Geology and Availability of Ground Water in the Northern Part of the White Sands Missile Range and Vicinity New Mexico

By JAMES E. WEIR, JR.

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GEOLOGY AND AVAILABILITY OF GROUND WATER IN THE NORTHERN PART OF THE WHITE SANDS MISSILE RANGE AND VICINITY, NEW MEXICO

By JAMES E. WEIR, JR.

ABSTRACT

The report describes the geology and ground-water resources of the northern part of the White Sands Missile Range and vicinity in south-central New Mexico.

Rocks ranging in age from Precambrian to Quaternary crop out in fault-block mountains and in the adjacent desert basins; only two geologic periods—Silurian and Jurassic—are not represented in the rock sequence.

Unconsolidated rocks of Tertiary and Quaternary age contain vast quantities of water and locally yield moderate to large amounts of water to wells and springs. In a few localities, rocks of Permian and Cretaceous ages yield small to moderate amounts of water from joints and fractures, which have locally been enlarged by solution. Transmissibilities, determined from two pumping tests of wells tapping the least permeable part of the Tertiary rocks, range from 170 to 2,800 gpd per ft (gallons per day per foot). Pumping tests of wells tapping the Bursum Formation of Permian age indicated transmissibilities ranging from 9 to 75,000 gpd per ft. A pumping test of a well in the Yeso Formation, also of Permian age, showed a transmissibility of about 45,000 gpd per ft and a storage coefficient of 2.36×10^{-3}.

The chemical quality of the ground water in the area is predominantly poor because of high sulfate content and, in the Tularosa Basin, high sulfate and chloride content. Some of the water in the Bursum Formation is of good to fair chemical quality, but it locally contains an undesirably high nitrate content.

Small amounts of water of good to fair quality are present at six localities on the missile range: near the northwest corner; at Hardin Ranch near Rhodes Pass; at two wells north and south of Mockingbird Gap; at Trail Canyon well in sec. 36, T. 6 S., R. 5 E.; near Baca well in sec. 26, T. 6 S., R. 6 E.; and at scattered small springs issuing from Pennsylvanian rocks on the back slope of Sierra Oscura. Off the range, the alluvium west of the river in the Rio Grande Valley yields large quantities of water of good chemical quality.

The scarcity of water of good quality precludes general development of potable supplies within the White Sands Missile Range. Development of non-potable supplies for dual systems, however, warrants consideration.

INTRODUCTION

The White Sands Missile Range covers approximately 5,000 square miles in south-central New Mexico. Most of the area has been a military reservation since the early part of World War II and is now used for guided missile tests, bombing and strafing practice, and other tactical and testing maneuvers. The first atomic bomb was tested July 16, 1945, on the range, at Trinity Site, approximately 10 miles north of Mockingbird Gap. The area investigated for this report includes, in part, the northern third of the range (fig. 1).

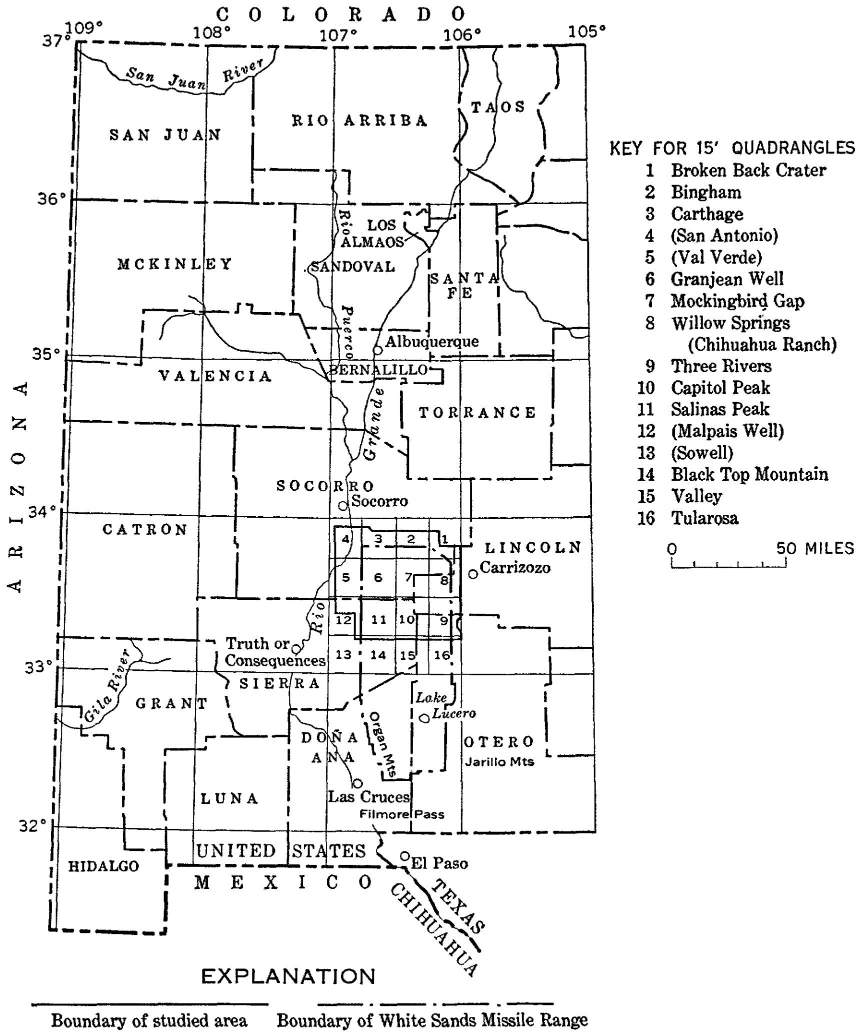

FIGURE 1.—Index map of western New Mexico. Names in parentheses are those of U.S. Geological Survey quadrangles (scale, 1:62,500). Other names are those of Army Map Service quadrangles (scale, 1:50,000). A.M.S. 7½-minute quadrangles, at a scale of 1:25,000, are also available, with or without photomosaics on back.

The chief military installation on the range is Headquarters, White Sands Missile Range, near Las Cruces, N. Mex. Major military installations outside the boundary of the missile range are Holloman Air Force Base, near Alamogordo, N. Mex., and Fort Bliss, at El Paso, Tex. Many smaller outlying installations serve as subsidiary bases of operation where troops are quartered. These installations are in almost all parts of the military reservation, and four of them are within the area studied. Oscura Range Camp near Oscura, Stallion Site Camp near Socorro, and North Oscura Peak Station near White Store are operated by the White Sands Missile Range. Red Canyon Range Camp, near Carrizozo, is maintained as a training and testing base by Fort Bliss (figs. 5, 6).

The principal purpose of this investigation was to determine if usable ground water could be obtained near the outlying installations on the northern White Sands Missile Range. When the investigation began (Feb. 1955), water was being trucked to Stallion Site Camp from Socorro, about 27 road miles from the installation; to Oscura Range Camp from the Mockingbird Gap well, 16 road miles from the camp; and to Red Canyon Range Camp and North Oscura Peak Station from Carrizozo, 17 and 35 road miles, respectively, from these installations. The overall objectives of the study were to delineate areas where potable or usable ground water is available and to estimate quantities therein, suggest methods of developing these sources, map the geology pertinent to the occurrence of all ground water in the area, and suggest possible uses of the great quantity of nonpotable ground water occurring in the area.

LOCATION AND ACCESSIBILITY

Almost three-fifths of the area inside lat. 33°–34° N. and long. 106°–107° W. was included in this study. The area covers 2,400 square miles, of which 1,500 square miles are within White Sands Missile Range. The area investigated has been mapped topographically as all or part of 30 published 15-minute quadrangle maps. (See fig. 1.)

The peripheral parts of the area are accessible by U.S. Highways 54, 85, and 380, and New Mexico Highway 52. Military and ranch roads branch off these main highways and provide access to almost all parts of the area. Some of the military roads have been paved in recent years, and almost all other military roads that lead to the various installations in the northern part of the range are gravel-surfaced all-weather roads; somewhat poorer roads stem from these. The military roads are constantly being improved, and new roads are added as needs arise. The mountainous parts of the area are the least accessible, but new roads, such as the one connecting north and south Oscura Peaks, are being built in these areas.

METHODS OF INVESTIGATION

Reconnaissance studies of hydrology and geology at and around each of the four installations in the northern part of the White Sands Missile Range were conducted in the following order: Stallion Site Camp, North Oscura Peak Station, Oscura Range Camp (including the Mockingbird Gap area), and Red Canyon Range Camp.

On the basis of the preliminary investigations, sites for seven test holes were chosen near three of the installations. These holes were drilled with cable-tool equipment to facilitate finding low-yield sources of perched ground water. Mud used in most rotary methods of drilling often seals off zones of perched water that could be of significant value if the water is potable. Moreover, cable-tool methods are adaptable to procuring samples of water as successive water-bearing zones are penetrated, thus offering a means of roughly determining any changes in the chemical quality of the ground water.

A test hole in sec. 6, T. 7 S., R. 6 E., near North Oscura Peak Station, called Air Force test hole, was deepened from 477 to 701 feet; and Baca test well in sec. 34, T. 6 S., R. 6 E. (pl. 1), was drilled to a depth of 210 feet. The drilling at these two sites was done between December 16, 1955, and March 12, 1956. The Baca well, about a quarter of a mile northeast of Baca test well, was cleaned out during the early part of December 1955.

Three test holes were drilled west of Stallion Site Camp between April 17 and September 19, 1956, to depths of 600–720 feet. The test hole, 6.2.1.444, nearest the camp (2 miles west) was cased and capped for possible future use as a source of nonpotable water. The westernmost hole, 6.2.10.141 (6 miles west), yielded potable water but in insufficient quantities—about 3 gpm (gallons per minute)—and was plugged and abandoned. The middle hole, 6.2.4.144 (5 miles west), yielded nonpotable water and was plugged and abandoned.

MacDonald 2 test hole, about half a mile southeast of Murray well, 8.5.32.431 (pl. 1), near Mockingbird Gap, 9.5.15.143, was drilled to a depth of 400 feet during the period July 3–20, 1956. This hole, which was dry, was subsequently plugged and abandoned. Information obtained from drilling MacDonald 2 hole, together with geologic mapping in that locality, has permitted deductions about the type of reservoir that yields water to Murray well. Also, the subsurface data obtained from MacDonald 2 have contributed substantially to an approximation of the quantity of water available to Murray well and to any future wells penetrating that reservoir.

Two holes were drilled just south of Red Canyon Range Camp between September and November 1956. Red Canyon 1, 7.8.8.412, was drilled to a depth of 702 feet; and Red Canyon 2, 7.8.8.332, was drilled to a depth of 710 feet. Both holes were completed as water wells to supply nonpotable water for camp use.

Descriptive logs of drill cuttings from most of these test holes are given in table 5.

Most hydrologic data used in the present report were collected during the preliminary site investigations. Reconnaissance mapping of geology and modifications of published and unpublished maps was done during periods when drilling of test holes was temporarily stopped and was completed after the test drilling was finished. Those areas that were not visited were mapped by photogeologic methods on aerial mosaics. In conjunction with geologic mapping, additional hydrologic data were obtained.

Aquifer tests were conducted in all test holes except Air Force test hole and MacDonald 2 hole, neither of which tapped water. Bailing tests were considered adequate aquifer tests for Stallion 2A and 3 holes and for the upper productive zone in Baca test well. Pumping tests were run on Murray well and Fite "PW" well, near Stallion 3 hole. The test on Fite "PW" well was finished on February 25, 1958.

SYSTEM OF NUMBERING WELLS AND SPRINGS

Wells and springs are located and numbered according to the system of common subdivision of sectionized land used throughout the State by the U.S. Geological Survey. The number of each well or spring consists of four segments separated by periods and locates the position to the nearest 10-acre tract of land. The segments denote, respectively, the township south of the New Mexico base line, the range east or west of the New Mexico principal meridian (designated with a "W" if west), the section, and the particular 10-acre tract within the section.

The fourth segment of the number consists of three digits denoting, respectively, the quarter section or approximate 160-acre tract, the quadrant (approximately 40 acres in size) of the quarter section, and the quadrant (approximately 10 acres in size) of the 40-acre tract in which the well is located. Figure 2 shows the system of numbering quarter sections and quadrants, which is done in reading order, as well as the usual numbering of sections within a township. The example given in the figure, 6.2.1.444, thus denotes a well in the SE¼SE¼SE¼ sec. 1, T. 6 S., R. 2 E. The letter "a" is added to the last segment of a well number to denote a second well located within the same 10-acre tract or quadrant. When a well or spring can be

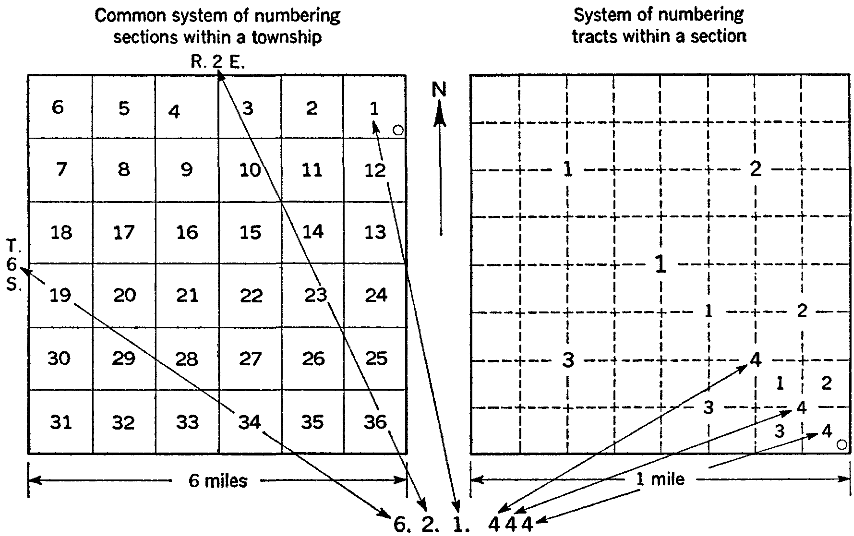

FIGURE 2.—System of numbering wells and springs in New Mexico.

located only within 40 or 160 acres, either the last or the last two digits of the fourth segment are zeros.

Although these location numbers are used primarily to designate and locate established wells and springs, they are used to some extent to designate locations for proposed test holes. The local designation of wells and springs is commonly used in this report, as well as the location number.

ACKNOWLEDGMENTS

This project was sponsored by the U.S. Army Corps of Engineers. Frequent help was obtained from personnel of the Albuquerque District office of the Corps of Engineers, headed by Col. L. C. Barnes and, later, by Col. R. E. Cron. Mr. Hugh E. McCarty of the Sandia Base Branch Office, Corps of Engineers, Albuquerque, was especially helpful during the test-drilling phase of the work.

The writer extends thanks to the civilian and military personnel of the uprange facilities and of the office of Installation Engineer, White Sands Missile Range (formerly White Sands Proving Ground), for their direct cooperation and interest in this project. Mr. F. B. Kidwell, in charge of maintenance for uprange facilities, and Mr. C. A. Farley, Installations Engineer of White Sands Missile Range, were particularly helpful in making arrangements for certain phases of testing, in obtaining facilities for aircraft reconnaissance, and in many other incidental ways which helped in expediting the work. The writer also acknowledges appreciation to the military personnel of both White Sands Missile Range and Fort Bliss, especially those who operate the various installations in the northern part of the White Sands Missile Range, for their friendly cooperation and for the interest they showed in the work.

Much gratitude is due the ranchers in and around the area for well data, historical background, and assistance given to the writer during the fieldwork.

Several members of the U.S. Geological Survey contributed data and advice that has proved invaluable in the preparation of this report. The chemical analyses of water were done by the Geological Survey, Quality of Water Branch, in Albuquerque, and several people in that branch contributed valuable suggestions concerning interpretation of the analyses data.

GEOGRAPHY

PHYSIOGRAPHY

Almost all the report area lies within the Mexican Highland section of the Basin and Range province (Fenneman, 1931). This province is characterized by two broad agraded basins having centripetal drainage that are separated by fault-block mountains. The basins—Tularosa and Jornada del Meurto—are structurally a graben and a syncline, respectively, and contain undetermined (in the report area) thickness of Tertiary(?) and Quaternary fill overlying the bedrock.

The east front of the San Andres Mountains, which separate the basins, is breached in many places by canyons that reach almost across the range. Thus, the greater part of the San Andres Mountains area drains into the Tularosa Basin through east-trending arroyos, several of which reach the alkali flat and playas along the west side of the basin. The smaller arroyos draining the San Andres Mountains disappear long before they reach the lower parts of the basin. The canyons that cut the frontal scarp of the San Andres are deeply incised, and some can be used as jeep routes for crossing the mountains. These arroyos carry considerable water during heavy rains in the mountains. During July and August, some canyons in the San Andres carry freshets perhaps several times during a single week.

The mountains that form the east boundary of the Jornada del Muerto appear strikingly similar when viewed from the floor of the basin. They typically rise along relatively steep dip slopes, broken by faults in places, that extend to peaks 1,500–4,000 feet above the basin floor. Two exceptions to this nearly uniform aspect are the Sierra Oscura, which rise above the basin along a massive frontal scarp, and the Organ Mountains (fig. 1), whose spires of monzonite shaped like organ pipes tower over the basin.

JORNADA DEL MUERTO

The floor of the northern Jornada is flat to hummocky and has little integrated drainage. Sand dunes are common, and sink holes or other depressions are characteristic of some parts of the basin. Gypsum flats and scattered erosional remnants of slightly higher gypsum flats or of anchored gypsite dunes are common in the central part of the northern Jornada.

Drainage is poorly defined except where centripetal drainage crosses peripheral pediments of the basin. A low area of major drainage, oriented generally northeast-southwest in conformance with the trend of the northern Jornada, slopes gently southwestward from the north end of the basin and terminates in a large gypsum-flat depression just east of the Jornada malpais. Most centripetal drainage empties into or terminates at the edge of the central area of subsidence.

The Jornada malpais, or basalt sheet, has a maximum relief of about 400 feet above the gypsum flat to the east. The lava of the malpais was apparently emplaced in a part of the flat or depression that was low at the time the molten lava was extruded.

The terrain of the Jornada malpais, covering about 100 square miles, is jagged and rough. Collapse holes and long roofed caverns are common. Although much of the surface of the Jornada malpais is smoothed somewhat by silty fillings in the depressions and cracks, the basalt sheet is, for the most part, difficult to cross even on foot and has been given the Spanish name "malpais" or "badland." A few ranch roads connect several stock watering places on the Jornada malpais, and one can go only a short distance in a vehicle after leaving these narrow roads.

NORTHERN TULAROSA BASIN

The surface of the Tularosa Basin is much like that of the Jornada del Muerto, even to the occurrence of a basalt sheet, although the drainage in northern Tularosa Basin is better integrated. Salt Creek, in the western part of northern Tularosa Basin, drains a large part of the upper basin, an area of natural ground-water discharge. The axis of drainage for Salt Creek is expressed as a long, low area extending downgradient (southward) to Lake Lucero nearly the full length of the basin; this area includes the playas and alkali flats near Lake Lucero (fig. 1). South of Lake Lucero, the lowest point in the Tularosa Basin, the southern part of this long, low area slopes gently northward toward the lake from the low divide between Filmore Pass and the Jarilla Mountains.

The dunes of the White Sands region, which are mainly gypsum sand, and the dunes farther north, which are mainly quartz sand, lie adjacent to and east of Lake Lucero and the alkali flats to the north. The gypsum sand dunes were apparently deposited by winds that carried the material from the playas and alkali flats of the Lake Lucero area. The origin of the quartz sand is not readily apparent, but presumably this sand also was derived by wind deflation from the alkali flats.

The Malpais of the Tularosa Basin, unlike that of the Jornada del Muerto, is considerably longer than wide, being about 30 miles long and ½–4 miles wide. The basalt was apparently emplaced in a stream valley. The Malpais covers approximately 50 square miles in the area of investigation but has a total area of slightly more than 100 square miles. Like that of the Jornada malpais, the basalt is difficult to cross even on foot. Only three roads traverse the Malpais: U.S. Highway 380 west of Carrizozo; a road near Willow Spring, mostly in sec. 30, T. 8 S., R. 9 E.; and the road west from Oscura.

Black Muley Draw, which is partly on the A. D. Helm Ranch, heads in the northwestern part of T. 7 S., R. 6 E., and trends southeastward ending in the Tularosa Basin in the southwestern part of T. 8 S., R. 7 E.

CLIMATE AND VEGETATION

Precipitation in the area studied ranges from less than 8 inches, in the lower part of the Jornada del Muerto and in the Rio Grande Valley, to more than 16 inches, in the mountains that separate the basins (fig 3). Most of the arid area investigated is within the basins, where the average precipitation is 8 inches or less. Precipitation occurs mostly during the summer months, mainly July and August, when thundershowers, often of great intensity, are fairly common.

About 860,000 acre-feet of precipitation falls annually within the watershed of the northern part of Jornada del Muerto, and roughly 450,000 acre-feet falls annually in the northern part of Tularosa Basin. These figures were derived by computing and adding volumes of average rainfall indicated between isohyetal lines shown in figure 3. For example, the area between the 14- and 16-inch isohyets in the highest part of the Jornada watershed is 100 square miles, or 64,000 acres. These rainfall figures multiplied by the average rainfall of 15 inches, or 1.25 feet, gives a figure of 80,000 acre-feet of water for that part of the watershed.

The average annual temperature of the area is about 59°F, and diurnal fluctuations range from 30° to 40° in both summer and winter. Summer maximums are slightly more than 100°F; winter minimums are seldom less than 25°F except in the higher mountains.

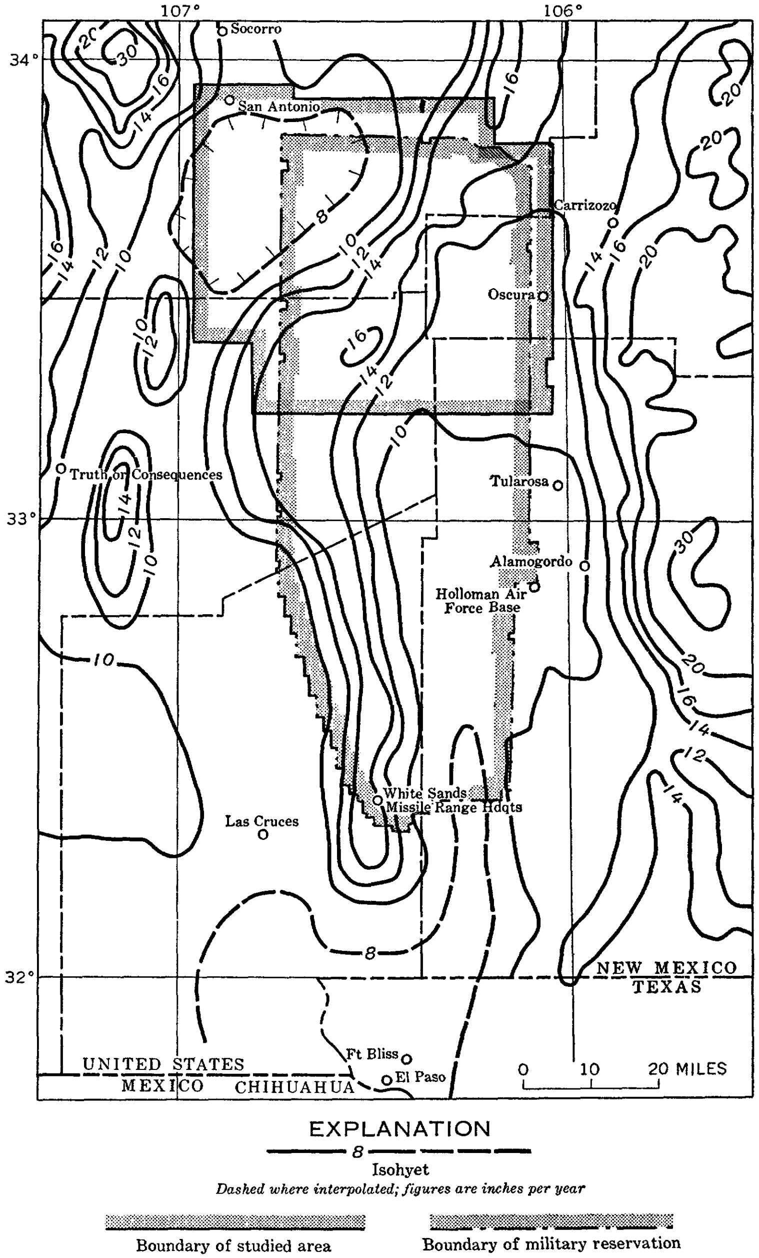

FIGURE 3.—Average annual precipitation in south-central New Mexico. From New Mexico State Engineer Office (1956, p. 7).

Annual evaporation in the area ranges from 85 to 93 inches. These quantities were measured in class "A" land pans of the U.S. Weather Bureau at three weather stations in and near the area. Evaporation from the barren floor of a playa in this region, such as Lake Lucero, may approach or exceed that at pan evaporation stations. Evaporation and transpiration return to the atmosphere almost all the water that falls on the desert basins, so that probably not more than 10 percent of the precipitation on the basins recharges ground-water aquifers. On the peripheries of the basins, possibly as much as 25 percent of the total precipitation becomes recharge.

Vegetation in the basins consists mainly of sage and soapweed but includes a few cacti and some desert bunch grasses. In the sand-dune areas, shin oak and a few mesquite grow. Along the courses of streams (Salt Creek and Rio Grande) and arroyos, saltcedar, willow, saltgrass, and mesquite grow. On the pediments and alluvial fans around the edges of the basins, growths of creosote bush, ocotillo, Spanish-dagger, yucca, century plant, grama grass, and many varieties of cacti are found to an altitude of about 6,500 feet. Above 6,500 feet, pinon, juniper, scrub oak, and grama grass grow in relative abundance; a few ponderosa pine grow on the higher peaks of the mountains.

CULTURE

The Jornada del Muerto was aptly named "Journey of the Dead" by the early Spanish freighters and travelers who risked death at the hands of hostile Indians, or from lack of water, to travel this route northward. The old Jornada trek is about 75 miles long, from Dona Ana to Fra Cristobal, at the north end of the Fra Cristobal Range, or about 20 miles or one day's journey shorter than the Rio Grande route. Even today potable water is rare throughout the Jornada. A map reproduced in Water Supply Paper 343 (Meinzer and Hare, 1915, pl. 4) and dated 1851 shows the location of Aleman, now called Aleman Ranch, about 12 miles south of Engle along the trail through the Jornada, where potable water apparently was available from springs or shallow dug wells. The present water level in the drilled well at Aleman Ranch is about 40 feet below the land surface, and the water is potable. Other watering places may have been present during the early days of the Jornada trail, but these sources of ground water probably did not yield water of good quality.

The area studied has been cattle- and sheep-raising country since the arrival of American settlers in the West more than 100 years ago. Almost all attempts at growing row crops have been in the Rio Grande Valley, where some irrigated crops are grown.

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Water supply has always been a problem for the people in this area. Almost all the ranchers in the Jornada del Muerto and the Tularosa Basin, parts of which constitute major parts of the White Sands Missile Range, have relied on rain-water cisterns for their drinking water.

GEOLOGY AND STRUCTURE

Rocks exposed in the area range in age from Precambrian through Recent. Rocks from Cambrian through Mississippian age are missing north of a line approximately coincident with the line between Tps. 7 and 8 S. South of this line all the lower Paleozoic systems except the Silurian are represented. No rocks of the Jurassic System have been recognized in the area.

The aggregate maximum thickness of sedimentary rocks overlying the Precambrian basement complex is about 8,000–9,000 feet. Where these strata are thinnest, and the lower Paleozoic systems are missing, only about 3,000–5,000 feet of rocks overlies the basement complex. In the subsurface of several parts of the eastern half of the Tularosa Basin, a section of nearly maximum thickness is present. These rocks are probably thinnest in the northeast and central parts of the Jornada del Muerto.

Parts of two major structural elements occur in the area: the Jornada del Muerto syncline and the Tularosa Basin graben. These structural features are separated by the Sierra Oscura and San Andres Mountains fault blocks. The Sierra Oscura fault block is entirely within the area described in this report, but only the northern part of the San Andres Mountains fault block is within the area (pl. 1).

The faults and folds that are best exposed in the region probably began to form during Late Cretaceous or Early Tertiary time, but most of the deformation probably occurred during Oligocene (Middle Tertiary) time, as indicated by the Baca Formation of Eocene(?) age, which is faulted and tilted. Along the front of the San Andres Mountains south of the area studied, vertical movement, apparently on an older fault, is evident in the Recent fan deposits. These small fault scarps may be due to general subsidence caused by leaching of soluble materials in the Tularosa Basin rather than to tectonic adjustment of the earth's crust.

The toe of the backslope of the northern Sierra Oscura is nearly continuous with the southern extremity of Chupadera Mesa, which bounds the Tularosa Basin graben on the northwest. The Transmalpais Hills, an outlier of Chupadera Mesa, protrude through the fill in the graben and is in an area that is more synclinal in structural form. Apparently either the Tularosa Basin graben or its synclinal northward extension continues approximately 30 miles beyond the northeast corner of the area described in this report.

The east boundary of the Tularosa Basin graben is a complex zone of poorly exposed step faults. Individual faults within the complex are characterized in places by eastward-facing cuestas. Stair-step fault blocks may also persist westward into the central graben, where they are buried beneath the fill.

Almost all the faults in the graben are normal faults that trend generally northward to slightly east of north. Another system of normal faults in the Sierra Oscura and San Andres Mountains trends northwestward and may extend beneath the fill in the northern part of the graben. One major cross fault in the Sierra Oscura trends west-northwest and divides the mountain range structurally. Rocks in the northern part of the range characteristically have eastward dips of 3°–6°, and those in the southern part of the range, eastward dips of 11°–17°.

Three small areas of folding were mapped in rocks associated with the Tularosa Basin graben. A syncline and a small anticline occur in gypsiferous rocks of Permian age along the Socorro-Lincoln County line in Tps. 7 and 8 S., R. 7 E. Both of these small flexures plunge toward the major cross fault of the Sierra Oscura and probably are genetically related to this fault. Farthest west along this fault zone, local drag folds occur on the downthrown (south) side.

A rather small anticlinal fold occurs mostly within secs. 17 and 20, T. 10 S., R. 5 E., in limestone of the Magdalena Group. The axis of this fold grades into a fault both up and down the plunge. The crest of the anticline has been breached by erosion and is partly covered by alluvium, which yields a small quantity of water to the Burris well (10.5.17.431).

Two small folds, both plunging southeastward, occur in Permian rocks in secs. 10 and 15, T. 9 S., R. 5 E. An anticlinal structure is well exposed in rocks of the Bursum and Abo Formations, and a synclinal structure is well displayed in rocks of the Abo and Yeso Formations. The Mockingbird Gap well (9.5.15.143) was drilled in the crest of the anticline and apparently obtains water from fractures formed by folding in the limestone conglomerate and siltstone of the Bursum Formation.

STRATIGRAPHIC UNITS AND THEIR WATER-BEARING CHARACTERISTICS

Rocks of Pennsylvanian age overlie the granite and quartzite of the Precambrian basement complex in the northern third of the area, and early Paleozoic rocks overlie the basement complex in the southern two-thirds of the area. Rocks of Permian age overlie the Pennsylvanian rocks, possibly disconformably. Triassic strata lie, apparently conformably, on the Permian rocks. A thick sequence of Cretaceous rocks unconformably overlies Triassic rocks and generally is best exposed in the eastern and northwestern parts of the area.

Tertiary and Quaternary sedimentary rocks were derived by weathering, principally from Paleozoic and Mesozoic rocks, and they generally have a chemical and mineralogic character much the same as that of the rocks from which they were derived. The lithologic character of the Tertiary and Quaternary rocks generally is not the same as that of the rocks from which they were weathered; however, a few conglomerate beds and sandstone beds found in the younger strata are equally as well indurated and cemented as are the older rocks.

Volcanic rocks exposed in the area range in age from Tertiary(?) to Recent (some probably not more than 1,000 years old) and are mainly basaltic. Intrusive rocks are probably Tertiary in age and mostly form dikes and sills in strata of Pennsylvanian through Cretaceous age. In a few places, granitic rocks that seemingly underlie the Paleozoic sequence contain zenoliths of material from the basal parts of overlying sediments and, therefore, must postdate the Paleozoic sedimentary rocks.

Strata of Mississippian through Cambrian age were grouped on the geologic maps (pl. 1) for reasons of map scale and because these rocks are of little significance as sources of ground water in the area. In the San Andres Mountains the Bursum Formation apparently was mapped (Kelley, 1955) with the Abo Formation. The Glorieta Sandstone is mapped with the San Andres Limestone, because the Glorieta is extremely thin, discontinuous, and poorly exposed.

PRECAMBRIAN

Rocks of Precambrian age in the area are composed mainly of granite and quartzite but include some gneiss and schist. At places, as on the knob in the NE¼NW¼NE¼ sec. 18, T. 9 S., R. 5 E., irregular moderate-size masses of white quartz occur in the granite.

The Precambrian rocks are best exposed in the northern part of the San Andres Mountains. They also crop out along the frontal escarpments of Sierra Oscura, the west side of the Mockingbird Gap Hills, and the east side of the San Andres Mountains. The thickest exposure noted is in the northern part of T. 12 S., R. 5 E., where at least 2,000 feet of Precambrian rocks crops out.

Precambrian rocks are not known to yield water in the area, and their upper surface is generally the lowest level at which ground-water supplies can be expected. Detritus weathered from granite, however, is not particularly soluble in water; and these deposits, often called "granite wash," locally may yield water of excellent chemical quality, as they do at Trail Canyon well (6.5.36.343). Other detrital deposits derived mainly from rocks of Precambrian age might be explored for potable water; however, only a few gallons a minute could be expected from a well tapping these deposits.

CAMBRIAN AND ORDOVICIAN

The Bliss Sandstone of Early Ordovician and Late Cambrian age overlies, with angular unconformity, the Precambrian rocks of the San Andres Mountains and southern Sierra Oscura. The Bliss is a dark-purplish-red and brown quartzitic sandstone having some calcareous cement. It ranges in thickness from about 20 feet in the southern part of the area to zero in the Sierra Oscura, where it wedges out approximately in the NE¼NE¼NE¼ sec. 12, T. 8 S., R. 5 E. The Bliss is prominently exposed as a ledge former in the frontal scarps of the San Andres Mountains, Mockingbird Gap Hills, and southern Sierra Oscura. The contact between the Bliss and the overlying Lower Ordovician El Paso Limestone is somewhat irregular and is at places gradational.

The medium-bedded El Paso Limestone and the massive Middle and Upper Ordovician Montoya Dolomite overlie the Bliss. These units are typically purplish-gray to brown dolomitic limestone and calcareous dolomite that crop out in uneven, ledgy slopes. At some places the Montoya forms a precipitous cliff and has a yellowish-brown to gray weathered surface. These units thin from south to north in the area, ranging in thickness from at least 400 feet in the south to about 80 feet in Mockingbird Gap Hills. They apparently pinch out in the southwestern part of T. 8 S., R. 6 E.

Cambrian and Ordovician rocks have no apparent significance to the ground-water hydrology of the area.

Rocks of Silurian age have not been recognized in the area, although they do crop out in the southern San Andres Mountains. Kottlowski and others (1956, p. 27) noted a pinch-out of the Fusselman Dolomite of Middle Silurian age about 6 miles south of Rhodes Canyon.

DEVONIAN AND MISSISSIPPIAN

Rocks of Devonian age in the area consist of shale, siltstone, and limestone that rest unconformably on Ordovician rocks. The principal unit of Devonian age is the Sly Gap Formation of Stevenson (1945). At its type locality (NW¼ sec. 25, T. 11 S., R. 5 E.), the Sly

Gap is 57 feet thick and is underlain by about 15 feet of Onate Formation of Stevenson (1945) and overlain by about 20 feet of the Contadero Formation of Stevenson (1945) (Kottlowski and others, 1956, p. 28–30). During the present study, an exposure in the NE¼ NW¼ sec. 7, T. 11 S., R. 6 E., about 3 miles north of the type section, was examined. This outcrop contains 62 feet of Devonian rocks, most of which is probably in the Sly Gap Formation; possibly a few feet of strata near the base may be Onate. The Contadero Formation was not recognized at this site. The Devonian rocks thin northward, and only 15–20 feet of Sly Gap is present in the Mockingbird Gap Hills. The Sly Gap Formation, like the Ordovician strata, presumably pinches out in the southwestern part of T. 8 S., R. 6 E.

The Devonian strata typically are rather poorly exposed in slopes along the frontal scarps and canyons of the mountain ranges, as the slopes are frequently covered with float debris. The best outcrops are in arroyos in the scarps and canyon walls. The Devonian strata generally contain many fauna.

The Mississippian rocks of the area consist mainly of limestone or cherty limestone—the Lake Valley Limestone. The Lake Valley crops out in the San Andres Mountains, where it is as much as 60 feet thick in the southern part of the area, and pinches out near the northwest corner of T. 10 S., R. 5 E. At least three of the six members, named by Laudon and Bowsher (1941, 1949), of the Lake Valley Limestone can be distinguished in the area. These are, from oldest to youngest, the Alamogordo Member, composed of about 30 feet of black limestone containing large elipsoidal brown and black banded chert nodules; the Nunn Member, composed of about 25 feet of shale and nodular limestone; and the Tierra Blanca Member, composed of about 5 feet of gray crinoidal limestone containing an abundance of light-gray to white chert nodules.

The Devonian and Mississippian rocks are not significant sources of ground water in the area.

PENNSYLVANIAN

Rocks of Pennsylvanian age unconformably overlie the Mississippian rocks in the southern part of the area and rest with angular unconformity on Precambrian rocks in the northern part. The Pennsylvanian rocks comprise the Sandia Formation and the Madera Limestone; these together with the Permian Bursum Formation constitute the Magdalena Group of Pennsylvanian and Permian age.

The Sandia Formation is composed of arkose, sandstone, conglomerate, and some limestone and shale. Only the member called the upper clastic member is present. The thickness of the Sandia Formation ranges from 10–50 feet in the northern Sierra Oscura to slightly more than 100 feet in the Mockingbird Gap Hills. In the mouth of Rhodes Canyon, just south of the area studied, Kottlowski and others (1956, pl. 1) measured approximately 80 feet of what is apparently Sandia Formation. Wilpolt and Wanek (1951, sheet 2) reported 635 feet of Sandia Formation immediately east of Socorro and 100 feet in the Joyita Hills just north of the northernmost part of the area described herein. The Sandia Formation apparently thickens in almost all directions from Sierra Oscura. Pray (1954, p. 93) measured approximately 300 feet of clastic sediments that probably are Sandia equivalents at the base of the Pennsylvanian section in the Sacramento Mountains to the east of the area.

The Sandia Formation crops out along the frontal scarps of the mountains. Exposures are not everywhere good, and slope debris from the overlying limestone commonly covers this relatively thin interval.

The Madera Limestone consists of a lower, gray member and an upper, arkosic member.

The gray member of the Madera Limestone consists of about 400–700 feet of dark-gray cherty limestone and some shale. At places the member is intruded by dioritic sills and a few dikes. The gray member is best exposed along the frontal scarps of the mountain ranges, including the Mockingbird Gap Hills; it is typically a cliff former.

The arkosic member of the Madera Limestone is extensively exposed in the higher parts and in the backslopes of the mountain ranges. This thick limestone unit contains considerable fresh pink feldspar fragments in some zones but generally contains less chert and more shale than does the underlying gray member. The unit typically underlies the dip slopes but is exposed sporadically in cliff faces and in canyon walls. The arkosic member of the Madera Limestone ranges in thickness from about 500 feet in Sierra Oscura (Wilpolt and Wanek, 1951, sheet 2) to as much as 1,600 feet in the Mockingbird Gap Hills and in Rhodes Canyon (Kottlowski and others, 1956, pl. 1).

The arkosic member has been intruded locally by relatively thin dioritic sills in the central Sierra Oscura and by thick monzonitic sills and perhaps other kinds of intrusive rocks in the San Andres Mountains. These rocks are nearly impermeable; but, locally, where the limestone is strongly faulted and fractured, small bodies of water may occur above the igneous sills.

Locally, springs yielding 1–3 gpm (gallons per minute) of water issue from the arkosic member where it crops out in the backslopes of mountains, principally the Sierra Oscura.

The springs commonly occur just above relatively impervious shale layers intercalated in the limestone. Many springs shown on topographic maps of the mountains were found to be dry at the time of the present study and probably are ephemeral springs. A few shallow wells obtain water from Pennsylvanian units also.

PERMIAN

Five formations of Permian age crop out in the area. These are, from oldest to youngest, the Bursum and Abo Formations of Wolfcamp age, the Yeso Formation of Leonard age, and the Glorieta Sandstone and San Andres Limestone of Leonard and Guadalupe age. The Glorieta Sandstone is thin in the area and has been combined with the San Andres Limestone in mapping. Kottlowski and others (1956, pp. 49–52) described 417 feet of rocks overlying the Bursum Formation in the Rhodes Canyon area and designated these strata as the Hueco Formation. If these rocks are present farther north, they are mapped with the Bursum Formation.

The total thickness of Permian rocks cropping out in the area ranges from about 1,800 to 2,500 feet.

BURSUM FORMATION

The Bursum Formation rests on Pennsylvanian rocks, possibly disconformably. Generally the Bursum is exposed in the lower third of the backslopes of the mountains and hills in the area. The formation is mainly composed of purplish-red to gray lime-pellet conglomerate, limestone, shale, sandstone, and arkose that resemble strata of the underlying Pennsylvanian rocks, in part, and the overlying Abo Formation, in part. The Bursum appears to show depositional features characteristic of transition from marine to arid continental environment.

The Bursum ranges in thickness from 90 feet at the type locality west of the Bursum triangulation station (SE¼ sec. 1, T. 6 S., R. 4 E.) to 250 feet in the central Sierra Oscura (Wilpolt and Wanek, 1951, sheet 2). The thicker section, in the Sierra Oscura, includes about 110 feet of limestone apparently identical with the underlying Madera. The base of the Bursum at this locality consists of a 3-foot bed of red shale that is probably a tongue of the Abo (Wilpolt and Wanek, 1951, sheet 1). In the central Sierra Oscura, only about 80 feet of typical Bursum can be mapped feasibly by reconnaissance methods. Kottlowski and others (1956, p. 48) reported 250 feet of Bursum Formation and about 425 feet of Hueco Limestone in Rhodes Canyon.

The Bursum Formation yields 2–30 gpm of water to wells in two localities: in Brush Tank Canyon (Baca and Baca test wells) and in an area just south of Mockingbird Gap. At Brush Tank Canyon, water is apparently in joints and other fractures in the Bursum. The Mockingbird Gap well is completed in the apex of a monocline, and folding of Bursum rocks there has created, by fracturing, a small underground reservoir.

ABO FORMATION

Conformably overlying the Bursum Formation are dark-purplish-red to brick-red siltstone, shale, and sandstone, and some conglomerate of the Abo Formation. These rocks are crossbedded and contain ripple marks, spheroidal gray reduction spots, tracks of vertebrate animals, and plant fossils.

Many of the rocks in the Abo are resistant to weathering and form ridges and hills low on the backslopes of the mountains and hills in the area. The Abo ranges in thickness from 790 feet in the central Sierra Oscura (Wilpolt and Wanek, 1951, sheet 2) to more than 800 feet in the Rhodes Canyon area (Kottlowski and others, 1956, p. 53).

The Abo Formation yields 3–4 gpm of water to springs and wells in Red Canyon (T. 7 S., R. 7 E.) and near Rhodes Pass (Hardin Ranch well 12.2.27.211). Rocks of the Abo Formation are impervious to water except where they are strongly jointed and fractured, as they apparently are at the above localities.

YESO FORMATION

The Yeso Formation ranges in thickness from 1,100 feet in the central Sierra Oscura and at Chupadera Mesa to a reported (Kottlowski and others, 1956, p. 5) thickness of 4,200 feet in the Heard 1 oil test (6.9.33.143), where the formation contains slightly more than 800 feet of halite. About 1,600 feet of Yeso crops out in the Rhodes Canyon area (Kottlowski and others, 1956, p. 55, 56).

The Yeso Formation is subdivided into four members in this region. From oldest to youngest they are the Meseta Blanca Sandstone, the Torres, the Cañas Gypsum, and the Joyita Sandstone. The Meseta Blanca Sandstone Member ranges in thickness from about 90 to 350 feet and is composed of sandstone, sandy siltstone, and some limestone. The Torres Member constitutes the bulk of the formation and consists of 800–1,000 feet of dark- to brick-red siltstone alternating with gypsum and gray limestone. Cavernous and sandy sections in the Torres Member yield small to moderate quantities of water to wells. The Cañas Gypsum Member is less than 200 feet thick and consists of massive white gypsum interbedded with gray gypsiferous siltstone and limestone. The Joyita Sandstone Member ranges in thickness from 30 to 150 feet (Wilpolt and Wanek, 1951, sheet 2) and is mainly orange-red sandstone and siltstone.

The Yeso Formation generally yields 3–15 gpm of water to many stock wells in the Tularosa Basin and in parts of the Jornada del Muerto. Well 7.8.8.322, however, yields more than 200 gpm, with only 2 feet of drawdown.

GLORIETA SANDSTONE

The yellow to gray silty sandstone assigned to the Glorieta Sandstone ranges in thickness from 10 to about 30 feet. Exposures of Glorieta are poor and discontinuous throughout the area. Northward, however, this unit thickens abruptly; and 50 miles north of the area, in the vicinity of Corona, the Glorieta is at least 250 feet thick and is widely exposed.

The Glorieta Sandstone yields about 100 gpm of water to the Murray well (8.5.32.431), where the standstone is intensely fractured along a fault zone.

SAN ANDRES LIMESTONE

The type locality for the San Andres Limestone, as described by Needham and Bates (1943, p. 1664–1666), is in the southern part of the area, near Rhodes Pass. At the type locality the San Andres is 600 feet thick and contains gray limestone and dolomitic limestone. North and east from the type locality the San Andres contains several gypsum layers and some sandstone. The maximum thickness in the eastern part of the area, based on exposures in sec. 11, T. 9 S., R. 8 E., is about 475 feet.

The San Andres Limestone is widely exposed on Chupadera Mesa, in Phillips Hills and Transmalpais Hills, and near the base of the backslope of most of the mountains and hills of the area. In the eastern and northeastern parts of the area, a karst topography has developed locally on the San Andres, and sink holes ranging from 30 to 100 feet in depth and from 100 to 500 feet in diameter have formed. Notable examples of sinks in the San Andres are in SE¼ sec. 6, T. 7 S., R. 8 E., and in the SE¼ sec. 2, T. 9 S., R. 8 E.

The San Andres Limestone yields a few gallons a minute of water to wells locally and about 900 gpm (1956) of water to the Sun Oil test (10.1W.25.341) by artesian flow.

TRIASSIC

Rocks of Late Triassic age crop out mainly in the eastern and northwestern parts of the area; 52 feet of the Dockum Group is exposed in secs. 11 and 12, T. 11 S., R. 3 E. (Kottlowski and others, 1956, p. 62). Wilpolt and Wanek (1951, sheet 2) reported that only 80 feet of Dockum remains after erosion in the Joyita Hills, but they estimated that the Dockum north and east of the Joyita Hills is 500 feet thick.

The Dockum Group consists of light-chocolate-red conglomeratic sandstone and siltstone at the base and dark-purplish-brown to red and yellow siltstone, shale, sandstone, and limestone at the top. These rocks overlie the San Andres Limestone of Permian age, probably unconformably. About 150 feet of Dockum crops out in sec. 12, T. 9 S., R. 8 E., and elsewhere along Bull Gap Ridge. The upper part of the Triassic section along Bull Gap Ridge contains petrified wood. Exposures of Triassic rocks in the south-central part of T. 6 S., R. 8 E., apparently belong to the middle part of the Upper Triassic section.

The Dockum Group yields a small amount of water to Bull Gap Spring (9.8.23.423) and to two wells (4.2.23.344 and 4.2.23.432) in the Joyita Hills.

The Upper Triassic rocks are separated from the Dakota Sandstone of Cretaceous age by a thin layer of white to gray chert. Jurassic rocks have not been recognized in this region.

CRETACEOUS

Rocks of Cretaceous age crop out in the eastern, northwestern, and west-central parts of the area. From oldest to youngest the units are the Dakota Sandstone, the Mancos Shale, and the Mesaverde Group.

DAKOTA SANDSTONE

The Dakota Sandstone consists of quartzitic and ferruginous gray to yellow and dark-reddish-brown crossbedded sandstone which lies, apparently unconformably, on the Dockum Group of Late Triassic age. The Dakota ranges in thickness from 40 feet in secs. 11 and 12, T. 11 S., R. 3 E. (Kottlowski and others, 1956, p. 66), to 71 feet in the northwestern part of the area (Wilpolt and Wanek, 1951, sheet 2) and to about 100 feet in Bull Gap Ridge, in the eastern part of the area.

Although its exposures are rather small, the formation is probably widespread in the subsurface of the Tularosa Basin and the Jornada del Muerto. A Sun Oil test well (10.1W.25.341) penetrated about 50–70 feet of the Dakota Sandstone. This unit reportedly discharged by flow 200 gpm of water during a drill stem test. The Dakota reportedly yields 2–500 gpm of water locally to other wells in its outcrop area.

MANCOS SHALE

The Mancos Shale, of Late Cretaceous age, consists of 700 feet (in the northwestern part of the area) to about 2,000 feet (in the eastern part of the area) of olive-green to greenish-gray shale, mudstone, and limestone and minor amounts of sandstone. The best exposures are in the southern part of the Joyita Hills and in the arroyos near

Bull Gap Ridge. In the Joyita Hills, Wilpolt and Wanek (1951, sheet 2) subdivided the Mancos into three members, which are unnamed. Further work in the Bull Gap Ridge area probably could result in a satisfactory fourfold subdivision.

The Mancos Shale locally yields 1–5 gpm of water to wells and springs, but the water is generally of poor quality. Apparently the poor quality is due to solution of secondary gypsum, which occurs in partings of the formation.

MESAVERDE GROUP

The Mesaverde Group, of Late Cretaceous age, consists of about 1,000 feet of light-gray to brown sandstone and shale and contains some coal beds in the eastern part of the area. Locally the Mesaverde Group is intruded by igneous sills and dikes. The Mesaverde crops out also in the northwestern part of the area, but exposures are poor and discontinuous, as they are in the eastern part. Wilpolt and Wanek (1951, sheet 2) reported, however, that a test hole, Stackhouse 3, in sec. 1, T. 5 S., R. 2 E., apparently penetrated 987 feet of Mesaverde.

The Mesaverde generally yields 2–4 gpm of impotable water to wells and springs in its outcrop area. One well (5.2.17.424) yields 75 gpm from the Mesaverde Group.

TERTIARY

Sedimentary rocks of Tertiary age crop out only in the western part of the area, but a few isolated small exposures of consolidated gravel were noted in the eastern half—in the SE¼ sec. 16, T. 7 S., R. 8 E., the NE¼ sec. 24, T. 9 S., R. 6 E., and the NE¼ sec. 21, T. 12 S., R. 6 E.—which may be Tertiary in age although they are mapped with other units, mainly Quaternary. These outcrops occur principally in areas where rainfall-runoff flows over limestone terrane before reaching the gravel, which is consolidated with calcareous cement. Consequently, these rocks probably are Recent in age but appear older because they are more highly indurated than most other Quaternary rocks in the area.

Tertiary intrusive rocks are widespread in the area and occur in strata of Pennsylvanian through Cretaceous age. The instrusive rocks are mainly sills and dikes ranging in composition from monzonite to diorite. Some extrusive volcanic rocks of Tertiary age are also in the area. These are mainly basalt, except in Tps. 10 and 11 S., Rs. 9 and 10 E., where a complex of flows, tuffs, and vitreous rocks are associated with rocks of Sierra Blanca.

Extrusive basalt of late Tertiary(?) or early Quaternary age crops out in the Jornada del Muerto northeast of Red Canyon Range Camp (pl. 1). In the Jornada del Muerto the basalt overlies the Santa Fe Group; near Red Canyon Range Camp it overlies Mesozoic rocks. On the basis of general appearance as well as stratigraphic position, these rocks are considerably older than the fresh-looking basalt of the Malpais in Tularosa Basin. The two exposures of older basalt may not be of the same age—probably the basalt in the Jornada del Muerto is the younger of the two. The basalt at both exposures, however, is at least as old as early Pleistocene and probably is Pliocene in age.

As only the sedimentary rocks contain ground water in the area, the intrusive and volcanic rocks of Tertiary age will not be discussed further in this report. The three sedimentary stratigraphc units of Tertiary age present in the area are (from oldest to youngest) the Baca Formation, the Datil Formation, and the Santa Fe Group.

BACA FORMATION

The Baca Formation, of Eocene(?) age, consists of 1,023 feet (Gardner, 1910, p. 454) of dark-red and gray coarse conglomerate, red and white sandstone, and red siltstone that lies with angular unconformity on the Mesaverde Group. Rocks that crop out farther south and are lithologically similar to the Baca Formation of this area are thought to be Late Cretaceous in age (Kottlowski and others, 1956, p. 68).

The only exposures of the Baca Formation are at two localities on the west and northwest flanks of Cerro Colorado, between Joyita Hills and Cerro Colorado, along the southeast flank of the Joyita Hills, and on the west and northwest flanks of Little San Pasqual Mountain. The upper part of the Baca Formation was penetrated in each of three Stallion test holes drilled around the south flank of Cerro Colorado (6.2.1.444, 6.2.4.144, and 6.2.10.141). (See table 5.)

In two of the Stallion test holes, the Baca was saturated. In Stallion 2A (6.2.10.141) all the Baca drilled was saturated except the upper 25 feet. The estimated maximum yield of the formation is about 50 gpm, from Stallion 1 (6.2.1.444). Stallion 3 (6.2.4.144) yielded only 3 gpm.

DATIL FORMATION

The Datil Formation, of Miocene(?) age, consists of rhyolite, rhyolite tuff and agglomerate, conglomerate derived mainly from volcanic rocks, and sandstone. The sedimentary parts of the formation vary in induration, and some of the sandstone, known only in the subsurface, probably is loosely consolidated. Wilpolt and Wanek (1951, sheet 2) reported 2,000 feet of Datil Formation about 20 miles north of the area. In the northwestern part of the area, the Datil is about 1,000 feet thick. Stallion 1 (6.2.1.444) penetrated 324 feet of Datil (table 5).

The Datil unconformably overlies the Baca Formation and at places rests on rocks of Cretaceous age. The Datil apparently thins southwest of Cerra Colorado, in the same area where the Santa Fe Group thickens.

The lower part of the Datil Formation locally contains the upper part of the same zone of saturation that is found in the Baca Formation. The Datil, however, seems to be less permeable than the Baca and thus will not yield as much water to wells. Two zones containing perched water in the Datil Formation were penetrated in Stallion 3 test hole, but these zones yielded less than 1 gpm.

TERTIARY(?)

SANTA FE GROUP

The Santa Fe Group, of probable Pliocene age in the report area, consists of at least 2,000 feet of pink and gray silt, sand, and gravel that is locally consolidated. It includes all the basin fill within the Rio Grande depression except the youngest alluvium of the central flood plain. Elsewhere the Santa Fe Group has been subdivided into two to four formations. No attempt was made to subdivide the unit in this area, as exposures are poor and subsurface control is lacking.

The Santa Fe is thickest in the northwestern part of the area along the Rio Grande, where it laps onto rocks which range in age from Pennsylvanian through Tertiary. The Santa Fe exposed in the area lithologically resembles the older part of the unit at its type locality near Santa Fe, N. Mex., and probably is Pliocene in age.

The Santa Fe Group yields 2–10 gpm of water to wells in its outcrop area. East of the Rio Grande the water from the Santa Fe generally is poor in quality, but west of the Rio Grande the Santa Fe generally yields potable water.

QUATERNARY

Rocks of Quaternary age are widespread throughout the area and are thickest in the Tularosa Basin and the Jornada del Muerto. These deposits consist mainly of silt, sand, and gravel weathered from the mountain masses surrounding the basins. Thus, deposits contain materials derived from rocks ranging in age from Precambrian through Tertiary.

The maximum thickness of Quaternary alluvium ranges from about 150 feet under the Rio Grande flood plain to 500 feet or more in some parts of the Tularosa Basin and the Jornada del Muerto. Exposures are poor, and subsurface data are lacking.

The Quaternary alluvium is the principal aquifer in the area, as it stores large quantities of water. Throughout the greater part of the area it yields 1–350 gpm of water to wells. In the Rio Grande Valley the Quaternary deposits that overlie the Santa Fe Group yield 1,400–1,600 gpm of water to irrigation, industrial, and municipal wells.

GROUND-WATER HYDROLOGY

PRINCIPLES OF OCCURRENCE, MOVEMENT, AND QUANTITATIVE MEASUREMENT

Water occurs underground in the interstices of clastic deposits, in fractures or joints, or in solutional channels. In the area studied for this report, the most common occurrence (of ground water) is in the interstices of unconsolidated materials such as the alluvium that fills the Jornada del Muerto, Tularosa Basin, and Rio Grande Valley. In these places the underground water bodies may be compared to a lake basin filled with sediments and water.

Where these aquifer materials are relatively well sorted and coarse grained, they normally are capable of yielding 200–1,600 gpm of water to wells. Physical conditions essential to a good aquifer are, in general, a permeability sufficient to allow easy migration of water toward wells, an adequate areal extent so that relatively large quantities of water can be stored, and composition of materials which are chemically inert so that the water passing through them remains sufficiently pure for general use.

Purity or chemical-quality standards for water may vary with the use that is to be made of the water. Standards established for drinking water (U.S. Public Health Service, 1962, p. 7) generally call for the best quality of water, but water of poor quality is used for drinking where better water is not available.

Precipitation is the original source of almost all usable ground water. Precipitation reaches the aquifers in the areas of recharge by downward percolation through the zone of aeration to the saturated zone, or the aquifer, and thence generally circulates through the aquifer to places of natural (springs or seeps) or artificial discharge (wells).

One hundred and fifty-eight wells, both used and unused, and 17 springs were investigated. Detailed records of the wells are given in table 1, and records of the springs are given in table 2. The location of both wells and springs is shown on plate 1.

Chemical analyses of water from selected wells are given in table 3, and those of water from selected springs, in table 4.

MOVEMENT IN THE ZONE OF SATURATION

Ground water migrates in the direction of hydraulic pressure. The water moves roughly at right angles to the contour lines drawn through points of equal water-table or pressure altitude (pl. 1) and toward points of lower altitude—that is, down the ground-water gradient.

In the Jornada del Muerto (pl. 1), ground water migrates generally westward toward the Rio Grande except in areas of recharge, where contour lines approximately parallel the contour of the high mountains and the hills. Thus, locally, the ground water moves southward, southwestward, and northwestward. Owing to local recharge, the water moves centrifugally away from Little San Pasqual Mountain, so that on the east side of the mountain the water moves eastward.

Gradients range from about 50 feet per mile near areas of recharge to as little as about 4 feet per mile in the area northeast of the Jornada malpais. At places east-southeast of Little San Pasqual Mountain, the only movement of water may be near wells pumping small quantities of water.

The Cerro Colorado volcanic plug disrupts westward circulation, and apparently the flanks of the cerro are recharge areas.

In the Tularosa Basin (pl. 1), ground water moves generally southward and basinward away from areas of recharge on alluvial sediments adjacent to the mountains and hills. Ultimate discharge of ground water in the basin is into the Rio Grande near El Paso, about 100 miles south of the area studied. In the northern part of the Tularosa Basin, however, much ground water is discharged into Salt Creek, at Mound Springs (10.6.23.242), and at Malpais Spring (12.7.8.422). Part of the water discharged in the northern part of the basin infiltrates again and continues to move southward.

Topographic contour lines in the Tularosa Basin roughly follow or parallel the bedrock margins. A trough in the surface of the water body rather closely follows the Malpais, which suggests that the basaltic lava was emplaced in the valley of a stream fed by ground water. Much of the water currently migrating into the Malpais area eventually is discharged at Malpais Spring.

Nose-shaped mounds on the water table in T. 9 S., R. 7 E., and T. 10 S., R. 6 E., may result from decreased permeability along fault zones in these areas.

Ground-water gradients in the Tularosa Basin range from about 100–200 feet per mile near the margin of the basin to about 20 feet per mile in the central part of the basin. The slope of the water table seems to be contiguous with that of the bedrock aquifers (Yeso Formation, and San Andres Limestone at the north; Pennsylvanian rocks and San Andres Limestone and Bursum Formation on the west and northwest; and Cretaceous and Triassic rocks to the east) into the basin alluvial fill. Thus, subsurface movement of ground water from bedrock into the alluvium is indicated.

COEFFICIENTS OF PERMEABILITY AND TRANSMISSIBILITY

Transmissibility is defined as the ease with which water moves through an aquifer. The coefficient is expressed by the Geological Survey in gallons per day through a strip 1 foot wide that extends the full thickness of the aquifer (Wenzel, 1942, p. 87) and is the average coefficient of field permeability multiplied by the thickness of the aquifer. Usually the Geological Survey expresses permeability in gallons per day of water, at 60°F, that will pass through a cross sectional area 1 foot square under a gradient of unity (1 ft per ft). Field permeability is defined in the same terms except that the temperature used is that of the water in the aquifer.

Pumping tests of wells are used to obtain the coefficient of transmissibility, T. For testing, a well is pumped, ideally at a constant rate of discharge, and the head in the aquifer or the water level in the well is observed as pumping progresses (drawdown) and after pumping has stopped (recovery). Drawdown and recovery, plotted against the logarithm to the base 10 of time, t, generally give straight-line plots. The rate of recovery of water level after pumping stops is related to permeability. Transmissibility can be obtained by applying the following formula (Theis, 1935; redescribed by Wenzel, 1942, p. 126) to values obtained from a graph of pumping-test data:

$$T=\frac{264Q}{s'}\log_{10} t/t'$$

where

T=coefficient of transmissibility in gpd per ft (gallons per day per foot)
Q=pumping rates or discharge of well, in gallons per minute
t=time (usually in minutes) since pumping began
t'=time since pumping stopped
s'=residual drawdown, in feet, at time t

The $\frac{\log_{10} t/t'}{s'}$ is represented by the slope of the line on the graph through one logarithmic cycle in which $\log_{10} t/t'$ becomes unity, and the formula is thus reduced to:

$$T=\frac{264Q}{\Delta s'}$$

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where $\Delta s'$ is the change in water level during one cycle on the logarithmic scale of the graph (figs. 5–7, 9–11).

A reliable value for the coefficient of permeability can be obtained in the laboratory provided representative undisturbed samples of the aquifer materials are available. Such samples usually are difficult to obtain, however. Permeability values derived by discharging-well methods are almost always more easily obtained and are possibly as reliable.

COEFFICIENT OF STORAGE

The coefficient of storage, S, may be defined as that quantity of water released from storage in an aquifer in each vertical column that has a base 1 foot square, when the water level declines 1 foot. The term is dimensionless but is expressed as a fraction of cubic feet of aquifer. The coefficient of storage for nonartesian aquifers is approximately the same as specific yield. Storage coefficient for an artesian aquifer—that is, an aquifer in which the water is confined and is under sufficient hydraulic head to rise above the saturated zone in a well depends on the compressibility of the aquifer and the water therein; normally the storage coefficient is a much smaller number than is the specific yield.

Like the coefficient of transmissibility, the coefficient of storage can be determined from pumping tests by observing water levels in an observation well near the well that is being pumped. These observed changes in head are then plotted against the $\log_{10} t/r^2$ (fig. 6), and the graph should be a straight line. The value of T can be determined from a t/r^2 graph in much the same manner as from the graph of drawdown of a pumped well, and S is computed by using the following formula:

$$S = 0.301\ T\ (t/r^2)_0$$

where $(t/r^2)_0$ is the zero-drawdown intercept.

As inferred previously, artesian aquifers generally have a very small S—on the order of 10^{-5}–10^{-3}. Nonartesian aquifers generally have storage coefficients on the order of 10^{-3}–10^{-1}.

The coefficient of storage is a major factor in dealing with development of an aquifer, as it shows the quantity of water per unit area that is released from the aquifer for a given change in head. Thus, computations of expected yield, life of the aquifer, and predicted lowering for any given amount of pumping are dependent on the use of an accurate value for S.

Because of a scarcity of observation wells, pumping tests conducted during this investigation were not amenable to determination of S except at Red Canyon Range Camp. Nonartesian aquifers predominate in the area of investigation; and where these are composed of alluvial material, relatively good estimates for specific yield might be made if comprehensive knowledge of the aquifer material were available.

SPECIFIC YIELD

The specific yield of an aquifer is the quantity of water that the aquifer will yield by gravity and is expressed as a fractional part of the total volume of saturated materials. Where compressibility of a nonartesian aquifer is negligible, as it is in many places, the specific yield is the same as the coefficient of storage. Because of difficulty in obtaining representative undisturbed samples of aquifer materials for use in determination of specific yield in the laboratory, such results often are not reliable.

Specific yield of a nonartesian aquifer can be determined from adequate data collected in the field. This is done simply by dividing the quantity of water withdrawn from the aquifer during a known period of time by the volume of the aquifer that was dewatered during that period. Careful and accurate records of pumpage and abundant data on lowering of water level must be available if this computation is to be accurate and meaningful.

RECHARGE AND NATURAL DISCHARGE

Most recharge to the aquifers in the Jornada del Muerto and Tularosa Basin occurs in the areas adjacent to the mountain masses. Precipitation falling in the recharge areas is partly absorbed by porous fan materials and mainly during wet years. This infiltrating water percolates downward to the water table. Part of the runoff in arroyos leading from the mountains also infiltrates and recharges the aquifers.

Recharge in the region is by no means great, and most ground-water bodies have reached their present condition of storage only after many hundreds, perhaps thousands, of years of accretion through recharge. One small ground-water reservoir (9.5.15.100) in the area responds immediately to recharge and can be refilled one or more times annually.

The quantity of annual precipitation that becomes recharge in the area probably ranges from 5 to 25 percent. Herrick (1960, p. 64) estimated that 25 percent of precipitation that falls in a drainage basin near the missile-range headquarters becomes recharge.

Annual recharge to the aquifers underlying the Jornada del Muerto and northern Tularosa Basin is only a very small part of the precipitation that falls in the region—probably about 6–7 percent. Moreover, average annual recharge to these aquifers is an insignificantly small quantity as compared to the vast amount of water stored in the aquifers.

Almost all recharge to the large aquifers in the basin fill occurs at the periphery of the basins. Impervious clay deposits at shallow depth beneath the central, lower parts of the basins permit only very small amounts of infiltration in these areas.

Moderately permeable fan deposits in narrow isolated strips adjacent to the mountains that surround the basins transmit some precipitation and runoff to the large aquifers. In general these quantities of recharge are small; locally, however, as much as 25 percent of the water falling on or running over the fan deposits of the region may become recharge (Herrick, 1960, p. 54).

The quantity of recharge in an area can roughly be estimated by computing the amount of water moving through a cross section of the aquifer underlying the area. Thus, 56,000 acre-feet of water is transmitted annually into the Rio Grande Valley through the cross section of the aquifer between the north end of the Fra Cristobal Range and the south end of Joyita Hills, at the west side of the northern Jornada. The cross section is 25 miles long, excluding little San Pasqual Mountain, and 100 feet deep. This depth was chosen arbitrarily, as it represents the depth of the most probable effective transmitting zone of the aquifer, which includes the Baca Formation and possibly some beds in the Datil Formation and Santa Fe Group. Average water-table gradient in the area of the cross section is about 10 feet per mile, and the transmissibility of the aquifer is about 2,000 gpd per ft, based on the pumping test at Stallion 1 (fig. 4). The computation of recharge is derived from the following formula:

$$Q=TIA$$

where

T= coefficient of transmissibility
I= average gradient of water table
A= width of section

The 56,000 acre-feet of annual recharge to the northern Jornada del Muerto is between 6 and 7 percent of the total annual precipitation on that sector and thus seems to represent a reasonable average for the entire area studied. In areas favorable to recharge, such as the upper parts of fans, the quantity of infiltration that becomes recharge may be 25 percent or more of the precipitation; whereas in areas underlain by less permeable materials, the quantity of infiltration is far less.

Although recharge is given as a certain amount annually, there may be no recharge during some years. During years when exceedingly large amounts of rainfall, recharge may be several times the 56,000 acre-feet that is thought to be the annual average.

Nearly all the ground water moving westward out of the Jornada del Muerto into the Rio Grande Valley discharges into the Rio Grande or is consumed by saltcedars growing in the river valley. Records of streamflow in the Rio Grande do not conclusively show accretion from ground water in the reach of the valley adjacent to the Jornada; therefore, the phreatophytes presumedly consume most of the ground water that comes into the valley. A phreatophyte eradication program in progress at the time of this investigation probably has changed the streamflow pattern, and accretion to the river may now be apparent.

The quantity of recharge to the aquifers in the northern Tularosa Basin probably is nearly equal to the combined discharge from Malpais Spring and Salt Creek, as the groundwater system in that area is nearly in natural equilibrium (discharge is approximately equal to recharge). The discharge of Malpais Spring was probably about 1,500 gpm in May 1955, and the flow in Salt Creek in sec. 16, T. 12 S., R. 6 E., was probably about 650 gpm in June 1955. At a few places in the basin, insignificantly small amounts of ground water are discharged northward and eastward from Malpais Spring, but these amounts combined would not have totaled more than about 150 acre-feet in 1955.

The sum of the discharge from aquifers of northern Tularosa Basin was

Source	*Discharge (gpm)*	*Total (acre-feet)*
Malpais Spring	1,500	3,468
Salt Creek	650	
Mound Spring plus small withdrawals from wells and springs		150
		3,618

or roughly 3,600 acre-feet. Thus, the annual recharge in the northern part of Tularosa Basin is about 1 percent of the precipitation.

Why the recharge percentage is so much less in the Tularosa Basin than in the Jornada del Muerto is not readily apparent. The difference may be related to gross differences in the permeability of materials in the recharge areas of the two basins.

In addition to large springs and spring areas along the Rio Grande and Salt Creek, four small springs issue from the Madera Limestone on the backslope of Sierra Oscura, two small springs issue from Permian rocks in the vicinity of Red Canyon, four springs issue from alluvium east of the Malpais in the Tularosa Basin, and a small spring issues from the Triassic rocks of Bull Gap Ridge. Except for Milagro (9.9.32.211) and Jake's Springs (9.9.10.343), in the extreme eastern part of the area, none of these springs yields more than about 3 gpm of water. Milagro and Jake's Springs yield 20 and 30 gpm, respectively.

One small spring (12.4.2.121) issues from Permian rocks on the back slope of the San Andres Mountains. Several other springs in the San Andres are shown on topographic maps of that area; but these are apparently ephemeral springs, as they were dry at the time of the investigation. No springs were found, nor were any reported, in the Jornada del Muerto.

The Sun Oil test well (10.1W.25.340), in the San Andres Limestone, will flow at a rate of about 900 gpm, but it is shut in and valved so that it does not flow constantly. An additional 200 gpm, reported from a drill-stem test, could be obtained from the Dakota Sandstone. If this well were allowed to flow for an extended period of time, the yield would probably diminish steadily.

DISCHARGE BY PUMPING FROM WELLS

Only a very few wells within the White Sands Missile Range are pumped. Those that are pumped supply water for military installations and for domestic, construction, and wildlife supplies. The Fite "PW" well (6.2.4.333) and the Cain well (11.2.16.422), which are just within the range boundary, are used by ranchers for stock and domestic supplies.

In the areas surrounding the range, many pumped wells furnish small stock and domestic supplies. Although most of these wells will yield only small to moderate amounts of water, two irrigation wells in the Bosque del Apache Wildlife Refuge yield as much as 1,600 gpm.

Most of the wells within the range that formerly were used for stock and domestic supplies are unused and capped.

In the Jornada del Muerto and vicinity, three wells are used: Murray well (8.5.32.431), pumped to supply water for Oscura Range Camp and Stallion Site Camp; Trail Canyon well (6.5.36.343), pumped with a windmill to obtain water for wildlife; and Hardin Ranch well (12.2.27.211), pumped to supply wildlife and, occasionally, range inspectors who live at the ranch and patrol the area. Murray well is equipped with a turbine pump and is pumped at a rate of about 100 gpm. Trail Canyon well reportedly yields 3 gpm by windmill pumping, and the Hardin Ranch well yields 4 gpm, also with a windmill pump.

In the northern Tularosa Basin, within the range boundaries, eight wells are used for purposes shown in the following tabulation:

Well	Location	Yield (gpm)	Use
Baca test	6.6.34.224	2	Oscura Peak supply.
Little (Robinson's)	6.6.24.424	5(?)	Wildlife.
North	6.8.33.241	8	Construction.
RC 1	7.8.8.412	38	General nonpotable supply.
RC 2	7.8.8.322	200+	Do.
Mockingbird Gap	9.5.15.143	30	Potable supply.
ORC Fire	9.7.25.134	125	Fire protection and general nonpotable supply.
Burris	10.5.17.431	4	Wildlife.

The wells at Red Canyon Range Camp (RC 1, 2) and the fire-protection well at Oscura Range Camp are used fairly frequently. Data are not available to estimate the annual withdrawal of water from these wells; however, as much as 50 acre-feet probably is withdrawn annually from them, most of which is pumped at Red Canyon Range Camp.

AQUIFERS

The principal aquifers in the area are the unconsolidated deposits of Tertiary and Quaternary age; however, the chemical quality of most of the vast quantity of water contained in these aquifers is such that the water is unusable for most purposes, including domestic and drinking supplies (table 3). The secondary aquifer is the rocks of Permian age. Most of the water in this aquifer also is of poor quality, except in two localities—the Mockingbird Gap area (8.5.32 and 9.5.15) and the area near Baca well (6.6.26 and 6.6.34). Cretaceous rocks contain small to moderate amounts of ground water along the east side of the Tularosa Basin, in the Jornada del Muerto in the southern part of the Joyita Hills, and in the vicinity of the Sun Oil test (10.1W.25.341).

TERTIARY AND QUATERNARY

BACA AND DATIL FORMATIONS AND SANTA FE GROUP

The Baca Formation, the basal part of the Datil Formation, and the Santa Fe Group contain water in the vicinities of Cerro Colorado and Little San Pasqual Mountain, where these formations crop out (pl. 1). The water body transgresses the subsurface contacts of these stratigraphic units as a single zone of saturation that is laterally and vertically continuous. Moreover, the aquifer probably is hydraulically contiguous with saturated parts of the Quaternary alluvium where the alluvium overlaps the Baca, Datil, and Santa Fe in the subsurface.

The movement of ground water in the Baca and Datil Formations is generally westward toward the river, primarily from areas of recharge on and near Cerro Colorado, to areas of discharge along the river. In its westward migration, the ground water interchanges from the Baca and Datil Formations to the Santa Fe, and thence into the alluvium of the river valley. The alluvium of the river valley seemingly is highly permeable. Permeable alluvium transmits large quantities of water to irrigation wells 5.1.17.344 and 5.1.18.434.

A relatively steep average gradient on the water table, as shown by contour lines on plate 1, suggests low to moderate permeability in the Baca and Datil in the vicinity of Cerro Colorado. The permeability of the Santa Fe is apparently slightly higher westward from Cerro Colorado. These interpretations are corroborated by tests of wells in the aquifer in the Baca and Datil and by the relatively large yields of wells that obtain part of their water from the Santa Fe in the valley (table 1).

Water is available to wells penetrating the aquifer in the Baca, Datil, and Santa Fe in the Cerro Colorado area and southwestward to the area around Little San Pasqual Mountain. Depths to water in wells in these areas range between 100 and 420 feet below the land surface. Yields range from about 3 gpm (6.2.4.144) to 20 gpm (6.2.1.444), obtained in wells penetrating only the Baca and the Datil, to as much as 1,600 gpm, in wells tapping alluvium and part of the Santa Fe Group.

CHEMICAL QUALITY OF THE WATER

Moderate to large amounts of sulfate in the ground water from the aquifer in the Baca, Datil, and Santa Fe is detrimental to the general utility of the water. Sulfate content in water from wells tapping the Baca and Datil around Cerro Colorado ranges from 218 ppm (well 6.2.4.144) to 2,090 ppm (well 6.2.1.444) (table 3). The ground water near the Fite "PW" well is best in chemical quality, and the water near Stallion 1 is the poorest. Well 6.2.25.342 possibly taps the Datil Formation, but most of the water that contains a high concentration of sulfate (3,260 ppm) probably is yielded to the well from alluvium.

The better water from the Baca and Datil is predominantly a calcium-sodium bicarbonate and sulfate type. The poorer quality water is a calcium-sodium-magnesium sulfate type.

Water from wells penetrating the Santa Fe Group east of the Rio Grande is similar in character to the water of poorer quality from the Baca and Datil Formations. Water from wells tapping the Santa Fe west of the Rio Grande has much less sulfate than does any water from the Baca and Datil and generally is potable. Gypsum, derived principally from Permian rocks, in the unconsolidated sediments of the Jornada del Muerto imparts the sulfate to the ground water. Gypsum also occurs locally in the Baca, Datil, and Santa Fe; but, unlike that in the alluvium, it is not apparent in exposures and drill cuttings.

PUMPING TESTS

Two wells that tap the aquifer in the Baca and Datil were test pumped during the study: Stallion 1 (6.2.1.444) and Fite "PW" (6.2.4.333) well. The wells were tested at rates of 20 and 12 gpm, respectively.

Maximum drawdown in Stallion 1 was nearly 16 feet during the 6-hour test; thus, the specific capacity of the well is 1.3 gpm per foot of drawdown. The graphs of test results (fig. 4) show the transmissibility of the aquifer to be about 2,800 gpd per ft (gallons per day per foot). This figure was determined from the recovery curve, on the basis of the interval between 30 and 100 minutes after pumping stopped.

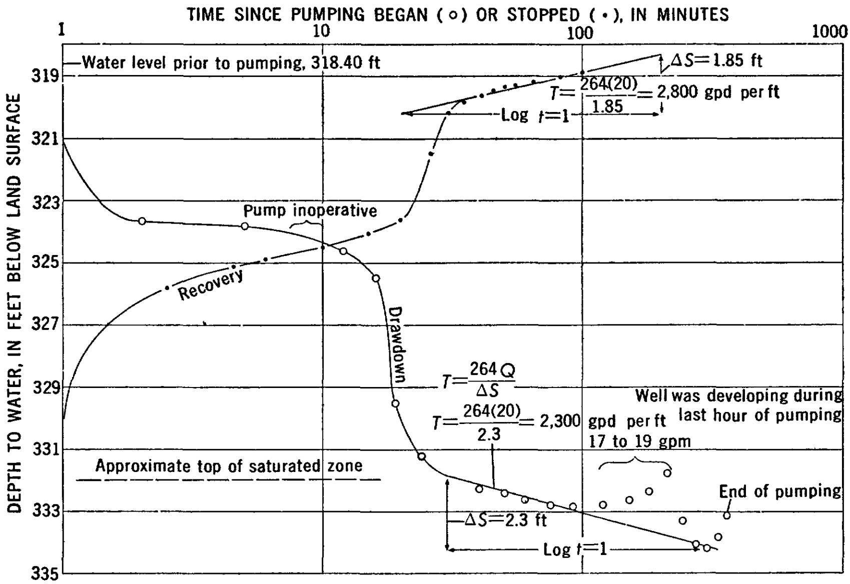

FIGURE 4.—Graph for aquifer test of Stallion 1 (6.2.1.444), April 18, 1956. Average discharge, 20 gpm; specific capacity, 1.3 gpm per foot of drawdown; altitude of land surface, 5,075 feet; pump setting for test, 552 feet below land surface.

The zone of saturation penetrated by Stallion 1, as determined largely from the log (table 5), is about 270 feet thick. Therefore, the average apparent coefficient of permeability of the aquifer in the Baca and Datil near Stallion 1 is approximately 10 gpd per square foot.

The pumping test at the Fite "PW" well, which taps Baca, Datil, and possibly some saturated Santa Fe, indicated a much lower transmissibility for the aquifer (fig. 5)—about 170 gpd per ft, computed for that part of the recovery curve representing the interval between 5 and 30 minutes after pumping stopped. As very little is known about the physical properties of this well and the subsurface geology at the well site, the permeability was not computed.

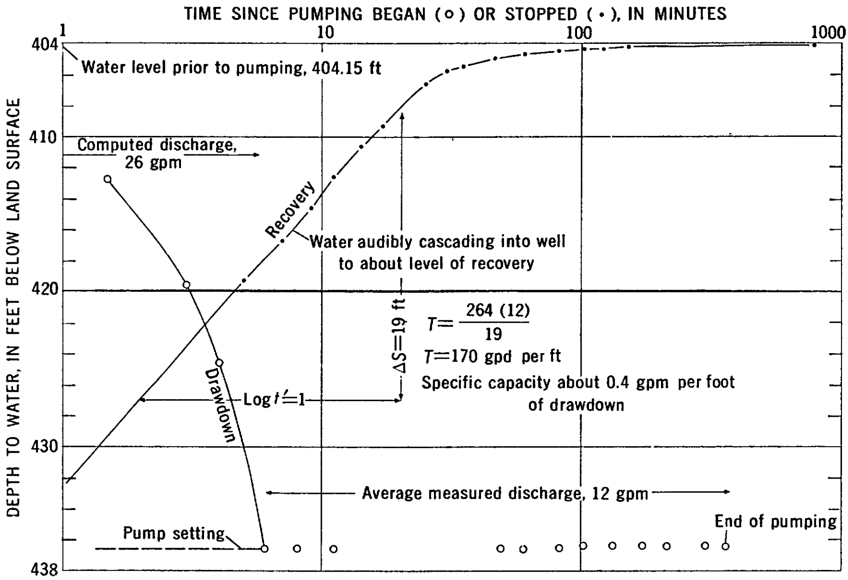

Figure 5.—Graph for aquifer test of Fite "PW" well (6.2.4.333), February 24 and 25, 1958. Altitude of land surface, 4,980 feet.

Results of the test of Fite "PW" well should be applied with a large degree of caution, because very little is known of the construction and condition of the well. Some reasonable reliability for results of the test is indicated, however, by bailing tests at Stallion 3 (6.2.4.144); this well, which is about half a mile northeast of Fite "PW," yields about 3 gpm from 300 feet of saturated material and has a calculated specific capacity no greater than 0.1 gpm per foot of drawdown. A rather close similarity of aquifer characteristics is evident from a comparison of data from Stallion 3 with data from Fite "PW." Therefore, at these well sites, the aquifer in the Baca and Datil, and perhaps a part of the Santa Fe Group, has low permeability. This low permeability is apparently due to the presence of fine materials and may reflect a great degree of cementation in the formations.

Stallion 2A (6.2.10.141), about 1 mile east of Fite "PW," was bailed at a rate of 11 gpm; the water level in the well is at such a great depth (405 ft) that 11 gpm was the maximum bailing rate possible.

At this bailing rate, no drawdown of water level occurred; thus, if the bailing rate had been greater, the well would undoubtedly have yielded a great deal more water, but the water level probably would have declined. This fact indicates that the aquifer permeability at Stallion 2A is considerably greater than that at Fite "PW." Stallion 2A was not test pumped, because the water was of poor chemical quality and information about the aquifer was deemed relatively unimportant.

No wells completed wholly in the Santa Fe Group were test pumped. Less steep gradients on the water table in areas where wells penetrate the Santa Fe, as compared to gradients in areas where wells penetrate Baca and Datil, tend to indicate comparatively higher transmissibility for the Santa Fe.

ALLUVIUM

Alluvium contains large quantites of ground water throughout most of the central parts of the Jornada del Muerto and Tularosa Basin, but nearly all this water is of poor chemical quality. Much water also occurs in alluvium in the Rio Grande Valley and, except for shallow water in marsh areas on the west side of the river, is of very good chemical quality.

Movement of ground water in the alluvium of the Jornada del Muerto is predominantly westward, although locally it may be southward, as north of Stallion Site Camp, or northward, as northwest of the San Andres Mountains. Ground water in the alluvium of the Rio Grande Valley moves generally riverward except west of the river along a short reach of valley in the north central Bosque del Apache, and in a downstream direction. The short reach in the Bosque del Apache where ground water moves anomolously westward away from the river may be an area where man-made drains influence the circulation of shallow ground water.

Ground water in the alluvium of northern Tularosa Basin moves generally southward toward Salt Creek, where ground-water discharge furnishes a small perennial flow. From Oscura Range Camp northeastward for several miles, the ground water in the alluvium moves toward the Malpais; thus, a zone of higher transmissibility is indicated beneath the basalt of the Malpais or adjacent to and northwest of the Malpais. The zone of higher transmissibility probably is in stream sediments deposited in a stream channel that is now filled with basalt or, locally, with alluvium.

Small to fairly large quantities of water are available to wells and springs from alluvium in the area. Depths to water in the alluvium in the Jornada del Muerto range from about 18 to 342 feet below the land surface (pl. 1; table 1). In the Rio Grande Valley, depths to water in alluvium range from zero to about 30 feet below the land surface. In the Tularosa Basin, depths to water in the alluvium range from zero, near Salt Creek, to approximately 330 feet below the land surface.

Although the permeability of the alluvium is of prime importance to the yield of a well, the thickness of the saturated material penetrated may also be a factor. Thus stock-watering wells that penetrate only the upper few feet of saturated alluvium generally yield less than 10 gpm, whereas wells 9.7.25.134, which reportedly penetrates slightly more than 100 feet of saturated alluvium, and 5.1.17.344, which completely penetrates the alluvium of the Rio Grande Valley, yield about 125–1,400 gpm. Nearly all the wells tapping alluvium in the Jornada del Muerto are stock-watering wells, as are most of the wells in the area studied. Therefore, little is known about the maximum yield of the full saturated thickness in the alluvium. No concerted effort was made during this study to test or evaluate the maximum yield of the alluvium, because this water is mostly of poor chemical quality and is not usable for drinking or many other purposes.

High sulfate content is the principal detriment to the general usability of water from alluvium; however, high chloride also contributes to the poor quality of water in the Tularosa Basin. The sulfate content of water in the wells sampled ranges between 274 ppm (well 9.8.36.244) and 3,160 ppm (well 9.4.4.134) (table 3). Most samples contained sulfate concentrations in excess of 1,500 ppm. Well 6.6.31.-343, Trail Canyon well, is the single source of water of good quality from alluvium in the Jornada part of the area. Water from Trail Canyon well contains 109 ppm sulfate and is a calcium-sodium bicarbonate water.

In the vicinity of Salt Creek, in the Tularosa Basin, the sulfate content in ground water apparently is slightly higher than it is elsewhere, as indicated by two analyses of base-flow water (that is, samples collected when the creek carried no storm runoff). These samples contained 4,250 and 4,590 ppm sulfate, respectively, and were very high in chloride content—7,660 and 8,440 ppm. Analyses of ground water from wells and springs near the Malpais indicated undesirably high chloride content ranging from 795 to 2,210 ppm; water from Mound Springs (10.6.23.242), northwest of the Malpais, contained 710 ppm chloride.

Water from alluvium west of the river in the Rio Grande valley is of good chemical quality except that from well 5.1W.36.234; analysis of water from this well showed 880 ppm chloride and 369 ppm sulfate. Well 5.1W.36.234 taps the aquifer in a marshy area, and brackish water having a high mineral concentration caused by evaporation from the marsh probably enters the upper part of the aquifer in the vicinity and influences the quality of the water. The water from the well is not typical of water in most of the alluvium west of the river.

The quality of ground water in alluvium east of the river in the Rio Grande Valley is not well known; however, two analyses (table 3) show that the quality probably is similar to that of water in the alluvium and other aquifers of the Jornada del Muerto. Water from well 5.1.27.332 has a higher concentration (1,420 ppm) of chloride than that typical of water in the Jornada. This analysis may reflect marsh concentration by evaporation in a shallow zone as does the analysis of water from well 5.1W.36.234.

YESO FORMATION

Small to moderate amounts of ground water occur in the Yeso Formation of Permian age in the vicinity of Red Canyon Range Camp, principally in Tps. 6 and 7 S., Rs. 8 and 9 E., and in the area north of Hansonburg Hills, in T. 5 S., R. 5 E. Near Hansonburg Hills, three stock-watering wells that yield 5 gpm or less are the only development in the aquifer. At Red Canyon Range Camp, two wells constructed for nonpotable supplies yield 38 and 200 gpm, respectively, from the Yeso; and nearby wells, mostly on reaches off the range, yield 3–15 gpm from the Yeso.

Ground water in the Yeso Formation occurs in cavernous gypsum and limestone and in thin layers of sandy siltstone. Caverns in the gypsum and limestone were apparently caused by solution along joints and fractures. Where the cavernous beds are below the water table, yields from wells tapping them are moderate to large.

Water-table contours (pl. 1) indicate that the ground-water body in the Yeso around Red Canyon Range Camp is hydraulically continuous with the ground water in the alluvium of the Tularosa Basin. A similar relationship is suggested by the altitude of the water level (pl. 1) in the three wells in the vicinity of Hansonburg Hills; there, water-table contour lines are omitted owing to insufficient data for the Yeso. Movement of the water in the Yeso Formation is generally southward into the alluvium of the Tularosa Basin from the area around Red Canyon Range Camp. Ground-water movement in the Yeso in the Hansonburg Hills is westward into the alluvium of the Jornada del Muerto. Throughout the area, however, faults in the Permian and Pennsylvanian rocks probably cause complexities in the circulation of the ground water that the available data do not show.

Depths to water in wells tapping the Yeso Formation range from 69 feet (well 7.7.9.222) to a reported 1,100 feet (well 6.9.33.143) below the land surface in the vicinity of Red Canyon Range Camp. Depths to water range from 168 to 218 feet below the land surface near Hansonburg Hills. Large variations in water levels in the vicinity of Red Canyon Range Camp are due to the great amount of relief at the well sites. The average gradient on the water table in the Yeso around Red Canyon Range Camp is about 100 feet per mile, and near Hansonburg Hills it is approximately 60 feet per mile.

CHEMICAL QUALITY OF THE WATER

Water in the Yeso Formation is a calcium sulfate type, and the high sulfate content makes the water unusable for most purposes other than watering livestock. Gypsum, which is commonly present in the saturated parts of the formation, imparts the calcium sulfate to the water. The sulfate content ranges between 678 and 2,850 ppm in the Red Canyon Range Camp area, and concentrations exceeding 1,900 ppm are prevalent. The sulfate content in water from the Yeso near Hansonburg Hills ranges from 1,930 to 2,410 ppm, as shown by analyses of water (table 3) from the three wells tapping the Yeso in that area.

PUMPING TEST

Red Canyon 2 (7.8.8.322), the second of two wells drilled at Red Canyon Range Camp to supply nonpotable water to the camp, was test pumped at approximately 200 gpm for 48 hours in November 1956. Graphs showing the results of the tests are shown in figure 6.

Water-level declines during pumping were observed in both the pumped well and Red Canyon 1 (7.8.8.412), 1,000 feet east of the pumped well. During the test, the water level in the pumped well declined 2.12 feet; that in the observation well (7.8.8.412), 1.25 feet. The specific capacity of the pumped well is approximately 100 gpm per foot of drawdown.

The graph of t/r^2 versus drawdown in observation well 7.8.8.412 offers the best means of evaluating the storage coefficient, S, as well as transmissibility, T, for the aquifer in the Yeso. As calculated from the t/r^2 graph, T is 44,750 gpd per ft, a value which is very close to the 45,500 gpd per ft calculated by using the final, relatively straight line part of the curve plotted for drawdown in the pumped well. The coefficient of storage is 2.36×10^{-3}, which is within an order of magnitude indicating water-table conditions (that is, ground water without artesian head) in the aquifer.

Changes in the slope of the drawdown curve (fig. 6) are difficult to explain without further, more closely controlled pumping tests and more detailed knowledge of the geology. These slope changes probably reflect faulting in the aquifer.

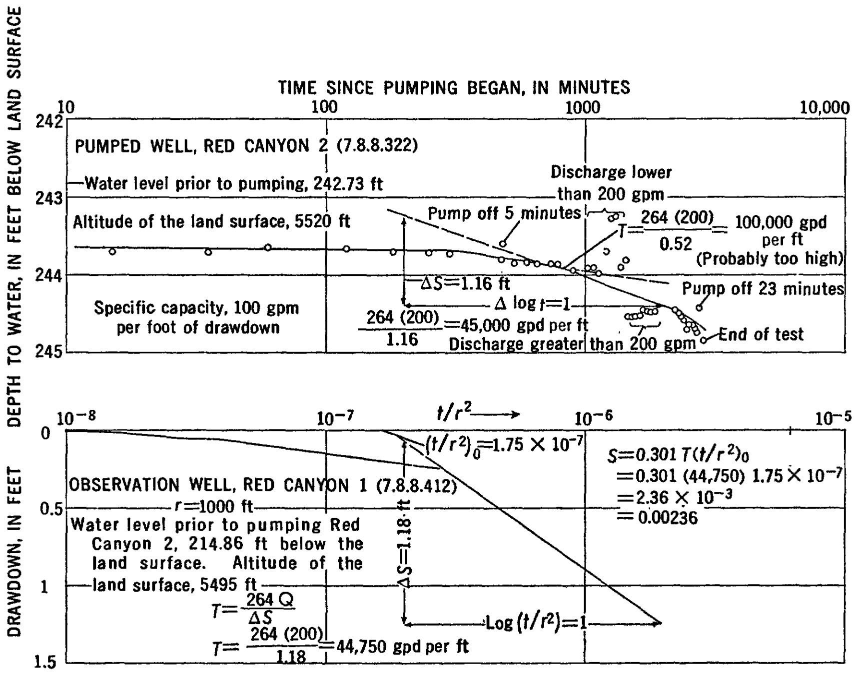

FIGURE 6.—Graphs for aquifer test Red Canyon Range Camp, November 21–23, 1956.

SAN ANDRES LIMESTONE AND GLORIETA SANDSTONE

Water occurs in the San Andres Limestone in the area of the Sun Oil test, 10.1W.25.341, where water under artesian head flows at approximately 900 gpm. A moderate amount of ground water occurs in the Glorieta Sandstone at Murray well, 8.5.32.431, where the water apparently is trapped on the downthrown side of a fault. Small amounts of water also may occur locally in the San Andres elsewhere in the area.

Movement of water in the San Andres in the vicinity of the Sun Oil test is generally westward, from recharge areas on the western slope of the San Andres Mountains to the area around the well. Possibly the water in the San Andres moves farther westward toward the Rio Grande and leaks slowly upward into overlying strata.

The saturated zone in the San Andres Limestone at the Sun Oil test is from 1,318 to 1,347 feet below the land surface. Regionally the San Andres dips westward; therefore, the water-bearing zone apparently lies at shallower depths east of the well and at greater depths west of the well. At well 11.2.16.422, about 10 miles east of the Sun Oil test, the depth to water in the San Andres is reportedly 150 feet.

In the vicinity of Murray well, the ground water in the Glorieta Sandstone percolates generally northwestward to a northeast-trending fault that impedes further northwestward movement. Thus, the reservoir in the Glorieta Sandstone consists of a fairly narrow belt along the southeast side of the fault.

The depth to water in the Glorieta along the fault trace near Murray well is 192–200 feet below the land surface. The altitude of the land surface rises to the northeast of Murray well, and about 0.5 mile from the well the depth to water probably is nearly 275 feet.

CHEMICAL QUALITY OF THE WATER

The sulfate content in water from the San Andres Limestone is high, being 1,240 and 1,660 ppm, respectively, in samples from well 11.2.16.422 (table 3) and from the Sun Oil test well. Water from well 11.2.16.422 is used for watering livestock. Water from the Sun Oil test well has a strong sulfurous odor, and cattle in the area when the well was visited rejected the water after tasting it.

Water obtained from the Glorieta Sandstone at the Murray well (8.5.32.431) is of better chemical quality than is the water from the San Andres Limestone in the vicinity of Sun Oil test. The sulfate content in water from Murray well is 298 ppm. The water is a calcium-sulfate and bicarbonate type containing about 450 ppm dissolved solids (see table 3). This water has been hauled to supply drinking and domestic water to Oscura Range Camp and Stallion Site Camp.

PUMPING TEST AND RESERVOIR PHYSICAL CHARACTERISTICS

A 36-hour pumping test was made on the Murray well August 7–10, 1956. The average discharge during pumping was 108 gpm, and maximum drawdown was 18.75 feet. The specific capacity of the well was 5 gpm per foot of drawdown.

Graphs of the results of the pumping test (fig. 7) display two slopes of curves. Transmissibility, T, calculated for the steeper sloping segment of the recovery curve (lower graph of residual drawdown plotted against time, t, since pumping began divided by time t', time since pumping stopped) is 8,400 gpd per ft., and T for the other, less steep segment is 75,000 gpd per ft.

Primarily on the basis of stratigraphic data gained from McDonald 2 (9.5.5.241) and geologic mapping in the vicinity of Murray well, the approximate capacity of the ground-water reservoir tapped by Murray well was estimated (fig. 8). This estimate is based on an average thickness of about 15 feet for the zone of saturation in the Glorieta and an arbitrarily but conservatively assumed porosity of 5 percent.

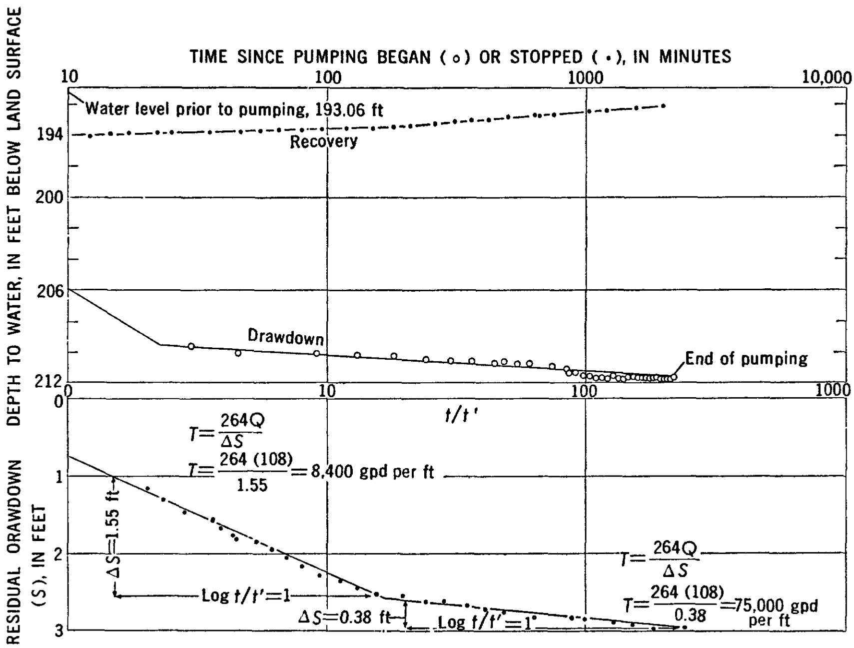

FIGURE 7.—Graphs for aquifer test of Murray well (8.5.32.431), August 7–10, 1956. Altitude of land surface, 5,115 feet; average discharge, 108 gpm; specific capacity, 5 gpm per foot of drawdown.

The table in the caption of figure 8 shows principally the expected life of the reservoir with various rates of withdrawal by pumping. Computations are based on 75 percent of the storage—that part of the total storage which is thought to be feasibly recoverable—and an estimated 25 acre-feet of recharge annually.

Recharge is a long-term consideration because of wide variations in rainfall; therefore, when anticipated withdrawal from a small reservoir approaches three times that of anticipated recharge and reservoir life is close to lengths of known drought, the recharge should be excluded from water-supply planning. Of the seven plans for utilization tabulated in the caption of figure 8, the one indicating an anticipated life of the reservoir of 9 years probably is best.

BURSUM FORMATION

Ground water occurs in joints and fractures in calcareous rocks of the Bursum Formation near the Mockingbird Gap well (9.5.15.143) and the Baca well (6.6.26.333) (table 1). At Mockingbird Gap the water is in solutionally enlarged tension cracks in folded rocks, and at Baca well, in joints, principally in conglomerate and limestone.

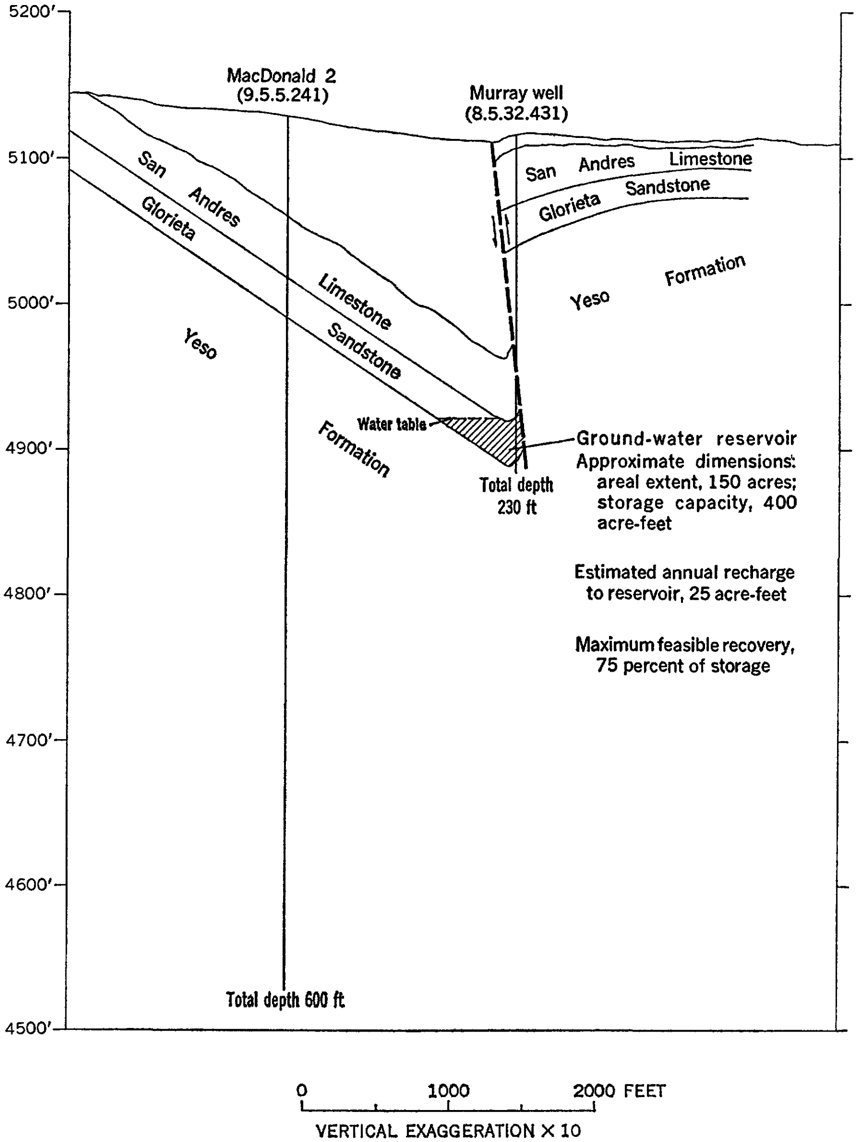

FIGURE 8.—Diagrammatic cross section through Murray well and MacDonald 2. Table below is based on data for Murray well.

Based on 100 gpm			
Hours pumped daily	Acre-feet annually	Life of reservoir (years)	Persons supplied 150 gpd
4	27	66	160
6	40	18	240
8	54	9	320
12	81	5	480
16	108	[1] 3	640
20	135	2.2	800
24	162	1.9	960

[1] Recharge will not be significant beyond an 80 acre-ft per year withdrawal rate.

The reservoir tapped by the Mockingbird Gap well is small and is subject to fairly rapid depletion as a result of pumping. The probable storage capacity of this reservoir is about 3 million gallons, based largely on approximate tabulations of the number and capacities of truck tankers hauling water from the well during a period in 1955 and 1956, when the reservoir was depleted after it had been recharged to almost full capacity from rainfall.

Recharge to the reservoir tapped by the Mockingbird Gap well is almost immediate during periods of runoff in the nearby arroyo and continues for extended periods following rainfall in the area. The water level in the well fluctuates widely from about 25 feet below the land surface, when the underground reservoir is nearly fully, to about 130 feet below the land surface (the pump setting), when storage is almost depleted. Reportedly the water level in the well has been at land surface during years of heavy rainfall in the area.

Movement of water in the Bursum at Mockingbird Gap is southward into the alluvium of the Tularosa Basin. In the vicinity of the Baca well, movement is northward beneath Brush Tank Canyon; possibly this water ultimately migrates into the Yeso Formation.

The depth to water in the Baca well and Baca test well is about 38 and 29 feet below land surface, respectively. Near Baca test well, the Bursum Formation has two separate water-bearing zones. The shallower zone is about 40–60 feet thick, and the deeper zone is about 85–125 feet thick. The water level is about the same in both water-bearing zones, but the shallower zone yields considerably more water than the deeper zone (table 1).

CHEMICAL QUALITY OF THE WATER

Water from the Bursum Formation is of good chemical quality except where it has an undesirably high nitrate content. The deeper water-bearing zone near Baca well (6.6.26.333) yields water low in nitrate, but the shallower zone yields water containing 112–181 ppm nitrate. Water from the Mockingbird Gap well (9.5.15.143) contained 23–79 ppm nitrate in nine samples collected during 1953, 1955, and 1956 (table 3).

A high nitrate content in ground water often indicates bacteriological contamination, and three bacteriological analyses of water from Baca well (6.6.26.333), which taps the shallow, high-nitrate zone, showed the presence of coliform bacteria. No bacteriological analyses were made of water from the Mockingbird Gap well as a part of this investigation, and results of such analyses that may have been done by military medical laboratories were not available; however, the absence of coliform bacteria is assumed for this water, as it was used for drinking at Oscura Range Camp.

Two bacteriological analyses of water from the deeper zone in the Bursum at the Baca test well (6.6.34.224) were made. Results of both these analyses were negative.

PUMPING TESTS

Data were obtained for a 24-hour pumping test of Mockingbird Gap well (9.5.15.143) made by missile range personnel in October 1953. The recovery data, as plotted on the lower graph of figure 9, show two straight-line segments, from which transmissibilities (T) of 2,500 and 500 gpd per ft can be calculated, and a segment for which the data are insufficient to describe a curve. The abrupt changes in the slope of the recovery curve may reflect the effects of differing permeability in the aquifer.

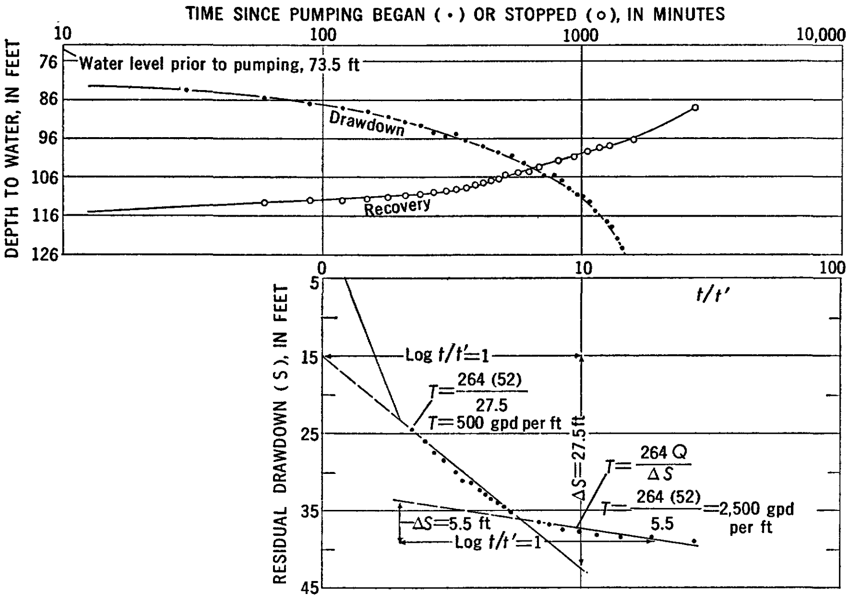

FIGURE 9.—Graphs for aquifer test of Mockingbird Gap well (9.5.15.143), October 2–5, 1953. Altitude of land surface, 5,020 feet; pumping rate, 52 gpm; specific capacity, 1 gpm per foot of drawdown.

The specific capacity of the Mockingbird Gap well was 1 gpm per foot of drawdown, as computed from drawdown near the end of pumping. All measurements of water level were determined from an air-line gage. The pumping rate, 52 gpm, exceeded the capacity of the well by about 30 gpm.

A 3-hour pumping test of Baca well (6.6.26.333) was made during the investigation, after the well had been cleaned and redeveloped by bailing. During the test a packer was set in the well at a depth of 95 feet in an attempt to prevent water from the shallower part of the aquifer from entering the well; the attempt, however, was unsuccessful, so water from the shallow zone was also included in the test.

The transmissibility calculated from the recovery curve in figure 10 was 840 gpd per ft. The specific capacity of the well was 1.5 gpm per foot of drawdown, computed at the end of 3 hours of pumping at 20 gpm.

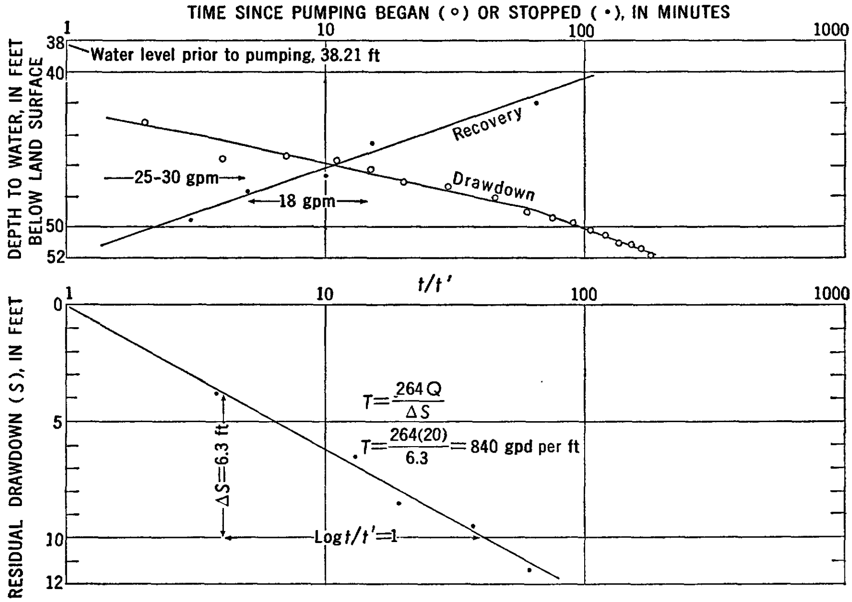

FIGURE 10.—Graphs for aquifer test of Baca well (6.6.26.333), December 10, 1955. Altitude of land surface, 6,444 feet; average pumping rate, 20 gpm.

Baca test well (6.6.34.224), 0.3 mile southwest of Baca well, was test pumped for 3 hours. During the test, inflow of water from the shallow water-bearing zone was prevented from entering the well by 54 feet of 8-inch casing set in drilling mud. After 30 minutes of pumping at a rate of 15–18 gpm, the water level had declined to the pump intake. During the remaining 2½ hours of pumping, the well yielded 3 gpm.

The transmissibility (T), calculated from the recovery curve (fig. 11), was 9 gpd per ft. The specific capacity of the well was about 0.03 gpm per foot of drawdown.

Baca test well was completed as a supply well by installing 70 feet of 8-inch surface casing, cemented in place to exclude water from the shallower water-bearing zone, and 210 feet of 6-inch well casing. An

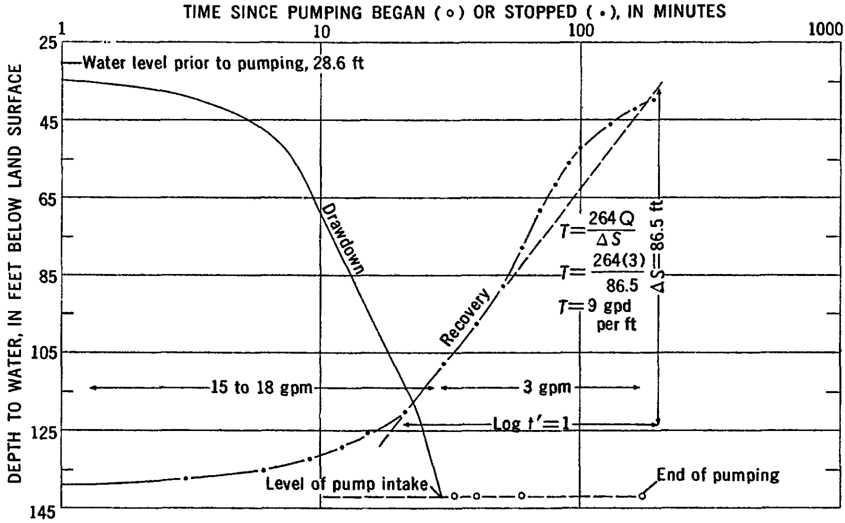

Figure 11.—Graphs for aquifer test of Baca test well (6.6.34.224), March 16, 1956. Altitude of the land surface, 6,500 feet.

acid treatment of the well to increase the yield resulted in a 65-percent decrease, to about 1 gpm.

CRETACEOUS

The Dakota Sandstone and rocks of the Mesaverde Group yield 2–40 gpm of water to wells and springs in the Joyita Hills and in the vicinity of the village of Oscura along the east side of the Tularosa Basin. The Dakota reportedly will yield 500 gpm to the JAC irrigation well (10.2.3.222a) and 200 gpm to the Sun Oil test (10.1W.25.341).

The Mancos Shale of Late Cretaceous age yields small quantities of water to Willow Spring (8.9.29.113) (table 2) and to two wells (10.8.1.211 and 10.8.3.424) (table 1) south of Oscura. The exceedingly small yields probably come from partings and joints in shale. Water from Willow Spring contains 1,140 ppm sulfate and 470 ppm chloride.

Measurements of the altitude of the piezometric surface are insufficient to allow determination of the direction of water movement in Cretaceous rocks except along the east side of the Tularosa Basin, where the water moves generally westward (see contour lines, pl. 1). Movement of water in the Joyita Hills probably also is westward, along faults.

Depths to water-bearing zones in the Cretaceous rocks of the Tularosa Basin range from zero to about 80 feet, and in the Joyita Hills, from 44 to 128 feet. The water-bearing zone in the JAC irrigation well reportedly is at a depth of more than 300 feet, and that in the Dakota Sandstone at Sun Oil test, at a depth of 1,002–1,008 feet. The hydraulic pressure in the Dakota at Sun Oil test was great enough to cause a flow of 200 gpm during a drill-stem test.

Data on chemical quality of the water from Cretaceous rocks in the Tularosa Basin and Joyita Hills indicate that the quality is generally poor because of high sulfate content. In the Joyita Hills the sulfate content ranges from 397 to 1,170 ppm, and in eastern Tularosa Basin, from 434 to 1,340 ppm. Data were not available on the quality of water from the Dakota at Sun Oil test and from JAC irrigation wells.

MINOR AQUIFERS

Rocks of Pennsylvanian age locally yield small amounts of water, principally from joints and fractures, to springs and shallow wells in the mountainous parts of their outcrop area. These widely scattered occurrences of water are large enough to supply only a small number of wild animals, and the aquifers at these places are not likely to be potential sources of larger amounts of water.

In general the water in rocks of Pennsylvanian age is of good chemical quality, although it generally contains abundant calcium bicarbonate and therefore is hard.

The Abo Formation of Permian age yields small amounts of water to springs and wells in the Red Canyon area in T. 7 S., R. 7. E. The Abo also yields small amounts of water to wells in and near its outcrop area in the San Andres Mountains. The water in the Abo seems to occur in joints and fractures in calcareous siltstone and sandstone.

Water from the Abo Formation at well 12.2.27.211, at Hardin Ranch in the San Andres Mountains, is of fairly good chemical quality: it contains 198 ppm sulfate and is a calcium bicarbonate and sulfate type (table 3). No data on quality of water from other wells tapping the Abo in the San Andres Mountains are available.

Water from the Abo in and near Red Canyon is poor in chemical quality because of moderately high sulfate content. The water analyzed from Seep Spring (7.7.6.124) was diluted by water of good quality from a surface reservoir about 50 yards upstream from the spring. When the surface reservoir is empty and is not contributing the largest part of the water discharged at the spring, the sulfate content of water from Seep Spring is probably about 1,100–1,880 ppm, similar to that of water from well 7.7.9.222 and from Red Canyon Spring (pl. 1; table 3).

Triassic rocks yield about 2 gpm of water at Bull Gap Spring (9.8.23.423), seemingly from joints and cracks in shale, sandstone, and very thin beds of limestone. Water from Bull Gap Spring is of poor chemical quality because of high sulfate content (2,680 ppm) and high chloride (830 ppm) content. (See table 4.)

SUMMARY OF THE AVAILABILITY OF GROUND WATER

Within the northern part of the White Sands Missile Range, small quantities of potable ground water can be obtained at Mockingbird Gap well (9.5.15.143), Trail Canyon well (6.5.36.343), Hardin Ranch well (12.2.27.211), two wells in the northwest corner of the range, Baca test well (6.6.34.224), and several very small springs that issue from Pennsylvanian rocks, principally in the Sierra Oscura. A moderate amount of nearly potable water (298 ppm sulfate) is available at Murray well (8.5.32.431), which is used as a source of supply for Oscura Range Camp and Stallion Site Camp.

A large quantity of potable ground water can be obtained from alluvium west of the river in the Rio Grande Valley, but this area is not within the boundaries of White Sands Missile Range. Other areas studied that are outside the boundaries of the range have no sources of potable water, although well 9.8.36.244, at the village of Oscura, yields water of nearly potable quality (274 ppm sulfate and 148 ppm chloride). The occurrence of water of better quality at Oscura evidently is characteristic of only a small area, as nearby wells yield water having the considerably higher sulfate and chloride contents more typical of ground water in the Tularosa Basin. The source of the water of better quality at Oscura is in Cretaceous rocks, as shown by analyses of water from two old railroad wells (Meinzer and Hare, 1915, p. 276). These wells were not located during the present investigation and probably have been destroyed.

Moderate to large quantities of nonpotable water are available to wells and springs from unconsolidated rocks of Tertiary and Quaternary age, the Yeso Formation and the San Andres Limestone of Permian age, and the Dakota Sandstone and Mesaverde Group of Cretaceous age. The most striking evidence of the availability of large quantities of water is at Malpais Spring (12.7.8.422), where the alluvium yields about 1,500 gpm, and at the Sun Oil test well (10.1W.25.341), which flows about 900 gpm from the San Andres Limestone and potentially will yield an additional 200 gpm by flow from the Dakota Sandstone. O. E. Meinzer (Meinzer and Hare, 1915, p. 300) visited Malpais Spring in 1910 and estimated a yield of 2,000 gpm. Moderate yields of nonpotable water are demonstrated by such wells as Red Canyon 2 (7.8.8.322), which taps the Yeso Formation and was tested at 200 gpm; well 9.7.25.134 (at Oscura Range Camp), which yields about 125 gpm; and Stallion 1 (6.2.1.444), which taps the Baca and Datil Formations and is capable of yielding more than 20 gpm.

Moderate to large supplies of nonpotable ground water are available in more than half the area studied. Logically this vast resource should be used wherever feasible to alleviate water shortages. Possibly this water could be used at most military installations in dual domestic supply systems wherein raw nonpotable water is used for the greater part of the supply, such as sanitation and most other purposes except drinking and culinary needs. The relatively small amount of water needed for drinking and cooking could be supplied by partly demineralizing some of the nonpotable water by one of several methods developed in recent years, or it could be hauled from the few known sources of potable or nearly potable water. This investigation indicates conclusively that potable ground water is not sufficiently plentiful to warrant attempting development of other than very small supplies in a few localities.

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BASIC DATA

TABLE 1.—*Records of wells in the northern part of the White Sands Missile Range and vicinity, New Mexico*

Location number: See text and fig. 2 for explanation of well-numbering system.

Field designation: If known, the name of the watering place or ranch installation as used by individual ranchers is used. An "M" following the field designation indicates that the name was taken from a topographic map. An "A" following the field designation indicates that the name was arbitrarily chosen by the author. Names in parentheses are those used by military personnel.

Altitude: Altitude of land surface at the wells has been extrapolated from topographic maps.

Depth: Measured with steel tape, except those followed by "R," which were reported.

Diameter: The inside diameter of the casing, or open hole, to nearest inch. Dug wells may have two dimensions (36×72), which indicate a rectangularly shaped hole.

Geologic source: Same as geologic map symbols.

Qal, Quaternary alluvium
Qb, Quaternary basalt
Ts, Santa Fe Group
Td, Datil Formation
Tb, Baca Formation
Kmv, Mesaverde Group
Km, Mancos Shale
Kd, Dakota Sandstone
Ћd, Dockum Group
Psg, San Andres Limestone and Glorieta Sandstone
Py, Yeso Formation
Pa, Abo Formation
Pb, Bursum Formation
Pm, Madera Limestone
(F), Fault fractures

Water Level: Measured with steel tape unless followed by "R", which indicates water level is reported.

Yield: R, reported; E, estimated. Other values were measured.

Type of pump and power: If two pumping units are shown for the same well, the first is the main unit and the second is the auxiliary unit.

J, Jack pump
T, Turbine
W, Windmill
N, None

Power: e, electrical; ic, internal combustion (gasoline or butane); n, none

Note: Most of the windmills and other pumping plants, especially those on the military reservation, are in various stages of disrepair or dismantlement.

Location No.	Owner	Field designation	Year completed	Altitude (ft)	Dimensions: Depth (ft)	Dimensions: Diameter (in.)	Geologic source	Water level: Depth below land surface (ft)	Water level: Date measured	Yield (gpm)	Type of pump and power	Chemical analyses in table 3	Remarks
4.2.23.344	F. Fernandez	Gonzales 1		5,170	90R	6	Ћd (F)	17.5	2-10-55	2.5R	W	×	Nearby well reportedly yields 13 gpm.
23.432	do			5,150	18	6	Ћd (F)	16.1	2-10-55		N		Nearby hole reportedly dry to 500 feet.
34.411	do	Anaya		5,180	25R	60	Qal (F)	13.2	2-10-55	14R	W		Constructed prior to 1938.
5.1W.26.213	U.S. Dept. Interior, F.W.S.	Well 1, unit D		4,775	230	6	Ts				W		
36.234	do	Well 2, unit D		4,520			Qal			2E	W	×	
5.1.17.344	do	Irrigation 1	1956	4,528	149R	14	Qal, Ts	15R		1,400	Te	×	
18.431	do	Irrigation 2	1956	4,530	125R	14	Qal, Ts	8R		1,600	Te	×	
18.434	do	C.C.C. camp		4,545		6	Qal	23.6	2-5-58	1	W	×	
27.332	do	Hacksaw		4,550	30R		Qal				W	×	
36.442	D. Fite	New	1951(?)	4,804	323	6	Ts	284.9	2-8-55		W		
5.2.2.133	F. Fernandez	Headquarters		5,030	50R	84	Kd (F)	44.4	2-10-55	40R	W	×	Domestic and stock.

10.223	L. Muncy	F. Padilla (M).		5,025		6	Km (F)	53.8	2-10-55		W	×	Unused.
16.323	D. Fite	Tokay	1940	5,076	145	6	Ts	127.8	2- 8-55	5E	W	×	Domestic and stock.
16.314	do	Jack pump (A).	1913	5,074	100R	8					Jn		Dug, cased, and back-filled, unused.
17.424	do	Swimming pool.	1900	5,049	290R	6	Kmv	86.8	2- 7-55	75	N	×	Cleaned out in 1957.
22.134	do		1930	5,195	440R		Kmv	Dry R			N		Reportedly dry after atomic test in 1945.
5.3. 9.244	U.S. Dept. Agriculture, S.C.S.			5,010		6	Qal	275.0	2-11-55	5E	W	×	
13.244	J. Muncy	Miera		4,945	100R	6	Qal	30.3	2-11-55	7E	W	×	
14.111	L. Muncy	Headquarters		4,980	237	6	Qal	171.6	2-10-55	5R	W		
17.111	J. Muncy	do	1934	4,976	337R	6	Td	243.8	2-11-55	3E	W	×	
24.213	L. Padilla			4,942	40	6	Qal	29.6	2-11-55		W		
25.121	L. Muncy	Romero	1947	4,928	140R	6	Qal	63.4	2-11-55	2E	W	×	
5.3.28.323	H. Bursum	Bursum (M)		4,980	180R	6	Td	155.0	2- 2-55	5E	W	×	
5.4.16.133	do	Pit Quarry (A).		4,970	53	6	Qal	37.9	2-15-55		N	×	Drilled for highway construction. Sample bailed.
17.442	do	Max		4,960	38	48	Qal	36.6	2-15-55		N		
18.243	L. Muncy	Nep Chavez		4,955	38	6	Qal	32.0	2-15-55	1R	W		
18.333	L. Padilla		1916	4,950	47R	48	Qal	37R	2-11-55	5R	W		
20.444	H. Bursum	Stockyard	1948	4,977	160R	6	Qal	84.1	2-15-55		W		
5.5.14.444	do	Sullivan	1947	5,515	300	5	Py	217.8	3- 7-55	4R	W	×	With 7-inch surface casing.
19.233	do	Hansonburg		5,200	190	6	Py	172.8	2-15-55	3E	W	×	Northernmost of two wells 50 feet apart.
32.444	do	South		5,390	180	6	Py	167.9	2-16-55	3E	W	×	
6.1W.12.233	U.S. Dept. Interior, F. W. S.	Headquarters		4,525			Qal	63R			W, Je	×	Two wells used for domestic supply.
12.431	do			4,510		36	Qal	2.5	2- 6-58	2E	W	×	
15.124	do	Burro		4,620	200R	5	Ts	115.9	2- 6-58		W	×	
36.412	do	Val Verde	1946	4,515	45R		Qal	22.5	6-10-56		W		
6.1.16.231	do	Antelope	1951	4,545	40R		Qal	26.5	6-10-56		W		
17.133	do	Jail	1951	4,502	10R	36	Qal	3.5	2-13-58		W	×	
36.223	D. Fite	Mike	1938	4,825	300R	6	Ts or Py	256.4	2- 8-55	2	W	×	
6.2. 1.444	White Sands Missile Range.	Stallion 1	1956	5,075	600	7	Tb, Td	317.7	4-17-56	20	N	×	Test hole, cased and capped.
4.144	do	Stallion 3	1956	5,065	720	8	Ts, Td, Tb	420.0	9- 7-56	3	N	×	Test hole, plugged and abandoned.
4.333	D. Fite	PW	1948	4,980	550R	6	Ts, Td, Tb	404.3	2- 8-55	4E	W	×	
6.2.10.141	White Sands Missile Range.	Stallion 2A	1956	5,050	600	8	Tb	405.0	5-31-56	11	N	×	Test hole, plugged and abandoned.
25.342	H. Bursum	Apodaca		4,775	140	6	Qal or Td	100.7	2- 2-55		W	×	Dry well 40 feet deep nearby.
28.413	D. Fite	Lower place	1930	4,775	320R	6	Ts, Td	258.7	2- 8-55	3E	W	×	
6.3.11.141	H. Bursum	(Assembly area).	1947	4,855	200	6	Qal	141.4	2- 3-55		W		
17.111	do	Harriet	1951	4,910	220	6	Td	183.0	2- 2-55	6R	W, Jn	×	

Table 1.—*Records of wells in the northern part of the White Sands Missile Range and vicinity, New Mexico*—Continued

Location No.	Owner	Field designation	Year completed	Altitude (ft)	Dimensions: Depth (ft)	Dimensions: Diameter (in.)	Geologic source	Water level: Depth below land surface (ft)	Water level: Date measured	Yield (gpm)	Type of pump and power	Chemical analyses in table 3	Remarks
20.233	H. Bursum	Field		4,797	160R	6 And 24	Td				W		Partly dug, partly drilled.
22.122	do	Viuda		4,803	35		Qal				N		Abandoned and partly filled.
25.122	C. Green	H. Long (M)		4,800	137	6	Qal	116.4	2- 3-55		W		
26.121	do	G. Green (M)		4,790	77	48	Qal	Dry			W		
6.4.10.131	H. Bursum	Sand		4,930	300R		Qal	110.0	2-23-55	10R	W		
6.5.36.343	do	Trail Canyon		6,020	330R	8	Qal (F)	300R	5- 7-55	3R	W	X	
6.6. 9.334	do	Garden		6,050	31	72X48	Pm	9.0	3- 3-55		N	X	Dug well, cribbed with juniper.
16.411	do	Ozane		6,175	18	60X36	Pm	14.55	3-17-55		N	X	Dug well.
24.424	do	Little (Robinson's).	1952	6,300	315R	6	Py or Pa	301.7	3- 8-55		W	X	
26.333	White Sands Missile Range.	A.F. Baca (A).	1952	6,444	205	6	Pb	39.5	3- 8-55	20	N	X	Drilled under contract by U.S. Air Force.
34.224	do	Baca test (A)	1956	6,500	210	8-6	Pb	29.2	2-27-56	2	Jic	X	Drilled under contract by U.S. Army.
6.8.33.241	L. Nolda	(North)		5,450	660R	6	Py	630R			W	X	Used occasionally for construction water.
6.9. 7.232	Lovelace Bros.	Crater		5,640			Py	450R			W	X	
6.9.19.441	Lovelace Bros.			5,480		6	Py	550R			W	X	
33.143	do	Oil test		5,815			Py	1,100R			Jic	X	
7.1. 2.334	N. Bruton	North	1951	4,790	247	6	Ts	201.2	2- 9-55	8	Je	X	
14.341	do	Olguien		4,791	215	6	Ts	202.9	2- 9-55		N		
27.214	do	Headquarters	1930	4,808	256R	6	Ts	226R		8R	Je	X	
7.2.16.133	M. Harriet	Tecolote		4,805		7	Qal or Ts	230.0	7- 4-56	4E	W	X	
26.322	do	Granjean		4,750	180	6	Qal	174.0	2-18-55		Jn		Well with windmill 20 feet north.
7.3. 4.231	C. Green	Green (M)		4,777	160	6	Qal	143.67	2-23-56	4	W	X	
22.314	N. Bruton	Headquarters		4,727		6	Qal	115.8	2-23-56		W		Formerly Headquarters ranch.
36.333	M. Harriet	Chamise		4,689	94	6	Qal	90.4	2-23-56		N	X	Sample bailed.
7.4.23.312	A. and L. Story	Chas. Story (M).		4,772	130		Qal	11.9	5-20-55	5E	W	X	
28.334	C. Green	Littleton		4,696	80	6	Qal	45.6	5-23-55	10E	W		Tested with turbine in 1956.

33.434	G. MacDonald	Burnt		4,749		6	Qal			5E	W	×	
7.7. 9.222	H. Bursum	Hill		5,775		6	Py	68.5	5-19-55		W	×	
18.444	W. Withers			5,760	160	5	Pb	136.3	3-10-55		N	×	Well never used, reportedly very weak. Sample bailed.
7.8. 8.322	Fort Bliss	Red Canyon 2	1956	5,520	710	10	Py	242.8	11-21-56	200+	Te	×	Non-potable supply at Red Canyon Range Camp.
8.412	do	Red Canyon 1	1956	5,495	702	10	Py	214.9	11-21-56	38R	Te	×	Do.
14.323	M. Rentfrow	North	1915	5,160	700R	6	Py	405.0	1-12-57	15R	Jic	×	
22.223	do	Home	1956	5,140	630R	6	Py	103.8	1-12-57	3R	Jic	×	Cased to 540 Feet.
7.8.29.144	M. Rentfrow	Stevens Tank		5,245	370	6	Py	225.3	6-22-55		N	×	
34.322	do	South	1956	4,930	675R	6	Py	251.6	1-12-57	5E	Jic	×	Cased to 565 feet.
7.9. 8.344	Lovelace Bros	Transmalpais (A).		5,505	300	6	Py	288.4	1- 8-57	3E	W		Field specific conductance 2,900 micromhos at 25° C.
8.1W.23.224	Diamond A. Ranch.	North		4,743	290R	6	Ts	231.3	8-14-56		W		
33.341	do	Antelope		4,772	340R	6	Ts	275.9	8-14-56	5E	W		Pumping when measured.
8.1.16.441	M. Harriet	Malpais	1938	4,740	230	6	Qal	189.8	2- 9-55		W		
25.421	do	Headquarters		4,740	225R	6	Ts	163R			W		
8.2.17.224	do	Fite (M)		4,748	183	6	Qal	169.4	7-13-56	3E	W	×	
23.313	do	Von Cain		4,730	165		Qal	151.0	2-18-55		W		
25.241	do	Newberry	1948	4,750	220R	7	Qal	175.0	7- 4-56		W		
8.3. 9.434	do	Thompson		4,700	185R	6	Qal	104.8	7- 4-56		Jn		Well with windmill 50 feet north.
8.4.10.334	G. Foster	East (A)		4,720		6	Qal	91.7	7-12-56	6	W	×	
21.123	do	Tank (A)		4,678	75	6	Qal	45.8	5-23-55		W		
8.5. 5.311	G. MacDonald	Headquarters		5,035	360	6	Qal	342.5	5- 9-55		W		
32.431	do	Murray	1903	5,115	230	6	Psg	192.3	5-20-55	100	Tic	×	Supplies water to Oscura Range and Stallion Site Camps.
8.6.22.424	T. Spencer	Palomas Moonshine.		5,550	17	48×24	Pm	14.4	3-31-55		W	×	
8.7. 8.124	P. Withers	J. G. Tank		5,200	155	6	Py	133.5	3-30-55	3E	W	×	
8.9. 9.243	M. Crockett			5,055			Py			3	W	×	
29.414	G. MacDonald	Malpais (A)	1949	4,960	50R	6	Qal	26R		4E	W	×	Formerly used for domestic supply.
8.9.32.222	E. Sprole			5,000	54	60×60	Qal	53.0	1-10-57	2E	W		Field specific conductance 4,000 micromhos at 25°C.
34.333	B. Nickels	Cattle Guard		5,110	75R	6	Qal	36.3	9-20-55	3E	W	×	
9.1W.23.311	Diamond A. Ranch.	Hackberry		4,790	300	6	Ts	272.4	8-14-56		W	×	
9.1.18.341	do	Crater		4,855	355	5	Ts	326.1	8-14-56		W		
9.2.25.311	M. Harriet	Marcial (A)		4,675	45	72×72	Qal	36.8	2-11-57		N		Water dripping from sides of hole. Dug well.
34.211	G. Baca	Baca (M)		4,680	180	6	Qal	48.9	7-13-56		W		

TABLE 1.—*Records of wells in the northern part of the White Sands Missile Range and vicinity, New Mexico*—Continued

Location No.	Owner	Field designation	Year completed	Altitude (ft)	Dimensions: Depth (ft)	Dimensions: Diameter (in.)	Geologic source	Water level: Depth below land surface (ft)	Water level: Date measured	Yield (gpm)	Type of pump and power	Chemical analyses in table 3	Remarks
36.413	M. Harriet	Anderson Tank.		4,673	103	6	Qal	47.2	7-13-56		W		
9.3.28.324	do	Old Well (M)		4,696		6	Qal	39.3	6-29-55		W		
34.443	W. Martin	Headquarters		4,748		8	Qal	54.6	7-10-56		W		
9.4. 4.134	R. MacDonald	Guard Camp		4,700	360R	14	Qal			50R	N	×	Filled with rocks above water level. Well with windmill 20 feet west.
18.344	M. Harriet	Mike Arrieta		4,674		72	Qal	18.4	6- 2-55		N		Drilled well with windmill 50 feet north.
9.5.15.143	R. MacDonald	Mockingbird Gap.		5,020	160R		Pb	69.2	8-31-53	30	Te	×	Used intermittently to supply water for Oscura Range Camp.
34.313	do	New (A)	1951	5,125	175	5	Psg	138.6	4-11-55		N	×	Well never used. Sample bailed.
9.6. 2.442	J. Dillard	Scholle		5,055	24	48×48	Pm	13.8	3-31-55		W	×	
24.221	T. Spencer	Old Mills		4,795	45	6	Pm	22.5	5-10-55		W	×	
9.7. 9.411	do	New Mills		4,705	205	4	Qal or Psg	198.7	5- 9-55		W	×	
25.134	Holloman AFB	ORC Fire (A)	1949	4,518	200R	10	Qal	90R		125E	Te	×	
25.143	T. Spencer	ORC Windmill (A).		4,515		5	Qal	72.6	5-19-55		W		
9.8. 5.421	G. MacDonald	Chihuahua		4,635	335R	6	Qal	330R		12R	W, Jic	×	Jack pump; small-scale irrigation.
15.233	P. Withers	New	1954	4,680	275R	6	Qal or Py	270R		10R	W		Drillers log in USGS file.
20.434	do	Malpais (A)		4,580	150R	8	Qal or Py			40R	N		Two other wells with windmills nearby.
22.311	do	Home (A)	1949	4,675	265R	6	Qal or Py	165R		12R	W, Je	×	
31.343	do	Roberson		4,515		6	Qal	116.3	5-31-55	4	W	×	Measured while pumping.
35.141	Rube MacDonald	Windmill (A)		4,885	60R	6	Qal	43.5	6- 1-55		W	×	
35.142	do	Irrigation (A)		4,900	90R		Qal	46R		350E	Tic	×	Used to irrigate about 40 acres.

9.9. 36.244	L. Drake	Atomic Bar	1955	5,025	135R	6	Qal	48R	6-1-55	50R	Te	X	
7.312	B. Nickels	Rim Rock		4,950	259R		Kd	79.2	8-25-55	2R	W	X	
29.424	do	McKim (A)	1953	5,325	96R	6	Kmv or Qal	62.7	9-20-55	4E	W	X	
31.233	do	School (A)	1954	5,085	95R	6	Qal and Kmv (?)	43.8	8-23-55	2E	W	X	
10.1W.25.341	Diamond A Ranch	Sun Oil test	1952	4,800	6,053R (plugged back to 1,400R)		Psg	Flows	7-8-55	900E	N	X	Hydraulic head approximately 165 feet above land surface. Equipped with shutoff valve on casing head.
10.2. 3.222	M. Harriet	JAC Ranch		4,685	100	6	Qal	52.0	7-8-55		W		
3.222a	do	JAC Irrigation.	1951(?)	4,685	400	12-8	Kd(?)			500R	Tn		Tested but never used.
4.313	G. Baca	Chavez		4,680	125	6	Qal	55.1	7-13-56	3	W	X	
10.4.31.242	W. Martin			5,150	97	6	Pa(F)	26.0	7-10-56		W		
10.5.17.431	B. Burris	Headquaters		4,840	50	6	Qal	37.4	5-31-55	4	W	X	Unequipped wells nearby.
10.6.28.434	T. Spencer	Hayfield		4,272		6	Qal	40.2	8-7-56		W		
10.7.15.334	do	Mayes Ranch		4,397	80	6	Qal	62.0	5-26-55		W		
34.131	New Mexico Tax Commission.	Coon		4,330	30	36	Qal, Qb	23.1	5-26-55		W	X	Sample bailed.
10.8. 1.211	A. Helm	Helm Oscura (A).		5,000	160R	6	Km	114.9	1-11-57		W		Field specific conductance 2,700 micromhos at 25° C.
3.424	do	Helm Sisters (A).		4,850	140	5	Km	122.3	7-20-55		W		
18.131	do	Lathan		4,455		72	Qal	63.1	5-26-55		W	X	
30.233	do	Gilliland (M)		4,400	120	6	Qal or Py	68.6	5-26-55		W		
10.9. 5.123	B. Nickels	New	1954	5,180	90R	6	Qal or Kmv	51.2	9-20-55	4	W	X	
8.121	Mr. Harrold	Plastered Tank (A)		5,198		6	Qal or Kmv				W	X	
11.2.16.422	D. Cain	Headquarters		5,465		6	Psg	150R			W	X	
11.3.12.211	D. Gilliland	Headquarters		5,285		6	Psg	71.8	7-8-55		W		
36.132	J. Wood			5,805	100	6	Pa or Qal	86.9	7-11-56		W		
11.4.27.241	D. Gilliland	Grapevine (M)		5,650	125	5	Pm	42.0	7-11-56		W, Jn		Gear jack with gasoline motor nearby.
29.141	J. Wood	Smith		5,600		36	Pa	2.0	7-25-56		N		Water siphoned down-canyon to water game.
11.5. 8.241	H. Wood	Brown		5,130	24	36×36	Pa	21.5	7-3-56		W		
19.121	do	Thurgood		5,465	62	7	Pm	35.2	7-3-56		W		
11.5.34.313	L. Greer	Juniper		5,650	16	72×48	Qal	15.1	5-25-55		W		Dug well with windmill nearby.
11.6. 3.443	B. Burris	North		4,255	65	6	Qal	52.7	5-27-55		W		
28.343	do	South		4,175	41	60×24	Qal	39.9	5-27-55		W		

TABLE 1.—*Records of wells in the northern part of the White Sands Missile Range and vicinity, New Mexico*—Continued

Location No.	Owner	Field designation	Year completed	Altitude (ft)	Dimensions: Depth (ft)	Dimensions: Diameter (in.)	Geologic source	Water level: Depth below land surface (ft)	Water level: Date measured	Yield (gpm)	Type of pump and power	Chemical analyses in table 3	Remarks
12.2.13.213	J. Wood			6,190		6	Py	72.8	7- 5-56		W		Three wells nearby, one with windmill.
27.211	C. Hardin	Headquarters		6,430		6	Pa	204.1	7- 5-56	4	W	×	Unequipped well nearby.
28.141	L. Miller			6,390	460	9	Pa	Dry	7-25-56		Jic		
35.434	do	Red House		6,300			Pb			1E	W	×	
12.3.11.231	J. Wood			6,130	120	8	Pa	116.7	8-15-56		W		
36.344	P. Potter	Henderson (M).		5,700	35		Qal (F)	21.8	8- 7-56		W		
12.5.25.321	D. Cain	Jackson (M)		4,117	110	7	Qal	91.4	8- 1-56		Jn		

TABLE 2.—*Records of springs in the northern part of the White Sands Missile Range and vicinity, New Mexico*

Location number: See text and fig. 2 for explanation of numbering system.
Altitude: Altitude of land surface at the springs has been extrapolated from topographic maps.
Geologic source: Same as geologic map symbols.

Qal, Quaternary alluvium
Qb, Quaternary basalt
Kmv, Mesaverde Formation
Km, Mancos Shale

Trd, Dockum Group
Pa, Abo Formation
P, Madera Limestone

Location No.	Owner	Field designation	Date observed	Altitude (ft)	Type of rock	Geologic source	Estimated yield (gpm)	Chemical analysis in table 4	Remarks
6.6.20.412	H. Bursum	Deer	3- 4-55	6,550	Limestone over diorite	Pm	3	×	Gallery spring.
20.441	do	Rabbit	3- 4-55	6,560	do	Pm	3	×	Pool spring.
31.223	do	Council	3- 2-55	7,475	Limestone over shale	Pm	3	×	Gallery spring.
7.6. 9.143	do	Yates	3- 4-55	6,800	do	Pm	1	×	Do.
29.414	A. Helm	Dripping	3-30-55	6,200	Limestone	Pm	2	×	Do.
7.7. 6.124	H. Bursum	Seep	3-17-55	6,100	Red-bed sandstone and siltstone.	Pa	1	×	
15.421	L. Nolda	Red Canyon	5-19-55	5,550	Red-bed sandstone	Pa	3	×	Gallery spring.
8.6. 9.441	J. Dillard	Del Cuerto	4- 1-55	5,850	Arkosic limestone	Pm	1		Do.
8.9.29.113	G. MacDonald	Lower Willow	5-18-55	4,875	Alluvium	Km, Qal	5	×	
9.8.23.423	P. Withers	Bull Gap	11- 3-55	4,825	Sandstone and limestone	Trd	2	×	
34.143	T. Spencer	Phillips	5-31-55	4,750	Sandstone	Kd	3	×	
9.9. 9.222	B. Nickels	Root	8-23-55	5,200	do	Kmv	5	×	Gallery spring.
10.343	do	Jake's	8-23-55	5,290	Sandstone and alluvium	Kmv	30	×	
32.211	C. Crews	Milagro	8-18-55	5,265	Sandstone over sill	Kmv	20	×	Unused.
10.6.23.242	T. Spencer	Mound	6- 2-55	4,350	Gypseous alluvium	Qal	3	×	
12.4. 2.121	R. Tucker	Grapevine	7-11-55	6,060	Limestone	Pm	1		
12.7. 8.422	U.S. Dept. Interior	Malpais	5-25-55	4,123	Basalt and alluvium	Qb, Qal	1,500	×	

TABLE 3.—*Analyses of water from selected wells in the northern*

[Analyses by U.S. Geol. Survey.

Location No.	Owner	Field designation	Date of collection	Depth of well	Temperature (° F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)
4.2.23.344	F. Fernandez	Gonzales 1	2-10-55	90R		22		101
5.1W.36.234	U.S. Dept. Interior, F.W.S.	Well 2, unit D	2- 5-58		62			
5.1.17.344	do	Irrigation 1	2- 5-58	149R	62	31		52
18.431	do	C.C.C. Camp	2- 5-58		65			
18.434	do	Irrigation 2	2- 5-58	125R	65	39		66
27.332	do	Hacksaw	2- 6-58	30R				
5.2. 2.133	F. Fernandez	Headquarters	2-10-55	50R	53			
10.223	L. Muncy	F. Padilla (M)	2-10-55		66			
16.323	D. Fite	Tokay	6-29-53	145				43
16.323	do	do	12- 6-54	145	60	15	0.01	34
16.323	do	do	2- 7-55	145	66	25		37
17.424	do	Swimming pool	5- 1-57	290R				
5.3. 9.244	U.S. Dept. Agriculture, S.C.S.		2-10-55		46(?)			
13.244	J. Muncy	Miera	3-17-55	100R	62			
17.111	do	Headquarters	2-10-55	337R	71			
25.121	L. Muncy	Romero	3-17-55	140R	62			
28 323	H. Bursum	Bursum(M)	6-29-53	180R				540
28.323	do	do	2- 1-55	180R	67			504
5.4.16.133	do	Pit Quarry (A)	3- 1-55	53				
5.5.14.444	do	Sullivan	3- 7-55	300	55			
19.233	do	Hansonburg	2-15-55	190	67			
32.444	do	South	3-17-55	180	63			
6.1W.12.233	U.S. Dept. Interior, F.W.S.	Headquarters	2- 5-58			38		21
12.431	do		2- 6-58		60	42		37
15.124	do	Burro	2- 6-58	200R		26		12
6.1.17.133	do	Jail	2-13-58	10R				
36.233	D. Fite	Mike	2- 8-55	300R	70			
6.2. 1.444	White Sands Missile Range.	Stallion 1	4- 4-56	600	72			
1.444	do	do	4-18-56	600	76	37		391
4.144	do	Stallion 3	8-22-56	720				
4.144	do	do	9-14-56	720	83			33
4.333	D. Fite	PW	2- 7-55	550R	74	28		47
4.333	do	do	12- 3-56	550R		25		49
4.333	do	do	2-14-58	550R	77			
4.333	do	do	2-24-58	550R	77	25		50
4.333 [2]	do	do	2-24-58	550R	77			
10.141	White Sands Missile Range.	Stallion 2A	5-21-56	600	78			
25.342	H. Bursum	Apodaca	6-29-53	140				530
28.413	D. Fite	Lower Place	2- 2-55	320R	76			198
6.3.17.111	H. Bursum	Harriet	6-29-53	220				428
6.5.36.343	do	Trail Canyon	2-16-55	330R		27		70
6.6. 9.334	do	Garden	3- 3-55	31		24		123
16.411	do	Ozane	3-17-55	18	50	20		93
24.424	do	Little (Robinson's).	2-25-54	315R		7.1		30
24.424	do	do	8-13-56	315R	77			
26.333	White Sands Missile Range.	A.F. Baca (A)	3- 8-55	205	60	11		72
26.333	do	do	12-10-55	205	58	10		79
26.333	do	do	12-11-55	205		10		81
26.333	do	do	12-11-55	205		11		83
26.333	do	do	12-11-55	205		10		83
34.224	do	Baca test (A)	2-23-56	210	58			
34.224	do	do	3-13-56	210	59			
34.224	do	do	3-16-56	210				
34.224	White Sands Missile Range	Baca test (A)	3-16-56	210				
34.224	do	do	3-16-56	210	59			
34.224	do	do	12-18-56	210				
34.224	do	do	5- 7-57	210		7.2		10
6.8.33.241	L. Nolda	(North)	3-31-53	660R				
33.241	do	do	7-24-56	660R		17		594

See footnotes at end of table.

part of the White Sands Missile Range and vicinity, New Mexico

Chemical constituents are in parts per million]

Magnesium (Mg)	Sodium (Na) and potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue at 180° C)	Hardness as $CaCO_3$		Specific conductance (micromhos at 25° C)	Percent sodium	Sodium adsorption ratio (SAR)	pH
									Calcium magnesium	Noncarbonate				
57	148	317	0	491	18	0.1	16	1,010	486	226	1,440	40	2.9	8.0
----	----	150	0	369	880	----	----	----	975	852	3,430	----	----	7.5
9.2	79	161	0	84	84	.4	.1	397	168	36	640	51	2.7	7.8
----	----	225	0	91	33	----	----	----	114	0	583	----	----	8.0
13	150	226	0	234	81	.8	0	684	218	33	1,030	60	4.4	7.8
----	----	301	0	1,280	1,420	----	----	----	1,320	1,070	6,480	----	----	7.6
----	----	286	0	1,050	31	----	----	[1] 1,860	1,040	806	2,140	----	----	----
----	----	320	0	1,170	32	----	----	[1] 2,100	985	723	2,460	----	----	----
23	200	243	0	380	28	----	2.2	795	202	3	1,240	68	----	7.5
20	212	236	0	368	30	2.8	1.1	799	167	0	1,240	73	7.1	8.0
28	208	237	0	397	33	1.5	2.2	849	208	14	1,290	69	6.2	7.9
----	----	302	0	1,560	30	----	----	----	910	662	3,610	----	----	7.3
----	----	42	0	2,720	36	----	----	[1] 4,240	2,680	2,650	3,940	----	----	----
----	----	106	0	1,920	48	----	----	[1] 3,160	2,200	2,110	3,060	----	----	7.7
----	----	43	0	751	44	----	----	[1] 1,210	375	340	1,689	----	----	----
----	----	106	0	2,180	106	----	----	[1] 3,710	2,540	2,450	3,680	----	----	7.6
110	349	38	0	2,340	59	----	12	3,430	1,800	1,770	3,790	30	----	7.6
114	----	32	0	2,300	62	----	----	[1] 3,580	1,730	1,700	3,770	----	----	----
----	----	110	0	2,160	83	----	----	[1] 3,430	2,280	2,190	3,360	----	----	----
----	----	198	0	1,930	50	----	2.8	[1] 3,180	2,200	2,040	3,090	----	----	----
----	----	135	0	1,980	76	----	----	[1] 3,180	2,130	2,020	3,210	----	----	----
----	----	236	0	2,410	135	----	----	[1] 4,040	2,770	2,580	3,900	----	----	7.5
3.8	102	184	0	59	48	2.8	2.3	341	68	0	540	77	5.4	8.1
5.2	201	357	0	109	98	2.8	.7	614	114	0	980	79	8.2	7.9
7.6	86	148	0	85	22	.6	5.9	301	62	0	484	75	4.7	8.2
----	----	264	0	344	155	----	----	----	430	214	1,480	----	----	8.0
----	----	204	0	1,800	127	----	----	[1] 3,020	1,400	1,230	3,490	----	----	----
----	----	57	0	2,040	39	----	----	----	1,630	1,580	3,310	----	----	7.8
177	271	58	0	2.090	44	1.0	7.3	3.050	1.700	1.660	3.080	26	2.9	7.4
----	----	104	0	----	14	----	----	----	107	22	475	----	----	7.9
8.8	126	141	0	218	24	1.6	16	496	118	3	771	70	5.1	7.6
22	78	109	0	240	19	1.0	10	499	208	118	742	45	2.3	7.8
21	77	106	0	241	20	1.8	10	497	209	122	729	44	2.3	7.4
----	----	122	0	248	19	----	----	----	222	122	730	----	----	7.6
20	82	109	0	245	19	1.8	11	508	207	118	707	46	2.5	7.5
----	----	108	0	247	18	----	----	----	218	128	713	----	----	7.5
----	----	64	0	904	39	----	----	----	416	364	2.010	----	----	7.8
491	99	137	0	3,260	36	----	.2	4,480	3,340	3,230	4,550	6	----	7.5
66	----	84	0	870	85	----	----	[1] 1,560	766	696	1,970	----	----	----
163	276	73	0	2,120	47	----	6.4	3,080	1,740	1,680	3,450	----	----	7.7
22	33	177	9	109	33	1.0	17	408	265	105	658	21	.9	8.2
24	31	440	0	83	17	.2	16	520	406	45	818	14	.7	7.7
25	22	356	0	69	12	.6	1.2	418	335	44	677	13	.5	7.8
36	429	290	45	398	300	2.3	.7	1,390	223	0	2,260	81	----	----
----	----	400	10	342	231	----	----	----	----	----	2,010	----	----	8.4
74	103	410	0	155	56	.2	161	834	484	148	1,310	32	2.0	7.8
71	123	414	0	156	48	1.4	[3] 173	851	489	150	1,320	32	2.1	7.4
71	120	414	0	159	52	1.4	178	862	494	154	1,320	31	2.0	7.4
71	120	412	0	156	54	----	181	865	499	162	1,320	31	2.0	7.4
71	123	411	0	161	54	1.4	[4] 173	864	499	162	1,330	31	2.1	7.4
----	----	----	----	----	31	----	[5] 112	----	----	----	1,180	----	----	----
----	----	----	----	----	55	----	[6] 1.4	----	----	----	1,490	----	----	----
----	----	----	----	----	----	----	----	----	----	----	1,260	----	----	----
----	----	----	----	----	----	----	----	----	----	----	1,260	----	----	----
----	245	586	0	126	51	3.6	[6] 3.0	----	163	0	1,250	77	8.3	8.4
----	----	800	0	----	122	----	[6] .3	----	34	0	1,850	----	----	7.9
7.6	331	624	33	124	52	2.6	[6] .2	875	56	0	1,410	93	19	8.8
----	71	214	0	1,930	76	----	2.2	[1] 3,220	2,140	1,960	3,150	----	----	----
164	68	203	----	1,950	75	----	1.4	2,970	2,160	1,990	3,160	6	----	----

TABLE 3.—*Analyses of water from selected wells in the northern part of*

[Analyses by U.S. Geol. Survey.

Location No.	Owner	Field designation	Date of collection	Depth of well	Temperature (° F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)
6.9. 7.232	Lovelace Bros	Crater	2-26-54			7.0		370
19.441	do		2-26-54			20		604
33.143	do	Oil test	6-31-55					
7.1. 2.334	N. Bruton	North	9-26-56	247	71			
27.214	do	Headquarters	8-14-56	256R	74			278
7.2.16.133	M. Harriet	Tecolote	7- 4-56					
7.3. 4.231	C. Green	Green (M)	3-29-55	160	70			
36.333	M. Harriet	Chamise	3- 1-55	94				
7.4.23.312	A. and L. Story	Chas. Story (M)	5-20-55	130	66			
33.434	G. MacDonald	Burnt	6- 2-55		65			
7.7. 9.222	H. Bursum	Hill	2-25-54			16		176
18.444	W. Withers		7-18-55	160		13		7.5
7.8. 8.322	Ft. Bliss	Red Canyon 2	10-31-56	710				
8.322	do	do	11-23-56	710	69	19		596
8.322	do	do	10-16-57	710	50	16	0.05	576
8.412	do	Red Canyon 1	9-13-56	702		16	.00	635
8.412	do	do	9-15-56	702				
14.323	do	North	2-26-54	700R		10		536
22.223	do	Home	11-22-56	630R		3.8		
29.144	do	Stevens Tank	6-24-55	370	68			
34.322	M. Rentfrow	South	11-22-56	675R		15		
7.9.33.143	Lovelace Bros	Oil test	6-31-55					
8.2.17.224	M. Harriet	Fite (M)	12- 9-55	183	70			
8.4.10.334	G. Foster	East (A)	5-31-55		66			
8.5.32.431	G. MacDonald	Murray	5-31-55	230	71	31		117
32.431	do	do	5-11-56	230	70	31		117
32.431	do	do	8- 8-56	320	70			
32.431	do	do	8- 9-56	230	70	19		118
32.431	do	do	5- 9-57	230	70	28		115
8.6.22.424	T. Spencer	Palomas Moonshine.	3-31-56	17	60	17		143
8.7. 8.124	P. Withers	J. G. Tank	5-30-55	155	63			
8.9. 9.243	M. Crockett		9-15-55		66			
29.414	G. MacDonald	Malpais (A)	5-18-55	50R	68			
34.333	B. Nickels	Cattle Guard	9-20-55	75R	66			
9.1W.23.311	Victorio L&C Co	Hackberry	8-14-56	300	76	30		484
9.4. 4.134	R. MacDonald	Guard Camp	9-13-45	360R		11	.03	474
9.5.15.143	do	Mockingbird Gap	6-29-53	160R				73
15.143	do	do	8-12-53	160R		22	.02	61
15.143	do	do	2- 8-55	160R		23		63
15.143	do	do	3-29-55	160R	65	25		60
15.143	do	do	5-13-55	160R	65	30		54
15.143	do	do	6- 2-55	160R	66	19		52
15.143	do	do	8-19-55	160R	65	23		75
15.143	do	do	4-11-56	160R	65	30		62
15.143	do	do	7- 9-56	160R	66	22		56
15.143	do	Mockingbird Gap	2-17-58	160R		24		67
34.313	do	New (A)	4-11-56	175				
34.313	do	do	4-11-56	175			.11	
9.6. 2.442	J. Dillard	Scholle	3-31-55	24	59	19	.01	145
24.221	T. Spencer	Old Mills	6- 1-55	45				
9.7. 9.411	do	New Mills	6-29-55	205	67			
25.134	Holloman AFB	ORC Fire (A)	3-30-49	200R				694
25.134	do	do	10-27-52	200R		24	0.01	668
25.134	do	do	5-19-55	200R	65			
9.8. 5.421	G. MacDonald	Chihuahua	6- 1-55	335R	68			
22.311	P. Withers	Home (A)	5-31-55	265R	72			
31.343	do	Roberson	5-31-55		65			
35.141	Rube MacDonald	Windmill (A)	6- 1-55	60R	73			
35.142	do	Irrigation (A)	6- 1-55	90R	67			
36.244	L. Drake	Atomic Bar	6- 1-55	135R	70			
9.9. 7.312	B. Nickels	Rim Rock	4-23-57	259R	62			
29.424	do	McKim (A)	2-20-55	96R	65	30		134
31.233	do	School (A)	9-23-55	95R	77			
10.1W.25.341	Victorio L & C Co	Sun Oil test	7- 8-55	1,400	94			
10.2. 4.313	G. Baca	Chavez	7-13-56	125	68			
10.5.17.431	B. Burris	Headquarters	5-31-55	50	68			

See footnotes at end of table.

the White Sands Missile Range and vicinity, New Mexico—**Continued**

Chemical constituents are in parts per million]

Magnesium (Mg)	Sodium (Na) and potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue at 180° C)	Hardness as $CaCO_3$: Calcium magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25° C)	Percent sodium	Sodium adsorption ratio (SAR)	pH
184	122	86	0	1,740	41	1.6	0.0	2,510	1,680	1,610	2,820	14	----	----
164	82	224	0	1,970	87	1.4	.1	3,040	2,180	2,000	3,250	8	----	----
----	----	72	0	2,850	155	----	----	----	2,320	2,260	4,760	----	----	7.8
----	477	198	0	1,480	81	----	11	----	790	680	3,150	57	7.4	7.3
119	272	162	0	1,520	41	----	0	----	1,180	1,050	2,800	33	3.4	6.6
----	472	104	0	2,630	73	----	4.1	----	1,970	1,880	4,260	34	4.6	7.8
----	----	105	0	3,150	40	----	----	[1] 4,720	3,260	3,170	4,400	----	----	7.5
----	----	96	0	1,780	79	----	----	[1] 2,840	940	862	3,090	----	----	----
----	----	32	0	2,290	32	----	----	[1] 3,520	2,220	1,990	3,480	----	----	7.1
----	----	43	0	2,230	35	----	----	[1] 3,310	2,100	2,060	3,370	----	----	7.7
93	322	278	14	1,100	86	1.0	1.9	1,950	822	571	2,430	46	----	----
4.0	326	477	0	205	85	7.0	.5	883	35	0	1,410	95	24	8.2
----	----	----	----	1,970	93	1.4	5.0	----	----	----	3,220	----	----	----
183	20	190	0	1,910	92	1.6	5.4	2,920	2,240	2,080	3,160	2	.2	7.1
172	6.2	90	0	1,870	92	1.8	4.5	2,780	2,140	2,070	3,150	1	.1	7.4
209	9.7	234	0	2,050	94	1.8	2.4	3,130	2,440	2,250	3,350	1	.1	7.5
----	----	204	0	----	91	----	----	----	2,360	2,190	3,200	----	----	7.1
225	146	92	0	2,310	67	1.9	.2	3,340	2,260	2,190	3,720	12	----	----
----	142	44	0	2,010	118	1.0	13	----	2,000	1,960	3,370	13	1.4	7.3
----	----	387	0	678	96	----	----	----	960	643	2,110	----	----	7.8
----	56	101	0	2,220	80	1.8	261	----	2,600	2,520	3,720	4	.5	8.1
----	----	72	0	2,850	155	----	----	----	2,320	2,260	4,760	----	----	7.8
----	----	107	0	3,080	26	----	----	[1] 4,650	2,980	2,890	4,320	----	----	----
----	----	40	0	2,470	123	----	----	[1] 3,930	2,050	2,020	4,060	----	----	7.7
37	35	162	0	302	48	1.0	4.3	655	444	312	949	15	.7	7.6
38	33	159	0	302	47	1.0	8.3	655	448	318	948	14	.7	7.4
----	----	162	0	----	44	----	----	----	----	----	932	----	----	7.6
38	28	160	0	298	45	.8	6.7	632	451	320	935	12	.6	7.5
38	34	159	0	299	48	1.0	7.4	648	444	313	944	14	.7	7.5
90	26	359	0	330	102	.8	.6	886	727	431	1,360	7	.4	7.4
----	----	266	0	1,660	19	----	----	[1] 2,650	1,890	1,670	2,760	----	----	7.2
----	123	120	0	1,650	88	1.5	17	----	1,690	1,590	2,870	14	1.3	7.3
----	----	178	0	1,190	440	----	----	[1] 2,610	1,440	1,290	3,350	----	----	7.3
----	308	179	0	1,380	525	.3	5.7	----	1,660	1,510	3,860	29	3.3	7.2
221	286	98	0	2,300	185	.5	1.5	3,560	2,120	2,040	3,980	23	2.7	7.4
202	639	82	0	3,160	32	.5	0	----	2,010	1,950	5,030	----	----	----
33	27	306	0	86	10	----	27	406	318	67	687	----	----	7.3
31	43	284	6	87	15	.5	23	429	280	37	663	25	----	----
34	29	286	0	77	11	.2	36	414	297	62	672	17	.7	----
34	45	289	0	84	12	.6	55	458	290	52	686	25	1.2	7.4
33	52	300	0	91	10	.6	33	452	270	24	716	29	1.4	7.6
32	57	296	0	94	11	.6	33	445	261	18	711	32	1.5	7.6
39	21	301	0	63	12	.4	79	460	348	101	710	12	.5	7.4
34	39	289	0	86	10	.6	46	450	294	58	684	22	1.0	7.5
29	59	296	0	94	11	.6	37	455	258	16	715	33	1.6	7.6
26	35	280	0	84	12	1.0	17	387	274	44	609	22	.9	7.8
----	84	0	0	2,210	----	----	----	----	2,130	----	3,190	----	----	4.5
----	----	18	0	2,280	39	----	----	----	2,360	----	3,180	----	----	6.8
115	45	409	0	516	41	1.0	.4	1,080	835	500	1,520	11	.7	7.5
----	----	456	0	561	109	----	----	[1] 1,370	850	476	1,880	----	----	7.4
----	----	110	0	2,430	163	----	----	----	1,980	1,890	4,300	----	----	7.6
182	354	128	0	1,930	795	----	19	4,040	2,480	2,380	5,160	24	----	7.5
152	339	142	0	1,910	650	1.0	5.0	3,820	2,290	2,180	4,730	24	----	7.2
----	----	135	0	1,900	640	----	----	[1] 4,020	2,330	2,220	4,690	----	----	8.1
----	----	126	0	1,830	320	----	----	[1] 3,370	2,090	1,990	3,670	----	----	7.4
----	----	175	0	2,160	960	----	----	[1] 4,960	2,620	2,480	5,870	----	----	7.7
----	----	97	0	1,440	262	----	----	[1] 2,670	1,480	1,400	3,150	----	----	7.6
----	----	143	0	784	385	----	----	[1] 1,920	1,160	1,040	2,600	----	----	7.9
----	----	148	0	773	320	----	----	[1] 1,830	1,080	958	2,440	----	----	7.6
----	----	475	0	274	148	----	----	[1] 1,030	108	0	1,670	----	----	8.1
----	----	210	0	1,340	384	----	----	----	1,530	1,360	3,430	----	----	7.0
58	98	184	0	434	127	.3	4.3	976	573	422	1,440	27	1.8	7.4
----	436	243	0	1,420	530	.3	2.5	----	1,480	1,280	4,070	39	4.9	7.4
----	----	136	0	1,660	22	----	----	----	1,850	1,740	2,600	----	----	7.2
----	----	170	0	2,050	24	----	----	[1] 3,180	2,100	1,960	3,180	----	----	7.5
----	----	295	0	528	128	----	----	[1] 1,290	920	687	1,690	----	----	7.4

TABLE 3.—*Analyses of water from selected wells in the northern part of*

[Analyses by U.S. Geol. Survey.

Location No.	Owner	Field designation	Date of collection	Depth of well	Temperature (° F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)
10.7.34.131	New Mexico Tax Commission.	Coon	5-26-55	30	61			
10.8.18.131	A. Helm	Lathan	6- 2-55		66			
10.9. 5.123	B. Nickels	New	9-20-55	90R	65			
8.121	Mr. Harrold	Plastered Tank (A).	9-20-55		69			
11.2.16.422	D Cain	Headquarters	7- 8-55		70			
12.2.27.211	C. Hardin	do	5-26-54		68	34	.00	101
35.434	L. Miller	Red House	7-24-56		72	23		

[1] Residue on evaporation. Dissolved solids otherwise determined as the sum of analyzed constituents.
[2] Sample collected after 6 hours of pumping.
[3] Sample from lower(?) part of well analyzed for bacteria; analysis indicated presence of coliform group.
[4] Sample from upper part of well and sample from open cased hole (12/16/55) indicated presence of coliform

the White Sands Missile Range and vicinity, New Mexico—Continued

Chemical constituents are in parts per million]

Magnesium (Mg)	Sodium (Na) and potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue at 180° C)	Hardness as $CaCO_3$: Calcium magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25° C)	Percent sodium	Sodium adsorption ratio (SAR)	pH
--------	--------	275	0	2,180	2,210	------	-------	[1] 7,480	3,720	3,490	9,440	----	------	7.6
--------	--------	379	0	2,340	840	------	-------	[1] 5,260	2,980	2,670	6,030	----	------	7.6
--------	165	158	0	716	288	.3	20	[1] 1,650	940	810	2,230	28	2.3	7.4
--------	514	155	0	1,030	278	1.0	4.0	--------	480	353	2,940	70	10	7.2
--------	--------	224	0	1,240	36	------	-------	--------	1,400	1,220	2,370	----	------	7.4
67	47	394	0	198	70	.2	2.9	714	528	204	1,100	16	.9	7.7
--------	49	390	0	509	49	.5	8.8	[1] 1,150	820	500	1,500	12	.7	7.6

group.

[5] Sample bailed from well 53 feet deep in which water level was at 33 feet; no coliform bacteria present.

[6] Sample from lower water-bearing zone.

TABLE 4.—*Analyses of water from selected springs in the northern part of the White Sands Missile Range and vicinity, New Mexico*

[Analyses by U.S. Geol. Survey. Chemical constituents in parts per million]

Location No.	Owner	Field designation	Date of collection	Temperature (°F)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na) and Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue at 180°C)	Hardness as $CaCO_3$: Calcium magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	Percent sodium	Sodium adsorption ratio (SAR)	pH
6.6.20.412	H. Bursum	Deer	3-4-55	38	20	114	12	8.0	336	0	50	11	0.2	10	390	334	58	625	5	0.2	7.8
20.441	do	Rabbit	3-4-55	42	5.9	90	13	17	308	0	40	14	.2	.1	331	278	26	570	11	.4	7.5
31.223	do	Council	3-2-55	45	13	127	7.6	3.4	344	0	39	9	.2	25	393	348	66	650	2	.1	7.7
7.6.9.143	do	Yates	3-4-55	49	15	106	17	20	260	0	99	37	.2	12	434	334	122	706	12	.5	7.8
29.414	A. Helm	Dripping [1]	3-30-55	44	20	96	11	112	533	0	51	17	.4	15	584	284	0	1,260	46	2.9	7.8
29.414	do	do [2]	3-30-55	49	21	71	11	60	171	0	167	14	.4	22	450	222	82	451	37	1.8	7.5
7.7.6.124	H. Bursum	Seep	3-17-55	53	46	81	68	80	556	0	137	33	1.0	.1	724	42	18	1,130	27	1.6	7.8
6.124	do	do	7-11-55		41	75	87	129	626	0	225	53	1.0	.4	919	544	32	1,400	34	2.4	7.8
7.7.15.421	L. Nolda	Red Canyon [3]	2-25-54						192	0		42						2,990			
15.421	do	do [4]	2-25-54		20	479	276	58	160	0	2,170	45	1.0	.1	3,130	2,330	2,200	3,300	5		
15.421	do	do	6-21-55	75					190	0	1,880	43				2,060	1,900	3,030			7.7
8.9.29.113	G. MacDonald	Lower willow	5-18-55	62					150	0	1,140	470			[5] 2,560	1,420	1,300	3,340			7.4
9.8.23.423	P. Withers	Bull Gap	11-3-55		20	578	301	684	249	0	2,680	830	.5	1.0	5,220	2,680	2,480	6,290	36	5.7	7.6
34.143	T. Spencer	Phillips	5-31-55	68					204	0	810	272			[5] 1,760	970	803	2,420			7.9
9.9.9.222	B. Nickels	Root	8-23-55	63				170	177	0	842	285	.2	7.0	[5] 1,840	1,060	915	2,420	26	2.3	7.7
10.343	do	Jake's	8-23-55	63				135	105	0	744	166	.5	9.8	[5] 1,480	810	724	1,920	27	2.1	7.6
32.211	C. Crews	Milagro	8-18-55						198	0	564	280			[5] 1,430	820	658	2,050			7.5
10.6.23.242	T. Spencer	Mound	6-2-55	61					151	0	1,950	710			[5] 4,170	2,450	2,330	4,850			7.6
12.7.8.422	do	Malpais	5-29-52	75		700	164	589	70	0	1,920	1,160		11	4,580	2,420	2,360	5,980	35		7.7
8.422	do	do	6-2-55	60					57	0	1,910	1,200			[5] 5,100	2,520	2,470	6,170			7.5

[1] South gallery.
[2] North gallery.
[3] Cave gallery.
[4] Sump in arroyo.
[5] Residue on evaporation. Dissolved solids otherwise determined as the sum of analyzed constituents.

TABLE 5.—*Descriptive logs of drill cuttings from wells and test holes in the northern part of the White Sands Missile Range, N. Mex.*

Material	Thickness (feet)	Depth (feet)
Stallion 1 (6.2.1.444) Altitude of land surface, 5,075 ft. Drilled by R. L. Newberry, Socorro, N.Mex. Completed April 17, 1956.		
Alluvium:		
Dune sand, very fine grained to fine-grained, subrounded to subangular; mostly quartz grains and feldspar; 5 percent calcareous gypsum	13	0– 13
Datil Formation:		
Fanglomerate: Subrounded to subangular; very fine grained sand to pebbles; pebbles composed of rhyolite, latite, calcareous gypsite, and rhyolite tuff; sand composed of quartz and magnetite	32	13– 45
Conglomerate; subrounded to subangular coarse-grained sand to pebbles; composed mostly of rhyolite, latite, and some andesite with some quartz, calcite, and feldspar crystals	49	45– 94
Conglomerate; subangular to angular very coarse grained and fine-grained sand and granules; granules composed of rhyolite, latite, and tuff; sand composed of quartz, orthoclase, plagioclase, magnetite, and calcite	36	94–130
Conglomerate; subangular to angular coarse-grained to very coarse grained sand and granules; granules composed of rhyolite, latite, and tuff; sand composed of quartz, orthoclase, plagioclase, magnetite, and calcite; varying amounts of silt and clay noted	62	130–192
Conglomerate; subangular to angular very fine grained to very coarse grained sand and granules composed of rhyolite, quartz, feldspar, and magnetite, with some dolomitic limestone; water tapped at 333 ft and rose about 10 ft	145	192–337
Baca Formation:		
Conglomerate; sand and granules as from 192 to 337 ft but with one pebble of light-reddish-brown siltstone; water bearing in parts	38	337–375
Conglomerate: very fine grained and coarse-grained to very coarse grained sand and granules; subangular to angular with some large pieces subrounded; consists mainly of rhyolite tuff with some rhyolite and latite; varying amounts of red-brown siltstone; water bearing	56	375–431
Sand, very fine grained to fine-grained and very coarse grained subrounded to subangular, conglomeratic; consists of quartz, orthoclase, plagioclase, and magnetite, with granules of tuff, rhyolite, latite, and pinkish-brown siltstone; water bearing	71	431–502

TABLE 5.—*Descriptive logs of drill cuttings from wells and test holes in the northern part of the White Sands Missile Range, N. Mex.*—Continued

Material	Thickness (feet)	Depth (feet)
Stallion 1 (6.2.1.444)—Continued		
Baca Formation—Continued		
Sand, very fine grained to medium-grained, conglomeratic, subrounded to subangular; consists of quartz, feldspar, magnetite, tuff, rhyolite, and latite; some silt; better sorted toward base	98	502–600
Bottom of hole.		
Well yielded 20 gpm with 16 feet of drawdown; cased and capped; torch-slotted casing set: 309–330, 369–391, 434–453, 495–516, and 563–579 ft.		
Stallion 2A (6.2.10.141)		
Altitude of land surface, 5,050 ft. Drilled by R. L. Newberry, Socorro, N. Mex. Completed June 22, 1956		
Alluvium:		
Dune sand, fine-grained, rounded to subrounded, quartz and feldspar, and subrounded to subangular gravel composed of rhyolite, latite, and tuff	3	0– 3
Santa Fe Group, undifferentiated:		
Sand, pink, medium to coarse grained, subrounded to subangular, conglomeratic; consists mostly of rhyolite, tuff, and latite, but includes some quartz; contains subangular granules of same composition as sand and some very fine subrounded quartz, feldspar, and magnetite grains	47	3– 50
Conglomerate: subangular to subrounded granules and pebbles, composed mostly of latite, red rhyolite, and tuff, and very fine grained to very coarse grained sand composed of quartz, plagioclase, orthoclase, and magnetite; fine particles increase toward base	165	50–215
Sand, conglomeratic; same as that at 50–215 ft but no material larger than granules; composed mostly of tuff	62	215–277
Datil Formation:		
Sand, fine- to coarse-grained, slightly conglomeratic; composed exclusively of gray and red rhyolite	13	277–290
Sand, fine- to medium-grained, subrounded to subangular, and yellowish-brown conglomeratic siltstone	26	290–316
Fanglomerate, brown to red-brown, subrounded, boulder-and-cobble; composed mostly of rhyolite; sand is rhyolite, quartz, and orthoclase; clay and silt increases to-toward base	34	316–350
Mudstone, red, sandy and silty, tuffaceous; some gravel near base	46	350–396
Sandstone, variegated, medium-grained, silty, slightly conglomeratic	20	396–416

TABLE 5.—*Descriptive logs of drill cuttings from wells and test holes in the northern part of the White Sands Missile Range, N. Mex.*—Continued

Material	Thick-ness (feet)	Depth (feet)
Stallion 2A (6.2.10.141)—Continued		
Baca Formation:		
Sandstone, pinkish- to purplish-gray, medium-grained, clayey; contains some gravel and silt; composed mainly of volcanic debris with some pink mudstone; volcanics become andesitic toward base; water tapped at 442 ft and rose to 405 ft	147	416–563
Sandstone, gray to buff and tan, fine-grained to very coarse grained, subrounded and rounded, friable, argillaceous, arkosic; a few granules of gray igneous material present; some yellow sandstone locally	37	563–600
Bottom of hole.		
Well yielded about 11–15 gpm of water containing 904 ppm sulfate; plugged and abandoned.		
Stallion 3 (6.2.4.144)		
Altitude of land surface, 5,065 ft. Drilled by R. L. Newberry, Socorro N. Mex. Completed September 12, 1956.		
Alluvium:		
Sand, fine- to coarse-grained, rounded, quartzose, and subrounded granule-and-pebble gravel consisting of volcanic debris; poorly cemented with caliche in some parts	20	0– 20
Santa Fe Group undifferentiated:		
Conglomerate; fine- to coarse-grained sand, granules, and pebbles of quartz; loosely cemented	5	20– 25
Sand, medium-grained, rounded, conglomeratic; some silt; granules and pebbles of rounded latite and rhyolite; very poorly cemented with carbonate	15	25– 40
Gravel, granule-and-pebble, and very fine-grained to coarse-grained subrounded and rounded sand composed of latite, rhyolite, and quartz; some pink silt, yellow sandstone, and magnetite	55	40– 95
Conglomerate: subrounded to angular granules and pebbles, and rounded sand; composed of latite, rhyolite, and quartz; very silty; friable	5	95–100
Gravel : rounded and subangular granules and pebbles composed of latite, rhyolite, sandstone, and quartz, and rounded sand; some silt; may be poorly cemented in parts	25	100–125
Gravel: rounded granules and pebbles composed of latite and rhyolite, and some rounded sand composed of quartz and volcanic debris	15	125–140

TABLE 5.—*Descriptive logs of drill cuttings from wells and test holes in the northern part of the White Sands Missile Range, N. Mex.*—Continued

Material	Thickness (feet)	Depth (feet)
Stallion 3 (6.2.4.144)—Continued		
Santa Fe Group undifferentiated—Continued		
Sand and gravel: medium-grained rounded sand composed of quartz and some volcanic detritus, and gravel composed of subrounded and rounded granules and pebbles of latite, rhyolite, and some quartz	60	140–200
Siltstone, reddish-tan, very sandy and conglomeratic, friable; sand is rounded and composed of quartz and volcanic debris; granules and pebbles are subangular and composed of latite and rhyolite	20	200–220
Sandstone, pinkish-red to orange-tan, medium-grained, rounded, very silty and conglomeratic, quartz; contains rounded granules and pebbles of tuff and rhyolite; zone of perched water at base	80	220–300
Siltstone, grayish-orange, clayey and sandy, slightly conglomeratic; sand is fine- to coarse-grained rounded quartz and volcanic debris; granules and pebbles are rounded and composed of tuff and rhyolite	10	300–310
Sandstone, grayish-orange, very fine grained to medium-grained, rounded, silty, slightly to very conglomeratic, quartzose; granules and pebbles are rounded and composed of tuff and rhyolite; perched water from 350 to 370 ft	140	310–450
Conglomerate: rounded granules and pebbles of volcanic debris; some rounded quartz sand; slightly silty; olivine and magnetite noted	10	450–460
Datil Formation:		
Sandstone, grayish-orange to pink, medium-grained to very coarse grained, rounded, conglomeratic, friable; silty in parts; sand is quartzose and slightly arkosic; granules and pebbles are rounded and composed of volcanic debris; magnetite and olivine noted; slightly calcareous near base; water tapped at 490 ft and rose to 460 ft	133	460–593
Baca Formation:		
Sand, tannish-gray, grayish-buff, and pink, fine-grained to very coarse grained, rounded, silty, slightly cemented; arkosic in parts; very slightly effervescent in acid; magnetite, olivine, and phlogopite noted	42	593–635
Sandstone, grayish-tan to pinkish-gray, fine- to coarse-grained, subrounded, conglomeratic, silty, slightly calcareous; composed mainly of quartz; some red-bed mudstone	45	635–680

TABLE 5.—*Descriptive logs of drill cuttings from wells and test holes in the northern part of the White Sands Missile Range, N. Mex.*—Continued

Material	Thickness (feet)	Depth (feet)
Stallion 3 (6.2.4.144)—Continued		
Baca Formation—Continued		
Sand, pinkish-gray, medium- and coarse-grained; composed of quartz, plagioclase and other feldspar, magnetite, and igneous detritus; probably derived from tuff; some granules and a few pebbles of igneous material and reddish-brown sandstone; phlogopite noted	10	680–690
Sandstone, grayish-tan to pink, medium- to coarse-grained, subrounded, conglomeratic, slightly calcareous; silty in part; composed of quartz, magnetite, and igneous debris; several pieces of red-bed mudstone noted	30	690–720
Bottom of hole.		
Well yielded 3 gpm; plugged and abandoned.		
Air Force test hole (6.6.6.243)		
Altitude of land surface, 7,775 ft. Drilled by R. L. Newberry, Socorro, N.Mex. Completed January 27, 1956. (Deepened from 477 ft)		
Madera Limestone—Lower gray member:		
Limestone, gray, and some brown to dark-brown silty shale; small amount of coarse-grained to very coarse grained subangular to angular quartz sand; arkosic in parts	88	477–565
Limestone, sandy, light- to dark-gray, cherty	120	565–685
Diorite, greenish- to blackish-gray; composed of plagioclase feldspar, pyrobole, and magnetite; very small amount of quartz	16	685–701
Bottom of hole.		
Dry hole; plugged and abandoned.		
Baca test well (6.6.34.244)		
Altitude of land surface, 6,500 ft. Drilled by R. L. Newberry, Socorro, N. Mex. Completed March 12, 1956.		
Bursum Formation:		
Limestone, dark-gray; some recent fluviatile silt, clay, and sand; sand is reddish brown, coarse grained to very coarse grained, angular to subrounded, highly calcareous	8	0– 8
Limestone, dark-gray, arkosic; arkose is coarse grained to very coarse grained, angular to subrounded	7	8– 15
Limestone, white to gray, and pinkish-gray conglomerate, mainly granules, consisting of limestone, and coarse-grained to very coarse grained subrounded to angular sand consisting of orthoclase and quartz; small amount of magnetite	7	15– 22

TABLE 5.—*Descriptive logs of drill cuttings from wells and test holes in the northern part of the White Sands Missile Range, N. Mex.*—Continued

Material	Thickness (feet)	Depth (feet)
Baca test well (6.6.34.244)—Continued		
Bursum Formation—Continued		
Limestone, gray to light-gray, clay and silt red beds, and a little sand; sand is fine to coarse grained and subrounded to angular and is composed mostly of limestone particles; a few fragments of shale	14	22– 36
Limestone, gray, clayey, sandy	6	36– 42
Siltstone, reddish-brown, calcareous, conglomeratic; granules are subangular to rounded; water tapped at 44 ft and rose to 34 ft	5	42– 47
Conglomerate, reddish-brown; mainly granules in limestone groundmass; composed of limestone, siltstone, and quartz; sand is coarse grained to very coarse grained and subangular to rounded	4	47– 51
Siltstone, reddish-brown, calcareous, and gray limestone; water bearing from 51 to 53 ft	7	51– 58
Limestone, light-gray; some calcite crystals and a few fragments of siltstone; water bearing in upper part	24	58– 82
Limestone, light-gray, and light- to dark-gray calcareous siltstone	11	82– 93
Siltstone, reddish-brown, calcareous, clayey, slightly sandy; some light- to dark-gray limestone; water bearing from 102 to 104 ft	14	93–107
Siltstone and shale, reddish-brown to black, calcareous, and light- to dark-gray argillaceous limestone	31	107–138
Limestone, light- to dark-gray, shaley, slightly sandy; magnetite and pyrite noted	14	138–152
Limestone, light- to dark-gray, and light- to dark-brown calcareous siltstone; some dark-gray to black calcareous shale	6	152–158
Silstone, brown to dark-brown, calcareous, and light and dark-gray to brown silty limestone; some feldspar, pyrite, and magnetite	7	158–165
Shale, reddish-brown to black, calcareous, and light-gray to gray limestone; small amount of magnetite and pyrite	3	165–168
Siltstone, brown to black, calcareous, and light-gray to dark-brown silty limestone; small amount of magnetite and pyrite	7	168–175
Conglomerate: granules and pebbles composed of limestone and siltstone; small amount of pyrite and magnetite	14	175–189
Limestone, light- to dark-gray and reddish-brown to gray calcareous siltstone	11	189–200
Conglomerate: coarse-grained sand to granules composed of light- to dark-gray limestone and reddish-brown to dark-brown calcareous siltstone	10	200–210

TABLE 5.—*Descriptive logs of drill cuttings from wells and test holes in the northern part of the White Sands Missile Range, N. Mex.*—Continued

Material	Thickness (feet)	Depth (feet)
Baca test well (6.6.34.244)—Continued		
Bottom of hole.		
Upper water-bearing zone (44–47 ft) yields 7 gpm of water containing 122 ppm nitrate; thin, lower water-bearing zones (51–104 ft; mainly 51–65 ft) yield about 3 gpm; well cased and equipped with pump Dec. 18, 1956.		
Red Canyon 1 (7.8.8.412)		
Altitude of land surface, 5,495 ft. Drilled by B. and W. Drilling Co., Borger, Tex. Completed September 1956.		
Alluvium:		
Sand, silt, gravel, boulders, and clay, unconsolidated	25	0– 25
San Andres Limestone:		
Limestone, light-grayish-tan and dark-gray, sandy, silty; sand is fine to medium grained and rounded; samples contain considerable quartz vein material showing fairly well developed crystal growth	95	25–120
Sandstone, yellow, fine- and medium-grained, rounded, quartzose, and light-grayish-tan to gray gypsiferous, partly dolomitic limestone	40	120–160
Glorieta Sandstone:		
Sandstone, yellow, fine- and medium-grained, rounded, silty, quartzose, calcareous; some gypsum	50	160–210
Yeso Formation:		
Sandstone, white, fine- and medium-grained, rounded, very friable, quartz, and white to gray slightly calcareous gypsum	30	210–240
Sandstone, reddish-tan, fine- and medium-grained, rounded, silty, quartzose, calcareous; possibly water bearing in some zones	80	240–320
Siltstone, reddish-tan, very sandy, calcareous; sand is very fine grained and fine-grained rounded quartz	50	320–370
Sandstone, light-reddish-tan, medium- and coarse-grained, rounded, slightly silty, quartzose; some gypsum	20	370–390
Sandstone, reddish-orange to orange-pink, medium-grained, rounded, silty, quartz; gypsum in some samples; possibly water bearing in some zones	90	390–480
Gypsum, tan to gray, granular, very sandy, silty; sand is fine-grained to very coarse grained rounded friable quartz; some sand is black and gives sample "salt-and-pepper" appearance; silt is gray to pink; probably water bearing	60	480–540

TABLE 5.—*Descriptive logs of drill cuttings from wells and test holes in the northern part of the White Sands Missile Range, N. Mex.*—Continued

Material	Thickness (feet)	Depth (feet)
Red Canyon 1 (7.8.8.412)—Continued		
Yeso Formation—Continued		
Siltstone, light-reddish- to grayish-orange, sandy, slightly calcareous, gypsiferous; sand is very fine grained and fine-grained rounded quartz	30	540–570
Gypsum, gray and white to red and tan, sandy, partly silty; sand is very fine grained and fine-grained rounded quartz	110	570–680
Limestone, medium-dark-gray, and reddish-tan very sandy gypsiferous siltstone; sand is very fine grained and fine-grained rounded quartz	10	680–690
Limestone, dark-gray to black, and reddish-brown very fine grained rounded very silty quartzose sandstone; some gypsum; reportedly water bearing	12	690–702
Bottom of hole.		
Cased with 10-in. steel tubing that has torch-cut slots from 602 to to 702 ft; well yielded about 35 gpm; will be used for nonpotable-water supply at Red Canyon Range Camp.		
Red Canyon 2 (7.8.8.322)		
Altitude of land surface, 5,520 ft. Drilled by B. and W. Drilling Co., Borger, Tex. Completed November 21, 1956.		
Alluvium:		
Sand, grayish-orange, rounded, unsorted, silty, and subrounded granules and pebbles, sand composed of quartz with some gypsum; granules and pebbles composed of limestone; silt is calcareous	30	0– 30
San Andres(?) Limestone:		
No samples obtained	20	30– 50
Glorieta Sandstone:		
Sandstone, orange-tan, medium- and coarse-grained, rounded, silty, quartz; gypsum and calcite noted	55	50–105
Yeso Formation:		
Limestone, gray to tan, sandy, slightly silty, and gray to orange-tan silty and sandy gypsum; sand is rounded quartz	15	105–120
No sample obtained	10	120–130
Sandstone, very pale orange, fine- to medium-grained, rounded, slightly silty, quartzose, calcareous	30	130–160
Gypsum, light-gray and white, calcareous, probably massive; varying amounts of pale-red silt	40	160–200
Gypsum, white and light-gray, sandy, and yellowish-tan calcareous silt	20	200–220
Gypsum, white to gray and light-gray, silty to slightly silty	55	220–275

TABLE 5.—*Descriptive logs of drill cuttings from wells and test holes in the northern part of the White Sands Missile Range, N. Mex.*—Continued

Material	Thickness (feet)	Depth (feet)
Red Canyon 2 (7.8.8.322)—Continued		
Yeso Formation—Continued		
Sandstone, yellowish-gray, fine- and medium-grained, rounded, very friable; composed of gypsum and quartz; highly calcareous clay at top; water tapped which reportedly rose about 30 ft	30	275–305
Limestone, pale-yellowish-brown, sandy, silty; sand is coarse and fine to medium grained and subrounded; some very pale orange silt	5	305–310
Limestone, light- to dark-olive-gray, silty	15	310–325
Sandstone, white to very light gray, very fine grained to medium-grained, rounded, calcareous; some gypsum and silt	15	325–340
Siltstone, light-reddish-brown, gypsiferous, slightly sandy and calcareous; light-mustard-yellow highly calcareous sandy clay noted	10	340–350
Gypsum, white to grayish-white, sandy, silty	10	350–360
No samples obtained	20	360–380
Sandstone, very light gray, very friable; composed of fine- and medium-grained rounded quartz; varying amounts of white and gray gypsum; probably water bearing	50	380–430
Sandstone, very pale orange, fine-grained, rounded, quartzose, silty, very slightly calcareous; gypsum noted; water bearing	20	430–450
Gypsum; very pale orange, silty; some very light orange-tan siltstone	20	450–470
Dolomite, light- to medium-gray, crystalline; gypsum noted	30	470–500
Sandstone, pale-yellowish-brown, unsorted, rounded, slightly conglomeratic, silty, calcareous, friable, quartzose; gypsum noted; probably water bearing	50	500–550
Sandstone, grayish-orange-pink, fine- to medium-grained, silty, calcareous, quartzose; some igneous material	10	550–560
Siltstone, light-brown, sandy, slightly calcareous; sand is very fine grained and fine-grained rounded quartz; gypsum noted	30	560–590
Gypsum, white and light-gray; some rounded fine-grained quartz sand and calcareous silt	10	590–600
Siltstone, pale-reddish-brown, gypsiferous, calcareous, very sandy; sand is very fine grained and fine-grained rounded quartz	40	600–640
Limestone, light-gray to very light gray, partly crystalline, sandy, somewhat silty; sand is fine-grained and very fine grained rounded quartz	20	640–660