Geology and Ground-Water Resources of McMullen Valley Maricopa, Yavapai, and Yuma Counties, Arizona

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By William Kam

ABSTRACT

McMullen Valley is located in western Arizona about 80 miles west-northwest of Phoenix. It is about 48 miles long and 15 miles wide and is drained by Centennial Wash, an intermittent tributary of the Gila River. The annual average precipitation is 9 inches.

The rock units in McMullen Valley are (in ascending order): (1) Precambrian igneous and metamorphic rocks, (2) Paleozoic sedimentary rocks, (3) Mesozoic(?) intrusive rocks, (4) Tertiary(?) sedimentary rocks, (5) Tertiary(?) extrusive rocks, (6) Tertiary(?) intrusive rocks, (7) Quaternary volcanic rocks, and (8) Quaternary valley-fill deposits. The valley-fill deposits are divided into four subunits, as follows: (1) Conglomerate, (2) alluvial-fan deposits, (3) lake-bed deposits, and (4) alluvium. The most conspicuous structural features in the area are tilted horsts and grabens.

The principal aquifer consists of valley-fill deposits in the trough between the mountain ranges. The buried parts of the mountain ranges, which are the boundaries of this aquifer, are effective barriers to subsurface movement of ground water into or out of the valley-fill deposits. The general direction of the movement of ground water in the valley-fill deposits is southwestward to Salome and then southeastward through Harrisburg Valley. A buried bedrock ridge beneath the surface outlet at the southeast end of Harrisburg Valley is a partly effective ground-water dam. (See p. 23.)

The ground-water reservoir in the valley-fill deposits is recharged principally by seepage from streams, especially when they flood, and to a lesser extent by seepage from irrigation. Prior to the development of irrigation, ground water was discharged from the valley primarily as underflow and by evapotranspiration; however, pumping has been relatively heavy in Harrisburg Valley so that little or no ground water now leaves the valley as underflow, and evapotranspiration probably has been lessened. During 1953 about 6,000 acre-feet of water was pumped for irrigation, and in 1957 the annual pumpage had increased to 21,000 acre-feet.

The rate of discharge from irrigation wells ranges from 150 gpm (gallons per minute) to as much as 3,500 gpm, and the specific capacity of the wells ranges from 2 to 114 gpm per ft of drawdown. In the Aguila area, the wells having the higher specific capacities produce principally from alluvium; whereas, in the Wenden and Salome-Harrisburg Valley areas, the wells having the higher specific capacities produce principally from the alluvial-fan deposits. The water table has declined in areas of concentrated pumping, particularly in the southeastern part of Harrisburg Valley and north of Aguila.

The volume of the valley-fill deposits must be very large, because the deposits underlie an area of about 500 square miles and their maximum thickness exceeds 1,800 feet. The specific yield of the material is estimated to be about 15 percent, and, therefore, large quantities of water are available for withdrawal.

The concentration of dissolved solids in samples of water from 53 wells ranged from 200 to 7,410 ppm (parts per million) but in all but 17 was less than 400 ppm. Although the ground water used for irrigation contains a high percent sodium, most of the water is satisfactory for this purpose, because the total dissolved-solids content is relatively low. Some of the water, however, may cause damage to the soil and crops if not used with caution. Much of the water has a fluoride content of more than 1.5 ppm, which is the limit for drinking water recommended by the U.S. Public Health Service.

INTRODUCTION

PURPOSE OF INVESTIGATION

The investigation was made to ascertain geologic and hydrologic conditions in the relatively undeveloped McMullen Valley and to determine, if possible, the probable effects of extensive ground-water use. It consisted principally of collecting and analyzing data pertaining to: (1) the lithologic characteristics, thickness, and extent of the water-bearing materials; and (2) the origin, movement, quantity, availability, and quality of the ground water. The U.S. Geological Survey made the investigation in cooperation with the Arizona State Land Department, Obed M. Lassen, Commissioner, as part of the Federal-State cooperative program of ground-water studies in Arizona.

PREVIOUS INVESTIGATIONS

Bancroft (1911), in a reconnaissance report on the ore deposits of northern Yuma County, described part of the general geology of McMullen Valley and the detailed geology at the mines. Jones and Ransome (1920, p. 137) described one mining claim in the vicinity of Bullard Peak. Ross (1923) described in greater detail the geology and also described some of the wells and ground-water conditions at that time. Darton (1925) reported on the occurrence of Paleozoic fossils in the Harquahala Mountains. The Paleozoic rocks have been studied at Martin Peak by E. D. Wilson, who found fossils of Cambrian age in quartzite and shale at the base of the stratigraphic section and fossils of Permian age in the limestone near the top of the sequence (Metzger, 1957, p. 18). Kam (1957) prepared an interim report on the ground-water resources of the area.

FIELDWORK AND MAPS

Fieldwork for this investigation was begun in November 1956 and continued intermittently until the fall of 1958. The geology was recorded on contact prints of aerial photographs and then projected onto a base map with a focalmatic desk projector. The base map was prepared from grazing maps and land plats provided by the Bureau of Land Management. Geologic mapping of the mountain areas was of the reconnaissance type, but the geology of the valley-fill deposits was studied in more detail. Fieldwork included the collection of all available well logs and the examination of drill cuttings from wells. Geophysical well-exploration equipment was used on a few deep wells.

Hydrologic records have been collected for 169 wells of all types in the area. These data were collected from the files of the Arizona State Land Department, from previous reports, and from interviews with well drillers, well owners, pump company officials, and other persons. Many of the data were collected in the field by U.S. Geological Survey personnel.

To determine the position of the water table and to record water-level fluctuations, 268 water-level measurements were made in 113 wells. Five of the wells had been used for several years as observation wells. Hydrographs and water-table contour maps were drawn from selected data. To determine the quality of the water, detailed chemical analyses were made of water samples collected from 53 representative wells.

WELL-NUMBERING SYSTEM

The well numbers used by the Ground Water Branch of the Geological Survey in Arizona are based on the Bureau of Land Management's system of land subdivision. The land survey in Arizona is based on the Gila and Salt River base line and meridian which divide the State into four quadrants (fig. 1). These quadrants are designated counterclockwise by the capital letters A, B, C, and D. All land north and east of the intersection of the meridian and base line is in A quadrant, that north and west is in B quadrant, that south and west in in C quadrant, and that south and east in in D quadrant. The first digit of a well number indicates the township, the second the range, and the third the section. The lowercase letters a, b, c, and d after the section number indicate the well location within the section. The first letter denotes the 160-acre tract, the second the 40-acre tract, and the third the 10-acre tract. These tracts also are designated counterclockwise beginning in the northeast quarter. If it is known in which 10-acre tract the well is located, three lowercase letters are shown in the well number. In the example shown, well number (B-4-2)19caa indicates that the well is in the NE¼NE¼SW¼ sec. 19, T. 4 N., R. 2 W. Where more than one well is within a particular tract, the wells are distinguished by adding consecutive numbers beginning with 1 after the lowercase letters.

ACKNOWLEDGMENTS AND PERSONNEL

The cooperation of the residents of the area in supplying information concerning their wells is very much appreciated. Especial thanks

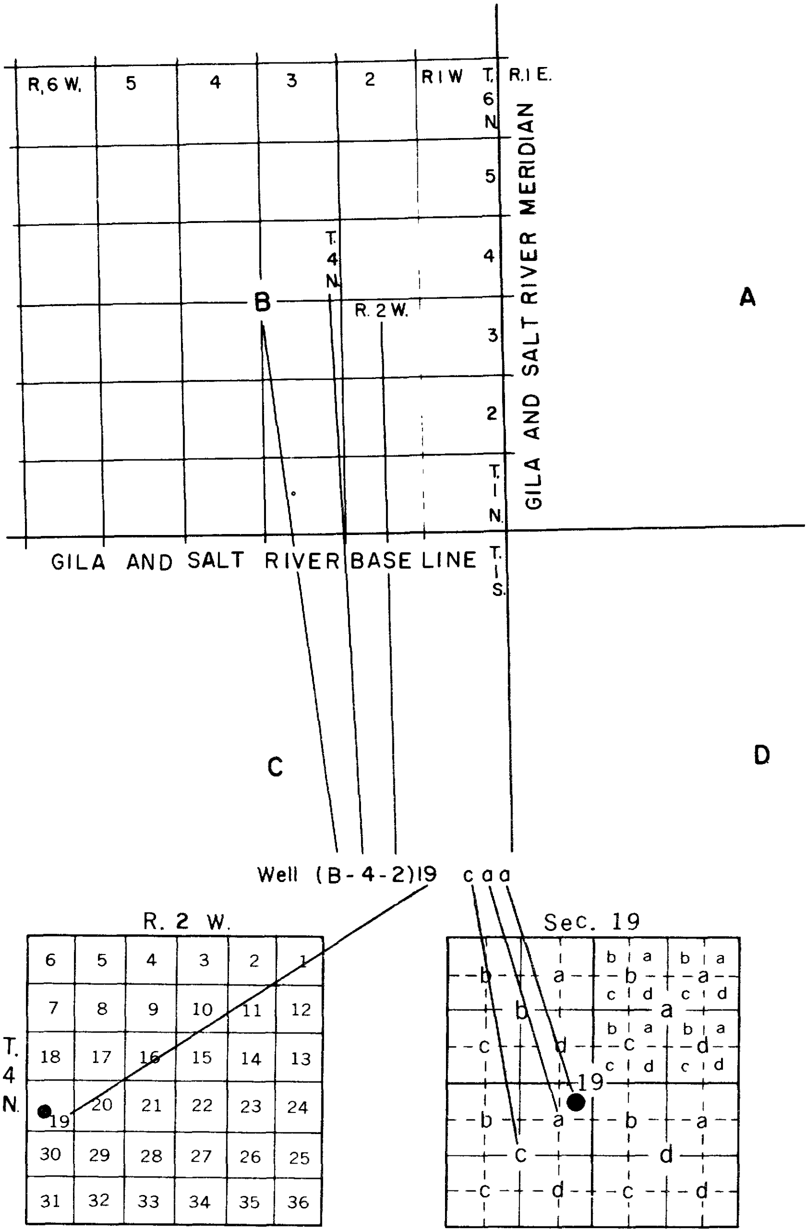

FIGURE 1.—Sketch showing well-numbering system used in Arizona.

are given to the Farmers Investment Co., Aguila Farms, the Wilco Produce Co., Hogue-McDaniels Farms, Inc., and several individuals for allowing geophysical logs to be made of their wells. The writer is indebted to the well drillers and pump-company officials for their interest and cooperation in the collection of drill cuttings and for furnishing logs of the wells and pump-test data. Messrs. K. F. Hanson and P. J. Schiele of the Bureau of Land Management provided the base map and data on the "narrows" detention dam. J. F. Lance of the University of Arizona spent several days in the area and offered helpful comments on the breccia pipes and sedimentary rocks exposed at Eagle Eye Peak.

Personnel who aided in the collection of hydrologic and geophysical data for this investigation include R. S. Stulik, J. M. Cahill, H. T. Chapman, C. S. English, E. K. Morse, and A. E. Robinson. Personnel who collected data prior to this investigation were Floyd Bluhm, the late Guy Hazen, and A. D. Pulido.

GEOGRAPHY

GEOGRAPHICAL SKETCH

McMullen Valley is in the western part of Arizona about 80 miles west-northwest of Phoenix (fig. 2). The western half of the area is in

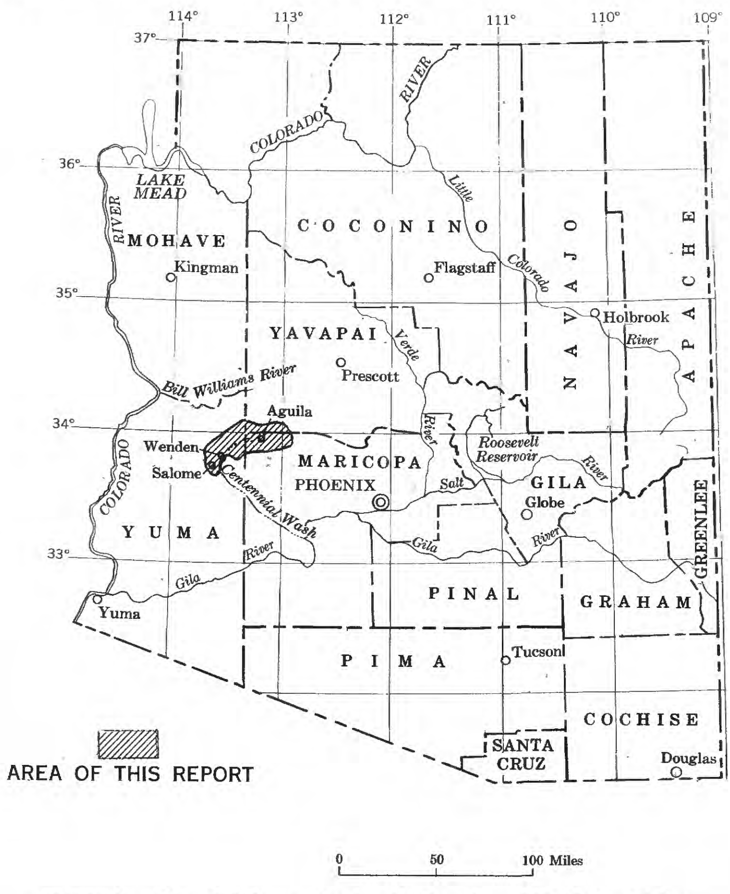

FIGURE 2.—Map of Arizona showing the location of McMullen Valley.

Yuma County and the eastern half in Maricopa and Yavapai Counties. The valley floor is roughly kidney shaped and is nearly surrounded by mountains. The Harquahala and Little Harquahala Mountains border the valley on the south; the Harcuvar and Granite Wash Mountains border it on the north and west, respectively. The highest of several prominent peaks in the area is Harquahala Mountain. Eagle Eye Peak, a well-known landmark, derives its name from a natural arch that resembles the eye of an eagle (fig. 3).

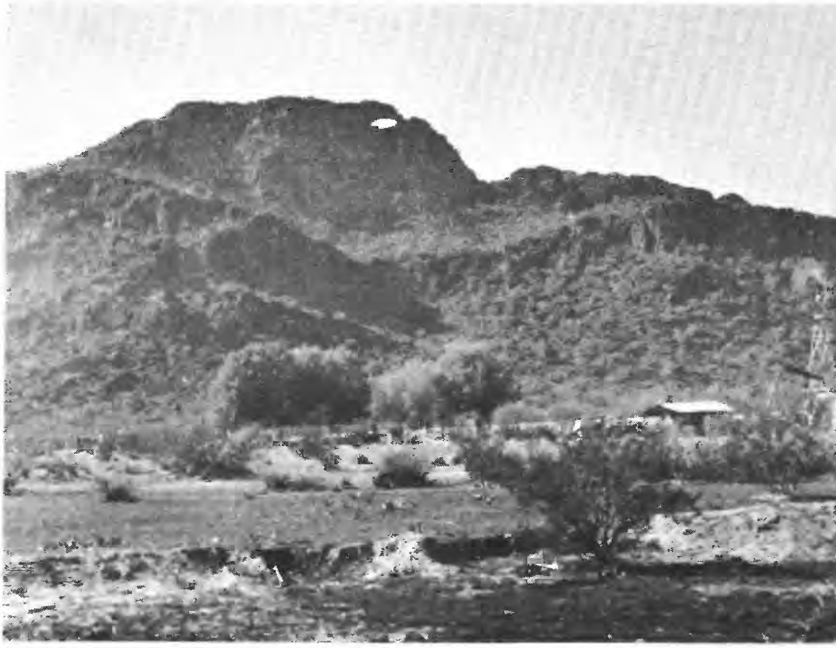

FIGURE 3.—Eagle Eye Peak, 3½ miles south of Aguila. View looking southwest.

McMullen Valley is about 48 miles long and 15 miles wide and is elongated southwestward. Harrisburg Valley, which is the outlet for drainage from McMullen Valley, lies in the southwestern part of the area and trends southeastward.

A line of the Atchison, Topeka and Santa Fe Railway crosses McMullen Valley from east of Aguila to Granite Wash Pass about 4 miles west-southwest of Salome. U.S. Highway 60–70 parallels the railroad most of the way through the valley. Other roads that provide access to the area are Arizona State Highway 71 in the northeastern part and the Salome-Buckeye road in the southwestern part. Access to the developed parts of the valley is made possible by a network of graded roads.

According to estimates made by the postmasters of Salome, Wenden, and Aguila, the population of McMullen Valley is about 1,100.

Salome is at the southwestern end of the area at the intersection of U.S. Highway 60–70 and the Salome-Buckeye road. Wenden is on U.S. Highway 60–70 about 5 miles northeast of Salome. A manganese mill at Wenden is the only industrial development in the valley. The community of Aguila is about 22 miles northeast of Wenden, and it has become, since 1954, the center of a large-scale farming development. The permanent population of Aguila is about 450. For several months of the year, however, transients may increase this total to more than 900.

Prior to the recent development of about 12,000 acres for irrigation, McMullen Valley was primarily a ranching and mining area. Stock raising remains an important part of the economy of the area, but the mining industry is no longer important.

TOPOGRAPHY AND DRAINAGE

The topographic features of McMullen Valley area are characteristic of the Basin and Range province as described by Fenneman (1931, p. 367–377). The Harquahala, Little Harquahala, and the Harcuvar Mountains trend northeastward and the Granite Wash Mountains northwestward.

The Little Harquahala Mountains are separated from the Granite Wash Mountains by Granite Wash Pass, and the Harquahala and Little Harquahala Mountains are separated by Harrisburg Valley. The mountain ranges bordering McMullen Valley rise abruptly from the alluvial slopes to a maximum altitude of 5,720 feet at Harquahala Mountain. Eagle Eye Peak at the eastern tip of the Harquahala Mountains has an altitude of 2,858 feet. Salome Peak in the Granite Wash Mountains and Harcuvar Peak in the Harcuvar Mountains have altitudes of 3,991 and 4,630 feet, respectively. Eastward from Harcuvar Peak, the summits of the Harcuvar Mountains increase in altitude to 4,957 feet at Smith Peak; from here to the pass east of Bullard Peak, the peaks gradually decrease in altitude. The average altitude of the valley floor is about 2,000 feet, and the maximum relief in the area is about 4,000 feet.

About 75 percent of the drainage area of McMullen Valley is occupied by the alluvial valley between the mountain ranges and 25 percent by the bare mountain slopes. The valley floor is elongated southwestward and has an average gradient of about 10 feet per mile between Aguila and Salome and 34 feet per mile between Salome and the narrows dams. The detrital slopes are concave and rise gently to the base of the mountains. Two areas, one along the base of Granite Wash Mountains and the other near the eastern limits of the area, consist of gently sloping bedrock. Such areas are termed "pediments."

McMullen Valley is drained by Centennial Wash, an ephemeral tributary of the Gila River. The name probably was derived from the length of the wash. It continues through McMullen Valley into the Harquahala Plains and thence to the Gila River—a distance of about 110 miles.

The character of Centennial Wash in McMullen Valley varies considerably. In the area north of Aguila, the drainage has been rerouted into a man-made channel to protect farmland; but at the west edge of the cultivated area, the watercourse consists of a main channel and a series of shallow braided washes which trend southwestward. Near Wenden the channel has well-defined vertical walls 8 to 10 feet high and a flat narrow bed. It retains this characteristic until it makes a right-angle bend southeast of Salome toward the southeast and enters Harrisburg Valley. The streambed is about 400 feet wide at one point in Harrisburg Valley, and the banks are 2 to 4 feet high. Where the wash leaves Harrisburg Valley, the channel narrows and is controlled by a bedrock outcrop. The gradient of Centennial Wash in McMullen Valley ranges from 12 feet per mile along the axis of the valley to 27 feet per mile in the southeastern part of Harrisburg Valley.

The drainage divide in the western part of the area crosses the alluvial material east of Granite Wash Pass instead of the crystalline rocks of the mountains. This condition is common in several places in the area; however, near Granite Wash Pass, the eastern slope of the Granite Wash Mountains is drained by deep ravines that drain toward the valley and that then abruptly turn westward and enter the Ranegras Plain area through Granite Wash Pass. The topographic features of this divide, the steep gradient leading to Ranegras Plain on the west, and the low gradient leading toward Centennial Wash suggest that headward erosion in Granite Wash Pass will result in the capture of the upper Centennial drainage.

VEGETATION

Cactus of many varieties is the most abundant type of vegetation on the higher slopes of McMullen Valley. The varieties of cactus include the saguaro, prickly pear, and cholla. Along the drainage channels, mesquite and paloverde are abundant. The vegetation along Centennial Wash in Harrisburg Valley differs from place to place according to the type of soil and depth to water. Several of the plants and shrubs are classified as phreatophytes, which depend on ground water for their water supply.

CLIMATE

The climate of McMullen Valley is similar to that of other parts of southwestern Arizona. It is arid and, so, is characterized by low precipitation, high rates of evaporation, and large daily variations in temperature. Normally, the relative humidity is low and sunshine is abundant. Precipitation on the valley floor averages about 9 inches annually but is greater on the bordering mountains. On the basis of extrapolated data, Hiatt (1953, fig. 11.11) prepared an isohyetal map that indicates that the average annual precipitation ranges from 16 to about 18 inches in the Harquahala Mountains and from 16 to about 20 inches in the Harcuvar Mountains.

The U.S. Weather Bureau maintains climatological stations in the vicinity of Aguila and Salome (table 1). At the Aguila station, precipitation has been recorded for 28 years and temperatures for 15 years. At the Salome station, precipitation has been recorded for 44 years and temperatures for 24 years. The altitudes of the Aguila and Salome stations are 2,280 and 1,775 feet, respectively.

TABLE 1.—*Annual precipitation and annual mean, maximum, and minimum temperatures at Aguila and Salome*

[From records of the U.S. Weather Bureau]

Year	Precipitation (inches)		Temperature (°F)					
			Aguila			Salome		
	Aguila	Salome	Mean	Maximum	Minimum	Mean	Maximum	Minimum
1908		11.55						
1909								
1910								
1911								
1912								
1913								
1914		9.69						
1915		10.05						
1916		8.89						
1917		9.03						
1918		11.20						
1919		10.48						
1920		10.96						
1921		9.17						
1922		8.03						
1923		13.48						
1924	5.45	3.14						
1925	10.14	8.45						
1926	13.30	8.71						
1927	12.18	9.56						
1928								
1929	6.51	2.20						
1930	10.61	7.23						
1931	18.63	10.92						
1932	10.51	8.70				67.3	113	17
1933	6.63	6.81				67.3	117	18
1934	5.67	5.09				70.6	116	24
1935	18.29	12.74				66.9	115	24
1936	8.71	6.70	66.1	111	22	69.6	115	24
1937	13.19	9.31	66.2	112	14	68.1	114	15
1938	8.79	7.99	65.4	113	21	68.0	115	24

TABLE 1.—*Annual precipitation and annual mean, maximum, and minimum temperatures at Aguila and Salome*—Continued

[From the records of the U.S. Weather Bureau]

Year	Precipitation (inches)		Temperature (°F)					
			Aguila			Salome		
	Aguila	Salome	Mean	Maximum	Minimum	Mean	Maximum	Minimum
1939	11.02	10.57	64.8	115	18	68.0	116	22
1940	9.83	7.03	67.7	113	20	69.7	117	24
1941	18.72	16.75	63.9	114	24	65.6	112	26
1942	5.35	4.94	65.3	114	23	67.0	115	24
1943		6.99						
1944		10.53				66.2	113	24
1945		6.62				67.0	114	23
1946		7.58				67.6	113	23
1947		2.99				68.0	114	21
1948	6.53	4.72	65.2	112	18	66.9	115	17
1949	7.91	5.00	64.5	112	18	66.9	114	18
1950		5.29				68.8	118	15
1951	10.44	10.51	65.2	110	20	67.0	114	22
1952	11.73	9.11				66.7	110	24
1953	3.95	3.99	65.5	112	17	67.3	111	16
1954	4.46	5.71	67.4	112	16	69.0	113	20
1955	8.67	7.12	64.2	113	19	66.5	114	22
1956	2.45	1.28	65.3	113	12	67.2	115	15
1957	10.65		65.8	115	22			
Mean	9.45	7.97	65.5	112.7	18.9	67.6	114.3	20.9

August is the month of greatest precipitation and May and June are the months of least precipitation. Summer rains generally are torrential downpours that cause flash floods. A major part of the runoff occurs at this time. Winter rains commonly are gentle, and much of the precipitation infiltrates the soil.

The minimum annual precipitation in the area, 1.28 inches, was recorded at the Salome station in 1956 and the maximum annual precipitation, 18.72 inches, was recorded at the Aguila station in 1941.

The mean annual temperature is about 65.5°F at Aguila and 67.6°F at Salome. The highest temperature recorded in the valley was 118°F on August 1, 1950, at the Salome station, and the lowest temperature was 12°F on February 3, 1956, at the Aguila station.

HISTORY OF GROUND-WATER DEVELOPMENT

Development of the ground-water supplies in McMullen Valley was begun in 1875. Water was obtained from a dug well, which was used as a watering place on a stage coach route (Ross, 1923, p. 169). In 1907 the Arizona and California Railroad (now a part of the Atchison, Topeka and Santa Fe Railway) was completed from Wickenburg to Parker, and wells were drilled along the right-of-way at Aguila and Salome.

Ross (1923, p. 193) reported that in 1909 the Bonanza Mine in the Little Harquahala Mountains obtained water from a well in Harrisburg Valley and pumped it through a 30,000-foot pipeline to the mine workings. Bancroft (1911, p. 22) reported the existence of "an extensive flow of water" a few feet below the surface along Centennial Wash in Harrisburg Valley. A proposal to build a dam that would force ground water to rise and thus provide a cheap source of water for irrigation was abandoned, probably because of the prohibitive cost of excavating the alluvial material to bedrock.

Wenden obtained its water supply from a well drilled at the schoolhouse in 1916. By 1918 at least 24 stock and domestic wells had been dug or drilled in McMullen Valley (Ross, 1923).

Ground water for irrigation was first used in Harrisburg Valley. Ross (1923, p. 169) stated that in 1917 Mr. Read of the Harquahala Livestock Co. was irrigating with water from 4 wells in the vicinity of the old town of Harrisburg and that an irrigation well about 4 miles to the northwest was capable of producing 400 gpm (gallons per minute). Records indicate that at least five irrigation wells had been drilled between 1917 and 1951 in the Salome-Harrisburg Valley area. The first deep irrigation well in the Aguila area was drilled in 1954. The successful completion of this well, reported to yield more than 2,000 gpm, gave impetus to the development of irrigation. By 1959, 27 more wells had been drilled in that part of McMullen Valley. In the Wenden and Salome-Harrisburg Valley areas, 23 irrigation wells were drilled between 1954 and 1959. Well-drilling activity was greatest during 1957 and 1958.

In 1957 an industrial well was drilled in Wenden to supply water for the Dasco Mine Mill. Another was drilled in the Aguila area in 1958 to supply water for a lettuce-packing plant.

GEOLOGY

The distribution of the various rock units in the McMullen Valley is shown on plate 1. The rocks include granite, gneiss, schist, and quartzite of Precambrian age; metamorphosed limestone, quartzite, and dolomite of Paleozoic age; granite and quartz monzonite of Mesozoic(?) age; sedimentary and igneous rocks of Tertiary(?) age; and lava flows and valley-fill deposits of Quaternary age.

ROCK UNITS AND THEIR WATER-BEARING CHARACTERISTICS

PRECAMBRIAN IGNEOUS AND METAMORPHIC ROCKS

The oldest rocks exposed in the mountains bordering McMullen Valley are regarded as Precambrian in age. These rocks constitute more than 80 percent of the outcrops in the mountains. Although they include granite, gneiss, schist, basic intrustives, and quartzite, they have been mapped as a single unit. Dikes, mostly of aplite and pegmatite, are common throughout this unit. Some of the dikes may be younger than Precambrian.

The predominant rock in the Harcuvar Mountains is gneiss. The textural forms, however, range from gneiss to normal granite.

Precambrian rocks of the Harquahala Mountains are principally gneisses, although some coarse-grained granite crops out in the southwestern part of the mountains. Wilson and others (1957) considered the granitic and associated crystalline rocks in the east-central part of the range to be Laramide in age, but in this report these rocks have been included as part of the Precambrian complex. In the southwestern part of the Harquahala Mountains, about 4 miles south-southwest of Wenden, fine-grained calcareous, quartz-mica schist and a thin bed of quartzite overlie quartz-diorite gneiss. The same rock sequence crops out about 3 miles south of Salome on the southwest side of Harrisburg Valley. Bancroft (1911, p. 109) considered these rocks to be of Precambrian age.

Metamorphosed sedimentary rocks exposed in the Granite Wash Mountains also have been included in the Precambrian complex. These rocks consist principally of mica schist, quartzite, and some recrystallized limestone. Darton (1925, p. 221–223) stated that some of the limestone in this area is Paleozoic in age.

Many of the isolated mountains and hills north and east of Forepaugh are composed primarily of coarse-grained gray biotite granite of Precambrian age. Dikes of pegmatite and aplite, some several hundred feet long, occur in the granite.

Intense folding and other crustal movements resulted in planes of schistosity, joints, shear zones, and other openings in the crystalline rocks of the mountains. The quantity of water that moves through the openings is undoubtedly small, however. According to the driller's log, well (B–6–11)13bb was drilled through 379 feet of granite before it penetrated a 4-foot bed of water-bearing "sand." Probably the so-called sand is either breccia or gouge. Water production from this well was insufficient for a stock-water supply.

Bancroft (1911, p. 118) reported that the water level in a mine near Cunningham Pass was about 320 feet below the collar of the shaft and that water occurred in gneiss and schist.

Few data are available to evaluate the permeability and porosity of the Precambrian rocks in McMullen Valley. Nevertheless, in most places these rocks probably are not sufficiently permeable to yield large amounts of water.

PALEOZOIC SEDIMENTARY ROCKS

Sedimentary rocks of Paleozoic age crop out in the Harquahala Mountains about 8 miles south-southeast of Wenden. The mapped outcrop within the drainage area is less than 1 square mile in areal extent and consists principally of quartzite, limestone, and some dolomite. The sedimentary rocks are part of a much larger outcrop of Paleozoic rocks on the south side of the Harquahala and Little Harquahala Mountains.

These rocks were first assigned to the Paleozoic era by Darton (1925, p. 221), who found fossils of Carboniferous age. Metzger (1957, p. 18) reported that E. D. Wilson of the Arizona Bureau of Mines found fossils of Cambrian and Permian age at Martin Peak in T. 4 N., R. 13 W. According to McKee (1951), the Paleozoic rocks are 2,235 feet thick. Thrust faulting has disturbed the original attitude of the rocks. The strike is generally northeast, and reversals of dip appear to be common.

Rocks of probable Paleozoic age are exposed at Eagle Eye Peak and in the Granite Wash Mountains but were not mapped because of their small areal extent. The outcrop at Eagle Eye Peak consists of dark-gray cherty limestone. The stratigraphic relationship is obscured by overlying volcanic material, but the lithologic character of the limestone indicates that it is probably of Paleozoic age. In the Granite Wash Mountains, limestone that Darton (1925, p. 223) believed to be of Paleozoic age is closely associated with quartzite and schist.

Most of the Paleozoic sedimentary rocks are many hundreds of feet above the valley floor and therefore lie above the water table and are not water bearing. Some of the Paleozoic rocks at the southeast end of Harrisburg Valley, however, form the upper part of a subsurface dam. The impervious part of the dam is formed by Precambrian rock.

The hydrologic properties of the Paleozoic strata in the area of the subsurface dam are important, not so much because of their relation to well-water supplies but because these properties affect the rate of ground-water movement from McMullen Valley to the Harquahala Plains where the water table intersects these strata. The strata have been shattered and apparently displaced by faulting. Brecciated fault zones, fractures, and cavities are exposed in the limestone outcrop. Prior to the development of irrigation wells in this area, well (B–5–12)32acc, about 1.4 miles northwest of the narrows, had a depth to water of 18 feet in May 1921. It seems probable that during this time the water table intersected the Paleozoic strata overlying the Precambrian gneiss and that ground water moved through the openings in the limestone into the Harquahala Plains.

MESOZOIC(?) INTRUSIVE ROCKS

Granitic intrusive rocks are exposed in the western part of the Harcuvar Mountains and in the Granite Wash Pass area in the

Granite Wash mountains. These rocks form the main part of the mountain mass within the drainage divide from west of Salome Peak to Low Mountain and on both sides of Granite Wash Pass. The granite in the Harcuvar Mountains is an extension of the laccolith mapped by Metzger (1951, pl. 1) in the Ranegras Plain area. The granite and quartz monzonite at Granite Wash Pass may be part of the same general intrusion that formed the laccolith (Metzger, 1951, p. 8).

The granite at Salome Peak is concordant with the Precambrian metamorphic complex. It is light tan where weathered and light gray on fresh fractures. The granite is medium to coarse grained and is composed principally of quartz and milky untwinned feldspar. It contains some biotite and white feldspar with albite twinning. Weathering along joints produces large rounded boulders.

The contact between the Mesozoic(?) granitic intrusive rocks and the Precambrian metamorphic rocks is exposed in a wash at the base of Salome Peak. It is sharp and irregular but generally is controlled by the bedding planes of the Precambrian host rock (fig. 4).

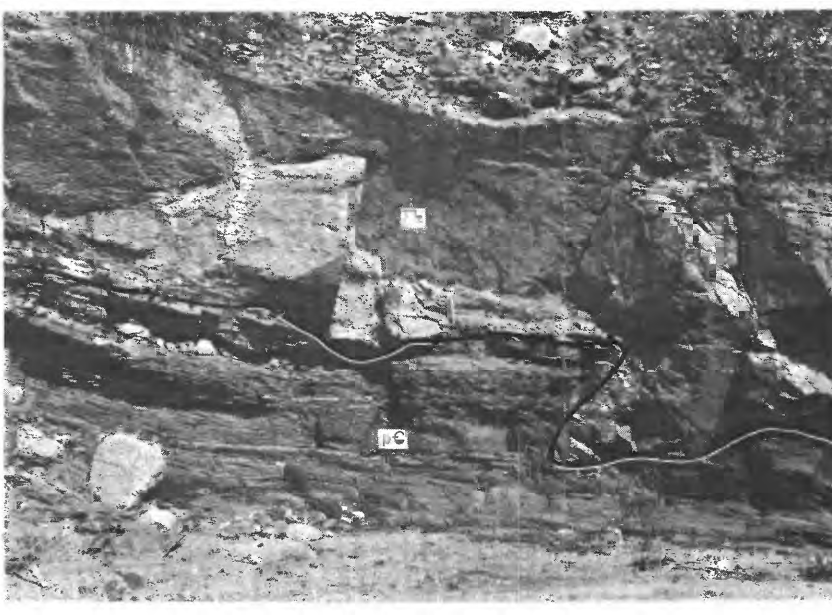

FIGURE 4.—Contact between granite of Mesozoic(?) age (Mz) and metamorphic rocks of Precambrian age (p€) at Salome Peak. View looking east.

West of Harcuvar Peak the granite is in contact with the Precambrian metamorphic rocks which dip into the base of the peak. Here, the foothills are composed of granitic gneiss with innumerable stringers of granite, probably offshoots of the main granitic intrusion, which run in diverse directions.

Dikes, which are alined roughly northwestward parallel to the trend of the Granite Wash Mountains, are associated with the granitic rocks of the Harcuvar and Granite Wash Mountains. Although they vary in composition, their texture is generally fine. Aplite is the most common type in all the areas of granitic intrusions, but—according to Bancroft (1911, p. 30)—some of the dikes in the vicinity of Harcuvar and Salome Peaks are composed of vogesite. The formation of the dikes probably was contemporaneous with the major intrusions. As the upper part of the granitic mass cooled, the lower part continued to push forward rupturing the upper part and permitting the dike material to intrude.

Bancroft (1911, p. 29) and Ross (1923, p. 29) considered the granitic intrusive rocks in the Harcuvar and Granite Wash Mountains to be of probable Mesozoic age. Because no evidence to the contrary has been presented, these rocks are considered by the writer to be of probable Mesozoic age.

The water-bearing properties of the Mesozoic(?) intrusive rocks are generally similar to those of the older granitic rocks in the area. Although small quantities of water probably can be obtained from the fractures, no large supplies can be developed from this relatively impermeable material.

TERTIARY(?) ROCKS

The rocks of probable Tertiary age constitute about 15 percent of the bedrock outcrop in McMullen Valley. The outcrops are limited to the eastern part of the valley, where they form discontinuous ridges and buttes. Sedimentary and volcanic rocks constitute the bulk of the exposures, but intrusive rocks of small areal extent also crop out.

SEDIMENTARY ROCKS

The lithologic dissimilarity of the Tertiary(?) sedimentary rocks in the more widely separated exposures precludes any correlation. The rocks are closely associated with volcanic rocks and owe their topographic prominence to the more resistant lava flows. The sediments have been faulted, tilted, and eroded so that the outcrops are discontinuous, are small in area, and do not occur as consecutive traceable sequences. For these reasons, they have been mapped as a single rock unit. The rocks are discussed according to their stratigraphic relation to volcanic flows and to the occurrence or lack of volcanic fragments in the strata. The units are as follows: (1) Basal arkose, (2) indurated fanglomerate, (3) thin-bedded limestone and sandstone, and (4) conglomeratic sandstone.

BASAL ARKOSE

A basal arkose of probable Tertiary age crops out along a southeastward-trending ridge in the northeastern part of the Harcuvar

Mountains, where it overlies the Precambrian crystalline rocks. The thickness varies, although it probably does not exceed 60 feet. The sorting is poor, and the bedding is indistinct. At the southeast end of the ridge in secs. 17, 19, and 20, T. 8 N., R. 8 W., the arkose contains lenses of conglomerate composed of boulders of granite and gneiss as much as 2 feet in diameter. It is overlain by volcanic flows that form the more resistant part of the ridge.

The arkose is composed of material derived from the granitic rocks upon which it lies and probably represents a fanlike deposit that accumulated along a border of considerable relief. The abundance of boulder beds and the size and character of the boulders in the southeastern part of the ridge indicate derivation from weathered boulder-clad surfaces that probably sloped southeastward. The absence of volcanic detritus from these sediments is significant, because other sedimentary rocks of Tertiary(?) age contain fragments of volcanic material.

Although its age is uncertain, the arkose is tentatively considered to be early Tertiary in age because of its similarity in lithologic character and physical setting to the deposit described by Lasky and Webber (1949, p. 18) as part of the Artillery Formation. The Artillery Formation is exposed in the Artillery and Rawhide Mountains about 35 miles northwest of Aguila and tentatively has been assigned an early Tertiary age by Lasky and Webber (1949, p. 21).

INDURATED FANGLOMERATE

An indurated fanglomerate of Tertiary(?) age crops out at Bullard Peak and consists of purple fragments of several types, principally andesites. The fragments range in size from less than 1 inch to angular blocks several feet in diameter. The fanglomerate is in contact with the Precambrian complex and is overlain by volcanic rocks. The deposit appears to be a clastic assemblage of brecciated volcanic rock (fig. 5), and the angularity of the fragments suggests local origin. The lack of stratification obscures the attitude of the deposit, and its thickness is unknown. The age of the fanglomerate is uncertain, but Bancroft (1911, p. 120) considered the material that constitutes Bullard Peak to be of probable Tertiary age. The fanglomerate is similar in some respects to the breccias in the Artillery Mountains area, which Lasky and Webber (1949, p. 47) considered to be of Tertiary(?) age.

THIN-BEDDED LIMESTONE AND SANDSTONE

Thin-bedded gray and pink limestone and gray coarse- to fine-grained sandstone are exposed at the north end of Eagle Eye Peak. These rocks are faulted, and step faulting has caused displacements

FIGURE 5.—Fanglomerate of Tertiary(?) age at the base of Bullard Peak.

ranging from a few inches to tens of feet. These sedimentary rocks have been intruded by breccia pipes and dikes.

CONGLOMERATIC SANDSTONE

Northeast of Eagle Eye Peak is a small butte composed of sandstone containing interbeds of conglomerate. The strata strike N. 60° E. and dip 26° NW. The sandstone consists of fine to very coarse sand of angular to subrounded quartz and volcanic detritus. The conglomerate consists of angular to rounded granules, pebbles, and boulders of volcanic and granitic rock and a fine to very coarse grained sandy matrix. The outcrop is dark reddish brown, and the rock fragments of the conglomerate are coated with desert varnish.

Southeast of Eagle Eye Peak in sec. 8, T. 6 N., R. 8 W., a conglomerate overlies volcanic rocks. The conglomerate consists of rounded to subrounded pebbles, cobbles, and boulders of granite, gneiss, and volcanic material as much as 1½ feet in diameter. The matrix is composed of a very coarse to fine-grained sand consisting of subangular to subrounded quartz and feldspar and minor amounts of accessory material (fig. 6). The contact of the conglomerate with the volcanic rocks strikes N. 53° W. and dips 56° SW.

Conglomerate crops out also along the drainage divide about 16 miles east of Aguila. It consists of well-cemented volcanic, granitic, and quartz fragments in a matrix of coarse-grained sand, and the bedding, generally indistinct, is flat where recognizable. The unit is underlain by aphanitic volcanic flows and overlain by vesicular basalt that is probably of Quaternary age. The stratigraphic relation of the conglomerate to the overlying basalt and the underlying aphanitic rocks plus the degree of consolidation of the conglomerate suggest a Tertiary age.

Southeast of Bullard Peak in secs. 12 and 13, T. 8 N., R. 10 W., and secs. 8 and 18, T. 8 N., R. 9 W., an isolated butte projects above the alluvium. It is composed of reddish-brown sandstone which contains granitic pebbles and cobbles as much as 12 inches in diameter, and fragments of vesicular basalt. The strata strike N. 35° W. and dip 30° SW. A fault has displaced the south end of the butte so that an underlying aphanitic fractured volcanic rock is exposed. Jones and Ransome (1920, p. 137) and Bancroft (1911, p. 32) considered this sandstone to be of probable Tertiary age. The relation of the outcrop to the other Tertiary(?) sedimentary rocks described is unknown. This outcrop, however, is underlain by volcanic material, and the fact that it contains fragments of vesicular basalt indicates that it probably is younger than the basal arkose that crops out along the ridge east of this point.

The lithologic character of the Tertiary(?) sedimentary rocks indicates that they are capable of transmitting water, although the

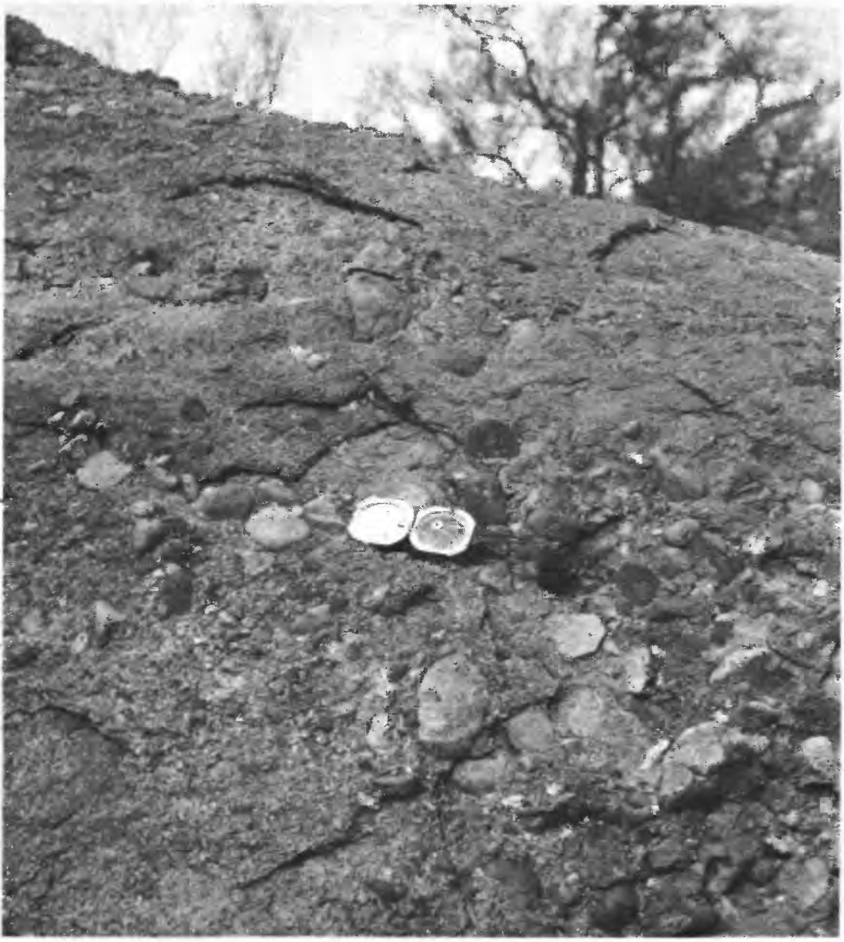

FIGURE 6.—Conglomerate of Tertiary(?) age southeast of Eagle Eye Peak. View looking east.

quantities probably are small owing to the degree of their consolidation and cementation. The potential for recharge from precipitation probably is small, because the outcrops are of small areal extent and are topographically high—a condition that causes rapid runoff.

EXTRUSIVE ROCKS

Extrusive rocks composed of felsite, andesite, and tuff crop out in the eastern part of the valley (pl. 1). Because most of the exposures are associated with the Tertiary(?) sedimentary rocks, these extrusive rocks are tentatively considered to be of Tertiary age.

The best exposure is northeast of Aguila on a prominent ridge that extends southeastward from the Harcuvar Mountains. There, steeply dipping multicolored felsites overlie the basal arkose of Tertiary(?) age. The angle of the west slope of the ridge conforms generally to the dip of the flows which ranges from 15° to 60° SW. The exposed volcanic sequence is estimated to be about 400 feet thick; the individual flows range in thickness from 2 to a little more than 50 feet.

Although most of the felsites lack any megascopically identifiable crystals, some are porphyries which contain rectangular phenocrysts of white feldspar and a few quartz grains in a fine-grained groundmass. The topmost flow, which is light pink on fresh fractures, contains secondary prismatic quartz in small spherical hollows throughout the flow. The other outcrops generally are similar in appearance, although some flows in sec. 32, T. 7 N., R. 7 W., have structures of perlitic form and nodules and stringers of chalcedony.

The lava flows exposed at Bullard and Eagle Eye Peaks are dark colored and similar in composition. Both resemble basalt, but Bancroft (1911, p. 20) identified the rock at Bullard Peak as an augite andesite. The andesite at Bullard Peak overlies a tuff about 100 feet thick, and these volcanic rocks are underlain by the indurated fanglomerate of Tertiary(?) age (fig. 5).

On the west side of Eagle Eye Peak the volcanic rocks overlie Precambrian rocks. The contact is irregular and dips eastward. At the north end of the peak the volcanic rocks are in fault contact with Tertiary(?) sedimentary rocks.

Although direct evidence as to the age is lacking, the extrusive rocks are considered to be of Tertiary age because of their similarity to other rocks of southern Arizona that have been assigned to that age. This supposition by many geologists is based principally on field relations of these lava flows to rocks of known age.

In general the Tertiary(?) volcanic rocks are relatively impermeable except along faults or fracture zones and are of little value in the storage or transmission of large quantities of ground water. Two wells, (B-6-9)2abd and (B-7-7)17add, that tap these rocks near Eagle Eye Peak and east of Forepaugh yield only sufficient water for domestic use.

INTRUSIVE ROCKS

Intrusive breccia pipes and dikes are limited to a narrow zone at the north end of Eagle Eye Peak. These intrusives, consisting of fragments of sedimentary and volcanic rocks trend northwestward and appear to be concordant to the general structure. Although direct evidence as to the age of these intrusives is lacking, they are younger than the Tertiary(?) sedimentary rocks they invade and probably are related genetically to the volcanic activity that produced the andesite constituting most of Eagle Eye Peak.

QUATERNARY ROCKS

Quaternary rocks in McMullen Valley include basalt and valley-fill deposits. The basalt crops out only in the upper part of the valley. The valley fill, which is the most important rock unit with respect to ground water, is the surface deposit in more than 75 percent of the area. As used herein, the term "valley-fill deposits" is applied to all the unconsolidated and semiconsolidated sedimentary rocks that occupy the structural trough, even though some of the rocks at depth probably are of Tertiary age. Because the thickness of the exposed valley fill is nowhere more than a few tens of feet, the lithologic character and the thickness of the valley-fill deposits in McMullen Valley are known only from well logs, drill cuttings, and electric logs.

The valley-fill deposits have been divided into four subunits (pl. 2), which, in ascending order, are as follows: (1) Conglomerate, consisting of cemented coarse sand and gravel, that may have been deposited contemporaneously with the semiconsolidated strata of Tertiary(?) age; (2) alluvial-fan deposits, composed chiefly of material laid down by torrential streams; (3) lake-bed deposits, composed of clay, silt, and fine sand deposited, in part, contemporaneously with alluvial-fan deposits; and (4) alluvium, consisting of gravel, sand, and silt deposited in the central part of the valley and along the present stream channels.

VOLCANIC ROCKS

Volcanic rocks of Quaternary age are present only in the eastern part of the valley. They consist of basalt and are dark gray to purplish gray and massive. The flows are largely dense but are generally vesicular in the upper part. Erosion has removed large quantities of this material from the area, leaving small and discontinuous remnants. These outcrops form the black buttes north, south, and east of Forepaugh. The contact relations of the basalt with the underlying material are generally obscured by a mantle of slope debris; however, in sec. 17, T. 7 N., R. 6 W., a thin vesicular flow overlies sedimentary rocks of Tertiary(?) age. Southwest of this outcrop, basalt, too small in areal extent to map, lies directly upon Precambrian crystalline rocks. The butte 2 miles south of Forepaugh is composed of a sequence of basalt flows and contains an 8-foot interbed of poorly consolidated conglomeratic sand. The sequence overlies unconformably the pink to red felsites of Tertiary(?) age. About 2½ miles north-northeast of Forepaugh, 2 small hills that project above the alluvium are composed of basalt, but the base of the flow is not exposed. The dip of the flow is less than 10°.

The unconformable relation of the basalt to the underlying Tertiary (?) volcanic rocks 2 miles south of Forepaugh and the gentle dip of the basalt flows in contrast to the steep dip of the older volcanics, lend credence to the designation of Quaternary age, although the basalt is probably not younger than early Pliestocene age.

The basalt is not an aquifer. It is of small areal extent and apparently is absent in the subsurface; so it does not affect the occurrence of ground water.

VALLEY-FILL DEPOSITS

Most of the valley fill in McMullen Valley is the result of stream transportation and sorting of rock material from the mountains and subsequent deposition of this material on the adjacent land surfaces, a process that is commonly operative in the arid to semiarid regions of southwestern Arizona.

The mechanics of the process are controlled by several factors, such as the stream gradient and shape of the stream channel, volume of runoff, character of the sediments transported, and position of the local base level. In the mountain areas the streams are confined to narrow channels of steep gradient. After torrential storms, the streams have high velocities and carry heavy loads of detrital material. As the streams emerge into the valley, their channels decrease in slope and widen, thus reducing the velocity of the streamflow. In the central part of the valley, the confluence of the mountain streams with the axial drainage forms an environment characterized by shallow shifting stream channels. Layers of debris accumulate on the surfaces of the slopes, as the valley-floor levels (local base levels) rise by aggradation. Hence, the deposition of material produces the detrital slopes and aggraded valleys which are characteristic of intermontane basins.

Under ideal conditions, the material from the mountain slopes would be arranged in zones parallel to the mountains and normal to the courses of the streams. The coarse material would be deposited near the flanks of the mountains, and the fine detritus would accumulate further downslope toward the central part of the valley. However, the variable factors of precipitation, local base-level fluctuations, and shifting stream channels modify the zonal arrangement. If a local base level lies within the valley and runoff due to precipitation exceeds the rate of dissipation, a body of water accumulates to form a lake. Fine-grained sediments are deposited within the lake concurrently with the deposition of the heterogeneous material around the periphery of the lake.

The total thickness of the valley fill in the deeper parts of the McMullen Valley's structural trough is unknown, but it may be several thousand feet. In the areas where the valley fill is relatively thin, boreholes have penetrated bedrock along which may be the buried periphery of the trough. In the drilling of a well upstream from the narrows in Harrisburg Valley, granite was penetrated at a depth of

52 feet. At the narrows, the fact that bedrock projects from the sediments on both sides of the stream channel indicates that a thin mantle of material covers a structural dam separating McMullen Valley from the Harquahala Plains.

In the western part of McMullen Valley, well (B-5-13)19bcd penetrated 282 feet of valley fill before reaching granitic bedrock. In the eastern part of the valley, wells (B-7-7)17add and (B-7-8)1dac reached volcanic rock at depths of 161 and 297 feet, respectively. However, well (B-7-8)15baa, which is only 2½ miles southwest of well (B-7-8)1dac, is bottomed in valley-fill deposits at a depth of 1,812 feet. This well is the deepest in the valley.

CONGLOMERATE

In the Aguila area drill cuttings indicate that conglomerate is present at a depth of about 850 to more than 1,600 feet. Greater cementation distinguishes the conglomerate from the overlying sediments. Because no well has been drilled completely through the conglomerate its thickness is not known, although 460 feet of this material was penetrated in well (B-7-9)17dcd.

Drill cuttings from deep rotary-drilled wells indicate that the conglomerate consists of a fine to very coarse sand and gravel that is well cemented with calcareous material. Whether argillaceous cement is present was not determined. The sand in the conglomerate is composed principally of angular to subrounded quartz grains. The gravel consists of angular to rounded fragments of volcanic, granitic, and quartzose material as much as 11 mm in diameter. Possibly the larger angular fragments were derived from boulders crushed by the drilling bit.

A qualitative analysis of an electric log of well (B-7-9)16add indicates that the conglomerate varies considerably in relative resistivity and, therefore, in permeability also. The variations are probably due to differential cementation.

The drill cuttings indicate that the conglomerate is sufficiently permeable to be a potential source of water supply. Although pumping tests were made of wells that bottom in the conglomerate, the data from the tests do not indicate the hydrologic properties of the conglomerate, because the wells also tap all the overlying water-bearing material.

ALLUVIAL-FAN DEPOSITS

The alluvial-fan deposits are composed of heterogeneous material laid down by torrential streams issuing from the mountains. In McMullen Valley the coalescing fans form an apron slope which projects from the base of the mountains toward the valley floor. These fan deposits also underlie most of the valley floor; in the Aguila area they overlie the conglomerate, and in Harrisburg Valley they overlie granitic gneiss. Although the buried fan deposits appear to be a continuation of the material on the valley slopes, those at depth in the central part of the valley are much finer grained than those on the slopes.

The alluvial-fan deposits range in thickness from a thin mantle on the slopes of the mountains to several hundred feet in the valley. In the Aguila area, the unit is about 800 feet thick in wells drilled in secs. 10, 11, and 12, T. 7 N., R. 9 W. In well (B–7–9)17dcd it is slightly more than 650 feet thick. An electric log of well (B–7–9)4bbb, 1,650 feet deep, indicated that the unit had not been completely penetrated.

In the Wenden area the total thickness of the alluvial-fan deposits is undetermined, because no wells have been drilled to bedrock. In well (B–6–12)22add the unit is at least 282 feet thick and in well (B–6–12)15bbb at least 232 feet.

The alluvial-fan deposits consist of gravel, sand, silt, and clay. These deposits occur generally as a heterogeneous mixture but locally as sorted gravel and sand containing little fine-grained material. Their accumulation may be illustrated by considering slope building in detail. During a torrential flood, boulders may be carried far out into the valley and deposited on top of fine sediments laid down by a previous smaller flood; in the lower stages after the crest of the flood and in succeeding small floods, sand and clay may, in turn, be deposited over and throughout the coarse material. Furthermore, the deposits of a stream draining a relatively large area may overlap and be interbedded with deposits of a neighboring stream draining a small area. Nevertheless, some stream channels may retain their positions for long periods of time, and in the process of carrying sediments the streams can deposit a train of well-sorted sand and gravel.

The alluvial-fan deposits constitute the principal water-bearing unit in McMullen Valley. Most of the irrigation wells obtain part or all their yield from them. Drill cuttings from wells indicate that the more permeable beds of sand and gravel are lenticular and not extensive. Obviously, the hydrologic properties of these deposits are not uniform.

Large-diameter irrigation wells tapping the heterogeneous lenticular deposits produce 150 to about 3,500 gpm. The wide range in production is due not only to the wide range in hydrologic properties of the material penetrated but also to the different depths and construction of the wells.

LAKE-BED DEPOSITS

Fine-grained materials in the lower part of the valley were probably deposited in a body of standing water. In contrast to the alluvial-fan deposits, these sediments are almost homogeneous. Apparently the material has undergone a more thorough and selective grading than it would have received under ordinary conditions of stream deposition.

The occurrence of gypsum and other salts, although not conclusive, suggests that the lake may have been ephemeral or nearly so, the salts precipitating when the lake was on the verge of drying up. Chemical analyses of water obtained from these sediments show a higher content of dissolved solids than the analyses of water from the underlying alluvial-fan deposits. The lithologic characteristics and thickness of the sediments have been determined from well data, because these deposits are not exposed.

The lake-bed deposits are thickest northeast of Wenden, where well (B-6-12)15bbb penetrated about 1,100 feet of reddish-orange to pale-red clay and silt containing grains of sand and some gypsum and salt (table 2). The driller's log of well (B-6-12)22add, 3½ miles northeast of Wenden, indicates that the lake-bed deposits are 584 feet thick (table 3), and well (B-6-12)29cdc, about half a mile northeast of Wenden, penetrated 400 feet of this material before entering the alluvial-fan deposits. A log of well (B-5-13)2caa, 3 miles southwest of Wenden, indicates a thickness of 150 feet of "bentonite" or silty clay. As illustrated in plate 2, the lake-bed deposits thin to the northeast and also to the southwest from the center of T. 6 N., R. 12 W., and probably thicken northward.

The lake-bed deposits underlie at least 30 square miles and possibly an even larger area. The dearth of subsurface data for the central part of the valley precludes delineation of the boundary of the clay body.

TABLE 2.—*Lithologic log of well (B-6-12)15bbb 4 miles north-northeast of Wenden*

[Colors determined by comparison with the color chips on the rock color chart distributed by the National Research Council (Goodard and others, 1948)]

Depth (feet)	*Description*
	Alluvium
0–90	Sand, silt, and gravel, moderate-orange-pink (5*YR* 8/2), poorly sorted. The sand consists of very fine to very coarse grained quartz. Gravel consists of fragments of granite as much as 6 mm in diameter. Weak calcareous cement.
90–100	Sand and silt, grayish-orange (10*YR* 7/2), poorly sorted. The sand consists of very fine to very coarse grained quartz. Weak calcareous cement.
	Lake-bed deposits
100–110	Silt, clay, and sand, moderate-reddish-orange (10*R* 6/6), poorly sorted. The sand consists of very fine to fine-grained clear and milky quartz. Calcareous and argillaceous cement.
110–160	Same as 100–110; fine-grained sand less abundant.
160–180	Silt, clay, and sand, pale-reddish-orange (10*Y* 5/4), poorly sorted. The sand is fine grained and contains a few coarse particles. Calcareous and argillaceous cement.
180–190	Sand, silt, and clay, moderate-orange-pink (10*Y* 7/4), poorly sorted. The sand grains are angular and consist of very fine to medium-grained clear and milky quartz. Calcareous cement.
190–350	Silt and clay, moderate-orange-pink (10*R* 7/4). Calcareous and argillaceous cement.

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TABLE 2.—*Lithologic log of well (B–6–12)15bbb 4 miles north-northeast of Wenden*—Continued

[Colors determined by comparison with the color chips on the rock color chart distributed by the National Research Council (Goddard and others, 1948)]

Depth (feet)	*Description*
	Lake-bed deposits—Continued
350–410	No sample.
410–510	Silt and clay, pale-red (10*R* 7/2). Calcareous and argillaceous cement.
510–530	Silt and clay, moderate-orange-pink (10*R* 7/4). Interval contains gypsum crystals. Calcareous and argillaceous cement.
530–610	Silt and clay, pale-red (10*R* 7/2). Calcareous and argillaceous cement.
610–620	Silt and clay, pale-red (10*R* 7/2). Interval contains gypsum crystals. Calcareous and argillaceous cement.
620–640	Silt and clay, pale-red (10*R* 7/2). Calcareous and argillaceous cement.
640–650	No sample.
650–660	Silt and clay, pale-red (10*R* 7/2). Interval contains few sand grains. Calcareous and argillaceous cement.
660–760	Silt and clay, pale-red (10*R* 7/2). Calcareous and argillaceous cement.
760–770	No sample.
770–790	Silt and clay, pale-red (10*R* 7/2). Calcareous and argillaceous cement.
790–800	No sample.
800–810	Silt and clay, pale-red (10*R* 7/2). Calcareous and argillaceous cement.
810–820	No sample.
820–840	Silt and clay, pale-red (10*R* 7/2). Calcareous and argillaceous cement.
840–850	No sample.
850–860	Silt and clay, pale-red (10*R* 7/2). Calcareous and argillaceous cement.
860–890	No sample.
890–900	Silt and clay, pale-red (10*R* 7/2). Interval contains salt and gypsum crystals. Calcareous and argillaceous cement.
900–960	Silt and clay, pale-red (10*R* 7/2). Calcareous and argillaceous cement.
960–979	No sample.
979–990	Sand and silt, pale-red (10*R* 7/2), poorly sorted. The sand consists of subangular to subrounded very fine to fine-grained quartz. Gypsum abundant. Some salt crystals. Calcareous cement.
990–1,000	Silt and clay, pale-red (10*R* 7/2). Contains gypsum. Calcareous cement.
1,000–1,010	Sand, pale-red (10*R* 7/2); composed of angular to subrounded very fine to coarse-grained quartz. Gypsum crystals abundant. Mica common. Calcareous cement.
1,010–1,180	Silt and clay, pale-red (10*R* 7/2). Interval contains very fine to coarse quartz grains, gypsum, and mica. Calcareous and argillaceous cement.
1,180–1,190	Silt and sand, pale-red (10*R* 7/2).
1,190–1,200	Silt, micaceous and sandy, pale-red (10*R* 7/2).
	Alluvial-fan deposits
1,200–1,210	Gravel, fine to coarse; angular to subrounded fragments of granitic composition.
1,210–1,230	Sand and gravel.
1,230–1,265	Gravel and sand. Gravel consists of granite, gneiss, schist, and quartz fragments, whose maximum diameter is 13 mm. Sand consists of coarse to very coarse-grained quartz.
1,265–1,280	Same as 1,230–1,265. Contains silt.
1,280–1,290	Silt and clay, pale-red (10*R* 7/2). Gypsum common.
1,290–1,300	Gravel and sand. Interval contains silt and gypsum.

TABLE 2.—*Lithologic log of well (B–6–12)15bbb 4 miles north-northeast of Wenden*—Continued

[Colors determined by comparison with the color chips on the rock color chart distributed by the National Research Council (Goodard and others, 1948]

Depth (feet)	*Description*
	Alluvial-fan deposits—Continued
1,300–1,320	Gravel.
1,320–1,345	Sand and gravel. Sand consists of subangular to rounded quartz grains.
1,345–1,400	Gravel.
1,400–1,405	Sand, silt, and gravel, pale-orange (10*RY* 8/2), poorly sorted. The sand consists of angular to subrounded very fine to very coarse-grained clear and milky quartz. Gravel about 10 percent of sample; maximum diameter 6 mm. Calcareous and argillaceous cement.

TABLE 3.—*Geologic interpretation of drillers' logs of wells in McMullen Valley*

Well location and rock description	Thickness (feet)	Depth (feet)	Altitude (feet)
(B–6–12)13dcc [Altitude 1,971 ft]			
Alluvium:			
Sand	40	40	1,931
Sand and gravel	90	130	1,841
Lake-bed deposits:			
Clay containing thin layers of sand	590	720	1,251
Alluvial-fan deposits:			
Sand with thin layers of clay	150	870	1,101
Sand and gravel with thin layers of clay	70	940	1,031
Hard sand	80	1,020	951
Decomposed granite	173	1,193	778
Total		1,200	
(B–6–12)18cdb [Altitude 1,978 ft]			
Alluvium:			
Soil	50	50	1,928
Caliche	100	150	1,828
Lake-bed deposits:			
Clay, gray to red, sticky	370	520	1,458
Clay containing thin beds of sand	140	660	1,318
Alluvial-fan deposits:			
Fine sand	40	700	1,278
Fine to coarse sand	200	900	1,078
Total		900	
(B–6–12)22add [Altitude 1,928 ft]			
Alluvium:			
Coarse sand and gravel	6	6	1,922
Sandy loam	20	26	1,902
Gray clay	14	40	1,888
Brown clay	28	68	1,860
Silt, sand, and gravel (seepage)	8	76	1,852
Lake-bed deposits:			
Brown clay, sticky	584	660	1,268

TABLE 3.—*Geologic interpretation of drillers' log of wells in McMullen Valley*—Continued

Well location and rock description	Thickness (feet)	Depth (feet)	Altitude (feet)
(B-6-12)22add—Continued			
Alluvial-fan deposits:			
Decomposed granite	10	670	1,258
Sand, water-bearing (hole filled up 400 feet within 2 minutes)	5	675	1,253
Gravel, water-bearing	10	685	1,243
Clay and gravel	8	693	1,235
Clay and gravel streaks	8	701	1,227
Decomposed granite	24	725	1,203
Gravel	15	740	1,188
Cemented gravel	5	745	1,183
Gravel, water-bearing	90	835	1,093
Decomposed granite	25	860	1,068
Gravel, water-bearing	10	870	1,058
Hard shell	5	875	1,053
Gravel, water-bearing	25	900	1,028
Hard shell	5	905	1,023
Gravel, water-bearing	5	910	1,018
Hard shell	20	930	998
Sand, water-bearing	10	940	988
Hard shell	3	943	985
Total		943	

Geologic literature on the western part of the United States is replete with data concerning lake-bed deposits in the intermontane basins of the Basin and Range province. Hundreds of ancient lakes have left deposits as evidence of their existence. Many of these lakes may have collected in basins, persisting only so long as the valley had not been filled with sediments up to the level of an outlet. Little is known of the climate that caused the lakes to form and then disappear, but it is a reasonable assumption that the climate was more humid than at present. Blackwelder (1948, p. 11) stated:

For reasons which are unkown, there occurred in the Pliestocene epoch at least four and perhaps five ages * * * of much colder climate which induced the formation of glaciers on all the higher mountains of the great basin and particularly upon the marginal ranges to the east and west. * * * During the coldest ages, when the temperature was probably * * * below the long term average, the evaporation was much slower, and hence the region must have been decidely less arid.

Thick bodies of clay are present along the Gila River in Arlington Valley, Salt River Valley, and other areas in southwestern Arizona. Ross (1923, p. 91), in his treatment of the Gila River, stated:

The formation of any such mass of clay as appears to be present in the valley of the Gila River must have occurred under conditions very different from those of the present day. Clay silts are deposited in quiet places in the present stream, but that hundreds of feet of clay, mixed with only minor amounts of sand, could be laid down by a turbulent and variable river like the Gila is not conceivable. It would appear that the clay must have been deposited in some quiet body of water such as a lake. The record of the presence of the clay is not continuous throughout the river valley, and the clay may not be a continuous and uninterrupted body. It may have been formed in a series of lakes, perhaps corresponding to the series of structural valleys that unite to form the long, sinuous valley of the Gila.

The fine-grained sediments in McMullen Valley may be contemporaneous with the clay described by Ross.

The lake-bed deposits in McMullen Valley are not considered to be a potential source of water supply for irrigation, because the fine-grained material has a very low permeability. Thus ground-water movement toward a well is retarded. Although some stock and domestic wells obtain water from these deposits, the quantities are small and the water has a higher concentration of dissolved solids than water from the other units.

ALLUVIUM

The upper part of the valley-fill deposits in McMullen Valley consists of alluvium deposited by Centennial Wash and its tributaries in late Pliestocene and in Recent time. The alluvium is composed largely of unconsolidated silt, sand, and gravel; in places, cementation by calcium carbonate has produced layers of caliche. In the central part of the valley the alluvium overlies lake-bed deposits, but elsewhere in the valley it overlies alluvial-fan deposits. The contact of the alluvium with underlying materials is generally apparent from drill cuttings, electric logs, and drillers' logs. The exposed contact of the alluvium with the alluvial-fan deposits mantling the lower slopes of the mountains is not so obvious, however.

The exposed alluvium along the channel of Centennial Wash is about 10 feet thick. Where penetrated by wells, the alluvium ranges in thickness from slightly less than 50 feet to about 470 feet. (See pl. 2.) The thickest section, as determined from an electric log, is 470 feet in well (B-7-9)16add. A driller's log of well (B-7-9)15cdd indicates that the alluvium is about 415 feet thick. The log of well (B-7-8)32ddd southwest of Aguila indicates a thickness of 190 feet. Well (B-7-8)1dac near Forepaugh penetrated 297 feet of alluvium, and well (B-7-7)17add, 3 miles southeast of Forepaugh, penetrated 161 feet of alluvium.

According to logs of wells, the thickness of the alluvium averages about 100 feet in the Wenden-Salome areas and is less than 50 feet near the southeast end of Harrisburg Valley. In both areas the alluvium thins to a featheredge along the margins of the valley floor.

The alluvium is not an important aquifer in the areas of Wenden, Salome, and Harrisburg Valley, because the water table lies near or below the base of the unit. In the Aguila area many of the domestic and stock wells obtain water only from the alluvium, but irrigation wells obtain water from both the alluvium and the alluvial-fan deposits.

STRUCTURE

McMullen Valley owes its origin to faulting rather than to erosion; thus, it is a structural valley similar to many others of the Basin and Range province. The alinement of the mountain ranges and valley area is the result of movement along major faults, the mountain block having been lifted and tilted in relation to the intervening valley.

Displacement along a major fault on the west side of the Granite Wash Mountains has elevated the mountains with respect to the Ranegras Plain. The northeastward alinement of McMullen Valley suggests that large-scale cross faulting is responsible for the trend of the Harquahala and Harcuvar Mountains. Ross (1923, p. 176) suggested that the northwest side of the Harquahala range facing McMullen Valley is a fault scarp. The steep southeastward dip of the Paleozoic sedimentary rocks in the Harquahala Mountains (Metzger, 1957, pl. 1) suggests that the range may be a tilted fault block. Similar conditions may be postulated for the Granite Wash Mountains, because highly metamorphosed sedimentary rocks in those mountains dip to the northeast. In contrast, steeply dipping volcanic and sedimentary rocks at the northeast end of the Harcuvar Mountains are tilted to the southwest. Harrisburg Valley, which separates the Harquahala from the Little Harquahala Mountains, trends northwestward. This small wedge-shaped valley appears to be a depressed block that is tilted northwestward. At the narrowest point of the wedge, bedrock was penetrated at less than 50 feet, whereas well (B–5–13)26acc was drilled to a depth of 570 feet without penetrating bedrock.

The bedrock that underlies the sedimentary deposits of the valley undoubtedly has an irregular surface of high relief which is more closely related to the structural history than to the erosional history of the area. The outlying granitic mountains, which in the eastern part of the area are almost buried by alluvium, and the sequence of steeply dipping volcanic and sedimentary rocks are an indication of the complexity of the structure. The attitude of the volcanic rocks in the eastern part of the valley indicates that the bedrock lies at a relatively shallow depth. This probability is verified by subsurface evidence obtained from drillers' logs of well (B-7-7)17add and (B-7-8)1dac. Well (B-7-7)17add penetrated "andesite rock" at a depth of 161 feet, and well (B-7-8)1dac penetrated volcanic breccia at a depth of 297 feet and red granite at a depth of 482 feet. It is significant that well (B-7-8)15baa, which is only 2½ miles southwest of well (B-7-8)1dac and 1,812 feet deep, did not reach bedrock.

The age of the structural trough occupied by McMullen Valley cannot be determined precisely. Displacement of Tertiary(?) sedimentary and volcanic rocks by faulting indicates that much of the major structural movement in the area probably occurred during Tertiary time. The youngest rocks known to have been deformed are the basalt flows of Quaternary age. These rocks, however, appear to be only slightly deformed, whereas the rocks of Tertiary(?) age have been considerably deformed. In all probability the elevation of the ranges proceeded step by step during an extended period, the displacement occurring along pre-existing planes of structural weakness. Displacement may still be in progress.

The configuration of the bedrock is one of the principal factors controlling ground-water movement. The relatively impervious mountain areas on the north, south, and west sides of McMullen Valley prevent subsurface inflow to and outflow from the area; although the bedrock surface at the southeast end of Harrisburg Valley is higher than the bedrock surface in the central part of the valley, it is the lowest part on the "rim" of the bedrock basin and so is the overflow lip for ground water.

GROUND WATER

OCCURRENCE

The principal ground-water reservoir in McMullen Valley consists of the valley-fill deposits that occupy the structural trough between the mountain ranges.

The porosity of the material within the ground-water reservoir determines the amount of water that can be stored. Porosity is the percentage of the total volume of the material that is occupied by interstices or pore space and is dependent upon the shape, arrangement, degree of sorting, and cementation of the component particles. Thus, an unconsolidated material consisting of well-rounded and well-sorted loosely arrayed particles has a high porosity. Unsorted material has a low porosity, because fine-grained material reduces the size of the voids between the larger particles.

The valley fill is saturated up to a surface termed the "water table," and the water occurs chiefly under nonartesian conditions. The buried parts of the mountains are relatively impermeable and thus are effective barriers to the movement of ground water out of the valley fill. The buried bedrock ridge at the southeast end of Harrisburg Valley controls the general elevation of the water table in the entire area of investigation. The water table has a gentle slope to the southwest conforming generally to the topography of the land surface. The land-surface gradient, however, is greater than the water-table gradient, and thus the depth to water increases northeastward along the valley floor. The depth to water also increases laterally from the axis of the valley. The average depth to water in the Aguila area is about 375 feet; in the Wenden area it is about 180 feet, if shallow water bodies perched on clay beds are discounted. (See p. 45.) The depth to water in the Salome-Harrisburg Valley area ranges from about 150 feet, just 1 mile north of Salome, to about 40 feet near the narrows dam.

The configuration of the water table may be depicted on maps by contour lines based on the altitude of the water level in nonartesian wells. Such maps show the general direction of ground-water movement. Some of the maps also indicate areas of recharge and discharge, major differences in the permeability of the water-bearing materials, and the location of sub-surface barriers to ground-water movement.

Under natural conditions of recharge and discharge, the shape and altitude of the water table in McMullen Valley are relatively stable for long periods. Man-made changes in the hydrologic regimen, such as pumping from wells, may cause significant corresponding changes in the configuration of the water table. Withdrawals by pumping, for example, result in the formation of a cone of depresesion in the water table in the pumped area. The lateral extent of such a cone depends on the quantity of water pumped, the permeability of the material that surrounds the well, and under some conditions the amount of water available for replenishment of the dewatered sediments.

Where adequate data were available, water-table maps and graphs were prepared for parts of McMullen Valley—the Salome-Harrisburg Valley and Aguila areas. The data are shown graphically in two ways, by hydrographs for selected wells which show changes at a single point and by maps prepared for the selected periods. The maps were drawn for periods in which irrigation was near minimum for the year.

In 1951, the altitude of the water table at measured wells ranged from about 1,811 feet in the Aguila area to 1,642 feet at the southeast end of Harrisburg Valley. The water-table gradient averaged about 5 feet per mile for about 32 miles along the axis of the valley to the narrows. The data available on the Salome-Harrisburg Valley area for this period show that the water-table gradient was about 18 feet per mile. Thus, the slope of the water table between Aguila and Salome was about 1½ feet per mile. The water table has a very low gradient throughout the Aguila area. The shallow slope suggests that the rate of ground-water movement in the valley-fill deposits is very slow under natural conditions and indicates that little recharge occurs. Sufficient control data are not available to depict the water table in the Wenden area in 1951. The data from eight wells provide the basis for very generalized contours of the water table in the Salome-Harrisburg Valley area in 1951 (pl. 3). The southeastward trend indicates ground-water movement parallel to the trend of Harrisburg Valley. The close spacing of the contour lines toward the lower end indicates a steep gradient. This increase in slope was necessary to move the ground-water inflow to Harrisburg Valley through the narrow discharge point at the southeast end of McMullen Valley.

The configuration of the water table as depicted for 1951 is, in general, assumed to be the original form of the ground-water surface in the area, because the aquifer in McMullen Valley probably was in effective hydrologic balance for many years prior to that year.

Subsequent ground-water development for irrigation in the Salome-Harrisburg Valley and Aguila areas caused major changes in the water table. These changes are reflected in the hydrographs of observation wells and the maps of both areas.

A comparison of the water-table contour maps prepared for 1951 (pl. 3) and October 1958 (pl. 4) for the Salome-Harrisburg Valley area shows the significant changes. The gradient of the water table increased from an average of about 18 feet per mile in 1951 to about 24 feet per mile in October 1958. The slope was steepest in Harrisburg Valley, where the potential volume of saturated sediments is least (near the narrows) and pumping has been more concentrated.

Declines of water levels in selected wells are shown on the hydrographs (fig. 7). The water level in well (B-5-12)32adb declined 42 feet from 1952 to October 1958. The use of this well and several others has been discontinued owing to the insufficient water supply, and some shallow wells have gone dry. The decline of the water level in well (B-5-13)9ddd near Salome was 7 feet from 1951 to 1958 (fig. 7). A reversal in gradient is indicated by the altitude of the water level in well (B-4-12)5baa at the narrows; in May 1958 the

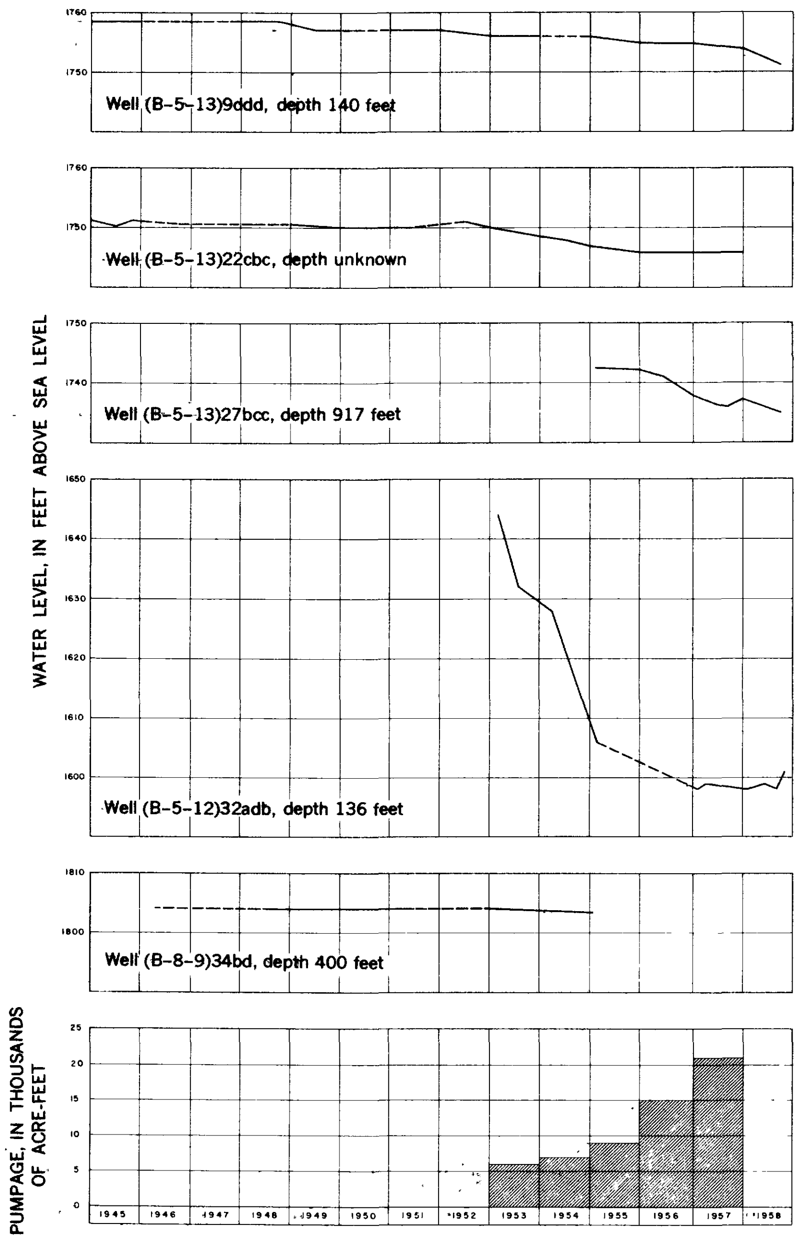

FIGURE 7.—Graphs of water-level fluctuations in observation wells and of pumpage in McMullen Valley, Ariz.

altitude was 1,625 feet, or 25 feet higher than that of the water level in the upstream well (B-5-12)32adb (table 4).

TABLE 4.—*Description of wells in McMullen Valley*

Well: See p. 3 for explanation of well-numbering system.
Type of well: Ct, cable tool; R, rotary; Dg, dug.
Depth to water: Reported depths indicated by (r).
Type of pump: C, cylinder; J, jet; N, none; T, turbine.
Type of power or fuel: D, diesel; E, electric; G, gasoline; NG, natural gas; W, wind.
Rate of discharge: All figures are rounded. Reported yields are indicated by (r).
Use of well: D, domestic; I, irrigation; Ind, industrial; N, none; O, observation; PS, public supply; S, stock.
Remarks: Ca, sample collected for chemical analysis.

Well	Owner or operator	Type of well	Year completed	Reported depth of well (feet)	Diameter of casing (inches)	Reported length of casing (feet)	Reported zone of perforated casing (feet)	Depth to water below land surface (feet)	Date of water-level measurement	Altitude of land surface (feet)	Pump: Type	Pump: Power	Pump: Horsepower	Rate of discharge (gpm)	Date of discharge measurement	Use of well	Remarks
(B-4-12)5aa	D. M. Brown	Ct	1958	730	22			340(r)	1958	1,664	N	N	N	450(r)		N	
								375	9-10-58								
								342	10- 7-58								
5baa	do	Ct			20			41	5- 8-58	1,666	N	N	N			N	
(B-5-12)6cab	H. Orrozco	Ct	1930	240		Uncased		77	2- 2-51	1,840	C	G				S	Ca.
								69	1-21-57								
								77	5-30-58								
								48	10-10-58								
30bcc1	D. P. McGarvin.	Ct	1950	250	16	54		42(r)	7- -50	1,746	T	E	25	350(r)		I	
								41	2-22-51					500(r)			
		Ct	1955	300				54(r)	3- 4-55					400	7-29-57		
								62	9-30-57								
30bcc2	do			98	16	98	48-98	56	11-28-56	1,744	C	E				D	
								64	10- 7-58								
30da	D. M. Brown.			340	16			130	1-16-57	1,758	N	N				N	Never tested. Drilling tools lost in hole. Reported to have struck granite.
								134	10- 7-58								
30db	Unknown	Ct	1952	500	20	4		98	5- 4-57		N	N				N	
								100	10- 7-58								
30dcc	D. M. Brown.	Ct	1951	174	16	154	0-154	35(r)	7-21-51	1,718	T	E	30	400	7-29-57	I	Ca.
								92	1-16-57								
30dd	do	Ct	1952	400	16	200	50-200	50(r)	1-15-52	1,739	T	E	25	250	7-29-57	I	Ca.
								95	2-27-53								
								115	1-16-57								
31aaa	do	Ct	1952	265	16	150	47-150	47(r)	2-20-52	1,714	T	E	75	2,100(r)		I	Ca.
31aab	do	Ct	1951	173	16			40(r)	10-10-51	1,718	N	N		1,800(r)		N	
								104	1-16-57								
								109	10- 7-58								
31ab1	do	Ct		300	14			100	1-16-57	1,719	N	N				N	Reported to have struck granite.
								105	5- 8-58								
								102	10- 7-58								

TABLE 4.—*Description of wells in McMullen Valley*—Continued

Well	Owner or operator	Type of well	Year completed	Reported depth of well (feet)	Diameter of casing (inches)	Reported length of casing (feet)	Reported zone of perforated casing (feet)	Depth to water below land surface (feet)	Date of water-level measurement	Altitude of land surface (feet)	Pump: Type	Pump: Power	Pump: Horsepower	Rate of discharge (gpm)	Date of discharge measurement	Use of well	Remarks
(B-5-12) [illegible]	Fred Miller	C[illegible]	1951	35	------	------	------	D[illegible]r)	------	------	N	N	------	------	------	N	Granite at 35 ft.
[illegible]	[illegible]																Dry hole.
31ab3	do		1951	[illegible]	------	------	------		------	------	N	N	------	------	------	N	Dry hole.
31ac	do	Ct	195[illegible]	[illegible]	[illegible]	101	50-10[illegible]	[illegible]	8- 52 10- -58	------	[illegible]	[illegible]	3	35(r)	------	N	
31ad	do	Ct	1944	72	10-8	72	12-72	[illegible] 55 Dry	3-26-46 2-22-51 1-16-57	1,722	N	N	------	------	------	N	Granite [illegible]
32acb	A. Nord	Ct	1952	52	20	52	32-50	31(r)	4- 6-52	------	------	------	------	------	------	N	Granit[illegible]
32acc	do	Dg	1921	36	96	------	------	18(r) 19 24(r) Dry	5- -21 3-26-46 10-26-50 1-16-57	1,698	N	N	------	------	------	N	Well [illegible] 3
32adb	D. M. Brown.	Ct	1952	80 136	16	------	------	53 64 69 90 98 98 99 98 99 99 95	2-27-53 7-20-53 3-29-54 2- 7-55 1-16-57 3-13-57 1-31-58 5- 8-58 8-22-58 8-29-58 10- 7-58	1,698	N	N	------	------	------	O	Unused irrigation well.
32add	do	Ct	1940	135	24	------	------	41 101	10-10-51 1-16-57	1,697	T	E	20	150	1-22-57	I	Ca.
33cbd	A. Nord	Dg	------	34	12	------	------	28 Dry	2-22-51 1-16-57	1,670	N	N	------	------	------	N	
(B-5-13) 1cba	O. J. Churchill.	Ct	1958	730	20	400	------	107 106	6-17-58 10-10-58	1,858	T	NG	150	------	------	I	
2baa	D. Anderson.	Ct Ct	1955 1957	300 692	16-12 ------	374 ------	------	140 145 145 147	1-17-57 10-17-57 1-29-58 10-10-58	1,898	T	G	200	2,500(r)	------	I	Ca.
2caa	T. Saunders	Ct	1954	265	18-12	160	------	105(r) 116 118 120	11-30-56 1- 9-57 1-29-58 10-10-58	1,874	N	N	------	------	------	N	

2dad1	Eli McCaslin.	Ct	1955	340	12	340	96–340	96(r)	7- -55	1,859	T	G	65	700(r)	----------	I	Ca.
								103	5-14-57								
								104	7-30-57								
2dad2	do	Ct	1956	200	8	200	180–200	95(r)	1-24-56	-------	C	E	1.0	----------	----------	D	
								104	11-27-57								
4cbb	H. L. Kirchener.	Ct	------	350	14	------	----------	208	3-25-55	1,964	T	E	75	900	3-30-54	I	Ca.
								211	10-11-57								
								216	10-10-58								
4ccb	do	Ct	1956	350	16	350	30–350	180(r)	4- -56	1,953	T	E	150	1,600(r)	----------	I	
								201	10-11-57								
								205	10-10-58								
4ccd	do	Ct	------	202	6	------	----------	195(r)	3-27-46	-------	C	E	------	----------	----------	D	
5adc1	D. P. Welch	Ct	1949	355	8	355	220–258	215(r)	7- -49	1,978	T	E	7.5	50(r)	----------	D	
							313–355										
5adc2	do	Ct	------	152	------	------	----------	Dry	3- 7-57	1,981	N	N	------	----------	----------	N	
		Ct	1958	300	------	------	----------	228	5- 8-58								Well cleaned out April 1958.
								Dry	10-10-58								
5cbb	V. B. Croaff	R	1958	550	16	550	----------	259(r)	7- -58	2,018	N	N	------	625(r)	----------	I	Not in use.
		Ct	1958	755	12	------	----------										
9dcc	Shefflers	------	1919	185	8	------	----------	135(r)	3-27-46	1,888	T	E	5.0	----------	----------	D	Ca.
								136	1-24-57								
9ddd	D. Wiley	Ct	1944	140	6	20	----------	107	1- 6-45	1,866	T	E	------	----------	----------	D,O	
								107	6-11-45								
								107	10- 3-45								
								107	10-20-48								
								108	7- 6-49								
								108	7-31-51								
								109	7-16-52								
								109	2-26-53								
								109	7-21-53								
								109	2- 8-55								
								[illegible]	3-15-56								
								[illegible]	1-22-57								
								[illegible]	[illegible]-30-58								
								[illegible]5	[illegible]-3-58								
[illegible]	[illegible]	[illegible]	[illegible]	504	[illegible]	504	160–459	[illegible]8	11- 4-57	1,904	N	N	------	2,600(r)	----------	I	
								148	1-29-58								
								151	10-10-58								
[illegible]cad	Chuck A Luck Cafe	Ct	1955	150	6	150	0–150	95(r)	11- -55	1,863	T	E	1.0	----------	----------	D	
								107	1-25-57								
10cda1	C. O. Walker	Ct	1948	220	8	200	160–200	97(r)	1955	1,862	T	D	30	----------	----------	I	Not in use.
								107	5- 7-57								
10cda2	Schuler	Ct	1951	165	6	165	90–165	107	1-25-57	1,863	T	E	.75	----------	----------	D	
10cda3	do	Ct	1957	327	12	327	150–327	110	1-29-58	-------	T	E	------	----------	----------	I	
10dba	C. O. Walker.	Ct	1958	------	16	------	----------	108	10- 8-58	-------	T	N	------	----------	----------	N	Not in use.
10dbc	H. Nicholls	Ct	1955	155	6	155	----------	103(r)	4- -55	1,861	T	E	.75	----------	----------	D	Ca.
11baa	N. M. Hughes.	Ct	1958	------	14	------	----------	108	10- 8-58	-------	N	N	------	----------	----------	N	Not in use. New well.

TABLE 4.—*Description of wells in McMullen Valley*—Continued

Well	Owner or operator	Type of well	Year completed	Reported depth of well (feet)	Diameter of casing (inches)	Reported length of casing (feet)	Reported zone of perforated casing (feet)	Depth to water below land surface (feet)	Date of water-level measurement	Altitude of land surface (feet)	Pump: Type	Pump: Power	Pump: Horsepower	Rate of discharge (gpm)	Date of discharge measurement	Use of well	Remarks
(B-5-13)12abb	T. Saunders	Dg		150				70-80(r)	11- -50		N	N				N	Caved. Not in use.
14bbb1	do	R	1948	301	18	301	93-301	Dry 75 80	4-17-57 1- 8-57 10-10-58	1,831	T	N		2,500(r)		I	Not in use.
14bbb2	do	Ct		180	18	180		70(r) 74	9- -48 1- 8-57	1,830	T	N				I	Do.
14cbb	do	Dg		100	54			40(r) 55 60 62 64	11- -50 3-26-46 2-23-51 1-16-57 10-10-58	1,816	C	W				S	Ca.
15bab	W. Ocheltree.	Ct	1957	662	20-16	662		99 103 103	4-26-57 6-17-58 10-10-58	1,853	T	NG	200	3,100(r)		I	Ca.
15bc	do	Ct	1958	143							T	E				D	
15ca1	Leo Stein		1924	128	6			80(r)	11- -50	1,843	T	E	7.5			D	
15ca2	C. E. Billings.	Ct	1956	220	6	220	85-220	79	1-24-57	1,834	T	E	1.0			D	
15ca	High School	Ct	1955	200	10	200	30-200	84 83	10- 7-58 12- 6-56	1,836	T	E	15			PS	Ca.
15dda	Arizona Public Service Co.	R	1957	180	6	180		75	4-25-57	1,804	N	N				N	Power-substation ground.
16aa1	E. V. Haydis.	Ct	1939	152	6	152		106(r) 115	4- 6-54 5-14-57		C	E	1.5			D	Ca.
16aa2	Taylor Estate.	Ct		300	8	300		112	2- 1-57		N	N				N	Not in use.
16aa3	J. F. Passey	Ct	1945	150	8	20		109(r) 112	1952 2- 1-57		T	E				D	Do.
16aa4	do	Ct	1943	150	8	20		105(r)	1943		C	E	1.0			D	Do.
16aa5	Charles E. Martin.	Ct		155	8	20					T	E				D	
16ab1	Sheffler	Ct	1928	350	18	350		121(r)	1929	1,878	T	E		400(r) 190(r)		PS	Town of Salome.
16ab2	do		1906	237	10	225		125(r)	1906		T	E		120(r)		PS	Town of Salome. Ca.
16add	J. King	Ct	1948	150	6			148	1-24-57		C	E		110(r)		D	Ca.

16bab	Unknown		1926		6			139	1-24-57	1,894	N	N				N	Not in use.
16ddb	R. K. R. Ranch.	Ct	1957	330	16	330	100–330	99	4-25-57		N	N				I	Do.
17da1	Dupler				6						T	E	1.0			D	
17da2	Monty's Gas Station.				6						T	E	1.0			D	
17dc1	White Distributing.	Ct	1950	205	6						T	E				D	Not in use.
17dc2	Whiting Brothers.	Ct		180				156	2- 1-57		T	E				D	Ca.
19bcd	J. Pappas	Ct	1935	282	8	260	210–260	200	2-22-51	1,958	C	G				D	
19dbc	K. Mork		1931	411	6			165	3-27-46	1,922	T	E	10	60(r)		D	Ca.
20ba	R. Granger			200	6			145	3-27-46		T	E				N	Not in use.
								153	2-22-50								
21dcc	R. K. R. Ranch.	Ct	1952	550	16	550	132–550	132(r)	12- -52	1,893	T	E	60	500	7-29-57	I	Ca.
								158	11-23-56								
								158	1-29-58								
								163	10-10-58								
22cbc	Gray				6			111	1- 6-45	1,862	C					D, O	Domestic well not in use. Observation well until 10-10-58.
								112	6-11-45								
								111	10- 3-45								
								111	2-19-46								
								112	7- 6-49								
								112	8- 1-50								
								112	2-21-51								
								111	7-16-52								
								116	5- 4-57								
								116	1-29-58								
23bda	T. Brown	Ct	1955	80	4	80	60–80	55(r)	2- -55	1,791	J	E	1.0			D	
23dcc1	S. Brown	Ct	1943	100	6			60(r)	1943	1,796	C	W				D	Ca.
								71	5-14-57								
23dcc2	do	Ct	1916	365	20			60–70(r)	11-23-56	1,796	T	E	15*	400(r)		I	
								81	10-10-58								
23dcc3	do	Ct		100	6	10		60–70(r)	11-23-56	1,797	C	E				S	
25abb	H. Kast	Ct	1955	300	8			40–50(r)	8- -55	1,761						D, S	
25abc	do										C	W				D, S	
25ad	Unknown	Ct	1949	100	8			40–50(r)	1949		T	E	1.0			D	
25ddb	J. Bell	Ct	1952	110	8			64	11-28-56	1,750	C	E	2.0	18(r)		D	Ca.
26acc	A. Liedig	R	1954	570	20–16	570		92	1- 7-57	1,804	T	E	100			I	Ca.
								88	10-10-58								
26dcc	do	Ct	1957	998	20	608	368–608	89	7- 9-57	1,803	N	N				I	Not in use.
								86	1-29-58								
								87	10-10-58								
27bcc	do	R	1953	917	20			162	3-25-55	1,904	N	N		450(r)		O	Do.
								162	3-15-56								
								166	11-23-56								
								168	4-12-57								
								168	10-11-57								
								167	1-31-58								
								169	10-10-58								

TABLE 4.—*Description of wells in McMullen Valley*—Continued

Well	Owner or operator	Type of well	Year completed	Reported depth of well (feet)	Diameter of casing (inches)	Reported length of casing (feet)	Reported zone of perforated casing (feet)	Depth to water below land surface (feet)	Date of water-level measurement	Altitude of land surface (feet)	Pump: Type	Pump: Power	Pump: Horsepower	Rate of discharge (gpm)	Date of discharge measurement	Use of well	Remarks
(B-5-13)28acc	R. K. R. Ranch.	Ct	1953	723	16	450	122–450	122 (r)	1953	1,918	T	E	60	400	7-29-57	I	Ca.
								195	11-23-56								
								194	10-11-57								
								196	10-10-58								
35ada	Charles Black.		1914	100	8			80 (r)	1954	1,792	C	G				D, S	
(B-6-9)2abd	H. C. Ross			680	8	300		445 (r)	1952	2,255	C	E				D	Ca.
(B-6-11)6da	Louis Sahhar.	Dg		208				177	4- 1-54		C	G				S	Noel well.
								178	2- 8-55								
								178	1-21-57								
								177	1-28-58								
								177	10-21-58								
11bcc	Farmers Investment Co.		1935	450	6	450		350 (r)	11- -49		C	G				S	Not in use.
13bb	Aguila Cattle Co.	Ct	1957	412	8			362	5- 1-57	2,174	N	N				N	Incomplete. Tools lost in hole.
								391	10-21-58								
31aa	Jack Clem				6			416	10-18-57		C	W				S	
								420	10-21-58								
(B-6-12)13bcc	J. P. Babcock.		1930	350	6			141	2-21-51		N	N				S	Not in use.
13cc1	do			350	6			130	2-21-51		N	N				S	Do.
13cc2	do			370	6						N	N				S	Do.
13dcc	do	R	1957	1,200	20–16	1,200	350–1,193	214 (r)	5-24-57	1,971	T	E		3,500 (r)		I	Ca.
								223	6- 5-57								
								220	10-18-57								
								217	1-28-58								
								223	3-25-58								
								225	10-21-58								
13ddd	do	R	1955	1,986	20–16	1,196	77–1,195	212 (r)	9- -55	1,982	T	E	250	2,500 (r)		I	Ca.
								230	1-21-57					2,300			
								222	10-18-57								
								219	1-28-58								
								221	3-25-58								
15bbb	F. Rolls	Ct	1958	1,432	16–12	1,432	950–1,000	230	7- 2-58	1,955	N	N				N	Never pumped. Ca.
							1,200–1,425										

(B-6-12)18cdb	B. and O. C. Mathews.	Ct	1956	900	16-12-8	900		213	12-7-56	1,978	T	D	125	500	7-30-57	I	Ca.
								220	10-11-57								
								216	1-28-56								
								217	10-10-58								
19acd	do	Ct	1933	207	12-6	207	177-207	146	2-22-51	1,936	C	E	1.0			D	Ca.
								148	1-30-57								
								148	10-11-57								
19cbd	Unknown				8			155	2-22-51		N	N				N	Well dry in 1957.
19dbb	W. Stephens.	Ct	1933	550						1,940							
		Ct	1956	1,000	16-12	1,000		168	11-27-56		T	D	80	500	6-6-57	I	Ca.
								189	10-11-57								
								183	1-28-58								
								185	10-10-58								
21dc	Unknown	Dg		135	36×48			104	1-8-57	1,896	N	N				S	Not in use.
								103	10-21-58								
22add	William Sudden.	Ct	1957	943	22-20-16	943		168	6-18-57	1,928	N	N		2,000(r)		I	Do. Ca.
								168	1-29-58								
								175	7-2-58								
								174	10-21-58								
29cdc	Dasco Mines, Inc.	Ct	1957	710	16	710	120-710	87	4-23-57	1,874	T	E	40			Ind	
31add	J. R. Wood			500	6			78	1-6-45		N	N				N	Not in use.
								79	6-10-45								
								80	10-3-45								
								81	2-19-46								
								87	6-9-48								
								85	10-20-48								
								86	7-6-49								
31bbb	Don Anderson.	Ct	1957	915	20-16	705		134	10-1-57	1,886	T	G		1,600(r)		I	Ca.
								133	1-29-58								
								136	10-10-58								
32bbc	Wenden Water Works.		1916	778	10			117(r)	3-27-46	1,873	T	E	10			PS	Ca.
								108	1-11-57								
(B-6-13)24bbb	Unknown		1950	700	12			244	5-14-57	1,999	N	N				N	Not in use. Never tested.
								245	1-29-58								
								244	5-30-58								
28dd	Hancock		1943	300	8		245-285	255(r)	2-16-43		C	G				S	Not in use.
(B-7-7)17add	Town of Wickenburg.	Ct	1942	966				480(r)	4- -56		T	E		80(r)		D	Ca.
17ddc	S. E. Thrasher.	Ct	1945	580			480-580	487	5-2-57	2,419	T	E				D	Ca.
(B-7-8)1daa	Farmers Investment Co.	Ct	1916	466	10-6						T	E	10			D	
1dac	do	Ct	1953	499							T	E		15(r)		D, S	
12abb	do	Ct		562													
12ccc	do		1915	510	6						N	N				N	Caved.

TABLE 4.—*Description of wells in McMullen Valley*—Continued

Well	Owner or operator	Type of well	Year completed	Reported depth of well (feet)	Diameter of casing (inches)	Reported length of casing (feet)	Reported zone of perforated casing (feet)	Depth to water below land surface (feet)	Date of water-level measurement	Altitude of land surface (feet)	Pump: Type	Pump: Power	Pump: Horsepower	Rate of discharge (gpm)	Date of discharge measurement	Use of well	Remarks
(B-7-8)15baa	Wilco Produce Co.	R	1958	1,812				442(r)	10- 3-58	2,246	N	N				I	
16aaa	do	R	1958	1,627	20-16	1,627	400-1,627	435 433	7-26-58 10- 2-58	2,236	T	G	300	2,600(r)		I	
18cc	Farmers Investment Co.		1900	400						2,198	C	E				S	
20ddd	A. T. Foster	Ct	1958	1,000	20-18	1,000	480-565 568-1,000	412	9-30-58	2,224	N	N				I	Not tested.
27dd	W. N. Talley.			388	8												Dry hole.
28add	Hogue-McDaniels.	Ct	1958	300												I	Well incomplete.
29ddd	do	R	1957	1,720	20-12	1,720	400-1,720	417 417	10- 4-57 4-15-58	2,225	T	E	400	2,500	5- 6-58	I	Ca.
30daa	Talley Ranch	R	1957	1,620	20-12	1,620		380 387 388 388 388 400	4-25-57 6- 5-57 1-28-58 4-17-58 9-30-58 10-23-58	2,199	N	N				I	
31ddd	Hogue-McDaniels.	Ct	1958	300	20	300				2,218	N	N				I	Well incomplete.
32add	do	Ct	1958	300	20	300				2,226	N	N				I	Do.
32ccc	Talley Ranch.	Ct	1935	462	6	462		387(r)	1955	2,219	T	E				D	Ca.
32ddd	Hogue-McDaniels.	Ct	1958	1,265	20-18	1,265	500-1,140 1,145-1,265	418	6-13-58	2,227	T	E		1,200	8- 6-58	I	Granite at 1,240 ft.
(B-7-9)4bbb	Farmers Investment Co.	R	1957	1,650	20-12	1,650	400-1,650	338 348 375 375	2-18-57 11- 4-57 4- 9-58 10-22-58	2,138	T	E	300	1,500	4-16-58	I	Ca.
4cbb	do	R	1957	1,650	20-12	1,650	400-1,650	349 347	10- 8-57 4- 9-58	2,130	T	E	300	2,000	4-16-58	I	Ca.
9aaa	do	R	1957	1,650	20-12	1,650	400-1,650	340 354	3- 8-57 4- 9-58	2,146	T	E	400	3,200(r) 2,300	 7-30-57	I	Ca.
10aaa	Aguila Farms.	R	1958	1,420	20-12	1,420	300-1,420	374	10- 1-58	2,174				3,000(r)		I	
11aaa	do		1954	1,020	16-12	1,020	380-1,014	385	1-10-57	2,195	T	E	400	2,200(r)		I	Ca.
11add	do	R	1956	1,317	20	1,317	250-1,317	379 392	1-10-57 10-22-58	2,189	T	E	300	2,400 2,600	12-24-56 5- 6-58	I	Ca.

11baa	do	R	1958	1,450	20-12	1,450	300-1,450	383	10- 2-58	2,186				3,200(r)		I	New well.
11ddb	do			431							T	E	7.5			D	
12aaa	do	Ct	1958	1,415	20			418	6-27-58	2,217				3,200(r)		I	New well.
								412	9-29-58								
12dad	do	R	1958	1,205	20-12			407	9-29-58	2,214				3,000(r)		I	Do.
14aba	do	Ct	1954	717	20	717	385-415	365	3-31-54	2,177	T	E	300	2,000(r)		I	Ca.
							425-412	369	6-19-57								
14cc	A.T. & S.F.R.R.		1910	450	13-10		357-388	355(r)	1936	2,167	T	E		150(r)		Ps	Ca. Town of Aguila.
								357	4-10-42								
14dda	U.S. Manganese Corp.	Ct	1949	475	10	450	425-448				T	E	7.5			N	Not in use.
15cdd	Farmers Investment Co.	Ct	1957	750	20	750	385-700	343	2-25-57	2,153	T	E	400	2,700	7-30-57	I	Ca.
								352	4- 9-58					2,500	4-29-58		
16add	do	R	1957	1,660	20-12	1,660	400-1,660	336	5- 1-57	2,145	T	E	400	3,200	7-30-57	I	Ca.
								342	4- 9-58					3,300	5- 2-58		
16ddd	do			387	6			338	5-23-57	2,147	C	E	7.5			D	
17dcd	H. B. Garriu Co.	R	1957	1,610	20-12	1,610		358	3-25-58	2,145	T	E	400	3,000(r)		I	Ca.
								337	4- 9-58					3,200	4-29-58		
21dc	Unknown			372							N	N				N	Not in use.
22bc	Reed & Hoyle Enterprises, Inc.	Ct	1947	380	8	380		347	2-21-51	2,155	T	E	7.0			D	Ca.
								355	10-3-58								
24aaa	Norton & McElroy.	R	1958	1,562	20-12	1,562	450-1,562	392(r)	2- -58	2,196	T	E	400	3,000(r)		I	
24bbb	Burro Jim Motel.	Ct	1953	413	8			360(r)	12- -53		T	E	3.0			D	
								365	11-26-57								
25bbd	Unknown		1910	398	10			366	2-20-51		N	N				S	Not in use.
34bbd	H. C. Rose			422	10			Dry	7- 6-49		N	N				N	
(B-7-10)13cdd	Farmers Investment Co.	Ct	1958	800	20		365-800	305	9-11-58	2,110	N	N				I	New well.
								305	10- 2-58								
16ddd	do			325	6			264	3- 8-57	2,017	C	W				S	
								264	7-17-58								
								264	10-22-58								
19adc	do		1950	360	6					2,048	C	W				S	
33ddd	Gladden Huthmacher.	Ct	1949	435	10			393	2-20-51	2,204	T	E				D	Ca.
								398	11- 6-57								
36bbb	Farmers Investment Co.			420	6	420		350(r)	11- -49	2,193	C	W				S	
								385	2-20-51								
(B-7-11)8dd	Unknown	Ct	1949	450	6						C	G				S	
27da	Unknown	Ct	1956	340				227	10-24-57	2,026	N	N				N	Not in use.
								227	9-23-58								

TABLE 4.—*Description of wells in McMullen Valley*—Continued

Well	Owner or operator	Type of well	Year completed	Reported depth of well (feet)	Diameter of casing (inches)	Reported length of casing (feet)	Reported zone of perforated casing (feet)	Depth to water below land surface (feet)	Date of water-level measurement	Altitude of land surface (feet)	Pump			Rate of discharge (gpm)	Date of discharge measurement	Use of well	Remarks
											Type	Power	Horsepower				
(B-8-8)30ddd	Mason Mines, Inc.	Ct		570	8			470(r)	1949	2,284	C	G	7.0			S	
(B-8-9)26cca	Pearl Ward	Ct	1945	428	8			379	1-9-57	2,190	T	E	10			D	
								380	1-28-58								
								384	10-3-58								
27dcc	Farmers Investment Co.															D	
32aaa	do	Ct	1954	1,352	20-12	1,352	375-590	354(r)	4-19-54	2,166	T	E	250	2,150(r)		I	Ca.
							600-1,340							1,600	7-30-57		
32baa	do	R	1955	1,003	20-16	1,003	418-1,003	365	12-14-56	2,166	T	E	150	1,400(r)		I	Ca.
								380	4-9-58					900	5-2-58		
32dd	do			410							N	N				N	Not in use.
33aab	do	Ct	1956	831	20	831	390-810	356	11-19-56	2,164	T	E	125	700	7-30-57	I	Ca.
								376	3-25-58								
								374	4-9-58								
33ddd	do	R	1957	1,650	20-12-8	1,650	400-1,650	348	2-25-57	2,152	T	E	200	1,800	4-30-58	I	Ca.
								357	11-4-57								
								368	4-9-58								
34bdd	do			400	20			354	3-27-46	2,158						N	Observation well until 2-8-55. Caved in.
								354	7-31-50								
								354	7-31-51								
								354	2-26-53								
								354	3-21-53								
								354	4-2-54								
								355	2-8-55								
(B-8-10)12cb	Develco, Inc.	Ct	1953	600	8			430(r)			N	N				N	Not in use.
27dc	do			451	6	451		430(r)			C	G	5			D, S	
35bbb	do	R	1958	1,402	20-12	1,402	350-1,402	419	10-1-58	2,216	N	N				I	New well.
36bbb	do	R	1958	1,352	20-12	1,352	287-1,352	393	5-30-58	2,198	T	E	400	2,000(r)		I	
								393	10-1-58								
(B-8-11)36bbb	C. Sykes	Ct	1952	500	6	500	420-500	492	10-2-57	2,294	C	N				S	
								491	9-30-58								

The water-table map of the Aguila area for April 1958 (pl. 5) shows an elongated cone of depression which extends southeastward. The cone of depression widened considerably between April 1958 (pl. 5) and September to October 1958 (pl. 6) because of an increase in the number of large-capacity wells. Water levels near the apex of the cone declined about 20 feet during this period.

The water-level data collected from wells in the vicinity of Wenden and along Centennial Wash indicate the presence of perched water bodies. A perched water body forms when the downward percolation of water to the saturated zone is retarded by relatively impermeable material. Brown and Skibitzke (1956, p. 45), in a discussion of perched water, stated:

> As a particle of water moves vertically downward in response to gravitational forces, it attains a certain velocity which is dependent on the permeability of the porous media being traversed. The velocity would be constant if the water particle continued to move vertically downward and if the porous media were homogeneous. However, * * * if lenses of vastly different permeability are encountered * * * (and) if one of these lenses has a low permeability, then the velocity at which a water particle can move through it under gravitational influence alone is proportionately low. Accordingly, a water particle arriving at the top of this layer will be slowed down and the particles following it will begin to pile up. In other words, pressure forces begin to build up until the water particle is forced through the less permeable lens or until some alternate flow path around the obstruction is found. This accumulation of water, because of retarded vertical movement, establishes what is called here a perched water table.

The perched water bodies in the area lie on scattered lenses of material of low permeability. As indicated by measurements made in deep and shallow wells, (B–6–12)19dbb and (B–6–12)19acd, the difference in altitude of the water levels on October 11, 1957, was 37 feet. The difference in altitude of the water levels in October 1958 in the shallow well (B–6–12)21dc and the deep well (B–6–12)22add was 39 feet. Wherever they could be measured, the water levels in the shallow wells in the vicinity of Wenden are anomalously high in comparison to the main water table and therefore indicates perched water. The source of recharge to the perched water bodies is apparently influent seepage from sporadic flow of Centennial Wash. For example, in shallow well (B–5–12)6cab the water level reached a high point of 48 feet below the surface in October 1958. This rise of 29 feet since May 1958 can be accounted for by the infiltration of water from the flow of Centennial Wash after the summer flash floods. Additional evidence of perched water is reported in the log of well (B–6–12)22add (table 3). Ground water entered the hole at a depth of 76 feet at the contact between the alluvium and the underlying lake-bed deposits. The altitude of this contact is 1,852 feet, 100 feet above the main water table.

MOVEMENT

Ground-water movement through an aquifer depends on the hydraulic permeability of the rock (Meinzer, 1923, p. 44), which is the capacity of a rock to transmit water under pressure. Rates of ground-water movement in McMullen Valley may range from a few feet per year to several feet per day, depending on the permeability of the material and the hydraulic gradient.

The rock types that have been described differ in their capacity to transmit water. The bedrock has a low permeability and forms the boundary of the valley-fill deposits. The alluvial-fan deposits, because of their heterogeneity, are not uniformly permeable. The difference in permeability affects both the rate and the direction of ground-water movement. If the permeability of the material is greater in a certain direction downgradient, a greater proportion of water will move in that direction. The permeability of the sand and gravel lenses is probably many times greater than that of the relatively homogeneous fine-grained lake-bed deposits. The very low permeability of the lake-bed deposits retards movement of ground water.

Ground water veers southwestward as it moves toward the axis of McMullen Valley; in the vicinity of Salome it turns abruptly to the southeast. The direction of ground-water movement is reversed in the Aguila area and in Harrisburg Valley. In the Aguila area the direction has changed owing to the development of the cone of depression. In the Harrisburg Valley area the reversal ingradient is indicated by the higher altitude of the water level in a well near the underground barrier than in an upstream well. This change in gradient indicates that ground water is moving from the vicinity of the barrier toward the area of pumping upstream.

RECHARGE

The valley-fill deposits are recharged principally by downward percolation from streams and to a lesser extent by return flow from irrigated fields. Although possibly some water enters the valley-fill deposits through fractures in the bedrock, it is unlikely that much, if any, of the water represents subsurface inflow from outside the boundary of the surface drainage basin.

Infiltration of flood runoff is the most significant source of recharge in McMullen Valley. The recharge occurs along the mountain fronts and along Centennial Wash where the runoff in channels crosses coarse, permeable materials. As the runoff proceeds to lower elevations, it passes over progressively finer grained materials, and a decreasing proportion of runoff recharges the ground-water reservoir. The construction of erosion-control dams along the upper part of

Centennial Wash has probably reduced the amount of recharge from this source, because (1) the silt in the runoff settles in the ponded water and probably hinders greatly the infiltration of water to the zone of saturation and (2) the ponded water is subject to the high evaporation rates common in southwestern Arizona.

Part of the water applied to the land for irrigation in McMullen Valley probably is returned to the ground-water reservoir by downward percolation, but the total quantity probably is small.

Direct recharge from precipitation is probably negligible. In the mountain areas where soil and vegetation are lacking, a part of the rainfall accumulates in channels as runoff. A small part enters the fractures in the rocks, but most of it is later discharged to the atmosphere by evaporation. Precipitation on the valley floor is prevented from recharging the ground-water reservoir principally by layers of clay or caliche near the land surface. The moisture is absorbed by vegetation or held in the soil until evaporated.

Data are not available for a quantitative estimate of recharge. On the basis of more detailed studies made in geologically and hydrologically similar valleys in the Southwest, the estimate of an average annual recharge of 13,000 acre-feet in McMullen Valley made by S. F. Turner, consulting engineer, in a hearing at the State Land Department on June 24–25, 1958, is probably approximately correct, although it cannot be confirmed.

DISCHARGE

Prior to the development of irrigation, ground water was discharged primarily by evapotranspiration in Harrisburg Valley and as underflow from the southeast end of McMullen Valley. Centennial Wash along the stretch in Harrisburg Valley is bounded by a thick stand of vegetation sustained by water drawn from the zone of saturation. No estimate of the quantity of water utilized by these plants, however, can be made from the available data. Because the subsurface outlet for ground water at the southeast end of Harrisburg Valley is narrow, the quantity of ground-water outflow probably never was very great. The amount of water discharged annually from wells probably was negligible.

Ground water has been pumped for irrigation in the valley since the early part of the century. No large demands, however, were made on the ground-water reservoir until 1952, when several irrigation wells were drilled in Harrisburg Valley. The water pumped from these wells was conveyed by canal to the upper part of the Harquahala Plains and used for irrigation. During 1953 about 6,000 acre-feet of water was pumped for irrigation in this area. No data are available for the rest of McMullen Valley, but ground-water withdrawals probably were small because no large tracts were under cultivation.

In the period 1954–57, pumpage in McMullen Valley increased from 7,000 to 21,000 acre-feet (table 5).

TABLE 5.—*Ground-water pumpage, in acre-feet, by area in McMullen Valley*

Area	1953	1954	1955	1956	1957
Harrisburg Valley and vicinities of Salome and Wenden	[1] 6, 000	[1] 7, 000	7, 000	7, 000	8, 000
Aguila	--------	--------	2, 000	8, 000	13, 000
Total	6, 000	7, 000	9, 000	15, 000	21, 000

[1] Pumpage in Harrisburg Valley only.

Annual ground-water withdrawals in the southwestern part of the area were nearly uniform during the 5-year period. The relative stability was due to the concurrent decrease in production of several of the older wells in the lower part of Harrisburg Valley and increase in production from new wells in the vicinities of Salome and Wenden. Large-scale irrigation in the Aguila area began in 1954 when the first deep well was drilled. The pumpage in this part of McMullen Valley was 2,000 acre-feet in 1955 and 13,000 acre-feet in 1957. Because several new irrigation wells were drilled in 1957 and additional wells were planned for 1958, annual ground-water withdrawals in 1958 undoubtedly were greater.

The discharge from irrigation wells in McMullen Valley varies considerably; well yields range from 150 to 3,500 gpm. The pumping lifts range from less than 150 feet to a little more than 500 feet.

The specific capacity of a well, the yield in gallons per minute per foot of drawdown, is an indication of the transmissibility[1] of the material tapped by the well. A high specific capacity indicates an aquifer of high transmissibility, but a low specific capacity does not necessarily indicate an aquifer of low transmissibility. The specific capacity of a well is a function of many factors, such as the diameter of the well, the thickness of aquifer that is penetrated by the well, the type, number, and condition of perforations in the casing, and the amount of well development. However, if several wells have been constructed and developed similarly, their specific capacities correlate closely with the transmissibility of the aquifer they tap.

The specific capacities for 13 wells in the Aguila area (table 6) were computed. The wells range in depth from 750 to 1,720 feet and in rate of discharge from 900 to 3,300 gpm. Seven of these wells were drilled and developed similarly and have the same general depth, diameter, and perforations in the casings. The specific capacities of

[1] The coefficient of transmissibility may be expressed as the number of gallons of water per day transmitted through each section of aquifer 1 mile wide extending the height of the aquifer under a hydraulic gradient of 1 foot per mile at the prevailing temperature. In McMullen Valley a transmissibility of 100,000 gpd per ft is assumed to be about the upper limit for the most productive water-bearing material.

these 7 wells ranged from 12 to 114 gpm per foot of drawdown. The wells having the highest specific capacity are in secs. 16 and 17, T. 7 N., R. 9 W., whereas those of lower specific capacity are to the north, east, and southeast. Because the wells having the highest specific capacities tap the greatest thickness of saturated alluvium, these wells probably obtain a large part of their water from the alluvium. If this is true, dewatering of the alluvium will cause a decline in specific capacity.

TABLE 6.—*Specific capacity of selected wells in McMullen Valley*

[Figures for discharge and specific capacity are rounded]

Well	Total depth (feet)	Depth to water (feet)	Pumping lift (feet)	Discharge (gpm)	Specific capacity (gpm per foot of drawdown)	Date measured
Salome-Wenden area						
(B-5-13)4cbb	350	211	255	700	16	8- 1-57
10bbb	504	148	[1] 199	[1] 2,600	51	12-28-57
15bab	662	99	128	[1] 3,100	107	4-26-57
21dcc	550	158	329	500	3	7-29-57
28acc	723	194	366	400	2	7-29-57
(B-6-12)13dcc	1,200	214	307	[1] 3,500	38	5-24-57
13ddd	1,196	222	283	2,300	38	7-30-57
22add	943	168	300	[1] 2,000	15	----------
Aguila area						
(B-7-8)16aaa	1,627	433	[1] 548	[1] 2,600	23	9-30-58
29ddd	1,720	417	[1] 500	[1] 2,500	30	5- 6-58
(B-7-9)4bbb	1,650	375	498	1,500	12	4-16-58
4cbb	1,650	347	448	2,000	20	4-16-58
11add	1,317	392	433	2,600	63	5- 6-58
12aaa	1,415	412	[1] 465	[1] 3,200	60	----------
12dad	1,205	407	[1] 470	[1] 3,000	48	----------
15cdd	750	352	383	2,500	81	4-29-58
16add	1,660	342	375	3,300	100	5- 2-58
17dcd	1,610	337	365	3,200	114	4-29-58
24aaa	1,562	[1] 392	[1] 446	[1] 3,000	56	----------
(B-8-9)32baa	1,003	380	495	900	8	5- 2-58
33ddd	1,650	368	475	1,800	17	4-30-58

[1] Reported.

The specific capacities of wells in the Wenden-Salome area also vary considerably. Wells tapping only lake-bed deposits have much lower specific capacities than wells deep enough to tap the underlying coarse alluvial-fan deposits. For example, well (B-6-12)29cdc was pump-tested at a depth of 446 feet before it had penetrated the lake-bed deposits completely. The drawdown was 332 feet in less than 4 minutes from the start of the test when the pump broke suction. When the well was deepened and penetrated almost 200 feet of the alluvial-fan deposits, the specific capacity was reported to be about 6 gpm per ft. In general, the greater the thickness of the alluvial-fan deposits penetrated by wells, the greater the specific capacities of the wells. For example, well (B-6-12)22add, which extends about 280 feet into the alluvial-fan deposits, has a specific capacity of 15, and wells (B-6-12)13dcc and (B-6-12)13ddd, which were drilled about 475 feet into the alluvial-fan deposits, have a specific capacity of 38.

Well (B-5-13)15bab, which was drilled near the featheredge of the lakebed deposits, extends 544 feet into saturated alluvial-fan deposits and has a specific capacity of 107.

STORAGE

The total volume of saturated valley-fill deposits in McMullen Valley cannot be computed from the few data available. The deposits underlie an area of about 500 square miles, and they range in thickness from less than a foot at the valley margins to more than 1,800 feet in the central part of the valley. However, because the bedrock floor on which the deposits rest is probably a surface of high relief, the thickness of the deposits may differ markedly within short horizontal distances. Without a great deal more information on the thickness of the valley-fill deposits and on the depth to the water table in all parts of McMullen Valley, estimates of the volume of saturated material would be purely hypothetical.

The quantity of water stored within the valley-fill deposits is a function not only of the volume of the saturated materials but also of their porosity. In saturated unconsolidated deposits the water content may be 40 percent or more of the total volume of the material. Because some of the water is held by molecular attraction to the grains of the material, however, not all the water can be drained away by gravity. Thus, even though a fine-grained material may store as much water as a coarse-grained material, the fine-grained material will yield less, because the surface area to which water molecules may adhere is much greater. The ratio of the volume of water that a saturated material will yield by gravity to the volume of the material is expressed as the specific yield of the material (Meinzer, 1923, p. 51). Data on the specific yield of similar deposits in other parts of Arizona (Halpenny and others, 1952, table 3) suggest that the average specific yield of the valley-fill deposits in McMullen Valley may be about 15 percent. If this value is nearly correct, a 100-foot thickness of saturated aquifer beneath an area of 100 square miles would yield about 1 million acre-feet of water. Because the rate of recharge is small and annual pumpage probably exceeds this rate, the amount of water in storage is decreasing. The results are a decline of the water table and a subsequent increase in pumping lifts.

CHEMICAL QUALITY

As part of this investigation, 48 samples of water from wells in McMullen Valley were collected and analyzed. The analyses of 5 samples collected in 1946 and 1 collected in 1917 are also included in this report. The analytical results (table 7) are useful in determining the suitability of the water for most uses but do not indicate the sanitary condition of the water.

TABLE 7.—*Chemical analyses of water from wells in McMullen Valley*

[Analyses in parts per million, except as indicated]

Location	Date of collection	Temperature (°F)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K) [1]	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Iron (Fe)	Dissolved solids	Hardness as $CaCO_3$		Percent sodium	Specific conductance (micromhos at 25 °C)	Remarks
																Total	Noncarbonate			
(B-5-12)6cab	5-14-57	74	33	22	12	127	335	0	33	24	3.2	37	--	0.15	456	104	0	73	713	
30dcc	3-13-57	80	30	24	6.6	98	204	0	62	40	1.8	9.5	1.1	--	373	87	0	71	630	
30dd	3-13-57	79	34	32	13	106	259	0	67	45	3.6	9.8	1.2	--	439	134	0	63	702	
31aaa	4-29-57	--	34	35	14	115	258	0	78	62	2.6	8.4	1.0	--	477	145	0	63	780	
32add	3-13-57	76	38	44	15	150	331	0	95	78	4.8	6.2	.78	--	595	172	0	66	955	
(B-5-13)2baa	5-14-57	80	9.7	5.6	1.7	235	367	0	92	86	4.8	.2	.11	--	615	21	0	96	1,040	
2dad1	5- 6-57	82	24	4.4	2.8	110	159	12	51	25	6.0	7.9	.40	--	322	22	0	91	515	
4cbb	11-21-56	80	38	54	24	45	210	0	50	71	.8	6.1	.06	--	392	233	61	30	671	
9dcc	3-27-46	--	--	20	12	112	224	0	58	56	3.2	13	--	--	384	100	0	--	666	
10dbc	12- 4-56	--	16	--	--	199	222	0	88	105	5.6	19	--	--	--	18	0	96	927	
14cbb	3-26-46	72	22	15	2.5	136	247	0	67	37	4.4	11	--	--	417	48	0	--	662	
15bab	4-11-57	82	19	14	5.5	103	172	0	60	45	4.0	4.1	.19	.07	340	58	0	80	554	
15ca3	12- 6-56	72	20	14	4.5	106	176	0	65	40	2.8	11	--	--	350	54	0	81	557	
16aa1	5-14-57	67	14	17	21	153	222	0	104	95	2.4	37	--	--	522	129	0	72	938	
16ab2	9-30-17	--	22	11	5.4	113	207	0	58	40	--	9.4	--	.25	361	50	--	--	--	
16add	3- 7-57	76	18	10	11	103	198	0	62	37	2.8	8.5	--	.13	349	70	0	76	572	
17dc2	5-14-57	--	37	37	19	54	202	0	45	50	.6	5.1	--	.06	347	170	5	41	574	
19dbc	11-20-56	53	25	25	9.5	102	193	0	66	53	1.2	25	--	--	402	102	0	69	657	
21dcc	5- 7-57	77	32	39	22	92	273	0	64	65	.8	7.0	.12	--	456	188	0	52	670	
23dcc1	10- 1-57	--	34	112	51	556	175	0	831	432	2.7	92	--	--	2,200	489	346	71	2,120	Owner reports change in quality in the last 2 months.
25dbd	11-28-56	74	32	37	14	76	204	0	62	52	1.2	9.6	--	--	384	150	0	52	635	
26acc	5-14-57	76	37	37	16	108	280	0	56	66	1.2	12	.02	--	471	158	0	60	648	
28acc	5- 7-57	78	28	30	15	104	211	0	86	66	1.0	4.1	.11	--	438	136	0	62	718	
(B-6- 9)2abd	2-12-57	78	33	49	15	51	199	16	33	28	3.6	27	--	.00	354	184	0	38	536	
(B-6-12)13dcc	5-24-57	98	--	--	--	--	--	--	48	65	--	--	--	--	--	--	--	--	616	
13ddd	12- 7-56	100	21	5.6	2.4	121	153	0	53	60	5.2	11	.12	--	354	24	0	92	581	
15bbb	5-27-58	79	7.8	502	15	1,850	99	0	4,820	165	4.3	.7	--	--	7,410	1,310	1,230	75	8,290	
18cdb	1-31-57	92	22	15	7.1	101	204	0	47	40	3.0	5.4	.23	.00	341	66	0	77	551	
19acd	1-30-57	74	14	5.2	8.1	345	160	0	85	398	2.6	12	--	.00	949	46	0	94	1,710	

TABLE 7.—*Chemical analyses of water from wells in McMullen Valley*—Continued

[Analyses in parts per million, except as indicated]

Location	Date of collection	Temperature (°F)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)[1]	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Iron (Fe)	Dissolved solids	Hardness as $CaCO_3$		Percent sodium	Specific conductance (micromhos at 25 °C)	Remarks
																Total	Noncarbonate			
(B-6-12)19dbb	1-30-57	87	26	25	5.2	217	245	0	71	186	3.0	13	.44	------	667	84	0	85	1,140	
22add	5-22-57	86	16	5.6	.5	280	178	10	279	62	22	10	1.4	------	792	16	0	97	1,240	Sampled at 800 ft.
	6-25-57	96	25	4.8	1.2	131	145	0	107	27	10	8.9	.33	------	386	17	0	94	615	Sampled at 943 ft.
31bbb	5-8-58	94	21	6.0	6.9	112	177	0	71	33	5.2	9.8	------	------	352	44	0	85	563	
32bbc	3-27-46	------	20	5.8	1.9	101	187	0	42	19	4.0	9.5	------	------	295	22	0	------	459	
(B-7-7)17add	3-26-46	85	20	7.0	5.0	84	151	0	38	25	6.0	8.2	------	------	268	38	0	------	427	
17ddc	7-19-57	86	26	5.2	1.7	111	132	0	55	37	15	5.0	------	------	321	20	0	92	511	
(B-7-8)29ddd	7-16-57	86	42	14	13	89	150	21	45	46	2.0	7.2	------	------	352	88	0	69	546	
32ccc	2-12-57	80	15	10	8.8	142	102	0	109	113	1.2	12	------	.02	461	61	0	83	796	
(B-7-9)4bbb	2-18-57	90	20	17	7.6	90	156	0	40	58	3.2	12	.44	------	325	74	0	73	542	
4cbb	4-16-58	89	20	13	5.7	95	157	0	63	35	3.2	14	------	------	333	56	0	79	437	
9aaa	3-14-57	85	24	17	9.3	71	175	0	30	32	2.4	11	.62	------	283	80	0	66	456	
11aaa	1-14-58	82	32	19	15	54	175	0	27	28	8.0	7.8	------	------	272	109	0	52	427	
11add	12-20-56	82	27	22	8.3	61	183	0	27	22	3.6	4.3	.02	------	265	89	0	60	415	
14aba	12-14-56	------	26	16	9.5	54	166	0	23	18	2.6	4.8	.04	------	235	79	0	60	375	
14cc	3-27-46	------	------	18	8.4	49	155	0	26	17	2.8	2.0	------	------	200	80	0	------	351	
15cdd	11-25-57	83	41	19	12	45	171	0	12	24	2.0	4.2	------	------	243	97	0	50	410	
16add	5-2-58	84	30	14	9.0	54	158	0	22	18	2.6	4.6	------	------	232	72	0	62	353	
17dcd	1-14-58	83	28	16	11	58	163	0	29	26	2.6	5.1	------	------	256	85	0	60	403	
22bc	5-17-57	80	27	23	13	61	181	0	34	35	1.8	6.5	------	------	290	111	0	54	452	
(B-7-10)33ddd	5-23-57	------	33	53	20	55	231	0	33	71	.6	11	------	------	391	214	24	36	639	
(B-8-9)32aaa	12-14-56	92	27	5.6	2.1	117	96	6	45	81	4.4	19	.09	------	354	22	0	92	586	
32baa	3-15-57	90	28	3.2	1.2	107	97	9	51	50	7.0	11	.67	------	316	13	0	95	507	
33aab	11-19-56	76	17	27	12	98	182	0	47	76	5.0	14	.12	------	385	117	0	64	654	
33ddd	4-16-58	87	24	17	8.6	88	147	0	39	63	2.8	14	------	------	328	78	0	71	543	

[1] Reported as sodium.

The concentration of dissolved mineral matter in the samples of water ranged from 200 to 7,410 ppm (parts per million). Because the concentration of dissolved solids was more than 500 ppm in only 8 samples, however, the ground water in McMullen Valley probably contains on the average less than 500 ppm. Most of the samples of least mineralized water were obtained from wells in the Aguila area; 9 of the 11 samples containing less than 300 ppm of dissolved solids came from that part of McMullen Valley. The water from wells in Harrisburg Valley and near Salome had a greater concentration of dissolved solids but generally was less than 500 ppm. The few samples of more highly mineralized water came from the wells that obtained all or a large part of their water from the lake-bed deposits. The analysis of water obtained from well (B–6–12)15bbb in the lakebeds during a bailer test shows a dissolved-solids content of 7,410 ppm, which indicates the quality of water in the lake-bed deposits. Because these fine-grained materials have a low permeability in comparison to the underlying alluvial-fan deposits, however, the dissolved-solids content of the water from this well will be much less when the well is pumped and most of the water is obtained from the alluvial-fan deposits. This predictable change may be illustrated by the 2 analyses of water collected from well (B–6–12)22add at 800 feet and at 943 feet. The water sampled at 800 feet was, for the most part, obtained from the lake-bed deposits and contained 792 ppm of dissolved solids. When the well was deepened to 943 feet, at which depth most of the water was obtained from the alluvial-fan deposits, the dissolved-solids content in the water sample was reduced to 386 ppm. In general, the wells in the Wenden area that penetrate the lake-bed deposits completely and obtain most of their water from the lower, coarser unit yield water similar in quality to the ground water found in other parts of McMullen Valley.

Most of the dissolved solids in the ground water of McMullen Valley are derived from the minerals in the rock material that constitutes the valley fill. Because the rocks of the valley fill are erosional products of many formations, their mineral content is heterogeneous; the composition and solubility of the minerals that are available for solution are factors that affect the amount of dissolved solids in the ground water. The locally high dissolved-solids content of the ground water in the valley fill may be related to the presence of gypsum and other salts formed by evaporation of water impounded during the deposition of the valley fill.

The chemical quality of water is an important factor in evaluating the usefulness of the water for irrigation. The total salt concentration, boron concentration, and percent sodium are especially important. Several methods of classification are used to evaluate irrigation supplies; however, it is very difficult to predict on the basis of water analyses alone what may take place in the soil when irrigation water is added. Other factors such as soil texture and mineral content, drainage, climate, and types of crops also are important.

A classification widely used to evaluate irrigation water was developed by Wilcox (1948). It is based on the dissolved-solids concentration and percent sodium. The classification is also based on the assumption that water will be used under average conditions with respect to quantity of water, soil permeability, drainage, climate, and types of crops. The water used for irrigation in McMullen Valley varies considerably in quality. In the Aguila area, most of the irrigation water is classified as "excellent to good" in quality according to Wilcox (1948, p. 26). In the northern part of the Aguila area 2 wells yield water in the "doubtful to unsuitable" classification, and 3 wells yield water in the "permissible to doubtful" classification. In the Wenden area most of the irrigation water now being used may be classified as "permissible to doubtful" or "doubtful to unsuitable" in quality. In the Salome-Harrisburg Valley area, 6 irrigation wells yield water classified as "excellent to good," 1 as "good to permissible," 2 as "permissible to doubtful," and 2 as "doubtful to unsuitable" in quality. In most of McMullen Valley, the percent sodium in water used for irrigation is high and ranges from 30 to 96. The application of water having a high percent sodium may cause the soil to become less permeable and so retard the downward movement of water. Good drainage and the use of excess water, however, tend to minimize this effect. Also, a high percent sodium is less deleterious in water of low or moderate dissolved-solids content than it is in more highly mineralized water.

Certain specific constituents in irrigation water are undesirable and may be damaging if present in only small quantities. Boron is one of the most important minor constituents in irrigation water. This element is essential to proper plant nutrition, but a small excess over the needed amount is toxic to some types of plants. Water having a boron content as small as 1 ppm is classified by Wilcox (1948, p. 27–28) as "permissible" to use in irrigating boron-sensitive crops, which includes most fruit trees. This classification considers only the boron content and not other dissolved mineral matter in the water. Only 3 of the samples analyzed for boron exceeded 1 ppm.

According to the standards recommended by the U.S. Public Health Service (1946, p. 12), drinking water should not contain more than 1.5 ppm of fluoride. Water containing excessive amounts of fluoride can cause mottling of enamel in the teeth of children who drink the water during the time their permanent teeth are forming (Dean, 1936). Ground water containing more than 1.5 ppm of fluoride is common in McMullen Valley, as indicated by the available analyses. Therefore, the fluoride content of drinking water to be used by young children should be determined. Small quantities of fluoride, as much as 1 ppm, are not objectionable, as they do not cause mottling of tooth enamel (California State Water Pollution Control Board, 1952, p. 257) and tend to reduce the incidence of tooth decay.

Most of the nitrate in the ground water in McMullen Valley probably is derived from sources other than human and animal wastes, although the presence of nitrate is sometimes an indication of such contamination. Waters containing more than 44 ppm of nitrate are considered by some authorities (Maxcy, 1950) to be a possible hazard when used for feeding infants, as a high nitrate concentration in water for such use has been associated with cases of cyanosis, or "blue-baby disease." Only 1 sample analyzed indicates a nitrate concentration in excess of 44 ppm (table 7).

Water used for domestic purposes in McMullen Valley ranges in hardness, expressed as calcium carbonate, from 18 to 489 ppm. Of 18 analyses of domestic-water samples, 9 show 100 ppm or less. Household use of hard water results in excess consumption of soap. Hard water when used in hot-water tanks or boilers causes the formation of objectionable scale.

SINKHOLES

During this investigation several circular sinkholes formed in the alluvium upstream from the detention dam at the narrow drainage outlet from the valley. The following details were obtained from P. J. Schiele (written communication, 1958) of the Bureau of Land Management and from data collected at the site:

In August 1958 a series of flash floods occurred above the narrows on Centennial Wash, and the runoff filled the detention basin to within half a foot of the outlet level. During the following days several sinkholes formed in the alluvium within the detention basin through which, according to reports, the impounded water drained at a rate of 10 acre-feet per hour. The sinkholes ranged in diameter roughly from 5 to 60 feet and in depth from a few feet to about 30 feet. The alluvium, where exposed in the walls of the sinkholes, consists of coarse sand and gravel, and cobbles as large as 6 inches in diameter are common (fig. 8). The volume of alluvial material that was carried into the subsurface is estimated to be about 10,000 cubic feet.

The formation of the sinkholes was directly related to the subsurface geology and the ground-water conditions in the area. The immediate cause seems to have been the impoundment of large quantities of water by the dam and the resulting increase in head.

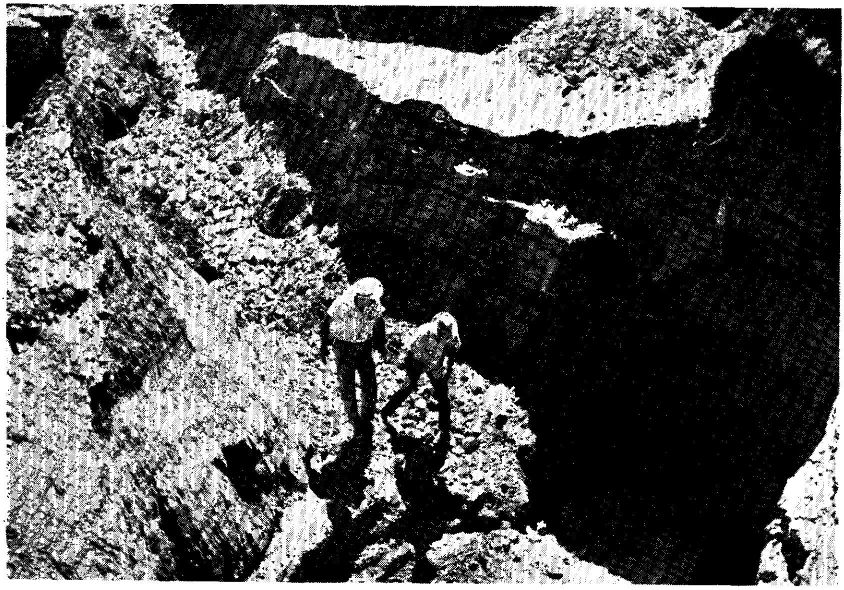

FIGURE 8.—Section of alluvium exposed in sinkhole. Photograph by J. A. daCosta.

The dam is anchored to limestone at both ends (fig. 9), but the central part rests on alluvium about 10 feet below the land surface.

FIGURE 9.—Aerial view from the southeast showing relation of limestone strata to the dam structure and to the position of sinkholes. Limestone (ls), dam structure (d) sinkholes (sh).

The axis of the dam parallels the general strike of the limestone outcrops. The rocks on both sides of the dam are shattered and displaced by faulting, and no consistent dip could be recognized. The faults, shear zones, and joints probably facilitated the development of solution cavities in the limestone sometime in the past when the water table was higher.

In August 1958 the storm runoff was impounded in the detention basin. The weight of the water overlying the coarse alluvial material probably caused caving of the material into already-formed solution cavities in the underlying limestone bedrock. The caving was facilitated by the dewatering of the valley-fill deposits caused by pumping, which caused the alluvial material that had been bridging the solution channels in the limestone bedrock to shrink and crack.

The vortical motion of the downward flow accounts for the spiral appearance of the sinkholes (fig. 10). The water that entered the sink-

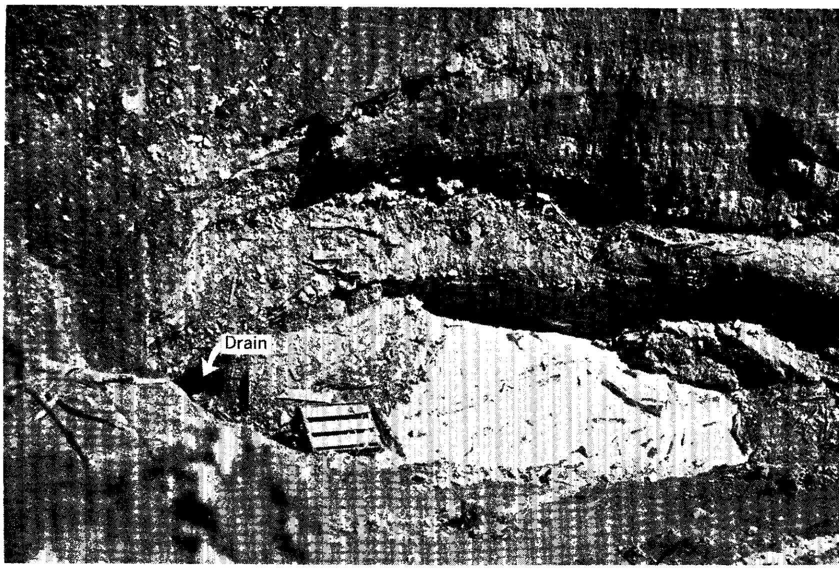

FIGURE 10.—Sinkhole showing spiral effect resulting from vortical action of water flow. Note drain at left of photograph. Photograph by J. A. daCosta.

holes moved underground toward the Harquahala Plains. A hydrograph of a well downstream from the dam (fig. 11) indicates that the water level rose more than 34 feet in 30 days after the sinkholes formed. It seems likely that the solution channels in the limestone are connected downstream with the overlying alluvium and that part of the water from the detention basin found its way into the alluvium through the channels, causing the rise in water level at the well. A

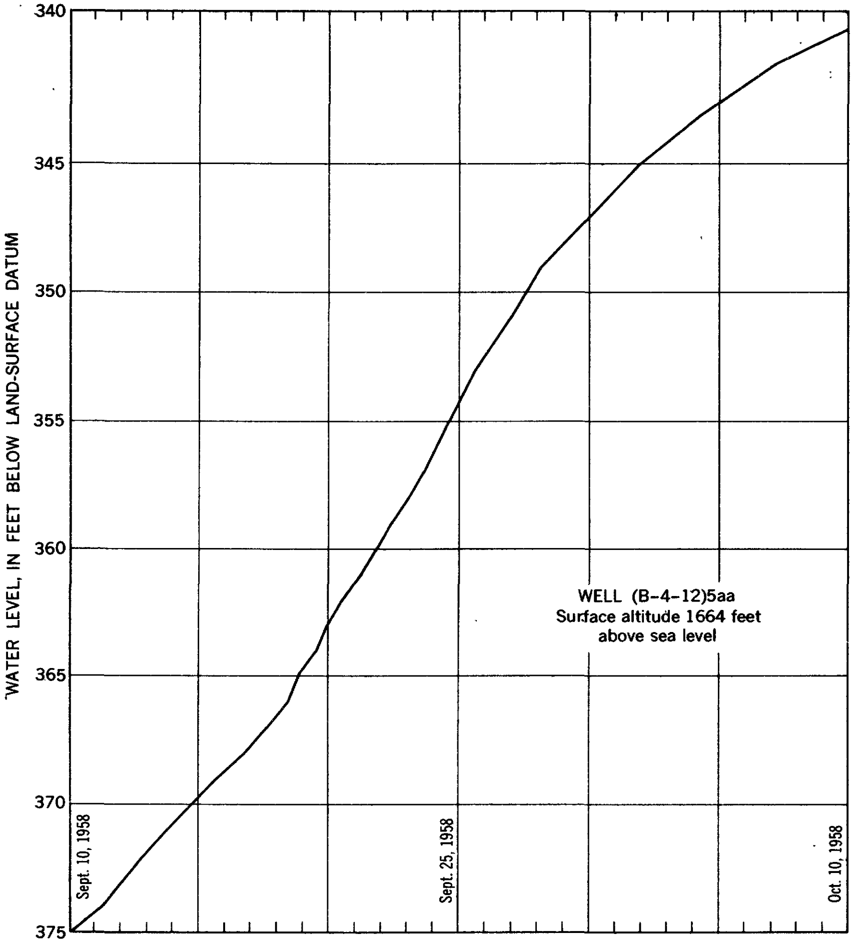

FIGURE 11.—Graph of water-level rise in well (B-4-12)5aa after development of sinkholes.

slight rise in the water level was noted in the observation well upstream from the dam; this rise is attributed to seepage into the coarse alluvial material from runoff in Centennial Wash and not to underflow from the sinkholes.

The presence of solution cavities indicated by the formation of the sinkholes shows that underflow out of McMullen Valley under natural conditions may have been greater than would be suggested by the narrowness and thinness of the alluvium at the outlet. Pumping has lowered the water table and consequently has reduced (and perhaps stopped) the outflow through the limestone as well as through the alluvium; thus, the water has been reserved for use in McMullen Valley.

SUMMARY

The principal aquifer in McMullen Valley is the valley-fill deposits in the trough between the mountain ranges. The buried parts of mountain ranges, which are the boundaries of this aquifer, are effective barriers to the subsurface movement of ground water into or out of the valley-fill deposits. The general direction of movement of ground water is southwestward to Salome and then southeastward through Harrisburg Valley. The buried bedrock ridge beneath the surface outlet at the southeast end of Harrisburg Valley is a partly effective ground-water dam.

The ground-water reservoir in the valley-fill deposits is recharged primarily by infiltration from the streams, especially when they flood. Prior to the development of irrigation, ground water was discharged primarily as underflow and by evapotranspiration; however, since relatively heavy pumping began in Harrisburg Valley, little or no ground water leaves the valley as underflow, and evapotranspiration has probably been lessened. During 1953, about 6,000 acre-feet of water was pumped for irrigation; by 1957 the annual pumpage had increased to 21,000 acre-feet.

The rate of discharge from irrigation wells ranges from 150 gpm to as much as 3,500 gpm, and the specific capacity of the wells ranges from 2 to more than 110 gpm per ft of drawdown. In the Aguila area, the wells having the highest specific capacities are those tapping the greater thickness of saturated alluvium, whereas in the Wenden and Salome-Harrisburg Valley areas the wells having the highest specific capacities are those tapping the greatest thickness of the alluvial-fan deposits.

The water table has declined in areas of concentrated pumping, particularly in the southeastern part of Harrisburg Valley and north of Aguila. The pumping may be exceeding the rate of recharge, and the decline may be expected to continue as water is taken from storage.

The volume of the valley-fill deposits has not been determined accurately; however, it must be very large because the deposits underlie an area of about 500 square miles, and their maximum thickness exceeds 1,800 feet. The specific yield of the material is probably about 15 percent, and therefore large quantities of water are available for withdrawal from storage.

Analyses of most of the water samples show that the water in McMullen Valley is relatively low in dissolved mineral matter but contains a high proportion of sodium. Most of the irrigation waters in the Aguila and Salome-Harrisburg Valley areas are classified as "excellent to good" but others range from "permissible to doubtful"

or "doubtful to unsuitable" because of the high percent sodium. Waters of these classifications should be used with caution to avoid damage to soils and crops. The analyses indicate that the water ranges from soft to hard and much of it has a higher concentration of fluoride than is recommended for domestic use.

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