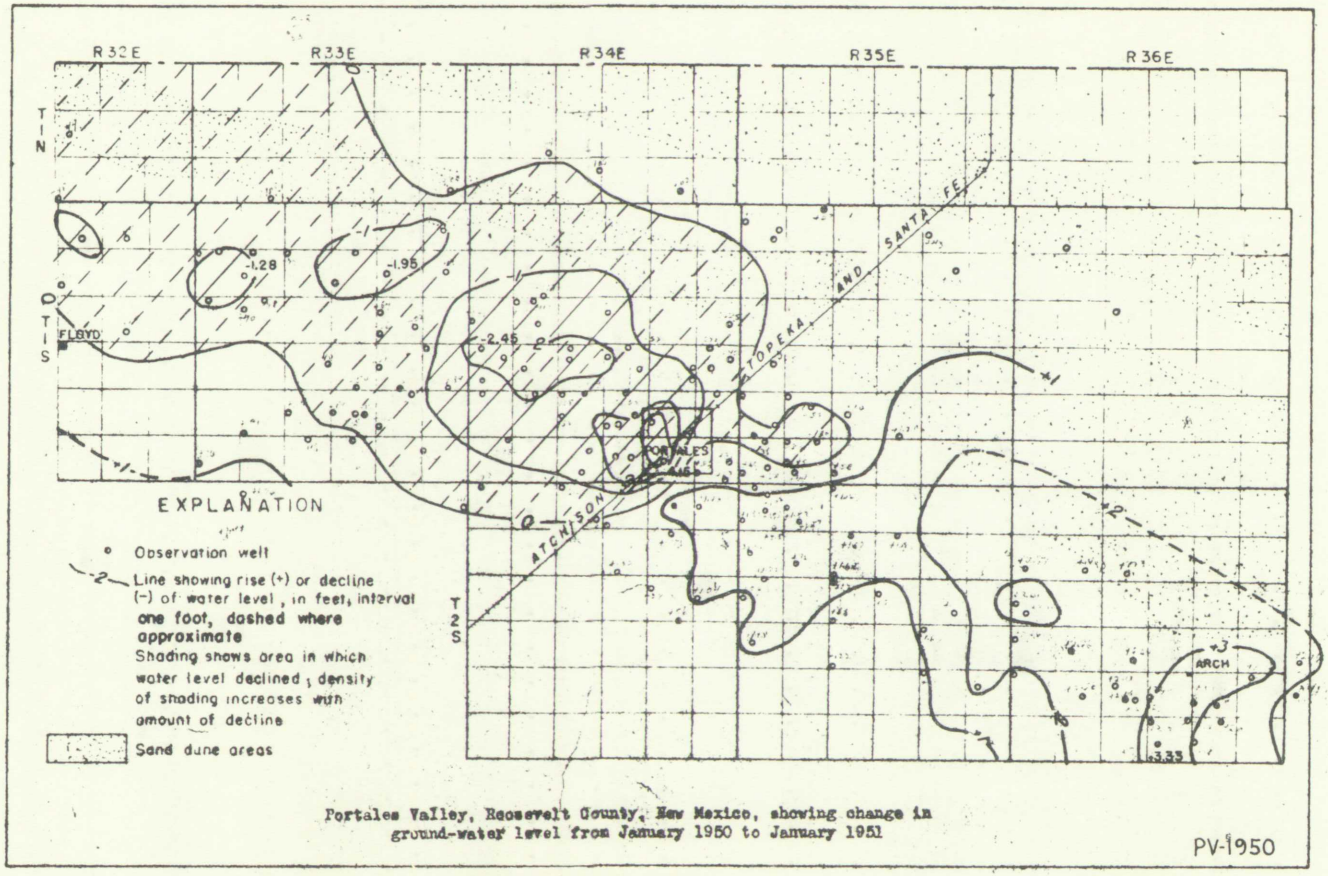


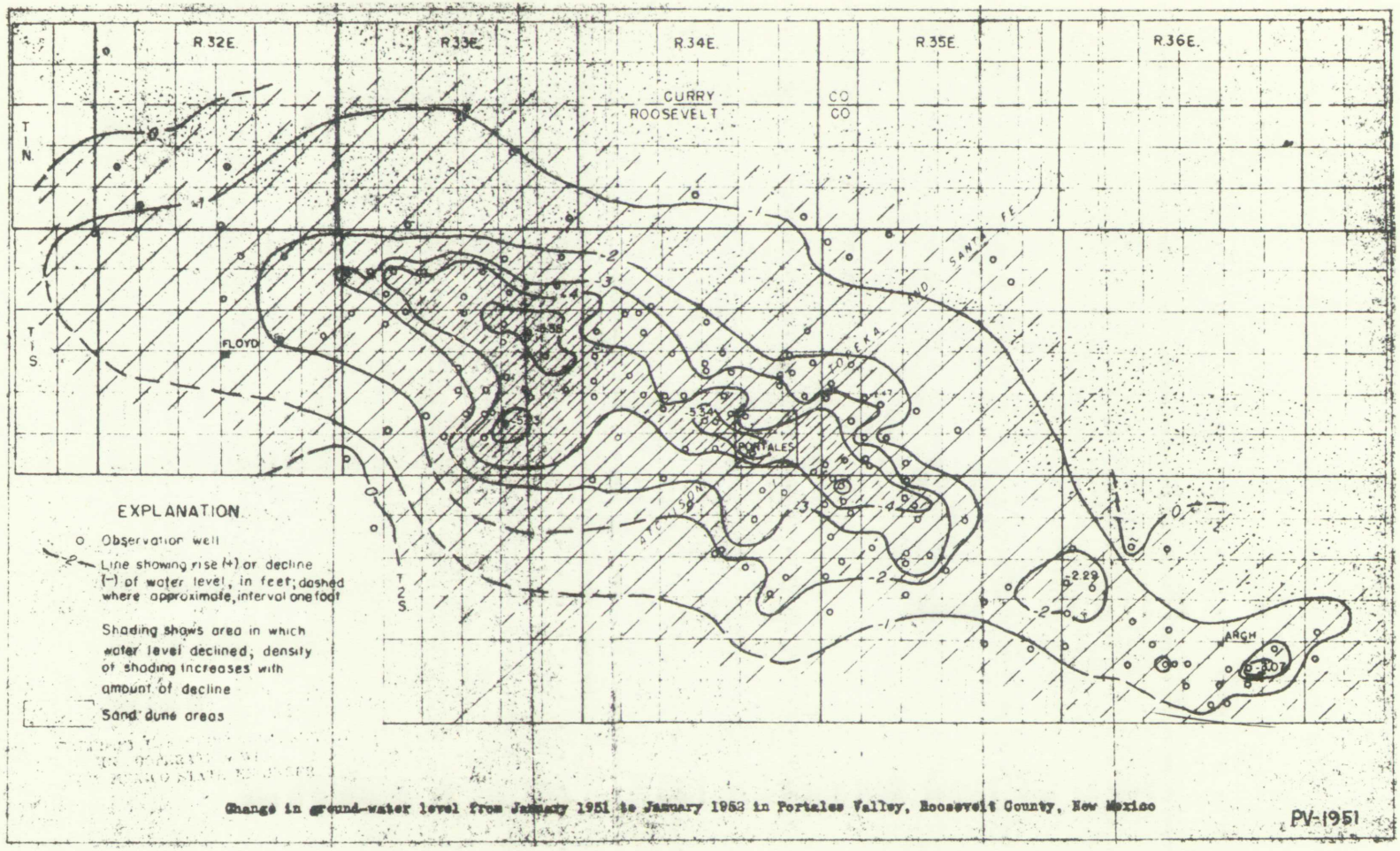
Figure . Portales Valley, Roosevelt County, New Mexico, showing change in ground-water level from January 1949 to January 1950

PV-1949



Portales Valley, Roosevelt County, New Mexico, showing change in ground-water level from January 1950 to January 1951

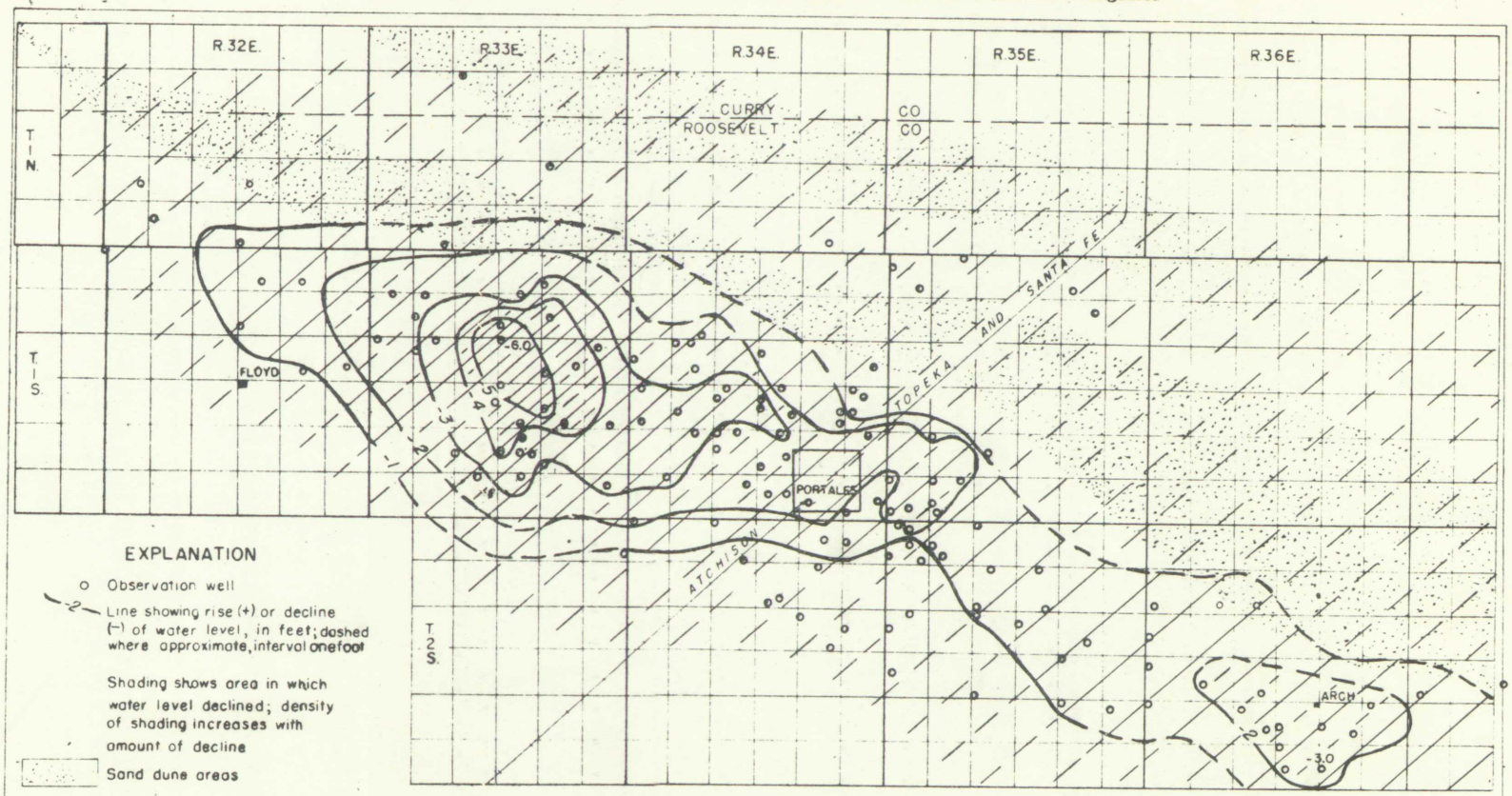
PV-1950



Change in ground-water level from January 1951 to January 1953 in Portales Valley, Roosevelt County, New Mexico

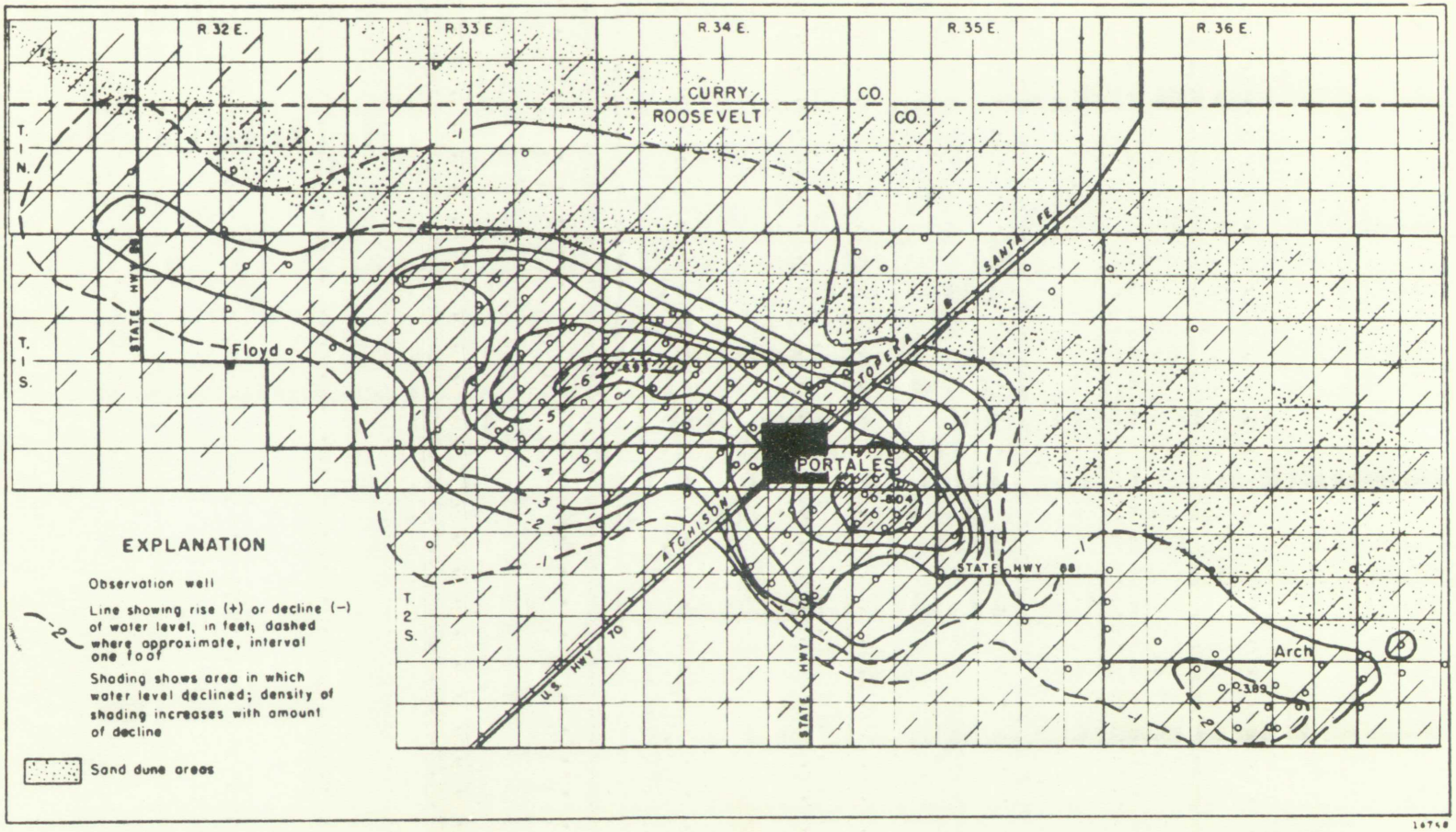
PV-1951

Prepared by U. S. Geological Survey in cooperation with New Mexico State Engineer



Change in ground-water level from January 1952 to January 1953 in Portales Valley, Roosevelt County, New Mexico

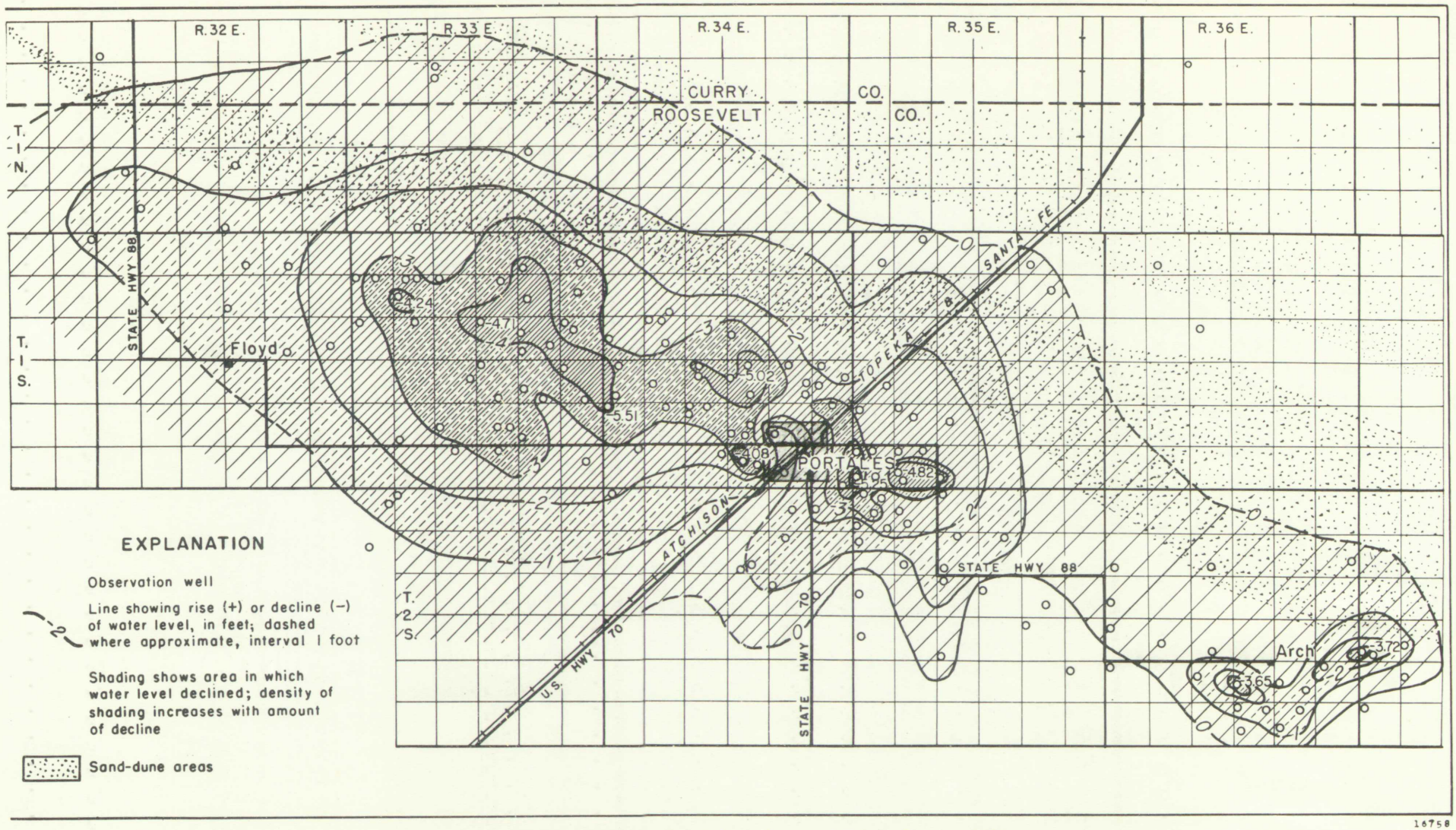
PV-1952



PV-1953

Change in ground-water level from January 1953 to January 1954 in Portales Valley, Roosevelt County, New Mexico.

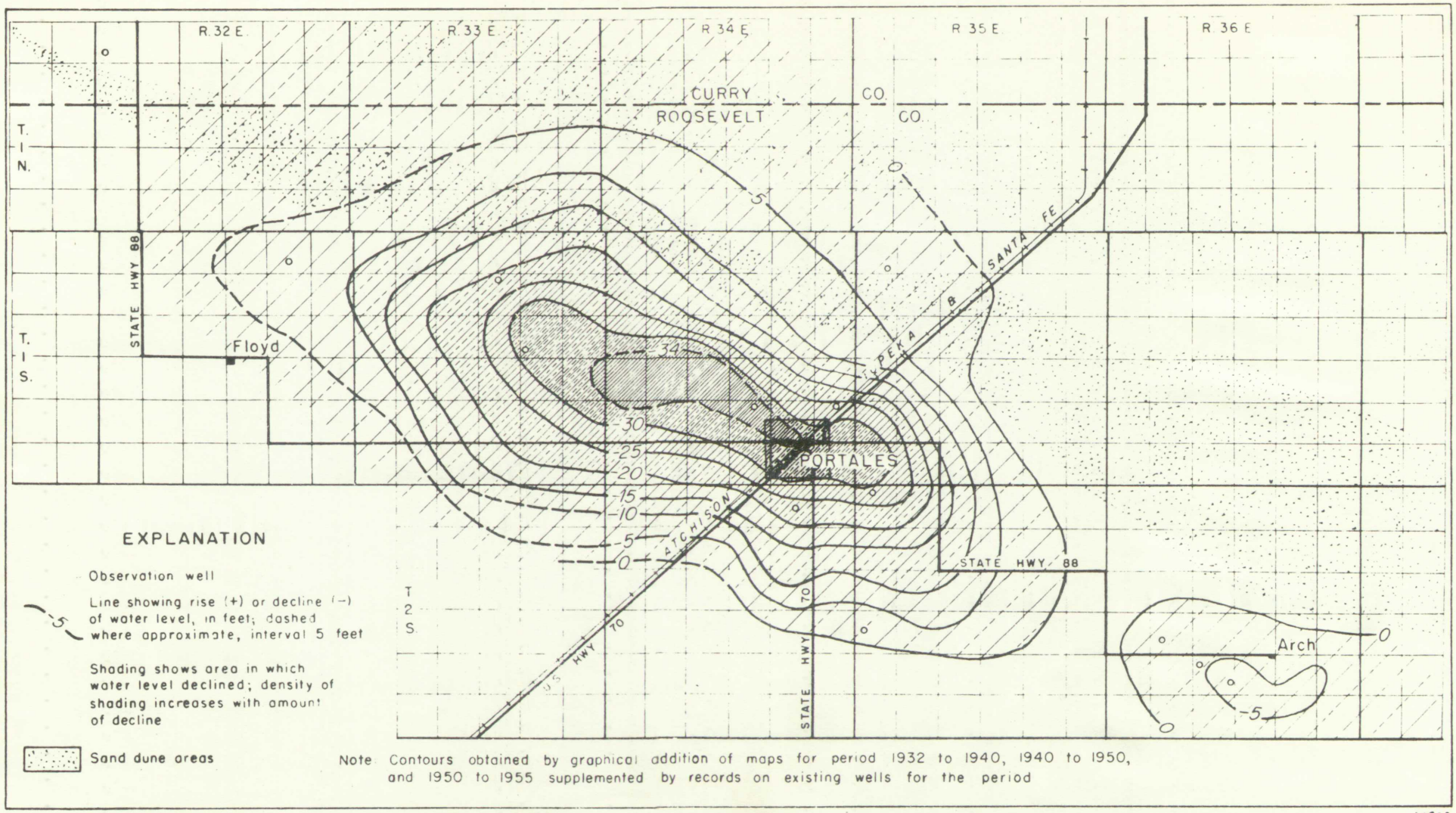
PREPARED BY U. S. GEOLOGICAL SURVEY IN COOPERATION WITH STATE ENGINEER OF NEW MEXICO



16758

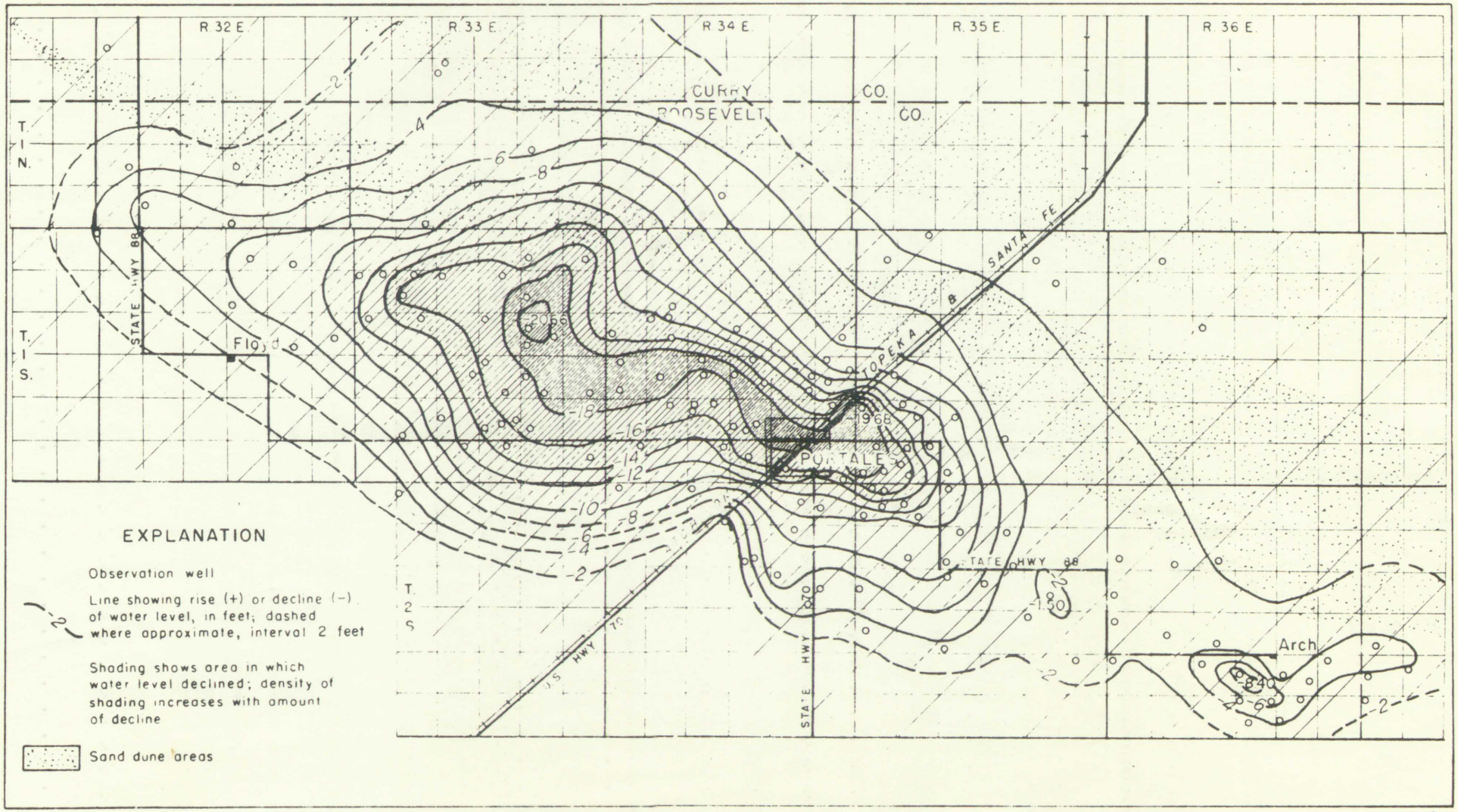
Change in ground-water level from January 1954 to January 1955
in Portales Valley, Roosevelt County, New Mexico.

PREPARED BY U. S. GEOLOGICAL SURVEY IN COOPERATION WITH STATE ENGINEER OF NEW MEXICO



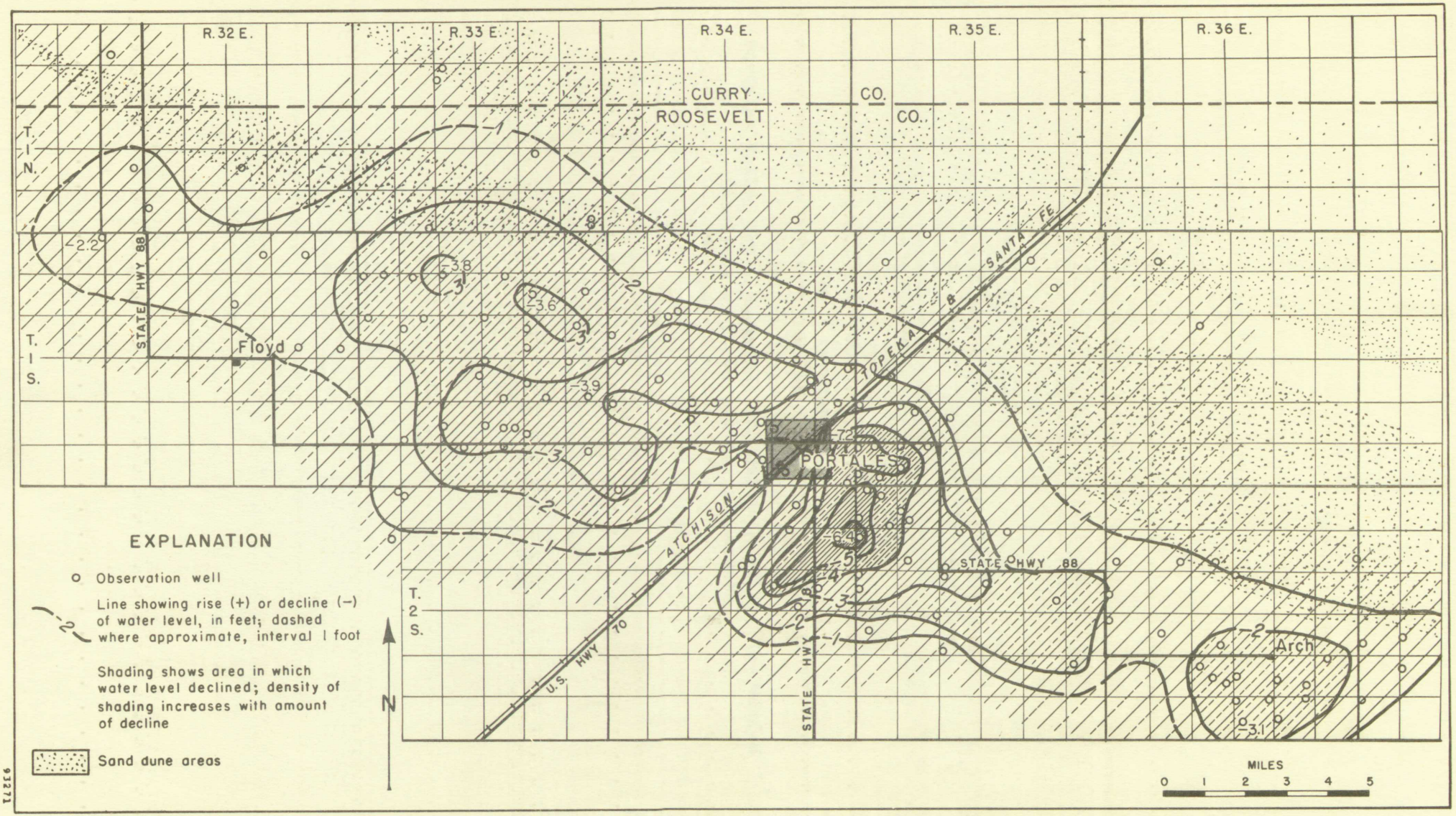
Change in ground-water level from January 1932 to January 1955 in Portales Valley, Roosevelt County, New Mexico.

PREPARED BY U. S. GEOLOGICAL SURVEY IN COOPERATION WITH STATE ENGINEER OF NEW MEXICO



Change in ground-water level from January 1950 to January 1955 in Portales Valley, Roosevelt County, New Mexico.

PREPARED BY U. S. GEOLOGICAL SURVEY IN COOPERATION WITH STATE ENGINEER OF NEW MEXICO



Change in ground-water level from January 1955 to January 1956
in Portales Valley, Roosevelt County, New Mexico.

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APPENDIX C

Chemical analyses of ground water,
Portales Valley area, Roosevelt and Curry Counties, New Mexico
(Analyses by U. S. Geological Survey)

APPENDIX C

Chemical analyses of ground water,
Portales Valley area, Roosevelt and Curry Counties, New Mexico
(Analyses by U. S. Geological Survey)

ANALYSES OF WELL WATER, PORTALES VALLEY AREA

Analyses by U. S. Geological Survey (Parts per million)

Location Number	2N.35.36.213	2N.36.31.211	2N.37.32.411	1N.31.26.112	1N.32.20.111	1N.32.27.134
Owner or Name	P. C. Edwards	C.L.Lockmiller	Joseph D.Crump	I. D. Bigler	A. E. Lee	Carl Essary
Use	Irrigation	Irrigation	Irrigation	Irrigation	Domestic-Stock	Domestic
Well Depth	311	337	296	160		
Water-bearing Formation	Ogallala	Ogallala	Ogallala	Valley fill	Valley fill	Valley fill
Date of Collection	3/5/54	3/3/54	3/1/54	11/1/55	11/1/55	11/1/55
Silica (SiO_2)		37		40	67	
Iron (Fe)						
Calcium (Ca)		33		35	111	
Magnesium (Mg)		30		40	67	
Sodium (Na)		32		84	277	
Potassium (K)						
Carbonate (CO_3)	0	0	0	0	0	
Bicarbonate (HCO_3)	220	233	221	194	303	194
Sulfate (SO_4)		38		153	607	
Chloride (Cl)	29	24	43	73	184	138
Fluoride (F)		2.0		3.6	4.7	
Nitrate (NO_3)		6.2		3.7	2.0	
Dissolved Solids (Sum).		317		527	1,470	
Total Dissolved Solids. Tons per acre-foot		0.43		0.72	2.00	
Specific Conductance (micromhos at 25° C.).	553	526	657	851	2,060	1,980
Ignition Loss						
Density						
Hardness as $CaCO_3$		206		252	552	
Noncarbonate hardness		15		93	304	
Percent Sodium (Na)		25		42	52	
Sodium-Adsorption-Ratio				2.3	5.2	
pH				7.4	7.5	7.2
Temperature (°F)		65	65	63	61	62

ANALYSES OF WELL WATERS, PORTALES VALLEY AREA

Analyses by U. S. Geological Survey (Parts per million)

Location Number	1N.32.30.421	1N.32.31.343	1N.33.25.444	1N.33.31.313	1N.35.35.423	1N.37.3.281
Owner or Name	R. P. Martin	W. C. Smith	J.L.Baldwin Estate	Maynard Miller		Joe Blair
Use	Irrigation	Domestic	Stock	Domestic	Stock	Irrigation
Well Depth	120					343
Water-bearing Formation	Valley fill	Valley fill	Valley fill	Valley fill	Ogallala (?)	Ogallala
Date of Collection	10/25/55	11/1/55	10/31/55	11/1/55	10/31/55	2/24/54
Silica (SiO_2)					40	
Iron (Fe)					75	
Calcium (Ca)					49	
Magnesium (Mg)					43	
Sodium (Na)						
Potassium (K)					0	
Carbonate (CO_3)						0
Bicarbonate (HCO_3)	194	301	350	246	255	206
Sulfate (SO_4)					179	
Chloride (Cl)	114	60	21	75	43	46
Fluoride (F)					5.6	
Nitrate (NO_3)					9.4	
Dissolved Solids (Sum)					577	
Total Dissolved Solids						
Tons per acre-foot					0.78	
Specific Conductance (micromhos at 25° C.)	1,260	731	614	1,300	912	642
Lyttlon Loss						
Deneity						
Hardness as $CaCO_3$					384	
Noncarbonate hardness					176	
Percent Sodium (Na)					30	
Sodium-Adsorption-Ratio					1.0	
pH	7.2	7.5	7.3	7.2	7.3	
Temperature (°F)	62	59	60.8	61	61	

ANALYSES OF WELL WATER, PORTALES VALLEY AREA

Analyses by U. S. Geological Survey (Parts per million)

Location Number	1S.31.2.122	1S.32.5.214	1S.32.10.211	1S.32.15.330	1S.33.7.111	1S.33.7.111
Owner or Name		Emil Bigler	Walter Gregory	Floyd School	J. F. Holman	J. F. Holman
Use	Stock	Irrigation	Irrigation	School Supply	Irrigation	Domestic
Well Depth		138	103			70
Water-bearing Formation	Valley fill	Valley fill	Valley fill	Valley fill(?)	Valley fill	Valley fill
Date of Collection	11/1/55	10/27/55	9/21/55	11/1/55	7/29/52	11/1/55
Silica (SiO_2)				33	60	
Iron (Fe)						
Calcium (Ca)				71	74	
Magnesium (Mg)				69	49	
Sodium (Na)				341	108	
Potassium (K)						
Carbonate (CO_3)				0	0	
Bicarbonate (HCO_3)	240	201	204	302	251	229
Sulfate (SO_4)				724	295	
Chloride (Cl)	201	88	132	124	64	76
Fluoride (F)				7.9	3.2	
Nitrate (NO_3)				5.3	11	
Dissolved Solids (Sum).				1,520	788	
Total Dissolved Solids.						
Tons per acre-foot				2.07	1.07	
Specific Conductance (micromhos at 25° C.).	1,500	984	1,240	2,150	1,190	1,260
Ignition Loss						
Density						
Hardness as $CaCO_3$				460	386	
Noncarbonate hardness				213	180	
Percent Sodium (Na)				62	38	
Sodium-Adsorption-Ratio				6.9		
pH	7.4	7.6	7.1	7.5		7.3
Temperature (°F)	63	62	63	62		61

ANALYSES OF WELL WATER, PORTALES VALLEY AREA

Analyses by U. S. Geological Survey (Parts per million)

Location Number	1S.33.11.343	1S.33.12.122	1S.33.12.421	1S.33.14.100	1S.33.19.123	1S.33.28.311
Owner or Name	Chas. Williams	Woodburn Bros.	Woodburn Bros.	J. V. Miller	Robert Compton	C. Roland
Use	Domestic	Irrigation	Irrigation	Domestic	Stock	
Well Depth	90	80	98			
Water-bearing Formation	Valley fill	Valley fill	Valley fill	Valley fill	Valley fill	Valley fill
Date of Collection	11/1/55	10/31/55	10/31/55	9/?/31	11/1/55	7/29/52
Silica (SiO_2)	40			55		32
Iron (Fe)				0.01		
Calcium (Ca)	145			36		92
Magnesium (Mg)	64			33		101
Sodium (Na)	97			49		242
Potassium (K)				6.2		
Carbonate (CO_3)	0			0		0
Bicarbonate (HCO_3)	201	259	226	216	215	205
Sulfate (SO_4)	453			114		689
Chloride (Cl)	126	37	113	26	110	194
Fluoride (F)	2.7					3.3
Nitrate (NO_3)	19			0.94		3.8
Dissolved Solids (Sum)	1,050			427		1,460
Total Dissolved Solids				418		
Tons per acre-foot	1.43					1.99
Specific Conductance (micromhos at 25° C.)	1,490	827	1,060		1,090	2,140
Ignition Loss				21		
Density						
Hardness as $CaCO_3$	625			225		645
Noncarbonate hardness	460					477
Percent Sodium (Na)	25					45
Sodium-Adsorption-Ratio	1.7					
pH	7.3	7.2	7.2		7.5	
Temperature (°F)	62	61.5	61.5		62.5	

ANALYSES OF WELL WATER, PORTALES VALLEY AREA

Analyses by U. S. Geological Survey (Parts per million)

Location Number	1S.33.28.311	1S.33.28.311	1S.33.28.433	1S.34.9.333	1S.34.22.111	1S.34.22.420
Owner or Name	Jolley	Jolley	C. J. Bennett	Minnie Morris	J.W.Zimmerman	R. C. Grunig
Use			Domestic	Stock	Domestic	Irrigation
Well Depth			100			111
Water-bearing Formation	Valley fill	Valley fill	Valley fill	Valley fill	Valley fill	Valley fill
Date of Collection	7/29/53	7/23/54	11/1/55	10/31/55	9/29/55	11/18/31
Silica (SiO_2)			50		33	36
Iron (Fe)						0.01
Calcium (Ca)			97		81	74
Magnesium (Mg)			84		13	14
Sodium (Na)			217		44	34
Potassium (K)						3.0
Carbonate (CO_3)	0	0	0		0	0
Bicarbonate (HCO_3)	224	210	179	247	236	232
Sulfate (SO_4)		711	591		96	90
Chloride (Cl)	174	192	200	26	34	21
Fluoride (F)			4.7		2.4	
Nitrate (NO_3)			2.9		3.9	2.4
Dissolved Solids (Sum)			1,330		423	389
Total Dissolved Solids						397
Tons per acre-foot			1.81		0.58	
Specific Conductance (micromhos at 25° C.)	1,990	2,150	1,920	582	652	
Ignition Loss						16
Density						
Hardness as $CaCO_3$			588		256	242
Noncarbonate hardness			441		62	
Percent Sodium (Na)			44		27	
Sodium-Adsorption-Ratio			3.9		1.2	
pH			7.2	7.8	7.6	
Temperature (°F)			58	65	71	63

ANALYSES OF WELL WATER, PORTALES VALLEY AREA

Analyses by U. S. Geological Survey (Parts per million)

Location Number	1S.33.28.311	1S.33.28.311	1S.33.28.433	1S.34.9.333	1S.34.22.111	1S.34.28.430
Owner or Name	Jolley	Jolley	C. T. Bennett	Minnie Morris	J.W.Zimmerman	R. C. Grunig
Use			Domestic	Stock	Domestic	Irrigation
Well Depth			100			111
Water-bearing Formation	Valley fill	Valley fill	Valley fill	Valley fill	Valley fill	Valley fill
Date of Collection	7/29/58	7/23/54	11/1/55	10/31/55	8/29/50	11/18/31
Silica (SiO_2)			50		33	36
Iron (Fe)						0.01
Calcium (Ca)			97		81	74
Magnesium (Mg)			64		13	14
Sodium (Na)			217		44	34
Potassium (K)						3.0
Carbonate (CO_3)	0	0	0		0	0
Bicarbonate (HCO_3)	224	210	178	247	238	232
Sulfate (SO_4)		711	581		80	80
Chloride (Cl)	174	138	290	26	34	21
Fluoride (F)			4.7		2.4	
Nitrate (NO_3)			8.9		3.9	2.4
Dissolved Solids (Sum)			1,230		493	389
Total Dissolved Solids						397
Tons per acre-foot			1.81		0.72	
Specific Conductance (micromhos at 25° C.)	1,800	2,150	1,920	382	692	
Ignition Loss						16
Density						
Hardness as $CaCO_3$			580		256	242
Noncarbonate hardness			141		69	
Percent Sodium (Na)			44		27	
Sodium-Adsorption-Ratio			2.9		1.2	
pH			7.2	7.8	7.9	
Temperature (°F)			58	65	71	62

ANALYSES OF WELL WATER, PORTALES VALLEY AREA

Analyses by U. S. Geological Survey (Parts per million)

Location Number	1S.34.22.421a	1S.34.22.421a	1S.34.22.421a	1S.34.24.222	1S.34.28.440	1S.34.28.422
Owner or Name	R. C. Grunig	R. C. Grunig	R. C. Grunig	R. T. Sharp	E. L. Gibson	Holbert Shirley
Use				Domestic	Irrigation	Domestic
Well Depth					56	110
Water-bearing Formation	Valley fill	Valley fill	Valley fill	Valley fill	Valley fill	Valley fill
Date of Collection	7/29/52	7/28/53	7/22/54	10/31/55	10/?/31	10/31/55
Silica (SiO_2)	32				50	
Iron (Fe)					0.01	
Calcium (Ca)	360				64	
Magnesium (Mg)	69				22	
Sodium (Na)	98				56	
Potassium (K)					3.1	
Carbonate (CO_3)	0	0	0		0	
Bicarbonate (HCO_3)	194	196	192	221	230	218
Sulfate (SO_4)	840		769		124	
Chloride (Cl)	249	245	240	15	36	131
Fluoride (F)	1.4					
Nitrate (NO_3)	9.3				3.9	
Dissolved Solids (Sum)	1,750				472	
Total Dissolved Solids					481	
Tons per acre-foot	2.38					
Specific Conductance (micromhos at 25° C.)	2,340	2,290	2,280	596		1,220
Ignition Loss					27	
Density						
Hardness as $CaCO_3$	1,180				250	
Noncarbonate hardness	1,020					
Percent Sodium (Na)	15					
Sodium-Adsorption-Ratio						
pH				7.1		7.1
Temperature (°F)				61.5	63.5	72

ANALYSES OF WELL WATER, PORTALES VALLEY AREA

Analyses by U. S. Geological Survey (Parts per million)

Location Number	1S.34.32.431a	1S.31.22.121a	1S.34.33.431a	1S.31.34.322	1S:34.28.440	1S.35.28.320
Owner or Name	R. C. Grundig	R. C. Grundig	R. C. Grundig	R. T. Sharp	E. L. Gibson	Hulbert Shirley
Use			Domestic		Irrigation	Domestic
Well Depth					56	110
Water-bearing Formation	Valley fill	Valley fill	Valley fill	Valley fill	Valley fill	Valley fill
Date of Collection	7\28\52	7\28\52	7\22\52	10\31\52	10\31\52	
Silica (SiO_2)					30	
Iron (Fe)					0.01	
Calcium (Ca)	360				64	
Magnesium (Mg)	88				32	
Sodium (Na)	98				96	
Potassium (K)					3.1	
Carbonate (CO_3)	0	0	0		0	
Bicarbonate (HCO_3)	194	188	192	321	230	218
Sulfate (SO_4)	940		788		128	
Chloride (Cl)	540	215	340	15	38	131
Fluoride (F)	1.4					
Nitrate (NO_3)	8.3				3.9	
Dissolved Solids (Sum)	1,750				472	
Total Dissolved Solids					481	
Hoss per acre-foot	2.56					
Specific Conductance (micromhos at 25° C.)	2,340	2,900	2,940	850		1,250
Hardness as CaCO3					27	
Noncarbonate hardness	1,180				250	
Percent Sodium (Na)	1,020					
Sodium-adsorption-ratio	10					
pH				7.1		7.1
Temperature (°F)				91.5	83.5	72

ANALYSES OF WELL WATER, PORTALES VALLEY AREA

Analyses by U. S. Geological Survey (Parts per million)

Location Number	Portales	Portales	Portales	Portales	Portales	1S.34.35.344
Owner or Name	City of Portales Municipal	City of Portales Municipal	City of Portales Municipal South Tower	City of Portales Municipal Lucust Street	City of Portales Municipal North Tower	City of Portales Municipal
Use						
Well Depth	123	94				120
Water-bearing Formation	Valley fill	Valley fill	Valley fill	Valley fill	Valley fill	Valley fill
Date of Collection	11/26/31	10/24/40	5/8/51	5/8/51	5/8/51	11/1/55
Silica (SiO_2)	42		51	46		53
Iron (Fe)	0.01		0	0		
Calcium (Ca)	86	105	123	84		162
Magnesium (Mg)	20	41	45	23		55
Sodium (Na)	45	71 Calc.	103	56		139
Potassium (K)	3.7		5.6	5.6		
Carbonate (CO_3)	0	0	0	0		0
Bicarbonate (HCO_3)	224	213	209	244		194
Sulfate (SO_4)	125	234	358	157		528
Chloride (Cl)	53	118	117	49		160
Fluoride (F)			1.7	1.8		1.9
Nitrate (NO_3)	6.2		7.6	5.1		7.4
Dissolved Solids (Sum)	491		915	548		1,200
Total Dissolved Solids	512	734	952	557		
Tons per acre-foot			1.24	0.75		1.63
Specific Conductance (micromhos at 25° C.)		1,120	1,330	827	865	1,670
Ignition Loss	36					
Density						
Hardness as $CaCO_3$	297	430	492	304		642
Noncarbonate hardness			320	104		48
Percent Sodium (Na)			31	28		32
Sodium-Adsorption-Ratio						2.3
pH			8.0	8.0		7.2
Temperature (°F)						59

ANALYSES OF WELL WATER, PORTALES VALLEY AREA

Analyses by U. S. Geological Survey (Parts per million)

Location Number	1S.35.9.423	1S.35.28.221	2S.33.4.133	2S.33.10.343	2S.33.18.344	2S.34.6.111
Owner or Name	Clinton Imoe	Carl Blair	Guy Martin	Wren Smith		B. E. Small
Use	Stock	Domestic	Domestic	Domestic	Irrigation	Domestic
Well Depth		60		86		
Water-bearing Formation	Ogallala (?)	Valley fill	Valley fill	Valley fill(?)	Valley fill	Valley fill
Date of Collection	10/31/55	11/1/55	11/1/55	11/1/55	11/1/55	11/1/55
Silica (SiO_2)				42		
Iron (Fe)						
Calcium (Ca)				101		
Magnesium (Mg)				81		
Sodium (Na)				≠) 293)		
Potassium (K)						
Carbonate (CO_3)				0		
Bicarbonate (HCO_3)	293	238	186	220	224	191
Sulfate (SO_4)				344		
Chloride (Cl)	7	60	138	475	230	272
Fluoride (F)				2.0		
Nitrate (NO_3)				10		
Dissolved Solids (Sum)				1,460		
Total Dissolved Solids						
Tons per acre-foot				1.99		
Specific Conductance (micromhos at 25° C.)	526	963	1,470	2,370	1,780	2,090
Ignition Loss						
Density						
Hardness as $CaCO_3$				585		
Noncarbonate hardness				404		
Percent Sodium (Na)				52		
Sodium-Adsorption-Ratio				5.3		
pH	7.4	6.8	7.4	7.4	7.5	7.2
Temperature (°F)	61	59	66	68	60	62

ANALYSES OF WELL WATER, PORTALES VALLEY AREA

Analyses by U. S. Geological Survey (Parts per million)

Location Number	2S.34.13.311	2S.34.15.214	2S.35.3.222	2S.35.5.113	2S.35.6.443a	2S.35.6.443a
Owner or Name	C. C. Merrell	C.T.Raulston	O.M. Rogers	Leo Simmaucher	J.A.Vandevender	J.A.Vandevender
Use		Domestic	Irrigation	Irrigation		
Well Depth		40?	130	118		
Water-bearing Formation	Valley fill	Valley fill	Valley fill	Valley fill	Valley fill	Valley fill
Date of Collection	7/28/52	11/1/55	10/31/55	10/31/55	7/28/52	7/27/53
Silica (SiO_2)	49				45	
Iron (Fe)						
Calcium (Ca)	436				117	
Magnesium (Mg)	401				44	
Sodium (Na)	756				67	
Potassium (K)						
Carbonate (CO_3)	0				0	0
Bicarbonate (HCO_3)	171	164	216	203	222	226
Sulfate (SO_4)	2,530				307	
Chloride (Cl)	1,130	750	17	58	78	103
Fluoride (F)	3.0				1.4	
Nitrate (NO_3)	6.8				4.6	
Dissolved Solids (Sum)	5,400				773	
Total Dissolved Solids. Tons per acre-foot	7.34				1.05	
Specific Conductance (micromhos at 25° C.)	6,880	4,060	698	928	1,190	1,230
Ignition Loss						
Density						
Hardness as $CaCO_3$	2,740				473	
Noncarbonate hardness	2,600				291	
Percent Sodium (Na)	38				24	
Sodium-Adsorption-Ratio						
pH		7.1	7.3	7.3		
Temperature (°F)		59	61	61		

ANALYSES OF WELL WATER, PORTALES VALLEY AREA

Analyses by U. S. Geological Survey (Parts per million)

Location Number	2S.35.6.443a	2S.35.11.313	2S.35.15	2S.35.16.111	2S.35.20.343	2S.35.21.433
Owner or Name	J.A.Vandevender	William Brown	Portales Springs	Bob Stokes	Jake Burkette	Willie McInnis
Use		Domestic,Stock		Irrigation	Domestic	Irrigation
Well Depth		47		128		
Water-bearing Formation	Valley fill	Valley fill	Valley fill	Valley fill	Valley fill	Valley fill
Date of Collection	7/21/54	11/1/55	11/25/31	10/31/55	10/26/55	9/21/55
Silica (SiO_2)		71	78			
Iron (Fe)			0.01			
Calcium (Ca)		139	106			
Magnesium (Mg)		69	75			
Sodium (Na)		109	159			
Potassium (K)			4.6			
Carbonate (CO_3)	0	0	0			
Bicarbonate (HCO_3)	222	246	212	220	299	229
Sulfate (SO_4)	500	510	487			
Chloride (Cl)	140	87	176	137	141	220
Fluoride (F)		1.5				
Nitrate (NO_3)		11	2.0			
Dissolved Solids (Sum)		1,120	1,192			
Total Dissolved Solids			1,245			
Tons per acre-foot		1.52				
Specific Conductance (micromhos at 25° C.)	1,630	1,510		1,750	1,490	1,750
Ignition Loss			87			
Density						
Hardness as $CaCO_3$		630	572			
Noncarbonate hardness		429				
Percent Sodium (Na)		27				
Sodium-Adsorption-Ratio		1.9				
pH		7.0		7.3	7.5	7.1
Temperature (°F)		60.5		61	60	64

ANALYSES OF WELL WATER, PORTALES VALLEY AREA

Analyses by U. S. Geological Survey (Parts per million)

Location Number	2S.35.25.412	2S.36.10.344	2S.36.13.343	2S.36.17.212	2S.36.28.114	2S.36.29.411
Owner or Name	E. T. Ward	Dee Spiney	H. B. Kennedy	Scott Davis	Nellie Trammel Estate	Chester Plummer
Use	Dom.&Irrigation	Stock	Stock	Stock	Stock	
Well Depth	100			40	40	
Water-bearing Formation	Valley fill	Valley fill	Valley fill	Valley fill	Valley fill	Valley fill
Date of Collection	10/26/55	11/1/55	10/26/55	11/1/55	10/31/55	7/30/47
Silica (SiO_2)	45				68	33
Iron (Fe)						
Calcium (Ca)	123				167	574
Magnesium (Mg)	117				100	1,150
Sodium (Na)	234				187	2,700
Potassium (K)						
Carbonate (CO_3)	0				0	0
Bicarbonate (HCO_3)	234	217	275	382	279	378
Sulfate (SO_4)	563				841	7,530
Chloride (Cl)	354	6	8	42	74	2,760
Fluoride (F)	5.9				1.5	
Nitrate (NO_3)	5.2				28	
Dissolved Solids (Sum). Total Dissolved Solids.	1,560	413	581	1,110	1,600	14,900
Tons per acre-foot	2.12				2.18	20.3
Specific Conductance (micromhos at 25° C.).	2,370				2,040	16,400
Ignition Loss						
Density						1.011
Hardness as $CaCO_3$	788				828	
Noncarbonate hardness	596				599	
Percent Sodium (Na)	39				33	
Sodium-Adsorption-Ratio	3.6				2.8	
pH	7.3	7.3	7.4	7.0	7.1	
Temperature (°F)	61	61	61	61	62	

ANALYSES OF WELL WATER, PORTALES VALLEY AREA

Analyses by U. S. Geological Survey (Parts per million)

Location Number	2S.35.25.412	2S.36.19.344	2S.36.13.343	2S.36.17.212	2S.36.26.114	2S.36.29.411
Owner or Name	E. T. Ward	Dee Sprinkle	E. B. Kennedy	Scott Davis	Nellie Tremmel Estate	Chester Plummer
Use	Domestic, irrigation	Stock	Stock	Stock	Stock	
Well Depth	100		60		40	
Water-bearing Formation	Valley fill	Valley fill	Valley fill	Valley fill	Valley fill	Valley fill
Date of Collection	10/29/58	11/1/58	10/28/58	11/1/58	10/31/58	7/30/47
Silica (SiO_2)	45				68	83
Iron (Fe)						
Calcium (Ca)	183				187	371
Magnesium (Mg)	117				136	1,120
Sodium (Na)	234				187	3,700
Potassium (K)						
Carbonate (CO_3)	0				0	0
Bicarbonate (HCO_3)	234	317	278	282	278	278
Sulfate (SO_4)	552				611	7,380
Chloride (Cl)	334	0	0	42	74	2,760
Fluoride (F)	3.0				1.5	
Nitrate (NO_3)	6.2				28	
Dissolved Solids (Sum)	1,500	412	321	1,110	1,600	14,600
Total Dissolved Solids						
Tons per acre-foot	2.12				2.18	20.3
Specific Conductance (micromhos at 25° C.)	2,370				2,640	16,400
Ignition loss						
Density						1.011
Hardness as $CaCO_3$	746				828	
Noncarbonate hardness	326				390	
Percent Sodium (Na)	39				33	
Sodium-Adsorption-Ratio	3.8				2.8	
pH	7.3	7.3	7.4	7.0	7.1	
Temperature (°F)	61	61	61	61	62	

ANALYSES OF WELL WATER, PORTALES VALLEY AREA

Analyses by U. S. Geological Survey (Parts per million)

Location Number	2S.36.33.420	2S.36.35.212a	2S.36.35.212a	2S.36.35.212a	2S.36.35.2213	2S.37.22.334
Owner or Name	W. A. Green	Eunice Harrison	Eunice Harrison	Eunice Harrison	Eunice Harrison	H. T. Ward
Use	Irrigation				Domestic	Stock
Well Depth	93				86	
Water-bearing Formation	Valley fill	Valley fill	Valley fill	Valley fill	Valley fill	Valley fill
Date of Collection	10/26/55	7/26/52	7/28/53	7/22/54	10/26/55	10/25/55
Silica (SiO_2)		56				
Iron (Fe)						
Calcium (Ca)		118				
Magnesium (Mg)		67				
Sodium (Na)		75				
Potassium (K)						
Carbonate (CO_3)		0	0	0		
Bicarbonate (HCO_3)	270	254	247	257	245	312
Sulfate (SO_4)		402				
Chloride (Cl)	1,280	62	48	51	47	51
Fluoride (F)		0.9				
Nitrate (NO_3)		21				
Dissolved Solids (Sum).		927				
Total Dissolved Solids.						
Tons per acre-foot		1.26				
Specific Conductance (micromhos at 25° C.).	8,360	1,300	1,080	1,120	846	867
Ignition Loss						
Density						
Hardness as $CaCO_3$		570				
Noncarbonate hardness		362				
Percent Sodium (Na)		22				
Sodium-Adsorption-Ratio						
pH	7.1				7.6	7.2
Temperature (°F)	61				58	64

ANALYSES OF WELL WATER, PORTALES VALLEY AREA

Analyses by U. S. Geological Survey (Parts per million)

Location Number	2S.37.29.131	2S.37.30.231	3S.30.24.400	3S.30.25.100	3S.30.35.400	3S.31.30.300
Owner or Name	B. R. Tate	H. C. Nickels	M. G. Vinther	M. G. Vinther	M.G.Vinther	M.G.Vinther
Use		Irrigation	Stock	Stock	Stock,Domestic	Stock,Domestic
Well Depth		130	100	30	120	117
Water-bearing Formation	Valley fill	Valley fill	Triassic (?)	Triassic (?)	(?)	(?)
Date of Collection	7/26/52	9/21/55	6/26/50	6/26/50	6/26/50	6/26/50
Silica (SiO_2)	33		23	29	13	9.8
Iron (Fe)						
Calcium (Ca)	67		78	132	39	9.5
Magnesium (Mg)	25		239	216	47	8.1
Sodium (Na)	41		614	661	304	417
Potassium (K)						
Carbonate (CO_3)	0		0	0	9	14
Bicarbonate (HCO_3)	242	241	418	329	317	312
Sulfate (SO_4)	110		1,450	1,660	461	497
Chloride (Cl)	25	38	430	450	131	115
Fluoride (F)	0.6		12	5.7	1.9	1.5
Nitrate (NO_3)	11		28	7.8	10	0.1
Dissolved Solids (Sum). Total Dissolved Solids.	432		3,080	3,320	1,170	1,220
Tons per acre-foot	0.59		4.19	4.52	1.59	1.66
Specific Conductance (micromhos at 25° C.)	665	805	4,260	4,500	1,800	1,900
Ignition Loss						
Density						
Hardness as $CaCO_3$	270		1,180	1,220	291	57
Noncarbonate hardness	72		834	948	16	0
Percent Sodium (Na)	25		53	54	69	94
Sodium-Adsorption-Ratio						
pH		7.0				
Temperature (°F)		63.5	64	64	63	63

ANALYSES OF WELL WATER, PORTALES VALLEY AREA

Analyses by U. S. Geological Survey (Parts per million)

Location Number	3S.31.30.300	3S.35.1.223	3S.35.12.233	3S.35.25.200	3S.36.12.122	3S.36.13.244
Owner or Name	M.G.Vinther			W. O.McCormick		H.C.Nickels
Use	Domestic,Stock	Stock	Stock		Stock	Stock
Well Depth	150			66		450-460
Water-bearing Formation	Triassic (?)	Valley fill(?)	Triassic (?)	Triassic	Triassic (?)	Triassic
Date of Collection	6/26/50	10/26/55	10/26/55	11/25/31	10/26/55	10/26/55
Silica (SiO_2)	28			38		9.2
Iron (Fe)				19.02*		
Calcium (Ca)	338			130		99
Magnesium (Mg)	545			73		36
Sodium (Na)	1,020			297		2,900
Potassium (K)				8.4		
Carbonate (CO_3)	0			0		0
Bicarbonate (HCO_3)	298	380	94	276	220	138
Sulfate (SO_4)	3,350			697		1,860
Chloride (Cl)	1,080	131	1,430	220	660	3,290
Fluoride (F)	6.4					0.5
Nitrate (NO_3)	46			36		1.1
Dissolved Solids (Sum)	6,560			1,635		8,260
Total Dissolved Solids				1,696		
Tons per acre-foot	8.92					11.2
Specific Conductance (micromhos at 25° C.)	8,280	1,450	7,570		4,940	12,700
Ignition Loss				103		
Density						1.003
Hardness as $CaCO_3$	3,080			624		395
Noncarbonate hardness	2,840					282
Percent Sodium (Na)	42					94
Sodium-Adsorption-Ratio						63
pH		7.4	7.9		7.1	6.8
Temperature (°F)	62	61	59.5		61	65

*The high iron content is derived from the piping.

ANALYSES OF WELL WATER, PORTALES VALLEY AREA

Analyses by U. S. Geological Survey (Parts per million)

Location Number	04.31.30.800	04.35.1.223	04.35.12.233	04.35.25.200	04.36.12.102	04.36.12.244
Owner or Name	M.C.Vinther			W. C.McCormick		E.C.Nichols
Use	Domestic,Stock	Stock	Stock		Stock	Stock
Well Depth	150			60		450-460
Water-bearing Formation	Triassic (?)	Valley fill(?)	Triassic (?)	Triassic	Triassic (?)	Triassic
Date of Collection	6/26/50	10/26/55	10/26/55	11/25/31	10/26/55	10/26/55
Silica (SiO_2)	30			38		8.2
Iron (Fe)				18.08*		
Calcium (Ca)	338			130		90
Magnesium (Mg)	145			73		36
Sodium (Na)	1,020			387		2,000
Potassium (K)				8.4		
Carbonate (CO_3)	0			0		0
Bicarbonate (HCO_3)	298	380	94	276	220	132
Sulfate (SO_4)	2,350			887		1,800
Chloride (Cl)	1,080	131	1,130	290	660	2,290
Fluoride (F)	0.4					0.6
Nitrate (NO_3)	46			36		1.1
Dissolved Solids (Sum)	4,600			1,625		4,280
Total Dissolved Solids				1,850		
Tons per Acre-foot	6.32					11.2
Specific Conductance (micromhos at 25° C.)	6,280	1,150	7,370	103	1,340	12,700
Hardness as $CaCO_3$	3,000			686		750
Noncarbonate hardness	2,840					282
Percent Sodium (Na)	42					42
Sodium-Adsorption-Ratio						
pH	7.4	7.8			7.1	7.8
Temperature (°F)	62	61	58.5		61	65

*Iron content in derived from the pipe.

ANALYSES OF WELL WATER, PORTALES VALLEY AREA

Analyses by U. S. Geological Survey (Parts per million)

Location Number	3S.36.13.422	3S.37.9.244	4S.31.23	4S.33.32	4S.33.32	
Owner or Name	H. C. Nickels	Lennard Leglieter	Robert Hollingsworth	M. V. Denton	M. V. Denton	
Use	Stock	Stock				
Well Depth	40-50		118	176	176	
Water-bearing Formation	Valley fill(?)	Valley fill(?)	Triassic	Triassic	Triassic	
Date of Collection	10/26/55	10/26/55	11/10/31	11/10/31	11/29/40	
Silica (SiO_2)			11	10		
Iron (Fe)			4.21	0.12		
Calcium (Ca)			35	19	14	
Magnesium (Mg)			39	11	9	
Sodium (Na)			491	316	302 Calc.	
Potassium (K)			5.9	1.8	)	
Carbonate (CO_3)			0	7.9	0	
Bicarbonate (HCO_3)	323	574	450	285	324	
Sulfate (SO_4)			626	314	281	
Chloride (Cl)	7	145	212	160	121	
Fluoride (F)						
Nitrate (NO_3)			3.2	0.25	0.50	
Dissolved Solids (Sum).			1,645	980	888	
Total Dissolved Solids.			1,672	981	884	
Tons per acre-foot						
Specific Conductance (micromhos at 25° C.).	674	2,290			1,430	
Ignition Loss			52	11		
Density						
Hardness as $CaCO_3$			247	93	72	
Noncarbonate hardness						
Percent Sodium (Na)						
Sodium-Adsorption-Ratio						
pH	7.3	7.5				
Temperature (°F)	61	60	63			

ANALYSES OF WELL WATER, PORTALES VALLEY AREA

Analyses by Cooperative Soils Laboratory, New Mexico College of Agriculture and Mechanic Arts

Location	Date of Collection	ECx10^6*	Milliequivalents per liter[1]							TDS[2] ppm.	Per cent Sodium[3]
			Ca	Mg	Na	Cl	SO_4	CO_3	HCO_3		
2N.35E.36	12/1/48	1,090	4.8	4.4	-	3.4	1.5	0	4.3	763	-
1N.33E.16	9/26/53	550	2.8	1.9	1.0	0.7	0.6	0.1	4.3	380	17.5
1S.33E.14	11/26/48	950	3.6	1.4	1.7	0.4	3.0	0	3.3	665	25.4
1S.35E.2	12/2/48	540	2.7	0.9	1.8	0.8	0.5	0	4.1	378	33.0
2S.34E.3	7/31/51	4,500	13.8	18.2	22.2	12.3	37.5	0.3	4.1	3,544	40.9
- .3	9/7/51	2,100	4.4	6.8	10.0	5.7	11.9	0.1	3.5	1,448	47.2
- .4	6/3/52	2,200	5.4	8.0	10.3	6.2	14.1	0.2	3.2	1,492	43.4
- .5	8/18/49	3,500	11.3	10.2	16.5	14.2	20.9	0	2.9	3,190	43.4
- .10	8/19/54	4,100	15.5	14.4	19.1	19.2	27.0	0	2.8	3,684	38.9
.13	2/27/55	4,500	11.0	18.8	21.2	12.4	35.5	0	3.1	3,432	41.6
.14	1/17/49	4,400	11.4	14.6	17.7	16.9	22.7	0	4.1	3,080	40.5
.14	3/25/49	3,400	12.6	12.6	14.4	17.1	19.4	0	3.1	2,508	36.3
.15	1/14/55	4,400	14.5	13.9	16.7	20.2	22.2	0	2.7	3,208	37.0
.24	5/14/53	4,400	13.3	20.3	29.5	20.1	39.8	0.3	2.9	3,540	46.7
.24	5/16/55	4,250	10.7	16.8	17.5	10.4	31.7	0.2	2.7	2,864	38.9

*Equivalent conductance in micromhos.

[1]Determined by analysis.

[2]Total dissolved solids determined by evaporation.

[3]Obtained by calculation.

ANALYSES OF WELL WATER, PORTALES VALLEY AREA

Analyses by Cooperative Soils Laboratory, New Mexico College of Agriculture and Mechanic Arts

Location	Collection	Date of	Ppm*	Ca	Mg	Milliequivalents per Liter[1] Na	Cl	SO_4	CO_3	HCO$_3$	pH	TDS[2] ppm.	Per cent Sodium[3]
2N.35E.36		12/1/48	1,000	4.8	4.4	-	3.4	1.3	0	4.3		763	-
1N.35E.1e		9/20/33	850	2.8	1.9	10.0	0.7	0.9	0.0	4.8		980	74.4
1S.33E.12		11/e/48	980	8.0	1.4	11.7	0.4	8.0	0	5.3		980	58.1
1S.38W.2		12/2/48	840	2.7	0.9	7.8	0.8	0.4	0	4.1		378	59.0
2S.34E.3		1/e/48	1,500	10.0	7.8	25.8	13.3	24.5	0.8	4.1		3,844	70.3
		8/1/41	1,000	4.0	2.0	10.0	5.7	11.0	0.1	3.6		1,446	72.3
		8/e/48	2,300	6.4	8.0	19.0	9.1	19.7	0.3	3.8		1,102	74.7
		6/2/44	5,500	11.3	10.2	35.5	11.3	30.9	0	5.2		2,190	82.4
		6/1e/48	2,100	15.5	11.4	17.3	18.3	47.0	0	3.8		1,944	38.9
		5/2/48	4,000	11.0	11.8	51.8	22.4	39.4	0	5.3		2,452	70.0
		5/1/48	4,000	14.0	14.0	52.0	23.0	45.0	0	5.2		2,960	70.0
		5/1/48	3,400	11.0	11.4	46.1	19.4	39.4	0	5.1		2,308	73.2
		5/1/48	3,000	10.0	10.0	39.3	16.7	35.4	0	5.2		2,208	72.0
		5/1/48	2,800	9.0	9.0	36.0	15.0	32.0	0	5.2		2,000	72.0
		5/1/48	2,500	8.0	8.0	32.0	13.0	28.0	0	5.2		1,800	72.0
		5/1/48	2,200	7.0	7.0	28.0	11.0	24.0	0	5.2		1,600	72.0
		5/1/48	1,900	6.0	6.0	24.0	9.0	20.0	0	5.2		1,400	72.0
		5/1/48	1,600	5.0	5.0	20.0	7.0	16.0	0	5.2		1,200	72.0
		5/1/48	1,300	4.0	4.0	16.0	5.0	12.0	0	5.2		1,000	72.0
		5/1/48	1,000	3.0	3.0	12.0	3.0	8.0	0	5.2		800	72.0
		5/1/48	700	2.0	2.0	8.0	1.0	4.0	0	5.2		600	72.0
		5/1/48	400	1.0	1.0	4.0	0.5	2.0	0	5.2		400	72.0
		5/1/48	200	0.5	0.5	2.0	0.2	1.0	0	5.2		200	72.0

*Parts per million.

[1] Milliequivalents determined by calculation.

[2] Total dissolved solids determined by evaporation.

[3] Sodium percentage.

ANALYSES OF WELL WATER, PORTALES VALLEY AREA

Analyses by Cooperative Soils Laboratory, New Mexico College of Agriculture and Mechanic Arts

Location	Date of Collection	$EC \times 10^6$ *	Milliequivalents per liter[1]							TDS[2] ppm.	Per cent Sodium[3]
			Ca	Mg	Na	Cl	SO_4	CO_3	HCO_3		
.24	6/3/55	5,200	15.5	20.7	23.2	19.6	37.5	0	2.3	3,868	39.1
2S.35E.10	6/24/53	1,440	5.8	4.7	6.7	3.7	8.8	0.2	4.5	1,156	38.9
.10	6/24/53	3,200	12.1	13.2	16.1	9.8	25.0	0.1	6.5	2,688	38.9
.22	7/20/53	7,500	20.0	40.0	49.4	40.1	65.2	0	4.1	7,180	45.2
2S.35E.28	8/25/53	1,400	4.7	6.7	4.0	4.1	5.9	0.1	5.3	916	25.9
.28	8/28/53	1,200	3.1	5.1	4.8	3.5	5.3	0.3	3.9	796	36.9
.28	8/28/53	920	2.3	4.3	3.4	2.2	3.2	0.4	4.2	568	34.0
.31	9/26/53	1,600	4.5	6.6	6.4	5.7	7.9	0	3.9	1,100	36.6
.31	9/26/53	2,150	5.6	8.0	8.9	8.4	10.7	0	3.4	1,440	49.4
.33	8/28/53	940	2.9	4.3	3.6	2.3	3.8	0.1	4.6	624	33.0
2S.36E.29	4/12/50	4,300	15.9	18.4	15.8	12.9	33.0	0	4.2	3,300	31.5
.35	8/15/49	1,650	6.4	3.9	7.9	2.6	11.1	0	4.5	1,535	43.4
3S.30E.7	7/1/54	7,000	21.4	20.2	39.5	36.4	41.2	0.4	3.1	4,956	48.7
3S.34E.31	5/1/54	5,000	8.1	2.2	35.4	17.2	26.2	0	2.3	3,496	77.5
3S.35E.4	6/13/53	2,050	4.8	8.1	10.7	9.7	10.3	0	3.6	1,520	45.3
4S.32E.14	10/26/54	10,000+	22.5	29.9	69.3	49.3	69.3	0.3	2.8	8,104	56.9
4S.33E.22	2/21/55	7,000	27.5	42.4	25.1	13.0	79.3	0	2.7	6,744	26.4
4S.34E.9	2/5/55	8,200	5.6	3.4	65.4	44.4	27.4	0	2.6	4,796	87.9

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Analyses by Cooperative Soils Laboratory, New Mexico College of Agriculture and Mechanic Arts

Location	Date of Collection	EC x 10^3*	Ca	Mg	Milliequivalents per liter Na	SO_4	CO_3	HCO$_3$	SAR	Parts per million B^3
23 32E.10	6/24/53	5,200	19.52	20.7	23.4	10.9	0.0	2.3	1,888	30.1
24 32E.10	6/24/53	7,000	40.00	40.0	60.0	40.0	0.0	0.0	2,688	38.3
26 32E.10	6/24/53	3,200	12.00	13.3	18.3	8.8	0.0	1.5	1,128	38.3
26 32E.10	6/24/53	7,000	40.00	40.0	60.0	40.0	0.0	0.0	2,688	38.3

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