TECHNICAL REPORT NUMBER 8

STATE OF NEW MEXICO
State Engineer Office
S.E. Reynolds
State Engineer

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RECONNAISSANCE OF GROUND-WATER CONDITIONS IN THE CROW FLATS AREA OTERO COUNTY, NEW MEXICO

Prepared in cooperation with the Geological Survey
U. S. Department of the Interior

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By

L. J. Bjorklund
U. S. Geological Survey

January 1957

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RECONNAISSANCE OF GROUND-WATER CONDITIONS IN THE CROW FLATS AREA, OTERO COUNTY, NEW MEXICO

By

L. J. Bjorklund

SUMMARY

The Crow Flats area is in the southeastern part of Otero County, N. Mex., in the Sacramento section of the Basin and Range physiographic province and within the Salt Basin portion of a large closed topographic basin. The winters generally are short and mild, the summers are hot, and sunny days are prevalent throughout the year. About 3,000 acres of land in New Mexico, mostly near the Texas State line, is irrigated from 17 wells, and several more wells have been constructed to irrigate additional acreage. The development in New Mexico is a northward extension of a large irrigation development in Texas centered around Dell City, which is a few miles south of the State line. The principal agricultural products are cotton, alfalfa, and livestock. The Crow Flats area is sparsely settled.

The valley occupied by Crow Flats is irregular in shape and ranges in width from about 5 miles to about 12 miles. The alkali flats at the bottom of the valley are about 3,614 feet above sea level, and sinkholes are common north of the alkali flats. A long slope, or bajada, lies between the valley floor and the base of mountains bordering the valley. Many isolated bedrock hills stand above the valley floor. The limestone uplands bordering the valley are drained by steep-sided, flat-bottomed canyons. Some smaller closed basins occur within, or adjacent to, the main closed drainage basin.

The exposed rocks consist mostly of limestones of Permian age and the valley fill of Quaternary age. The prominent land features are primarily the result of block faulting. West of the valley, in the southern part of the area, the upland is underlain by the Bone Spring limestone, which probably underlies most of the valley also. In the northern part of the area the Bone Spring limestone probably grades into the Yeso formation and the lower part of the San Andres formation. The Bone Spring limestone is the principal source of water in the Crow Flats area as well as in a large area in Texas in the vicinity of Dell City; it contains many interconnected cavities and solution channels which yield large quantities of water to wells. The valley fill, or alluvium, of Quaternary age has a maximum thickness of more than 1,620 feet but in most places is between 25 and 300 feet thick. This material also is capable of yielding large quantities of water to wells.

The piezometric surface in the southern part of the Crow Flats area is a nearly level surface extending about 15 miles northward from the State line. The principal reason for the remarkable levelness is the high permeability of the water-bearing materials. Water levels in the Bone Spring limestone in a large area fluctuate largely as a unit. Periodic water-level measurements made in the Dell City area, Texas, since 1947 show that groundwater levels have declined about 13 feet since 1948, and a similar decline is believed to have occurred also in parts of the Crow Flats area in New Mexico. The depth to water in the Crow Flats generally is less than 200 feet; in the upland area bordering the valley bottom the depth to water generally is more than 400 feet. A perched water table above the main zone of saturation is evident in the extreme northern part of the area.

Recharge to the ground-water reservoir is from infiltration of precipitation within the basin, and is believed to occur mainly from flash floods in the

beds of ephemeral streams. On the basis of the relation of the fluctuation of water levels in the limestone to the quantity of water pumped for irrigation it is inferred that the annual recharge to the ground-water reservoir is less than 100,000 acre-feet. Natural discharge occurs by evaporation from the alkali flats, which cover about 37,000 acres in New Mexico and Texas. It is estimated that about 100,000 acre-feet of water was discharged from wells in the northern half of the Salt Basin in New Mexico and Texas during 1955. Some of this water returned to the ground-water reservoir by infiltration.

The development of irrigation in the northern half of the Salt Basin in New Mexico and Texas has occurred mostly since 1950. About 228 irrigation wells were in use during April 1956, and approximately 32,000 acres of land were under irrigation as of January 1, 1956. In the specific area within New Mexico 17 wells were in use to irrigate about 3,000 acres. New land was being cleared and new wells were being drilled during the spring of 1956.

The yield of wells in the Bone Spring limestone ranges from 350 gpm to 3,620 gpm, and interference between wells is slight. The yield of wells in the valley fill ranges from 350 to 840 gpm. It is believed that better wells than now exist can be constructed in the valley fill.

The hardness of water sampled in the Crow Flats area ranged from 352 to 2,500 ppm (parts per million) and averaged 1,120 ppm. Both the hardest and the softest water came from the valley fill. The hardness of water in the Bone Spring limestone averaged 885 ppm. Water from the Bone Spring limestone and from the outlying parts of the valley fill is potable, whereas water from the valley fill in the lower parts of the valley generally is impotable. All the ground water pumped from wells in the area is suitable for irrigation or livestock use. The temperature of the ground water ranges from 61° to 72° F, and water in the limestone generally is warmer than water in the valley fill.

Land almost anywhere on the Crow Flats appears to be suitable for irrigation. The best possibilities for irrigation probably are south of T. 23 S., where pumping lifts are not excessive but where the chemical quality of the water may be below average. Water levels in the area can be expected to continue to decline. When ground-water levels in the heavily pumped areas are depressed below the water levels in the alkali flats, a deterioration of quality may occur as water moves from the alkali flats toward the wells. Water from some wells should be analyzed periodically to detect any change in chemical quality.

INTRODUCTION

The Crow Flats are situated in New Mexico and Texas in the northern part of the Salt Basin about 80 miles east of El Paso, Tex. They constitute a semiarid, windswept area surrounded by mountains and until a few years ago supported only a few scattered cattle ranches. Since the first irrigation wells in the Salt Basin area were constructed in 1947 and it became apparent that irrigation of lands was feasible, the area has developed rapidly. Initial development centered around what is now Dell City, Tex., about 4 miles from the New Mexico State line. In 1949 the development spread northward into New Mexico.

PURPOSE AND SCOPE OF THE INVESTIGATION

This report is based on data collected during a reconnaissance made in February and April 1956, to determine the general occurrence, availability, quality, movement, and use of ground water in the Crow Flats area, Otero County, N. Mex. The area studied lies immediately north of the heavily pumped irrigated area around Dell City, Tex. Information on the relation of the occurrence of ground water in the Crow Flats area to the occurrence of ground water in the heavily pumped Dell City area and the extent of the highly permeable aquifers, or water-bearing formations, in New Mexico is needed to aid residents, prospective developers, and others concerned with water supplies in making decisions concerning utilization of the resource. A part of the Crow Flats area is now utilized by the Armed Forces, but in the event this and other Federal land is released for homesteading, an influx of population can be expected and a knowledge of the ground-water resources is desirable.

Study of the Crow Flats area was made in cooperation with the New Mexico State Engineer under the direction of A. N. Sayre, Chief of the Ground Water Branch, Water Resources Division, U. S. Geological Survey, and under the immediate supervision of C. S. Conover, district engineer in charge of ground-water investigations in New Mexico, and W. E. Hale, assistant district engineer.

LOCATION AND EXTENT OF THE AREA

The Crow Flats area, as discussed in this report, includes about 650 square miles in the southeastern part of Otero County, N. Mex., and is included in the Sacramento section of the Basin and Range physio-

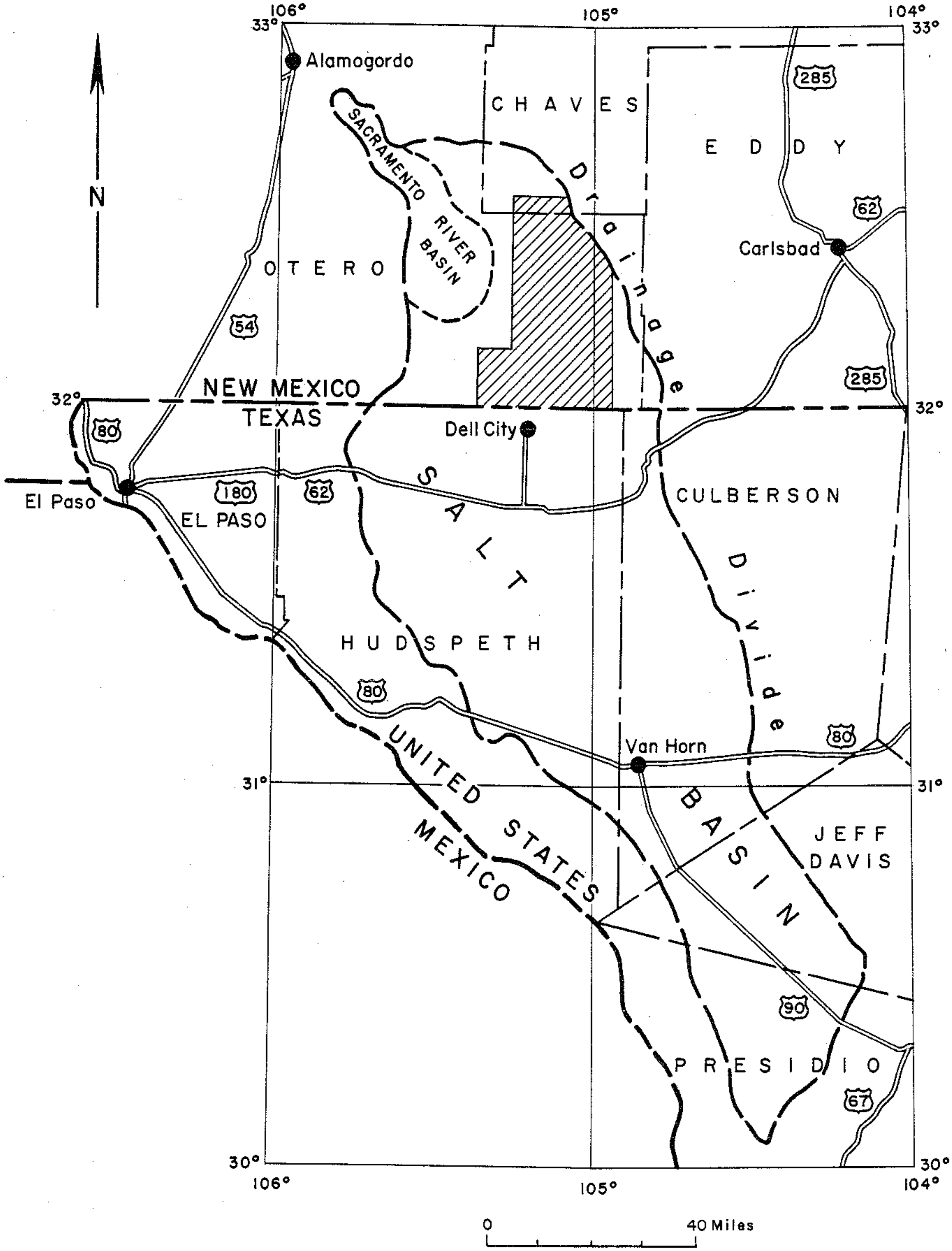


Figure 1.--Location of the Crow Flats area (hachured) in southeastern Otero County, N. Mex.

graphic province (Fenneman, 1946). The area is approximately 20 miles wide from east to west, extends about 36 miles northward from the New Mexico-Texas State line, and is in a closed basin immediately west of the Guadalupe and Brokeoff Mountains. Ready access to the area is mainly from the south, through Dell City, Tex., by turning northward off U.S. Highway 62-180 to Dell City and continuing an additional 4 miles to the State line (Fig. 1 and Pl. 1).

METHODS OF INVESTIGATION AND ACKNOWLEDGMENTS

The writer spent several days in the field in February 1956 making a water-well inventory and establishing observation wells in the Crow Flats area. The inventory was resumed and completed during the first 3 weeks of April 1956. All the irrigation wells and those intended for irrigation in the area were visited, and detailed information concerning them was collected where possible. Stock and domestic wells also were visited, especially in outlying areas. Information was collected on 51 wells, including 23 that are used or intended to be used to supply water for irrigation and 28 that supply water for domestic and stock use. This information is listed in Table 1. Measurements to water level were made with a steel tape. Wells selected for continued observation were measured in February and again in April 1956. Chemical analyses of samples of water from 20 wells are listed in Table 3. The residents, well drillers, pump agents, and others that were interviewed were cooperative and readily contributed information.

The mapping of the geology of the area was limited to differentiating areas underlain directly by limestones of Permian age and areas underlain by valley fill of Quaternary age. As time and funds allotted for fieldwork were limited, contacts of these two units are delineated only approximately on the map (Pl. 1), mostly on the basis of observations made during the well inventory and on the configuration of the land surface as indicated on maps obtained from the Grazing Service, U.S. Department of the Interior. The geologic map of King (1949) was utilized for the southern part of the area.

WELL-NUMBERING SYSTEM

The system of numbering wells in this report is the same as that used in other parts of New Mexico; it is based on the common designations of public-land divisions, and by means of it the well number, in addition to designating the well, locates its position to the nearest 10-acre tract. The number is divided into four segments by periods. The first segment denotes the township north or south of the New Mexico baseline, and the second segment denotes the range east or west of the New Mexico principal meridian. In the area covered by this report the first segment indicates the township south of the baseline and the second segment indicates the range east of the principal meridian. The third segment denotes the section.

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. The first digit of the fourth segment gives the quarter section, which is a tract of 160 acres. Similarly, the quarter section is divided into four 40-acre tracts numbered in the same manner, and the second digit denotes the 40-acre tract. Finally, the 40-acre tract is divided into four 10-acre tracts, and the third digit denotes the 10-acre tract. Thus, well 26.18.24.344 is in the SE¼SE¼SW¼ sec. 24, T. 26 S., R. 18 E. (Fig. 2). If a well cannot be located accurately to a 10-acre tract, a zero is used as the third digit, and if it cannot be located accurately within a 40-acre tract, zeros are used for both the second and third digits. If the well cannot be located more closely than the section, the fourth segment of the well number is omitted. 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, and d are added to the last segment to designate the second, third, fourth, and succeeding wells listed in the same 10-acre tract.

In applying the well-numbering system to the partial sections adjacent to the New Mexico-Texas State line (31, 32, 33, 34, 35, and 36), these are visualized as full sections, part in New Mexico and part in Texas.

GEOGRAPHY

CLIMATE

The climate of the Crow Flats area is typical of the semiarid Southwest. The winters are generally short and mild and the summers hot and dry. Sunny days are prevalent throughout the year and, although most summer days are hot, the nights generally are cool; temperatures during a year usually range from about 10° F to about 106° F. The average annual precipitation is about 9 inches in the valley and about

EXPLANATION

GEOLOGY

QUATERNARY

☐

VALLEY FILL

Alluvium and lacustrine deposits composed of boulders, cobbles, gravel, sand, silt, and clay. Contains some gypsum and salt in places. Yields large quantities of water to a few wells. Water is hard and saline in lowland areas.

PERMIAN

▨

LIMESTONE

Mostly massive gray limestone interbedded with black cherty limestone, shaly limestone, and siliceous shale. Contains many interconnected solution channels filled with potable but hard water. Yields large quantities of water to wells.

WELLS

Wells in valley fill indicated by solid circle, wells in limestone by open circle. Question marks indicate that water-bearing formation is not known. Wells classified only as to use or intended use.

◉ ◎

Irrigation Wells

● ○

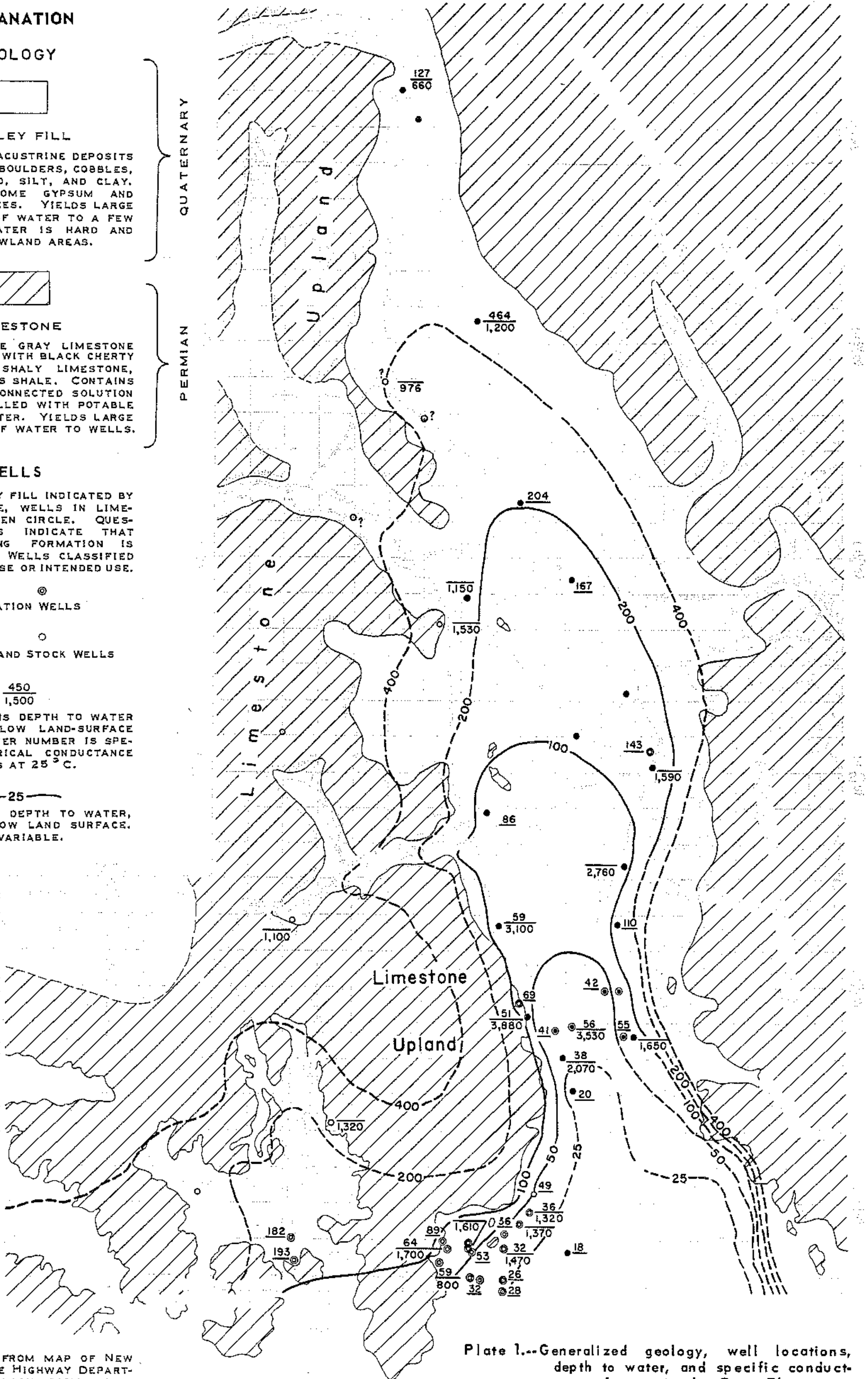
Domestic and Stock Wells

○ $\frac{450}{1,500}$

Upper number is depth to water in feet below land-surface datum. Lower number is specific electrical conductance in micromhos at 25 °C.

——25——

Lines of equal depth to water, in feet below land surface. Interval is variable.



Base modified from map of New Mexico, State Highway Department. Geology from state line northward about 9 miles after King (1949).

Plate 1.--Generalized geology, well locations, depth to water, and specific conductance of water in the Crow Flats area, Otero County, N. Mex.

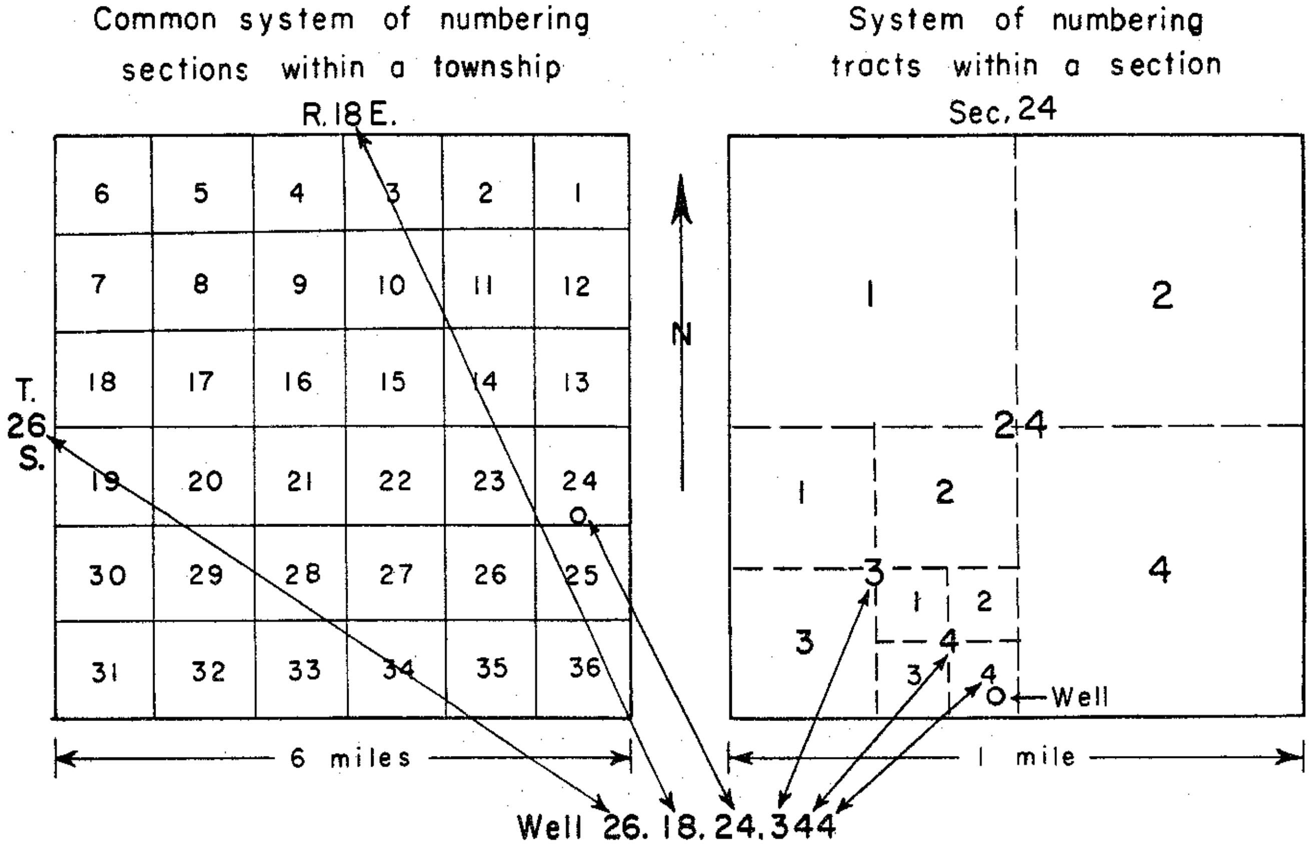


Figure 2.--System of numbering wells in New Mexico

20 inches on the Guadalupe Mountains east of the valley. Most of the rain falls during the months of May through October, when localized thunderstorms and cloudbursts are common, but the summer precipitation is not adequate for growing crops and must be supplemented by irrigation. Dust storms are common in the spring, and evaporation rates are high during the summer.

AGRICULTURE

Farming and ranching are the chief sources of livelihood of the residents of the Crow Flats area. However, farming is impracticable without irrigation, and wells provide the only water for that use. About 3,000 acres of land are irrigated from 17 wells. The lands and the wells used, or intended to be used, for irrigation are shown in Figure 3. Several more wells have been constructed for the purpose of irrigating additional acreage. Most of the irrigated area in New Mexico at the present time is at the south end of the Crow Flats area within 3 miles of the New Mexico-Texas line. The Armed Forces control most of the land north of the principal irrigated area. The principal irrigated crops are cotton and alfalfa, most of the acreage being planted to cotton.

Ranching is devoted chiefly to cattle, although some sheep and horses are grazed. During years of near-normal rainfall the livestock fare well on the natural vegetation of the range, but during periods of drought additional food for stock must be provided. Most of the livestock are watered from wells equipped with windmills, but water is supplied also from stock ponds built to intercept the flow of small ephemeral streams.

POPULATION

The Crow Flats area is sparsely settled, the population numbering about 150, most of whom live in the farming area within 3 miles of the New Mexico-Texas State line. North of the farming area the population generally is limited to scattered ranches, which usually are accessible but which may be isolated during wet weather, either by slippery and boggy roads or by washed-out roads at arroyo crossings. Many of the ranchers reside at Dell City, Tex., and live at their ranches only at intervals.

PHYSIOGRAPHY AND DRAINAGE

The Crow Flats area is part of a large closed basin (Fig. 1) which comprises about 5,900 square miles, of which about 4,000 square miles is in Texas and about 1,900 square miles is in New Mexico. The drainage of the basin is into a series of playas or alkali flats that extend along the valley floor from about 5 miles north to about 50 miles south of the New Mexico-Texas State line.

The central part of the closed basin is known as Salt Basin, and the Crow Flats area is in the northern part of Salt Basin. The southern part may be topographically separate from Salt Basin, as is the Sacramento River drainage basin in the northern part of the closed basin.

The valley occupied by Crow Flats is quite irregular in shape and ranges in width from about 5 miles to about 12 miles. It is bordered on the east by the Guadalupe and Brokeoff Mountains and on the west by a limestone upland. The valley floor north of the alkali flats or playas is relatively flat and uniform over a width of 2 to 5 miles. On each side of this relatively flat strip is a long, gentle slope between the base of the mountain and the middle of the valley. Such a slope, called a bajada, is formed by the coalescing of alluvial fans at the mouths of the many canyons. The *bajada* is steepest near the mountain and becomes progressively flatter toward the center of the valley. Differences in elevation from the toe to the top of the bajada range from about 500 feet to more than 1,000 feet. A bajada occurs on each side of the valley but it is better developed on the east along the bases of the Guadalupe and Brokeoff Mountains.

The playas or alkali flats, also called salt lakes, are approximately level, stand at an elevation of about 3,614 feet above sea level, and, within the Crow Flats area, are about 0.5 miles wide. They generally are bounded by an abrupt elevation rise of about 10 to 20 feet. An explanation of this feature as suggested by Meinzer and Hare (1915, p. 44-45), and later reiterated by King (1948, p. 137), is that the alkali flats probably are swept clear and extended by wind erosion. Apparently the wind has carried away the dry earth above ground-water level but has encountered an effective downward limit of cutting at the surface of the moist earth above the water table. Some dune and hummocky areas occur on the east side of the playas, where the eolian material has accumulated in hills and around clumps of vegetation. The dune material consists of quartz and gypsum sand.

Sinkholes are common in the valley floor, according to information received from various residents. A sinkhole about 50 feet across and 10 feet deep was observed in the SW¼ sec. 35, T. 25 S., R. 18 E. Small

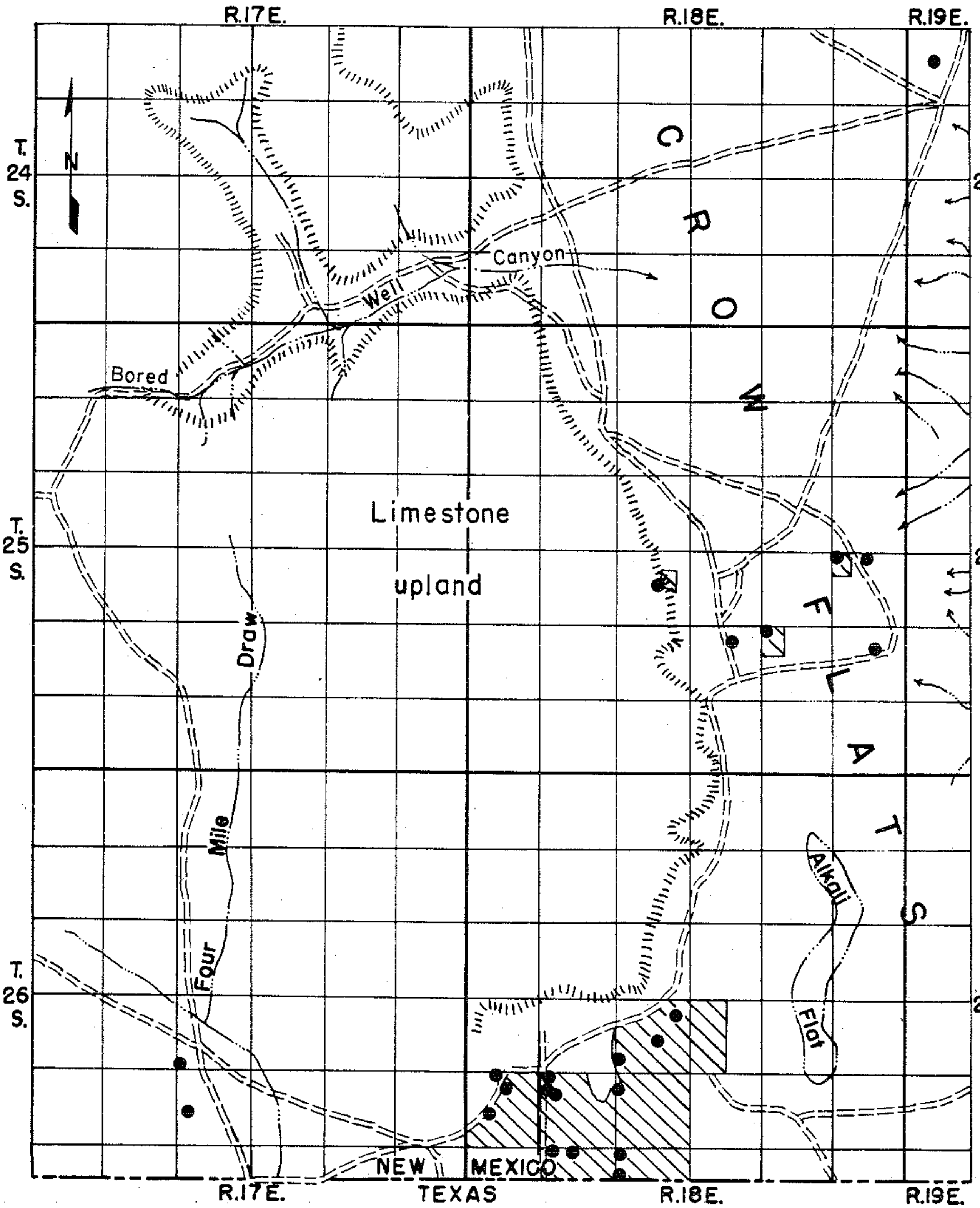


Figure 3.--Irrigated lands (hachured) and wells used or intended for irrigation in the Crow Flats area, Otero County, N. Mex., April 1956

caves around the edge of the hole lead to greater depths. These sinkholes probably are formed by solution of gypsum in the valley fill and possibly may be related to solution of the underlying limestone. Local residents report that large quantities of water drain into the sinkholes when floods from the uplands reach the valley floor.

Many bedrock hills composed of limestone stand above the valley floor like islands in a lake. These range in size from small mounds to hills 2 to 3 miles long and more than 200 feet high. The presence of these isolated hills suggests that the bedrock surface underlying the valley fill, and obscured by it, is irregular and broken by faults.

Canyons that drain the upland areas are steep sided and flat bottomed, their shape suggesting that at one time they were much deeper than they are today and that they have been partly filled, along with the valley, with material eroded from the highlands. These flat-bottomed canyons and their flat-bottomed tributaries range in length from about a mile to more than 20 miles, and each canyon bottom contains a broad creekbed strewn with cobbles and boulders, indicating the occurrence of many floods. The topography along these drainage courses is mature, although runoff is rapid. The various rock washes do not reach the bottom of the bajada but become obscure as the gradient flattens and floods spread out and lose velocity. The coarse material is dropped on the bajada and only silt, clay, and dissolved minerals are carried to the alkali flats.

Some of the principal drainage courses that enter the valley are Pinon Creek from the north; Little Dog Canyon, Big Dog Canyon, and West Dog Canyon from the east; and Cornucopia Draw and Bored Well Canyon from the west. All streams are ephemeral and flow only for brief periods after heavy precipitation. The Sacramento River flows toward Salt Basin, but it terminates in another subbasin north and west of the Crow Flats area.

Beyond the valley, and away from the steep-sided canyons, the limestone upland is a plain of low relief with slopes and drainage generally following the dip of the strata. Thus, Four Mile Draw and Cornudas Draw, sloping southward and southeastward respectively, are shallow erosional valleys that follow the dip of the limestone beds. Beyond the Guadalupe fault escarpment, east of the valley, the drainage follows the dip slope of rocks of Permian age eastward toward the Pecos River.

Smaller closed basins occur within, or adjacent to, the main closed basin in which Crow Flats is situated. The Brownfield flats in Tps. 24 and 25S., R. 16 E., are in a small, local drainage basin. Parts of the Brownfield flats resemble a playa, and water is reported to accumulate in the vicinity of well 25.16.-10.244 after rainy weather. The Sacramento River, when it flows, drains into another subbasin farther north and slightly west and outside of the area considered in this report. A more detailed and extensive study of the area probably would reveal the existence of additional subbasins in, or marginal to, the main closed basin.

GENERAL GEOLOGY

Rocks exposed in the report area consist mostly of limestone of Permian age and the valley fill of Quaternary age. A few miles outside the project area, to the south and the west, volcanic rocks of Precambrian age and igneous intrusive rocks of Tertiary age are exposed. Scalapino (1950, p. 5) reported that a sill was encountered in drilling several wells about 3 miles east of Dell City, Tex., and 4 to 5 miles south of the New Mexico-Texas State line. Only the Bone Spring limestone of Permian age and valley fill of Quaternary age are discussed in detail in this report.

The prominent land features of the area are primarily the result of block faulting. King (1948, p. 124-125) points out that the faults probably are tensional features because the fault planes dip toward the downthrown blocks and because there is no crumpling or folding near the faults, such as would be expected if the faulting had resulted from compressional stress.

ROCKS OF PERMIAN AGE

The valley in which Crow Flats is situated is underlain and bounded on both sides by rocks of Permian age. West of the valley in the southern part of the area the upland is underlain by the Bone Spring limestone of the Leonard series, and this formation probably underlies most of the valley in the southern part also. Rocks composing the upland were mapped as the Bone Spring by King (1949) as far north as latitude 32°07½', about 9 miles north of the State line, and it is believed that the same formation is exposed in the uplands extending farther north. However, the Bone Spring limestone probably grades into the Yeso formation and the lower part of the San Andres formation in the northern part of the area. Detailed study would be required to determine more precisely the correlation of these units and the area in which the transition from one unit to another occurs.

The exposed rocks east of the valley, in the Brokeoff Mountains, King mapped as consisting mainly of the Goat Seep limestone, which is the limestone facies of the middle part of the Guadalupe series. North of the Brokeoff Mountains, on the east side of the valley, the area is bounded by the Guadalupe Mountains, which rise abruptly about 2,000 feet above the valley. Rocks exposed in this escarpment north of the Brokeoff Mountains probably are limited to shelf- or back-reef deposits and consist mainly of San Andres formation and the underlying Yeso formation, which is probably the shelf equivalent of the Bone Spring limestone.

BONE SPRING LIMESTONE

The Bone Spring limestone is described by King (1948, p. 13) as the oldest formation exposed in the Guadalupe Mountains, as being several thousand feet thick, and as consisting almost entirely of limestone. The formation contains members of black cherty limestone, massive gray limestone, shaly limestone, and siliceous shale. Chert nodules are common in the formation, and they can be found on the land surface where they are residual from erosion of the parent rock. The formation underlies most of the area considered in this report, and it contains the principal supply of water used in the area. Other formations of Permian age may be important as aquifers in the northern part of the Crow Flats area, but details concerning their lithology and hydrologic properties are lacking.

Many interconnected cavities and solution channels have been formed in the Bone Spring limestone by the dissolving action of ground water. When these openings are encountered in a well they yield large quantities of water. The openings may exist as large cavities or caverns or as a zone of numerous small cavities which is called by local drillers and well owners "honeycomb limestone". The yield of water is large in either case. These solutional openings, according to reports from drillers, are not restricted to any particular depth but are found at depths ranging from less than 100 feet to more than 1,000 feet below the land surface. Two wells near each other may derive water from solution channels at different depths, and a third well drilled nearby may not encounter any solution channels and may be of no value as an irrigation well. Although solution channels are found at different depths they are interconnected.

The area underlain by the permeable, productive part of the Bone Spring limestone is large and probably includes most of the Crow Flats area. Within the Crow Flats area, 18 wells that derive water from solution channels in the formation are used, or are intended to be used, to supply water for irrigation. The northernmost of these wells, 24.19.18.144, is approximately 16 miles north of the State line. South of the Crow Flats area, in Texas, about 200 irrigation wells derive water from the limestone. A few of these wells are east of the alkali flats and south of Highway 62-180, about 17 miles south of the State line. An irrigation well recently drilled in Texas, just south of sec. 33, T.26 S., R.16 E., suggests that the aquifer extends into New Mexico in this longitude. Thus it is evident that the aquifer in the Bone Spring formation includes an area extending at least 33 miles in a north-south direction and 15 miles in an east-west direction.

VALLEY FILL OF QUATERNARY AGE

The area underlain predominantly by valley fill is shown on Plate 1. The valley fill is composed mostly of alluvium and lacustrine deposits. The deposition of alluvium, consisting of boulders, cobbles, gravel, sand, silt, and clay eroded from the highlands and carried to the lowlands by streams, has been going on since the valley was first formed by faulting. According to King (1948, p. 147), the faulting occurred in late Pliocene or early Pleistocene time. The coarser alluvium is deposited near the valley edge and the finer materials are carried toward the center of the valley. As the basin does not have a drainage outlet at its lowest point, a lake existed during relatively wet periods. Fine materials washed into the lake formed beds of silt and clay, and evaporation of lake water during dry periods resulted in deposits of soluble salts such as gypsum and halite. The ancient lake bottom, which has been altered somewhat by wind erosion, forms the present alkali flats.

The alluvium is composed mostly of fragments and derivatives of the limestones that are most abundant in the area. Fragments of chert derived from chert nodules and cherty layers in parts of the Bone Spring limestone are common. Fragments of intrusive igneous rocks, found in the gravel in the western part of the area, probably were eroded from the Cornudas Mountains which lie to the west. In the Crow Flats, deposits of gypsum are present and sinkholes in these deposits are common along the lower reach of Pinon Creek. In places the land surface is composed largely of gypsite, a flourlike soil derived from gypsum.

Alluvium 1,620 feet thick was reported to have been penetrated by wells outside the project area, about 30 miles southeast of Dell City, Tex., (Scalapino, 1950, p. 5), and a thickness of more than 500 feet was found in well 25.18.25.230. Alluvium more than 500 feet thick was found also in a well about 0.5 mile south of the New Mexico-Texas line and east of the alkali flats. The thickness of the alluvium penetrated in the drilling of most irrigation wells, however, ranges from about 25 to 300 feet.

Much of the alluvium was deposited during floods by overloaded streams. The streams changed their courses frequently as a consequence of such floods, leaving lenses of gravel or sand which were later covered by deposits laid down by other floods. Such bodies of material, when penetrated below the water table in a well, are capable of yielding large quantities of water. Five wells drilled into the alluvium in the project area are used, or are intended to be used, to supply water for irrigation. In the neighboring Dell City area about 30 wells are reported to derive water for irrigation from the alluvium.

GROUND WATER

Ground water in the Crow Flats area occurs mainly in two geologic units, the Bone Spring limestone of Permian age and the valley fill of Quaternary age.

Ground water in the Bone Spring limestone occurs in joint cracks and other crevices in the rock, particularly in those which have been opened by ground-water solution of the limestone. These solutionally-formed openings may occur as large cavities or caverns, or as numerous small openings which give parts of the limestone a honeycomb or spongelike structure.

In the valley fill, an unconsolidated deposit, the ground water occurs in voids or interstices between the particles of gravel, sand, silt, or clay. Solutional activity of ground water probably has increased the void space in some limestone gravels by dissolving some of the fine, calcareous material and thus has increased the capacity of the valley fill to contain and transmit ground water. Also, some cavities have been formed by the solution of gypsum in the gypsiferous silts that occur in parts of the valley. In both the Bone Spring limestone and the valley fill the ground water occurs in a zone of saturation, in which all voids or openings are filled with water. The quantity of water in storage depends on the number and size of the openings in the zone of saturation and extent of the aquifer.

THE WATER TABLE AND PIEZOMETRIC SURFACE

The upper surface of the zone of saturation, where not formed by an impermeable barrier, is called the water table. If the upper surface is formed by an impermeable barrier the water will be under pressure, the head of which will form an imaginary surface called the piezometric surface. The water table may be considered one type of piezometric surface, as it too reflects the head of the ground water. The water in the valley fill in the Crow Flats area is believed to occur under water-table conditions, whereas the water in the Bone Spring limestone is believed to occur under both water-table and artesian conditions. In this report the term "piezometric surface" will be used wherever there is a possibility that both unconfined and artesian conditions exist.

The piezometric surface usually is not a flat, stationary surface but a warped surface that slopes in the direction of ground-water movement and rises as water is added to and declines as water is taken from the ground-water reservoir. The slope depends upon the amount of ground water moving through an aquifer and the permeability of the water-bearing materials. Other things being equal, the more permeable the material the gentler will be the ground-water gradient.

In the southern part of the Crow Flats area the piezometric surface is a remarkably flat and almost level surface. Although instrumental levels were not run to the wells to determine the actual elevation of the water table at various points, several considerations indicate that it is nearly flat: 1) Depths to water in flat areas are almost uniform; 2) Depths to water appear to increase in the same proportion as the altitude of the land surface increases; 3) The piezometric surface of the Bone Spring limestone, in the neighboring Dell City area, was determined by spirit leveling and water-level measurements in 1949 to be nearly level and at an altitude of about 3,625 feet above sea level (Scalapino, 1950, p. 6).

The distance northward that the almost level piezometric surface extends cannot be determined accurately without spirit leveling to wells where the depth to water has been measured. It appears, however, to extend northward about 15 miles from the State line. Northward from this place the gradient becomes progressively steeper. However, the altitude of the land surface increases at a greater rate and hence the depth to water increases, in general, to the north.

The principal reason for the remarkable levelness of the piezometric surface in the southern part of the area is the unusually high permeability of the water-bearing materials, especially the Bone Spring limestone with its many solution channels. Water can move through these channels with relative ease to equalize the hydrostatic head over a large area, causing the water in wells to stand at nearly the same level regardless of the depth at which solution channels are encountered. It is evident, therefore, that the many solution channels are interconnected and belong to a common hydraulic system.

Local drillers report the depths to water in wells in the limestone or alluvium in a particular area to be about the same. Data tabulated by Scalapino (1950, p. 11-33) indicate that in 1947-49, in the Dell City area, water levels in the alluvium were about 1 to 5 feet lower than water levels in the underlying limestone. This condition indicates that water in the limestone was discharging to the alluvium. The limestone aquifer has been heavily pumped since that time and the above relation may not apply today. The two aquifers probably are interconnected and if left undisturbed for a long period of time would have a common water level, at least in some areas. The fact that the water levels are nearly the same, especially in areas where the piezometric surface is essentially level, indicates that water levels in the alluvium must be influenced to a large extent by the head of the water in the limestone.

FLUCTUATIONS OF THE PIEZOMETRIC SURFACE

Water levels in the Crow Flats area rise or decline as water is added to or taken away from the ground-water reservoir. Measurements of depth to water made in 8 wells in the vicinity of the irrigated part of the area, on February 13-14 and again on April 11-12, 1956, show a decline of water level, due to pumping for irrigation, ranging from 3.8 feet to 6.4 feet and averaging 5.3 feet. The decline in 6 of the wells within the irrigated and heavily pumped area ranged from 4.6 to 6.4 feet and averaged 5.6 feet. Two wells, 26.17.21.333 and 26.17.28.312, outside the heavily pumped area at distances of about 1.5 miles and 1 mile from the nearest irrigation well showed declines of 3.8 feet and 4.8 feet during the 57-day period. These were almost as much as declines in the wells within the heavily pumped area. This is further indicated in Figure 4 which shows water-level fluctuations in wells 26.17.21.333 and 26.18.28.113, both of which penetrate the Bone Spring limestone. Well 26.17.21.333, outside the heavily pumped area, though drilled for irrigation use was not pumped. Well 26.18.28.113, on the other hand, is one of the more intensively pumped and highest yielding wells in the heavily pumped area. The similarity of the pattern of fluctuation of water level in these 2 wells and the fact that the piezometric surface forms an essentially level surface indicate that water levels in the Bone Spring limestone fluctuate largely as a unit and they further indicate that water levels in the formation may be affected miles from a heavily pumped area.

Changes in water level discussed in the preceding paragraph and illustrated in Figure 4 are primarily seasonal and do not necessarily indicate general trends. When a well or group of wells are pumped the water levels in the area are depressed in order to provide a hydraulic gradient and cause ground water to move toward the well or pumped area. When pumping ceases at the end of the season, the in-moving water fills or partly fills the aquifer in the area of greatest decline. Thus, the most dependable water-level data with which to determine trends are measurements made in midwinter when the piezometric surface is least affected by pumping or residual drawdown from previous pumping. Several years of data generally are needed before safe conclusions can be made as to general trends in water level.

A 2-foot decline of water level in the Bone Spring limestone during the period April 1955-April 1956 is indicated by measurements in well 26.18.30.321. Although water-level data were not collected at other wells during 1955, the measurements made at this well are believed to represent the trend in water levels in the aquifer of the Bone Spring limestone in the Crow Flats area (see Table 2).

Periodic water-level measurements have been made since 1947 in the Dell City area south of Crow Flats. Because of the high permeability of the Bone Spring limestone, and the probable far-reaching effects of pumping from that formation, the fluctuations of water level in the Dell City area should be typical of fluctuations in at least the southern part of the Crow Flats area. These data and related information are contained in two reports, one by Scalapino (1950, p. 10) and one by Follett (1954, p. 20). The data show that fluctuations of water levels in wells tapping the Bone Spring limestone have been quite uniform and that water-level data collected at any high-

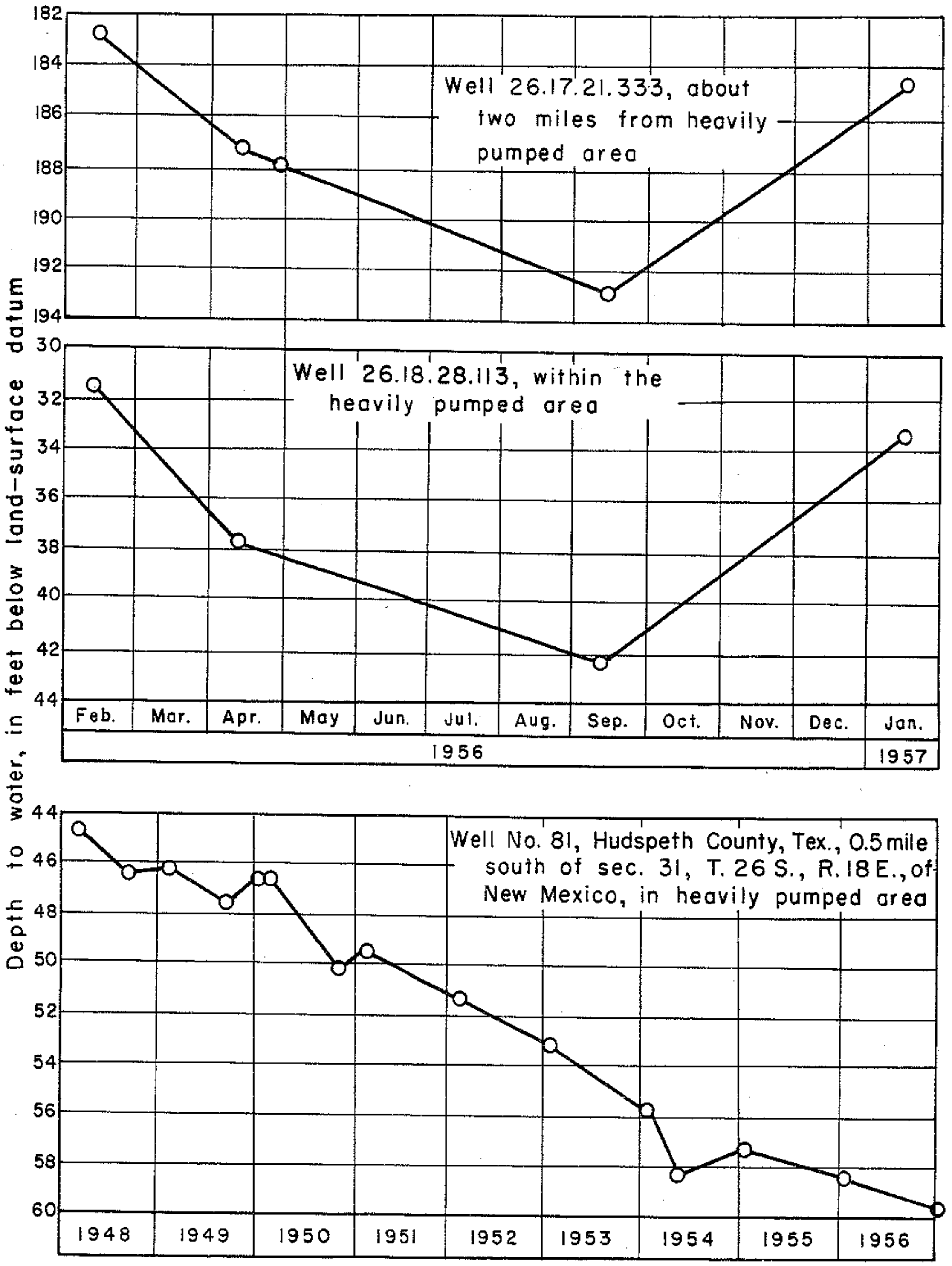


Figure 4.--Hydrographs of wells in the Salt Basin, New Mexico and Texas

yielding well should be representative of a fairly large area. It is believed, therefore, that the well listed as well 81 in the Dell City area, Hudspeth County, Tex., in Scalapino's and Follett's reports should give a good indication of changes in water levels that have occurred in the southern part of the Crow Flats area. Well 81 is 0.5 mile south of the New Mexico-Texas State line, directly south of sec. 31, T. 26 S., R. 18E. The well, according to Scalapino(1950, p. 20-21), is 154 feet deep, derives water from the Bone Spring limestone, and has a drawdown of 28 feet after being pumped for several days at a steady rate of 2,900 gallons a minute.

A hydrograph of well 81, shown in Figure 4, suggests that a steady decline of the piezometric surface has occurred also in the southern part of the Crow Flats area since 1948. The piezometric surface of the Bone Spring limestone in the vicinity of this well declined almost 13 feet during the 7-year period 1948-55. As the acreage irrigated in the general vicinity is increasing, especially in the Dell City area, the consequent increase in withdrawal of water may increase the rate of decline of water levels.

Many residents report that there has been no decline in water levels because their wells are just as productive as they ever were. Evidently aquifer yields to many wells are so great and drawdowns are so small that a few extra feet of pumping lift goes unnoticed.

One effect of the declining piezometric surface cannot be overlooked. Crow Spring, situated 0.5 mile south of the New Mexico-Texas State line along the west side of sec. 36, T. 26 S., R. 18 E. extended, has been used for many years as a watering place for livestock but it is now dry and a well is dug at the site. The static water level stands 8 feet below the land surface at the well. Scalapino (1950, p. 20-21) indicates a reported steady flow of 3 gpm from the spring at the time of his investigation.

DEPTH TO WATER

The approximate depth to water in the Crow Flats area is shown on Plate 1 by means of lines representing equal depths to water. In general, increases in depth to water coincide with rises in altitude of the land surface. In the valley occupied by Crow Flats the depth to water, in most places, is less than 200 feet. In the upland area bordering the valley bottom the depth to water is generally more than 400 feet.

PERCHED WATER

In most of the area studied only one saturated zone and water table are apparent. However, evidence exists of a perched, saturated zone above the main water table in the extreme northern part of the area at well 21.17.12.343, where the measured depth to water was 127.4 feet below land surface. The expected depth to water in this part of the area, on the basis of the depth to water in wells to the south and west, would be between 500 and 1,000 feet. The well derives water from the alluvium, presumably near the bottom of the deposit where it overlies bedrock. The bedrock may be relatively impermeable in this particular part of the area. As the well is near the rock-strewn, permeable bed of Pinon Creek, the source of water undoubtedly is flash floods. The depth to water in a valley about 5 miles west of Pinon Creek was reported to be about 800 feet.

RECHARGE TO THE GROUND-WATER RESERVOIR

Recharge or replenishment of the ground-water reservoir in the Crow Flats area is by infiltration of water derived from precipitation within the closed basin. This infiltration is believed to occur mainly in beds of ephemeral streams during flash floods. The runoff from the highlands, where precipitation is greatest, is rapid and results in many floods which flow down the flat-bottomed canyons, spread out over the bajadas and, in the heavier floods, reach the valley floor. In the course of the flood much water is lost by infiltration into the permeable canyon floor, more water is lost into the bajada, and water that reaches the valley floor drains into the various sinkholes. Part of the water absorbed by the alluvium is later evaporated or discharged by plant transpiration, but some moves downward to become part of the ground water. Local residents state that many floods in the various arroyos are dissipated before reaching the alkali flats in the lowermost part of the drainage basin. Important streams within the Crow Flats area that contribute water to the ground-water reservoir are Pinon Creek, Cornucopia Draw, Big Dog Canyon, Little Dog Canyon, West Dog Canyon, and Bored Well Canyon.

The Sacramento River drains the northwestern part of the closed basin but ends in a subbasin northwest of the project area. Infiltration from this stream may be a major source of recharge to the Bone Spring limestone. To determine if such recharge occurs would require fieldwork and study beyond the scope of this reconnaissance.

DISCHARGE OF GROUND WATER

The natural movement of ground water is from the area of recharge toward the area of discharge. In the Crow Flats area ground water is discharged naturally mainly by evaporation from the alkali flats. The surface of the flats is kept wet or damp by upward percolation of ground water in places where the water table, or the capillary fringe above it, reaches the land surface. In the process of evaporation the mineral matter in solution is retained at the land surface to accumulate and commonly to form crusts of salts. However, part of the ground water under the playas is not near enough to the surface to be concentrated by evapotranspiration but nevertheless becomes saline by means of circulation of water downward from the playas after heavy rains.

The alkali flats include an area of about 37,000 acres in New Mexico and Texas (Scalapino, 1940, p.7). The quantity of water evaporated from the alkali flats during a year is not known but it is believed to be much less than the 80 inches expected from a free water surface in the area. Furthermore, the quantity of water lost from the flats probably is being reduced each year because less and less water is discharged into the alluvium from the underlying Bone Spring limestone. The hydrostatic head of water in the limestone was at an altitude of about 3,625 feet in 1949 (Scalapino, 1950, p.6) and it had declined to an altitude of about 3,613 feet by January 1956. (Follett, 1954; R.W.Sundstrom, U.S.Geol. Survey, Austin, Tex., personal communication, 1956.) Inasmuch as the altitude of the alkali flats is about 3,614 feet and the water table is nearly at the surface, the discharge of water from the limestone into the alluvium must have virtually ceased. However, some water probably will continue to move through the alluvium toward the flats as the alluvium continues to receive recharge from irrigation return water and local precipitation. When the water table below the alkali flats is lowered by pumping for irrigation sufficiently to retard or stop evaporation, water will be salvaged for beneficial use. As the alkali flats become dry, however, they will become susceptible to increased wind erosion. It remains to be seen if the wind removes the dry silt as fast as the water table and capillary fringe are lowered.

The natural discharge from the alkali flats before the development of irrigation wells was approximately equal to the recharge to the aquifer of the Bone Spring limestone, and this amount was probably less than 100,000 acre-feet annually. This inference is based on the following considerations: 1) Most of the lateral movement of ground water in the area is through the highly permeable and widely extensive limestone aquifer. Most of the water discharged by evaporation from the alkali flats first moved in through the limestone under hydraulic pressure and then was forced upward through the alluvium to the land surface. 2) By 1955 water levels in the limestone aquifer had declined over a large area to a level a little below the surface of the alkali flats and perhaps below the level of water in the alluvium. This condition would cause the movement of water from the limestone into the alluvium to cease or even reverse. At this stage the water levels in the limestone aquifer would remain constant only when discharge by pumping is equal to the recharge. 3) During 1955 about 100,000 acre-feet of ground water was pumped from the aquifer and water levels in the limestone continued to decline. This fact suggests an excess of discharge over recharge. On this basis, recharge to the aquifer is inferred to be less than 100,000 acre-feet per year.

A few gallons a minute of ground water formerly was discharged at Crow Spring, about 0.5 mile south of the State line (see Plate 1). Flow from this spring stopped during recent years, when pumping for irrigation lowered the water table below the level of the spring orifice.

UTILIZATION OF GROUND WATER

Ground Water in the Crow Flats area is utilized for irrigation, stock, and domestic needs. Wells are drilled by the percussion (cable-tool) method, and water is pumped by electric, butane, or wind power. The location and type of wells are shown on Plate 1, and information about the wells is contained in Table 1.

DEVELOPMENT OF GROUND-WATER RESOURCES

The first irrigation wells drilled in the Crow Flats area were constructed in 1949 after development of the first irrigation wells around Dell City, Tex., in 1947 and 1948. Prior to 1947 ground water in the general area was utilized only for domestic and stock supply and the water was pumped largely by windmill. Some stock wells now in use were constructed as early as 1905. Dates of construction of most of the wells, and other well information, are shown in Table 1.

Of the 23 wells drilled to supply water for irrigation in the Crow Flats area, 17 were in use in April 1956 to irrigate about 3,000 acres. Cotton and alfalfa are the only crops irrigated and most of the farmland is used for cotton. The unused wells intended for irrigation were awaiting the clearing and preparation of land and installation of pumps. Location of irrigation wells and irrigated lands is shown in Figure 3.

Development of wells that derive water from the Bone Spring limestone in the northern half of the Salt Basin in New Mexico and Texas has occurred mostly since 1950. Scalapino (1950, p. 1) reported that 32 wells were irrigating 6,000 acres in the Dell City area in 1949, at which time the first irrigation wells were being constructed in the Crow Flats area in New Mexico. A. F. Stone, a pump dealer and well engineer of Dell City, has attempted to keep an account of all irrigation wells drilled in the area. He states that approximately 228 irrigation wells were in use during April 1956 in the general area and that there was approximately 32,000 acres of irrigated land as of January 1, 1956. During the course of fieldwork for this report, in February and April 1956, the clearing of considerable land and the drilling of several new wells for irrigation were observed in both Texas and New Mexico.

Pumps used in irrigation wells in the Crow Flats and Dell City areas are driven mostly by electric motors or by butane engines. Electric power is supplied by the Rio Grande Electric Cooperative, Inc., of Braketville, Tex. Transformers near the wells deliver energy to the 3-phase motors at 440 volts.

YIELD OF WELLS

The output of wells deriving water from the Bone Spring limestone and used for irrigation in the Crow Flats area ranges from about 350 gpm, reported for well 25.18.21.233, to 3,620 gpm, measured at well 26.18.28.113. As the drawdown at the latter well at the time it was measured was only 10 feet, the specific capacity was 362 gpm for each foot of drawdown, and the potential well capacity probably is much more than 3,620 gpm. Several wells have yields of more than 2,000 gpm. (See Table 1.)

Interference of wells in the Bone Spring limestone is evident, but the magnitude of interference generally is small because of the high permeability of the limestone. In the Dell City area, wells in a cluster are pumped simultaneously and only a small drawdown results. In the Crow Flats area wells 26.18.-29.113 and 26.18.29.113a are only 40 feet apart and, while both were being pumped, they were measured at 2,180 and 2,610 gpm, respectively. The owner could not notice any difference in output of either well whether it was being pumped alone or with the other. Evidently the drawdown, reported as 4 feet, is so small that interference effects cannot be detected in the discharge.

Irrigation wells deriving water from the valley fill in the Crow Flats area have yields ranging from a reported 350 gpm in well 25.18.24.122 to a measured 840 gpm in well 25.18.26.111. In the latter well the measured drawdown was 40 feet, and the specific capacity was thus 21 gpm for each foot of drawdown. Irrigation wells constructed in unconsolidated material, such as the valley fill in the Crow Flats area, need to be cased to prevent caving during pumping. One well, only partially cased, collapsed while being test pumped at a rate of 597 gpm. As more is learned about the nature of the valley fill, wells probably will be better constructed by use of adequate casing and properly slotted screens.

QUALITY OF GROUND WATER

Water samples were collected from 20 wells during April 1956, and the results of chemical analyses made in the Geological Survey laboratories at Albuquerque, N. Mex., are shown in Table 3. Well 26.18.-30.213 had been sampled in April 1955 and was resampled to detect any change in the chemical quality of the water. Of the sampled wells, 9 derive water from the Bone Spring limestone. Eleven wells are believed to derive water from the valley fill, although some of the deeper wells, such as well 22.17.26.221, may derive some water from the Bone Spring limestone also.

All water sampled from the Crow Flats area is hard, the hardness ranging from 352 to 2,500 and averaging 1,120 parts per million. The valley fill water hardness ranges from 352 to 2,500 and averages 1,320 parts per million, whereas that of water from the Bone Spring limestone ranges from 665 to 1,060 and averages 886 parts per million. It is obvious, therefore, that not only the softest but also the hardest water in the area is from the valley fill. On the other hand, water from the Bone Spring limestone is consistently hard despite the smaller range in hardness.

The softest and least mineralized water was collected from well 21.17.12.343, which is near the permeable streambed of Pinon Creek in the northernmost part of the area. The well taps a saturated zone in the alluvium, which may be perched. The zone may be replenished by infiltration of water from the streambed during flash floods. In spite of a rather high nitrate content, the water from this well is potable.

The hardest and most highly mineralized ground water utilized in the Crow Flats area was collected from wells finished in the valley fill in the lower parts of the valley in T. 25 S., R. 18 E. This area, which is just north of the alkali flats, is quite flat and the valley fill contains much silt and gypsum. Ground water in the alluvium beneath the alkali flats is highly mineralized inasmuch as an incrustation occurs on the flats. Water from floods in the valley enters the fill through sinkholes and solution channels caused by solution of gypsum, and the water becomes mineralized through contact with gypsum and other minerals in the fill. This is the only part of the Crow Flats area where ground water obtained locally is not generally used for human consumption, although it is used for irrigation and for livestock. A short distance east of the valley bottom, on the lower slopes of the bajada, ground water is somewhat less mineralized, probably because of movement of water from recharge areas in the bajada and canyons to the east. This is illustrated by the analysis of water from well 25.18.25.240 as compared to the analyses of water from wells 25.18.21.441, 25.18.26.111, and 25.18.27.443.

Water from the Bone Spring limestone, although consistently hard, is potable and is used by most of the residents of the area for domestic and livestock use and for irrigation of cotton and alfalfa. The mineral content of the water in the limestone seems to increase slightly southward.

Bicarbonate was high in all samples collected and its presence is probably due to the solution of limestone, which is the dominant rock in the area. Precipitation dissolves carbon dioxide from the atmosphere and from the soil. As the carbon dioxide-laden water percolates to the ground-water reservoir or through the aquifer it dissolves the carbonate rocks.

Sulfate resulting chiefly from the solution of gypsum is one of the principal dissolved constituents in water in this area. The highest sulfate concentration is in water derived from the valley fill in the lower parts of the valley, where gypsum is intimately associated with the alluvium of the fill. The lowest concentration of sulfate is in areas where wells were constructed in the alluvium near a recharge source such as a rocky streambed.

The chloride content of the water is relatively high in places. In general, the concentration of chloride increases toward the alkali flats and becomes greatest in the valley fill beneath the alkali flats.

Some relatively high concentrations of nitrate were found in the waters sampled. A concentration of 233 parts per million was found in the sample from well 24.18.36.410. The source of the nitrate is not known, as the well stands alone in that part of the area. It may be contributed by seepage from a stock-watering tank near the well. Some similar isolated concentrations of nitrate were reported also in the neighboring Dell City area (Scalapino, 1950, p. 38).

Boron in small quantity is required by all plants for normal growth, but it is injurious in concentrations only slightly above the optimum. Six analyses of ground water from the Crow Flats area showed boron concentrations ranging from 0.05 to 0.64 and averaging 0.35 part per million. According to Wilcox (1948, p. 4-7), water with this concentration is classed as excellent for cotton and alfalfa, which are listed as semitolerant and tolerant, respectively, to boron.

Most of the samples were slightly alkaline according to the pH scale, having pH values of 7.1 to 7.3. Two samples were in the slightly acid pH range, having a pH of 6.9, and several had a pH of 7.0. Water having a pH above 7.0 has a tendency to be encrusting, whereas water having a pH below 7.0 has a tendency to be corrosive. In the range described, however, neither tendency is marked.

A comparison of the analyses of samples collected from well 26.18.30.213, in April 1955 and 1956, indicates essentially no change in concentration of constituents during the year. Data collected at one well, however, are not sufficient to indicate what is happening in the area. Many of the well waters should be resampled periodically and the analyses compared with those in Table 3 to determine general changes in the ground-water quality. Changes in quality will more likely occur near the central part of the valley and will be related to the intensity of pumping and the amount of water pumped in the general area.

The measured temperature of ground water in the Crow Flats area ranges from 61° to 72°F, that of water in the Bone Spring limestone from 68° to 72°F, and that of water in the alluvium from 61° to 69°F. The lowest water temperature, 61°F, was measured at irrigation well 25.18.26.111. This low temperature suggests that recharge occurs nearby from floodwater, which generally is quite cold, and that the floodwater enters the ground-water reservoir through fairly open channels in the valley fill.

The highest ground-water temperature, 72°F, was measured at wells 26.18.21.411 and 26.18.28.113, which were two of the most productive wells in the area. Solution channels in the limestone near these wells may conduct the water upward from a deeper source than is tapped by most wells in the Bone Spring limestone. There is also a suggestion that the warmer water may have absorbed heat generated by faulting in the area. The three wells that yield water having a temperature of more than 70°F are immediately east and on the downthrown side of an inferred north-south-trending fault (Scalapino, 1950, Pl. 1).

FUTURE DEVELOPMENT OF THE CROW FLATS AREA

With the exception of the bajadas, which are rock strewn and have slopes that generally are too steep for normal irrigation, and land near the alkali flats, which is hummocky and composed of dune material, land almost anywhere on the Crow Flats valley floor is sufficiently level for irrigation. In many places sufficient water for irrigation can be developed in the underlying alluvium or Bone Spring limestone. However, the best possibilities for economical development of large amounts of water appear to be south of T. 23 S., where the depths to water are not excessive.

Irrigable lands are present and ground water may be available in sufficient quantity for irrigation in Four Mile Draw and Cornudas Draw, but pumping lifts are considerable. In a recently constructed well in Cornudas Draw, in Texas close to the New Mexico State line, the depth to water was 268 feet, and the pumping lift probably will be between 275 and 300 feet. In two unused irrigation wells near Four Mile Draw the depths to water are 182 and 193 feet (see Pl. 1).

CONCLUSIONS

Ground water, generally in sufficient quantity and of acceptable quality for irrigation, is available in both the Bone Spring limestone and the valley fill in the Crow Flats area. The Bone Spring limestone contains a greater quantity of available water, and water of more uniform quality, than that in the valley fill. Recharge or replenishment of water to both these geologic units is from infiltration of water derived from precipitation within the drainage basin containing the Crow Flats area. Wells yielding sufficient water for irrigation can be constructed in either the limestone or the alluvium, although considerable drilling at various sites generally is necessary in order to locate solution channels in the limestone or permeable gravel in the valley fill.

Data collected in the Crow Flats area in New Mexico and in the Dell City area in Texas indicate that the reservoir in the Bone Spring limestone is large; no attempt has been made, however, to estimate the quantity of ground water in storage. Irrigation wells in the area have not yet been seriously affected by decline of the water table. Use of water is increasing, however, and the water table may be expected to continue to decline, perhaps at a fairly uniform rate, as it has during the past several years. Some ground water is being lost by evaporation from the alkali flats, but as the water table in the area is lowered and the hydraulic gradient toward the alkali flats is reduced, more and more water will be diverted from natural discharge for beneficial use. As the hydraulic head in the limestone aquifer in 1956 was equal or below the altitude of the water table in the alluvium at the alkali flats, the movement of ground water from the limestone to the alluvium has virtually ceased. On the basis of the amount of pumping needed to stop movement of water from the limestone into the alluvium, it is inferred that annual recharge to the ground-water reservoir in the general area is less than 100,000 acre-feet.

When the water levels in the heavily pumped area are lowered below the levels at the alkali flats, the hydraulic gradient will be reversed and highly mineralized water may move from the alkali flats toward the wells, causing an eventual deterioration of the quality of the ground water. If and when such a condition should occur, the heavily pumped Dell City area should be affected before the Crow Flats area.

The quality of water in individual wells may change as land is developed because of the return flow of water used for irrigation and also because of movement of ground water from the alluvium to the limestone, or vice versa, in the vicinity of the wells. Periodic water-level measurements and water analyses should be made for selected wells in order to determine trends of water level and chemical quality.

The scope of this reconnaissance did not include long-period observations to determine trends of water level or quality. Data collected since 1947 in the Dell City area are representative of conditions in the southern part of the Crow Flats area in New Mexico. It is suggested, therefore, that those interested in the Crow Flats area should study also the reports on the Dell City area that have been prepared by the U. S. Geological Survey and published by the Texas Board of Water Engineers.

REFERENCES CITED

Fenneman, N. M., 1946, *Physical divisions of the United States:* U. S. Geol. Survey map.

Follett, C. R., 1954, *Records of water-level measurements in Culberson, Hudspeth, and Jeff Davis Counties, Tex.:* Texas Board Water Engineers Bull. 5415.

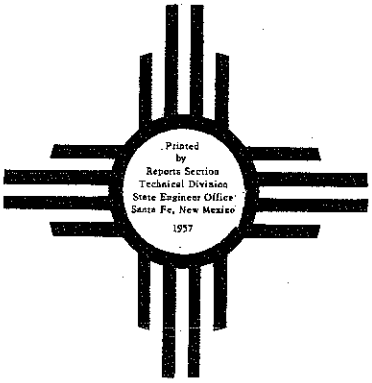
King, P. B., 1948, *Geology of the southern Guadalupe Mountains, Tex.:* U. S. Geol. Survey Prof. Paper 215.

———— 1949, *Regional geologic map of parts of Culberson and Hudspeth Counties, Tex.:* U. S. Geol. Survey Oil and Gas Inv. Prelim. Map 90.

Meinzer, O. E., and Hare R. F., 1915, *Geology and water resources of Tularosa Basin, N. Mex.:* U. S. Geol. Survey Water-Supply Paper 343.

Scalapino, R. A., 1950, *Development of ground water for irrigation in the Dell City area, Hudspeth County, Tex.:* Texas Board Water Engineers Bull. 5004.

Wilcox, L. V., 1948, *Explanation and interpretation of analyses of irrigation water:* U. S. Dept. Agriculture Circ. 784.



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TABLES

TABLE 1. Records of wells in the Crow Flats area, Otero County, N. Mex.

EXPLANATION

Location number designates well and its location. See page 4.
All wells listed are drilled wells unless otherwise noted under "Remarks."
The principal water-bearing beds are the sands and gravels of the valley fill of Quaternary age and the limestone of Permian age.
Measured depth to water in wells given to nearest 0.1 foot; reported depth given to nearest foot or tens of feet.

Type of pump and power: C, cylinder pump; T, turbine pump; E, electric motor, G, gasoline or butane motor; W, windmill; N, none.

Yield and drawdown: M, measured; R, reported.

Use of water: D, domestic; I, irrigation; N, none; S, stock.

Location Number	Owner or Name	Driller	Year Compl.	Topographic Situation	WELL		Water-Bearing Material	WATER LEVEL		Type of Pump and Power	YIELD		Draw-down *(ft.)*	Use of Water	MEASURING POINT		Remarks
					Depth *(ft.)*	Diam. *(in.)*		Below Land Surface *(ft.)*	Date of Measurement		Rate *(gpm)*	Date of Measurement			Description	Distance Above LSD *(ft.)*	
21.17.12.343	Sam Tanner	Copeland	—	Valley, near wash	190	6	Sand and gravel	127.4	Apr 26,1956	C, W	—	—	—	S	Top of casing	3.0	Temp. 65° F. Analysis in Table 3. Water may be perched.
13.400	do.	R. Harris	1946	Valley	210	6	do.	206	—	C, G	—	—	—	D, S	—	—	Water may be perched; 800 feet to water reported about 5 miles west.
22.17.26.221	R. B. Tatman	Lewis	—	do.	610	8	—	400	—	C, W	—	—	—	D, S	—	—	Analysis in Table 3.
36.222	do.	—	—	do.	465	8	—	380	—	C, W	—	—	—	S	—	—	— — —
22.18.17.140	Doyle Pate	—	—	Base of alluvial fan	510	8	Sand and gravel	464.3	Apr 26, 1956	C, W	—	—	—	S	Top of casing	1.2	Temperature 68° F. Analysis in Table 3.
23.17.10.440	R. B. Tatman	—	—	Valley, near wash	785	8	—	520	—	C, W	—	—	—	S	—	—	— — —
23.18. 9.233	Doyle Pate	—	—	Valley floor	210	8	Sand and gravel	203.8	Apr 25, 1956	C, W	—	—	—	S	Top of casing	3.0	Water reported as hard.
23.311	do.	—	—	do.	230	8	do	167.2	do.	C, W	—	—	—	S	do.	3.0	Do.
29.110	Eldo Lewis	Gage	1906	do.	296	8	Sand and gravel (?)	260	—	C, W	22	—	—	D, S	—	—	Temperature 69° F. Analysis in Table 3.
30.340	U.S. Air Force	U.S. Air Force	—	Ridge	300	8	Limestone	260	—	C, W	12R	—	—	D	—	—	Analysis in Table 3. Drawdown negligible.
24.17. 8.440	Howell Lewis	Ross	1947	Canyon	745	6	do.	620	—	C, W	8R	—	—	S	—	—	Water reported as good.
24.18. 1.432	Richard Lewis	M. Lewis	—	Valley	200	6	Sand and gravel	170	—	C, W	—	—	—	S	—	—	Temperature 65° F.
11.334	Eldo Lewis	—	1905	Valley floor	130	8	do.	118	—	C, W	—	—	—	S	—	—	Water reported as good.
29.210	Mrs. J. Gardner	—	1910	do.	190	6	do.	85.7	Apr 30,1955	C, W	—	—	—	D, S	Top of casing	1.0	Water rept'd. good; another stock well near, east.
24.18.36.410	Richard Lewis	—	—	Valley floor	90	8	Sand and Gravel	70	—	C, W	—	—	—	S	—	—	Temperature 64° F. Analysis in Table 3.
24.19.18.144	do.	E. J. Floynoy	1956	Valley	480	16	Limestone	143.0	Apr 18,1956	N	3,500R	January 1956	3R	I	Hole in east side of casing.	.5	Limestone 163 to 480 ft.; water first encountered at 150 ft. Most water 430-480. Water reported as of very good quality.
18.344	do.	—	1910	Valley floor	138	6	Sand and gravel	117	—	C, W	12R	—	—	D, S	—	—	Temperature 65° F. Analysis in Table 3.
25.16.10.244	Bryce Dugger	—	—	Flat, elevated basin	—	8	—	400+	—	C, W	—	—	—	S	—	—	Water reported as good.
25.17. 9.110	Howell Lewis	H. Harris	1946	Canyon	450	6	Limestone	435	—	C, W	12R	—	—	S	—	—	Temperature 69° F. Analysis in Table 3.
25.18 8.242	do.	—	1906	Valley, near side	70	6	Sand and gravel	58.6	Apr 17,1956	C, W	—	—	—	S	Top of casing	0	Temperature 65° F. Analysis in Table 3.
12.124	Ray Lewis	—	—	Alluvial fan	116	6	do.	110.2	Apr 20,1956	N	—	—	—	N	do.	1.0	Stock well, pump & windmill, about 50 ft. west.
21.233	Gene Lewis	Ross	1953	Valley, near side	—	6	Limestone (?)	68.8	do.	T, G	350R	—	—	I	do.	.5	Irrigates about 10 acres.
21.441	do.	do.	—	do.	—	8	Sand and gravel (?)	51.2	Apr 17,1956	C, W	—	—	—	D, S	do.	2.0	Temperature 65° F. Analysis in Table 3.
24.111	C. C. Chavez	—	1952	Valley floor	140	16	Sand and gravel	42.4	Apr 16,1956	T, G	400R	—	—	I	do.	1.0	Irrigates 20 acres; well bottomed in clay.
24.122	do.	G. Stevenson	1952	do.	140	16	do.	60	—	T, G	350R	—	—	I	—	—	Irrigates 10 acres; not used in 1956.
25.230	J. D. Lewis	E. J. Floynoy	1955	do	500	16	do.	55.4	Apr 16,1956	N	597R	—	55R	N	Top of casing	1.0	Good test for irrigation well, but well caved at 250 feet during test.
25.240	do.	—	1930	do.	80	6	do.	60	—	C, W	—	—	—	D, S	—	—	Analysis in Table 3.

TABLE 1. Records of wells in the Crow Flats area, Otero County, N. Mex. - *Continued*

Location Number	Owner or Name	Driller	Year Compl.	Topographic Situation	WELL		Water-Bearing Material	WATER LEVEL		Type of Pump and Power	YIELD		Draw-down *(ft.)*	Use of Water	MEASURING POINT		Remarks
					Depth *(ft.)*	Diam. *(in.)*		Below Land Surface *(ft.)*	Date of Measurement		Rate *(gpm)*	Date of Measurement			Description	Distance Above LSD *(ft.)*	
26.111	Ed Prather	Jordon	1952	Valley floor	140	16	Sand and gravel	56.5	Apr 13,1956	T, G	840M	Apr 16, 1956	40M	I	Top of casing	2.0	Temperature 61° F. Analysis in Table 3. Irrigates 50 acres; well bottomed in silt.
25.18.27.213	Dempson Lewis	—	1955	do.	165	16	do.	41.3	Apr 20,1956	N	—	—	—	I	Top of oil drum over well	3.0	Not in use Apr 20, 1956.
27.443	do.	Tinney	1906	do.	80	—	do.	38.5	Apr 12,1956	C, W	—	—	—	S	Top of pipe clamp	.5	Temperature 68° F. Analysis in Table 3. Water reported to be impotable.
35.330	do.	—	—	do.	30	60	do.	19.9	Apr 13,1956	C, W	—	—	—	S	Top of well cover	1.0	Dug well; sink hole 100 ft. east of well. Water reported to be gypseous and impotable.
26.16.13.320	—	—	—	Gently rolling	—	—	Limestone (?)	200?	—	C, W	—	—	—	S	—	—	Temperature 65° F. Water reported of very good quality.
26.17. 3.300	Mrs. K. Brownfield	—	1953	Rolling	315	8	Limestone	275	—	C, W	—	—	—	S	—	—	Temperature 68° F. Analysis in Table 3.
21.333	Bryce Dugger	—	1955	do.	1,100	18	do.	182.5	Feb 14,1956	N	475R	—	—	I	Top of casing	1.0	Depth to water Apr 11, 1956, 187.3 ft.; " " " Apr 27, 1956, 188.0 ft.
28.312	do.	—	1955	do.	875	18	do.	193.1	do.	N	475R	—	—	I	Top of well cover	.5	Depth to water Apr 11, 1956, 196.9 ft; " " " Apr 27, 1956, 197.6 ft.
26.18.16.424	D. F. Lewis	E. Prather	1951	Valley, near side	100	8	do.	49.0	Apr 12,1956	C, W	—	—	—	D, S	Top of wood pipe clamp	1.0	Temperature 68° F.
21.223	John Gailey	E. J. Floynoy	1955	Valley floor	105	16	do.	36.2	Feb 15,1956	T, G	2,860M	Apr 11, 1956	—	I	End of discharge pipe	7.8	Temperature 71° F. Analysis in Table 3. Reported 3-ft. drawdown at 1,900 gpm & capacity 6,000 gpm. Irrigates 500 acres.
21.331	Frank Gentry	Grank Gentry	—	do.	544	18	do.	35.5	Feb 14,1956	N	1,200R	—	78R	I	Top of casing	2.5	Depth to water Apr 12, 1956, 41.9 ft.
21.411	J. W. Hill	Hill	—	do.	426	18	do.	27	—	T, G	2,860M	Apr 11, 1956	—	I	—	—	Temperature 72° F. Analysis in Table 3. Well with another well, irrigates 750 acres.
27.242	Denman Lewis	—	—	do.	—	42	Sand and gravel	18.0	Apr 17,1956	C, G	—	—	—	S	—	—	Dug well. Depth to water, Apr 30, 1955, 17.2 ft.
28.113	Frank Gentry	Frank Gentry	1954	do.	394	18	Limestone	31.5	Feb 13,1956	T, E	3,620M	Apr 12, 1956	10M	I	Top of casing	2.0	Temperature 72° F. Analysis in Table 3. Depth to water Apr 12, 1956, 37.6 ft.
29.111	do.	Hassell	1949	do.	600	18	do.	54	—	T, G	—	—	—	I	—	—	Owner intends to convert well to domestic use.
26.18.29.113	Frank Gentry	Frank Gentry	1950	Valley	333	18	Limestone	52.8	Feb 13,1956	T, E	2,180M	Apr 11, 1956	4R	I	Land surface	—	Temperature 68° F. Analysis in Table 3. One of 4 wells used to irrigate 1,080 acres.
29.113a	do.	do.	1951	do.	298	18	do.	52.8	do.	T, E	2,610M	do.	4R	I	End of discharge pipe	6.5	About 60 ft. southeast of well 26.18.29.113. Both wells pumped Apr 11, 1956.
30.122	Ernest Shelton	do.	1955	Hillside	386	18	do.	89.1	Feb 14, 1956	T, G	2,000R	—	8R	I	Top of air-line flange	1.5	Irrigates 60 acres.
30.213	Gordon Parks	Ross	1950	Rolling	250	18	do.	63.5	Feb 13,1956	T, G	1,720M	Apr 11, 1956	—	I	Hole in pump base	1.0	Temperature 68° F. Analysis in Table 3.
30.321	Lendol Barker	Frank Gentry	1955	Eastward slope	445	18	do.	59.1	do.	T, G	—	—	—	I	Hole in north side of casing	0	Temperature 68° F. Analysis in Table 3. Depth to water Apr 30, 1955, 62.8 ft.; " " " Apr 11, 1956, 64.8 ft.
32.111	Mrs. K. Brownfield	J. W. Hill	1954	Valley floor	400	18	do.	32.3	Feb 15,1956	N	600R	—	100R	I	Land surface	0	Well kept for emergency use, has been replaced for general use. Water level Apr 11, 1956, 36.9 ft.
32.122	do.	do.	1955	do.	300	16	do.	31.8	do.	T, G	3,000R	—	45R	I	Top of casing	1.4	Irrigates 280 acres. Water level Apr 11, 1956, 37.8 ft.
33.111	J. W. Hill	do.	1949	do.	425	16	do.	26.1	do.	N	400R	—	50R	I	Land surface	0	Depth to water Apr 11, 1956, 26.3 ft. Well probably clogged.
33.133	do.	do.	1951	do.	435	14	do.	27.5	do.	T, G	1,200R	—	90R	I	Top of concrete pump base	3.0	Depth to water Apr 11, 1956, 32.6 ft.

TABLE 2. Water levels in the Crow Flats area, Otero County, N. Mex. in April 1955, February, April, and September 1956, and January 1957, in feet

Location number	Name	Water levels										
		April 1955		Feb. 1956		April 1956		Sept. 1956		Jan. 1957		Change*
		Level	Day	Level	Day	Level	Day	Level	Day	Level	Day	
22.18.17.140	Doyle Pate	–	–	–	–	464.30	26	–	–	–	–	–
23.18. 9.233	do.	–	–	–	–	203.85	25	199.18	12	209.60†	15	–
23.18.23.311	do.	–	–	–	–	167.15	25	162.49	12	166.26	15	–
24.19.18.144	Richard Lewis	–	–	–	–	142.98	18	†	12	144.60	15	–
25.18. 8.242	Howell Lewis	–	–	–	–	58.60	17	61.24	12	61.24	15	–
25.18.21.233	Gene Lewis	–	–	–	–	68.80	20	69.77	12	–	–	–
25.18.24.111	C. C. Chavez	–	–	–	–	42.45	16	42.59	12	42.75	15	–
25.18.25.230	J. D. Lewis	–	–	–	–	55.37	16	55.66	12	55.79	15	–
25.18.26.111	Ed Prather	–	–	–	–	56.48	13	†	12	50.49	15	–
26.17.21.333	Bryce Dugger	–	–	182.52	14	187.28	11	192.74	12	184.47	15	-1.95
26.17.28.312	do.	–	–	193.12	14	196.90	11	202.07	12	195.15	15	-2.03
26.18.21.331	Frank Gentry	–	–	35.50	14	41.89	12	45.40	12	33.64	15	–
26.18.27.242	Denman Lewis	17.15	30	–	–	18.03	17	18.60	12	19.03	15	–
26.18.28.113	Frank Gentry	–	–	31.50	13	37.60	12	42.12	12	33.33	15	-1.83
26.18.30.122	Ernest Shelton	–	–	89.08	14	–	–	99.58	12	90.84	15	-1.76
26.18.30.321	Lendol Barker	62.84	30	59.12	13	64.79	11	†	12	60.20	15	-1.68
26.18.32.122	Mrs. K. Brownfield	–	–	31.85	15	37.85	11	41.57	12	33.56	15	-1.71
26.18.33.133	J. W. Hill	–	–	27.50	15	32.60	11	33.49	12	28.50‡	15	–

*Change of water level in Bone Spring limestone, Feb. 1956 to Jan. 1957.

†Pumping.

‡Measurement uncertain.

Table 3. Chemical analyses of water from wells in the Crow Flats area, Otero County, N. Mex.

(Analyses by U.S. Geological Survey. Chemical constituents, unless otherwise indicated, are in parts per million. Figures for dissolved solids are the sums of the determined constituents.)

Location Number	Owner or Name	Date of Collection April 1956	Stratigraphic Unit	Temp °F	CHEMICAL CONSTITUENTS										DISSOLVED SOLIDS		HARDNESS AS $CaCO_3$		Percent Sodium	Sodium Adsorption Ratio *(SAR)*	Specific Conductance *Micromhos at 25° C*	*p*H
					Calcium Ca	Magnesium Mg	Sodium and Potassium $Na+K$	Bicarbonate HCO_3	Sulfate SO_4	Chloride Cl	Fluoride F	Nitrate NO_3	Boron B		Parts per million	Tons per Acre-foot	Calcium, Magnesium	Non-carbonate				
21.17.12.343	Sam Tanner	26	Alluvium	65	80	37	5.8	288	72	4	–	59	0.64		400	0.54	352	116	3	0.1	660	7.2
22.17.26.221	R. B. Tatman	25	Alluvium (?)	–	–	–	.7	336	277	2	0.4	1.8	–		–	–	568	292	0	0	976	7.3
22.18.17.140	Doyle Pate	26	Alluvium	68	–	–	7.8	220	496	14	–	13	–		–	–	710	530	2	.1	1,200	7.2
23.18.29.110	Eldo Lewis	18	do.	69	–	–	3.4	226	435	17	.7	29	–		–	–	680	495	1	.1	1,150	7.4
23.18.30.340	U.S. Air Force	18	Bone Spring limestone	–	220	95	6.2	222	698	19	1.1	18	.29		1,170	1.59	940	758	1	.1	1,530	7.2
24.18.36.410	Richard Lewis	20	Alluvium	64	–	–	27	156	1,300	92	–	233	–		–	–	1,740	1,610	3	.3	2,760	7.0
24.19.18.344	do.	18	do.	65	–	–	–	186	727	26	–	–	–		–	–	980	828	–	–	1,590	7.2
25.17. 9.110	Howell Lewis	18	Bone Spring limestone	69	–	–	–	318	367	9.0	–	–	–		–	–	665	404	–	–	1,100	7.1
25.18. 8.242	do.	17	Alluvium	65	–	–	–	284	1,820	65	–	–	–		–	–	2,200	1,970	–	–	3,100	6.9
25.18.21.441	Gene Lewis	17	do.	65	–	–	–	254	2,020	275	–	–	–		–	–	2,500	2,290	–	–	3,880	6.9
25.18.25.240	J. D. Lewis	13	do	–	–	–	–	158	719	70	–	–	–		–	–	940	810	–	–	1,650	7.2
25.18.26.111	Ed Prather	16	do.	61	556	264	65	202	2,230	82	3.2	2.4	.48		3,300	4.49	2,470	2,310	5	.6	3,530	7.1
25.18.27.443	Dempson Lewis	12	Alluvium	68	244	177	22	270	1,070	32	1.0	2.7	.43		1,680	2.28	1,340	1,120	3	.3	2,070	7.2
26.17. 3.300	Mrs. K. Brownfield	11	Bone Spring limestone	68	–	–	–	291	533	14	–	–	–		–	–	820	582	–	–	1,320	7.0
26.18.21.223	John Gailey	11	do.	71	198	77	4.4	272	547	15	1.1	4.1	.24		981	1.33	810	588	1	.1	1,320	7.0
26.18.21.411	J. W. Hill	11	do.	72	–	–	–	268	563	25	–	–	–		–	–	850	630	–	–	1,370	7.1
26.18.28.113	Frank Gentry	12	do.	72	–	–	–	265	590	47	–	–	–		–	–	890	673	–	–	1,470	7.0
26.18.29.113	do	11	do.	68	230	92	17	242	672	57	1.1	11	.05		1,200	1.63	952	754	4	.2	1,610	7.1
26.18.30.213	Gordon Parks	11	do.	68	–	–	–	207	751	60	–	–	–		–	–	990	820	–	–	1,700	7.0
do.	do.	30*	do.	68	–	–	–	214	749	56	–	–	–		–	–	1,010	834	–	–	1,700	7.1
26.18.30.321	Lendol Parker	11	do.	68	–	–	–	213	–	76	–	–	–		–	–	1,060	886	–	–	1,800	7.1

* 1955