# Ground-Water Resources of Pavant Valley, Utah

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1794

*Prepared in cooperation with the Utah State Engineer*

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*By* R. W. MOWER

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# GROUND-WATER RESOURCES OF PAVANT VALLEY, UTAH

By R. W. Mower


## ABSTRACT

Pavant Valley, in eastern Millard County in west-central Utah, is in the Great Basin section of the Basin and Range province. The area of investigation is 34 miles long from north to south and 9 miles wide from east to west and comprises about 300 square miles. Agriculture, tourist trade, and mining are the principal industries. The population of the valley is about 3,500, of which about half live in Fillmore, the county seat of Millard County.

The climate is semiarid and temperatures are moderate. Average normal annual precipitation in the lowlands is estimated to range from 10 to 14 inches. Precipitation is heaviest during the late winter and spring, January through May. The average monthly temperature at Fillmore ranges from 29°F in January to 76°F in July; the average annual temperature is 52°F.

Because of the aridity, most crops cannot be grown successfully without irrigation. Irrigation requirements were satisfied for about 60 years after the valley was settled by diverting streams tributary to the valley. Artesian water was discovered near Flowell in 1915. By 1920 flowing artesion wells supplied about 10 percent of the irrigation water used in the valley, not including water from the Central Utah Canal. The Central Utah Canal was constructed in 1916 to convey water to the Pavant Valley from the Sevier River. Especially since 1916, the quantity of surface water available each year for irrigation has changed with the vagaries of nature. The total percentage of irrigation water contributed by ground water, on the other hand, gradually increased to about 15 percent in 1945 and then increased rapidly to 45 percent in 1960; it will probably stabilize at about 50 percent.

Sand and gravel deposits of Recent and Pleistocene age are the principal aquifers in Pavant Valley. These deposits are coarser, more extensive, and more permeable near the mountains and become progressively finer and less permeable westward away from the mountains. As ground water moves westward from the recharge areas near the mountains, it becomes confined beneath clay beds; thus artesian conditions prevail in the lower parts of the valley. Although as many as 12 saturated beds of sand and gravel are penetrated in drilling wells to depths of 800 feet, they constitute, generally, one aquifer. The beds of coarser material are interconnected laterally, and the confining beds between them are not perfect aquicludes but merely impede the vertical movement of water. Artesian pressure increases with depth; thus, there is a continual upward flow of water from the lowest to the highest aquifer, and water not withdrawn through wells is discharged at the land surface or into basalt flows along the western edge of the valley.

Most recharge to the sand and gravel aquifers enters the ground on the alluvial fans as percolation from streams, irrigation ditches, and irrigated fields. Some

recharge results from underflow from the canyons and the face of the mountains and also from precipitation on the alluvial fans. Leakage from the Central Utah Canal is a major source of recharge to alluvial aquifers in the northern half of the valley.

The Pavant Flow in the western part of the valley and the basalt underlying the area west of the Black Rock Volcano in the southern part are both major unconfined basalt aquifers. The Pavant Flow is recharged by upward leakage of water from the underlying artesian aquifer, by percolation of irrigation water, by water moving laterally in shallow sand and gravel deposits, and by precipitation on outcrops along the western side of the valley. The basalt underlying the area west of the Black Rock Volcano is recharged by precipitation in the mountains, leakage from the artesian aquifer, and percolation of irrigation water. The basalt aquifers are relatively thin, averaging 30–60 feet in thickness where they supply water to irrigation wells.

The valley is divided into six districts based on geologic and hydrologic differences in the ground-water reservoir; these districts are designated from north to south: McCornick, Greenwood, Pavant, Flowell, Meadow, and Kanosh. Irrigation wells have been drilled in all these districts, but the Greenwood district shows the most promise for further ground-water development. During 1960 about 61,400 acre-feet of ground water was pumped for irrigation in Pavant Valley and about 5,900 acre-feet flowed from artesian wells. Total ground-water withdrawal, in acre-feet, through wells by district during 1960 was: McCornick, 7,100; Greenwood, 5,600; Pavant, 1,000; Flowell, 31,400; Meadow, 10,300; and Kanosh, 11,900.

The specific capacity of irrigation wells in the sand and gravel aquifers ranges from 6 to 100 gpm (gallons per minute) per foot of drawdown and averages 34 gpm per foot of drawdown. The wide range in specific capacity is due, in part, to the differences in the characteristics of the aquifers and, in part, to the differences in the construction and development of the wells. Specific capacities are smallest in the Pavant district, averaging about 10 gpm per foot of drawdown, and largest, commonly 80–100 gpm per foot of drawdown, in the vicinity of Hatton in the Meadow district.

The specific capacity of irrigation wells in the basalt aquifers ranges from 90 to 2,900 gpm per foot of drawdown and averages 850. The wide range is due almost entirely to differences in the characteristics of aquifers and only in small part to construction and development of wells.

The sand and gravel aquifers of the valley fill of Pavant Valley are moderately permeable and transmit water readily to wells. Pumping tests indicate that the coefficients of transmissibility range from 15,000 to 300,000 gpd per ft (gallons per day per foot) in unconsolidated aquifers, and from 180,000 to 22,500,000 gpd per ft in the basalt aquifers. The coefficient of storage ranges from $1.6\times10^{-3}$ to $2.5\times10^{-4}$ in the confined sand and gravel aquifers, from 0.10 to 0.25 in the unconfined sand and gravel aquifers, and about 0.06 in the basalt aquifer.

The total amount of ground water discharged in Pavant Valley during 1959 was about 98,000 acre-feet—60,000 acre-feet by wells, about 24,000 acre-feet by evapotranspiration, and 14,000 acre-feet by underflow from the valley. Discharge exceeded recharge by about 30,000 acre-feet of water, which was taken from storage. Total storage in the ground-water reservoir in 1960 was about 11,000,000 acre-feet, of which probably less than 1,000,000 acre-feet is recoverable. Most of the water not recoverable is held in fine-grained material and in areas where the aquifers are so thin that they will not yield sufficient water for irrigation.

Dissolved chemical constituents in the water in the sand and gravel aquifers increase with increasing distance from the mountains. Determined dissolved solids range from 284 ppm (parts per million) to 4,290 ppm. Water in the basalt contains more dissolved solids than water in the sand and gravel; it ranges from a low of 571 ppm in the Pavant Flow to 4,490 ppm in the basalt underlying the area west of the Black Rock Volcano.

Water from wells nearest the recharge areas is classified as low sodium hazard–medium salinity hazard. Most of the irrigation water, except in the Kanosh district, however, is classified as low sodium hazard–high salinity hazard. Water in the Kanosh district ranges from medium sodium hazard–very high salinity hazard to very high sodium hazard–very high salinity hazard. Because most of the soils in the Kanosh district are well drained and some soils contain appreciable quantities of calcium-bearing minerals, it is possible to use the water of poor quality. Boron content in water from wells ranges from none detectable to 2.5 ppm, which is about optimum for irrigation water for most crops normally grown in Pavant Valley.

The consumptive waste of ground water by plants of low economic value is not a serious problem now but could rapidly become serious. Indigenous phreatophytes occupy 35,000 acres of bottom lands in Pavant Valley. Most of them have low to moderate value for livestock grazing. Saltcedar, however, is encroaching on native pastures. The Central Utah Canal has been the means of spreading the growth of most of the saltcedar; but some of the shrubs have been imported and used as ornamental shrubbery, and some seed apparently have been spread by wind. The growth is sparse except for reaches along the Central Utah Canal, where there are a few narrow dense thickets. Enough saltcedar now grows in the valley so that under optimum weather and moisture conditions most of the noncultivated bottom land area could become infested within a few years.

## INTRODUCTION

### PURPOSE AND SCOPE

The ground-water resources of Pavant Valley were investigated to estimate the yield of the ground-water reservoir, to delineate parts of the valley where additional ground water can be developed for irrigation and parts where no further ground water should be developed, to estimate the recharge to the ground-water reservoir, and to determine the relation of the mineralized water west of Kanosh to recharge and to pumpage.

Ground water continues to increase in importance in the economy of Pavant Valley. At first, settlers in the valley used water from streams and springs in the valley for domestic and stock supplies and for irrigation of nearby lands; through the passage of time, however, ever-increasing quantities of ground water have been withdrawn to supply the water needs of the valley. The first wells in the valley were constructed in the late 1800's to obtain domestic and stock water in areas where water supplies from springs and streams were unavailable or were inadequate. It was not until the first flowing artesian wells in Pavant Valley were drilled in the vicinity of Flowell in 1915 that

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water from wells was used for irrigation. By 1920 about 75 flowing wells had been drilled, principally to supplement the irrigation water from several small intermittent, unreliable streams that enter the valley along its north and east sides. Some of the wells, however, were drilled to obtain irrigation water for land that had never been irrigated. Wells have been drilled at some place in the valley nearly every year since 1915.

The quantity of water withdrawn from the ground-water reservoir increased through the years in direct response to the number of wells in use. The increased ground-water withdrawal caused a general decline in artesian pressures and water levels and caused the natural discharge to diminish. Many springs, therefore, ceased to flow, marsh areas became dry, and many wells that were near the perimeter of the original area of artesian flow ceased to flow. Water levels in some wells have declined more than 50 feet since flowing wells were first drilled; however, in areas of little ground-water development, water levels have remained nearly stationary or have risen slightly.

Some wells drilled in the western part of the valley, from near Flowell southward, have tapped water too saline for irrigation, and the salinity of much of the other ground water used for irrigation in this general area approaches the maximum tolerated by the crops usually grown in Pavant Valley. The quality of the ground water in this part of the valley is deteriorating with time, apparently in response to declining water levels.

For an orderly development and use of the ground water, basic hydrologic information is needed by local and State officials who administer water rights, by Federal agencies who are concerned with land and water use, and by water users. Because ground water is a resource owned by the State and hence is public property, the amount of ground water used for irrigation in Pavant Valley is of concern to the general public. Such information assists the State Engineer in administering the State's ground-water laws and assists in adjudicating rights to the use of ground water. Federal agencies striving to conserve land and water and to administrate farm loans and Federal land on which homestead and desert-entry applications have been or may be filed need to know the perennial ground-water supply and whether the quality of the ground water will deteriorate as more is used.

## LOCATION AND EXTENT OF THE AREA

Pavant Valley is in eastern Millard County, which is in west-central Utah (fig. 1). The principal area studied is about 34 miles long, from near McCornick on the north to near Kanosh on the south, and is about 9 miles wide, from the foot of the Canyon Mountains and the Pavant

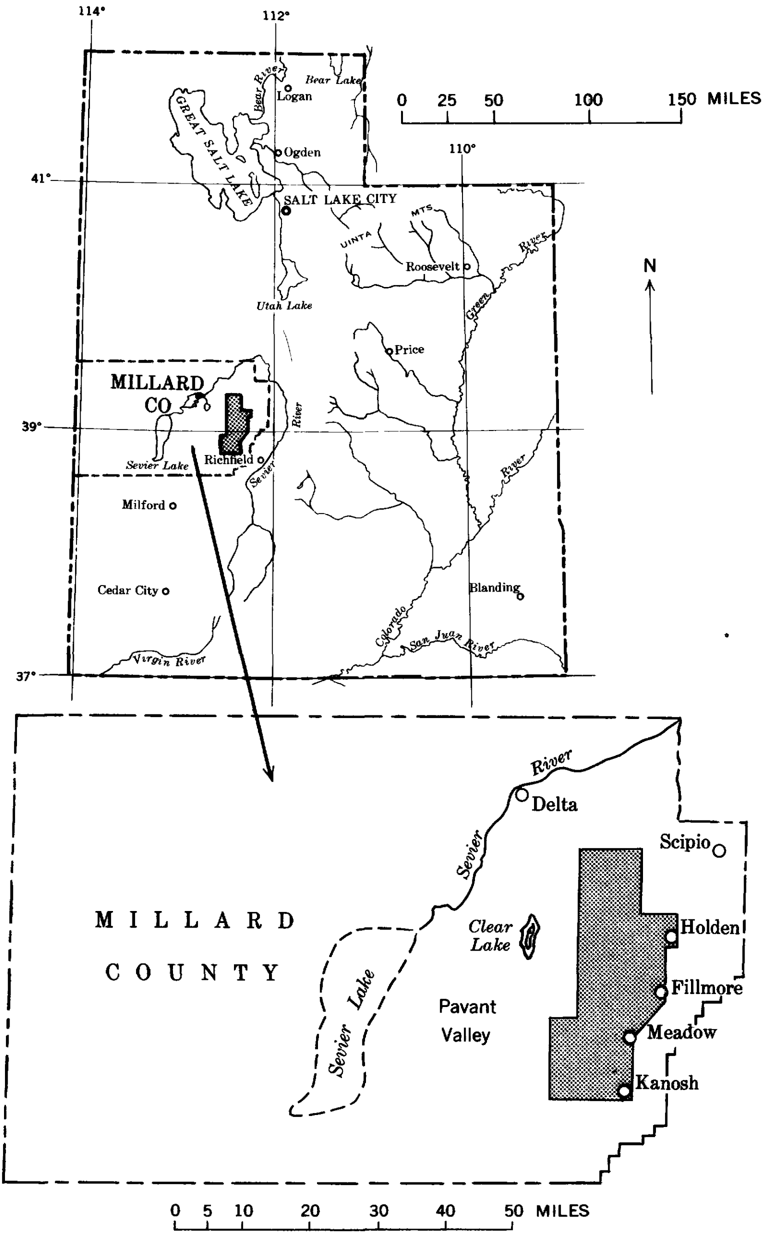


FIGURE 1.—Area (shaded) described in this report.

Range on the north and east to the exposed basalt on the west; the area includes 300 square miles. The generally north-south trending Pavant Range along the east side of the valley veers westward near Kanosh in the southern part of the valley; thus, it forms the south and the east boundaries of the valley. The south end of the Canyon Mountains forms the northeast boundary. The west boundary is marked by extinct volcanoes and basalt flows that rise 100–800 feet above the valley plain and extend northward to about the latitude of the south end of the Canyon Mountains. There is no prominent topographic relief to mark the northwest end of the valley, between the Canyon Mountains and the basalt flows, and the valley merges into the Sevier Desert plain, which covers a large part of west-central Utah. Because the northwest boundary is indistinct, it has been established, arbitrarily, at lat. 39°15′ N. for purposes of this report.

## PREVIOUS INVESTIGATIONS

Several ground-water investigations resulting in reports have been made in Pavant Valley, and observations have been made of various phases of the ground-water regimen since 1908. During the summers of 1908 and 1909, Meinzer (1911) included the Pavant Valley in a reconnaissance of the ground-water resources in Juab, Millard, and Iron Counties. The artesian water in the valley had not been discovered at that time. Several test wells had been drilled with the objective of locating artesian water; but all had failed, and the report stated that the prospect for obtaining copious supplies of artesian water of good quality at any place in the valley was unfavorable. The general conclusion was that the prospect for pumping domestic and stock water supplies and, locally, small irrigation supplies was favorable. In 1915, however, several flowing wells were drilled in the Flowell area.

Livingston and Maxey (1944) made a study of leakage from artesian wells in the Flowell area in the spring of 1943. The report showed that in the Flowell area during 1943 about 1,000 acre-feet of water flowed through leaky artesian wells from the strata tapped into strata having a low head. The largest waste, however, was found to be through uncontrolled flow at the land surface. Of the 15,000 acre-feet that flowed from wells, 3,000 acre-feet was wasted.

The first comprehensive ground-water study of the Pavant Valley was made in 1942–45 by Dennis, Maxey, and Thomas (1946); however, the principal part of the valley investigated was the Flowell-Hatton area. They determined that the total discharge from this part of the ground-water reservoir was more than 40,000 acre-feet annually, of which less than half was discharged from wells and only about a third was put to beneficial use. The other discharge was by evapotranspiration in the bottom lands where saturated sediments were at or near the land surface.

Water levels and artesian pressures in selected wells have been measured by the U.S. Geological Survey every year since 1935. Many of the measurements were reported in the annual series of water-supply papers for the years 1935–55. Chemical-quality data have been gathered intermittently since 1943. Chemical-quality data for ground water and surface water in Utah, including that of the Pavant Valley, were compiled by Connor, Mitchell, and others (1958) in a report that included all analyses made by public agencies through September 1955.

The first comprehensive geologic study of the general area of interest to the present study was the work done by Gilbert (1891), in which he described Lake Bonneville and the associated geology. Later, Maxey (1946) discussed in considerable detail the geology of the western slopes of the Pavant Range between Pioneer Creek and Corn Creek and the southern part of Pavant Valley. The geology of the Pavant Valley was discussed further by Dennis, Maxey, and Thomas (1946), who emphasized the relation of the geology to the occurrence of ground water. The geology of the Canyon Mountains was discussed by Christiansen (1951). Little, if any, geologic investigation has been made of that part of the present project area below the southern and western foothills of the Canyon Mountains and of the northern part of the Pavant Range; but, in general, the discussion of the Pavant Valley by Dennis, Maxey, and Thomas can be extrapolated into this area.

## ACKNOWLEDGMENTS

The writer wishes to express his appreciation to all who aided in this study. The residents of the area supplied useful information and granted permission for the measurement and testing of their wells. Well drillers and pump companies supplied logs and information relating to the drilling and testing of wells. W. D. Criddle, Utah State Engineer, and F. T. Mayo and D. G. Stewart, engineers in the State Engineer's office, gave helpful assistance and suggestions and permitted access to files containing well data. Officers of the local electric power companies made available records of power consumption for irrigation wells. Local officials of the Soil Conservation Service, particularly Dale Webber, provided useful information concerning snowfall in the Pavant Range and water-conservation programs in the Pavant Valley.

## METHODS AND PROCEDURES

Available hydrologic and related basic data for Pavant Valley were located, compiled, and evaluated before fieldwork was begun. The location of wells and of other features to be visited were plotted on a map.

Selected basic ground-water data including records of wells, well logs, water-level measurements, and chemical-quality-of-water analyses were compiled in a separate report (Mower, 1963) upon completion of the fieldwork to make this information available at an early date.

During February and March 1960, 530 wells were visited. The locations of selected wells in the valley are shown on plate 1. Water levels and artesian pressures in wells were measured where possible. The flow of wells were measured or estimated, and the type and condition of the control over the discharge was noted. Every flowing well known to the author in Pavant Valley was visited, and the rate of flow was measured or estimated from two to six times during 1960. The artesian pressure also was measured where feasible. The rates of flow and the artesian pressures of each well were compared to hydrographs of nearby observation wells to determine the average rate of flow from the wells during 1960.

Surveyed well locations were used where such information was available; however, most wells were located by automobile odometer and are accurate to within one-eighth of a mile. Aerial photographs were used for some locations in remote areas not accessible by automobiles.

Water-level measurements were made from a permanent measuring point near the top of each well. The altitudes of the measuring points for about half the wells had been determined previously; the altitudes of the measuring points for the other wells were estimated by aneroid barometer. Several field tests indicate that the error of the altitude measured with the barometer was generally less than 2 feet. However, errors approached 5 feet where the distance between bench mark and well was several miles, and where the change in altitude exceeded about 50 feet.

Water levels were measured by the wetted-tape method, using a steel tape graduated to hundredths of a foot; these measurements are accurate to 0.1 foot. Shut-in pressures in flowing wells, where the static water levels were more than 6 feet above the land surface, were measured with a mercury manometer; these measurements are accurate to within 0.2 foot. Where the static water level was above the top of the well and less than 6 feet above the land surface, a one-fourth-inch clear-plastic hose was connected tightly to the well, and the free end was raised until the flow of water ceased. The distance between the water level in the hose and the measuring point was measured with a steel tape; these measurements are accurate to 0.1 foot. A standard time of 10 minutes was allowed to elapse between the time that the well was shut in and the time that the pressure was observed. Recording gages were maintained on five wells, water levels were measured periodically several times a year in 11 wells, and water levels were measured in about 400 wells during February and March 1960 and in about 200 wells during August and September 1960.

Drillers' logs of 280 wells were obtained from well owners, well drillers, and the Office of the State Engineer, and 69 of these logs were reported by Mower (1963).

Irrigated acreage was obtained from landowners, the Office of the State Engineer, the Soil Conservation Service, and by planimetering aerial photographs after field checking the outline of the cultivated areas shown by the photographs.

The yields of 108 of the 110 pumped irrigation wells in use during 1960 were measured one to five times each during the 1960 irrigation season. The yields of the other two wells were estimated. When conditions allowed, yields of pumped wells and large-capacity flowing wells were measured both with Cox flowmeter and the Hoff current meter; other yields were measured with weirs, Parshall flumes, and by the coordinate or projection method (sometimes called the "California method"). Errors in measurement probably were generally less than 5 percent; however, measurements made by using the coordinate method may have been in error by as much as 15 percent. The yields of small flowing wells were measured by observing the time required to fill a container of known volume.

The rate of electricity consumption and the pumping levels were measured at the time that the yield was measured; these data were used to compute pumpage during 1960 for wells equipped with electric motors. The accuracy of the pumpage calculations is limited by the accuracy of the discharge measurement. These calculations are estimated to have a maximum error of 5 percent. For wells equipped with diesel and butane engines, it was necessary to observe the length of time that the engine was operated during the irrigation season to compute pumpage. As about half the engines were equipped with hour meters, the total time of operation could be read directly. For engines not so equipped, irrigators supplied estimates of operating time or amounts pumped during 1960. For engines equipped with hour meters registering the length of operating time, the accuracy is estimated to be within 5 percent; however, even for the few engines not equipped with hour meters, the accuracy is within 10 percent.

Pumping tests made at three sites during the present study and at three other sites earlier were used to determine the hydraulic properties of the aquifer. The specific capacity of a well was computed by dividing the yield (gallons per minute) by the drawdown (feet) and obtaining the yield in gallons per minute per foot of drawdown. Specific capacity is useful in comparing the efficiency of wells, and it was used to determine an approximate coefficient of transmissibility—one of the major hydraulic properties of aquifers.

### WELL-NUMBERING SYSTEM

The system of numbering wells in Utah is based on the cadastral land-survey system of the Federal Government. The well number, in addition to designating the well, locates its position to the nearest 10-acre tract in the land net. By the land-survey system the State is divided in four quadrants by the Salt Lake base and meridian, and these quadrants are designated by capital letters, thus: A, northeast quadrant; B, northwest quadrant; C, southwest quadrant; and D, southeast quadrant. Numbers designating the township and range follow the quadrant letter, and all three are enclosed in parentheses. The number after the parentheses designates the section, and the lowercase letters give the location of the well within the section. The first letter indicates the quarter section, which is generally a tract of 160 acres, the second letter indicates the 40-acre tract, and the third letter indicates the 10-acre tract. Numbers following the letters indicate the serial number of the wells within the 10-acre tract. Thus, well (C-22-6)3add-2, in Millard County, is in the SE¼SE¼NE¼ sec. 3, T. 22 S., R. 6 W., and is the second well constructed or visited in that tract. The following diagram (fig. 2) shows the method of numbering wells.

## GEOGRAPHY

### PHYSIOGRAPHY

Pavant Valley is in the Great Basin section of the Basin and Range province (Fenneman, 1931), and it forms the extreme southeast arm of the Sevier Desert. A low ridge formed of extinct volcanoes and basalt flows (pl. 2), which rise 100–800 feet above the valley plain, separates the Pavant Valley from the main part of the Sevier Desert to the west.

The rugged Pavant Range forms the east and south boundaries of the valley. It trends generally north-south, except near Kanosh where it veers sharply westward. The highest point on the range is about 10,300 feet above sea level and about 5,600 feet above the valley plain at Flowell.

The north end of the Pavant Range is separated from the Canyon Mountains by a low pass (Scipio Pass). The south end of the Canyon Mountains forms the northeast boundary of Pavant Valley. The Canyon Mountains trend north-south and are offset about 6 miles to the west of an extension of the axis of the Pavant Range. The maximum altitude of the Canyon Mountains is 9,240 feet and about 4,600 feet above the lowest part of the north end of Pavant Valley.

Beaches, bars, and spits of ancient Lake Bonneville are common in Pavant Valley. The Bonneville shoreline is particularly well defined and marks the highest altitude, about 5,130 feet, reached by Lake Bonneville. The Provo shoreline (an intermediate stage at which

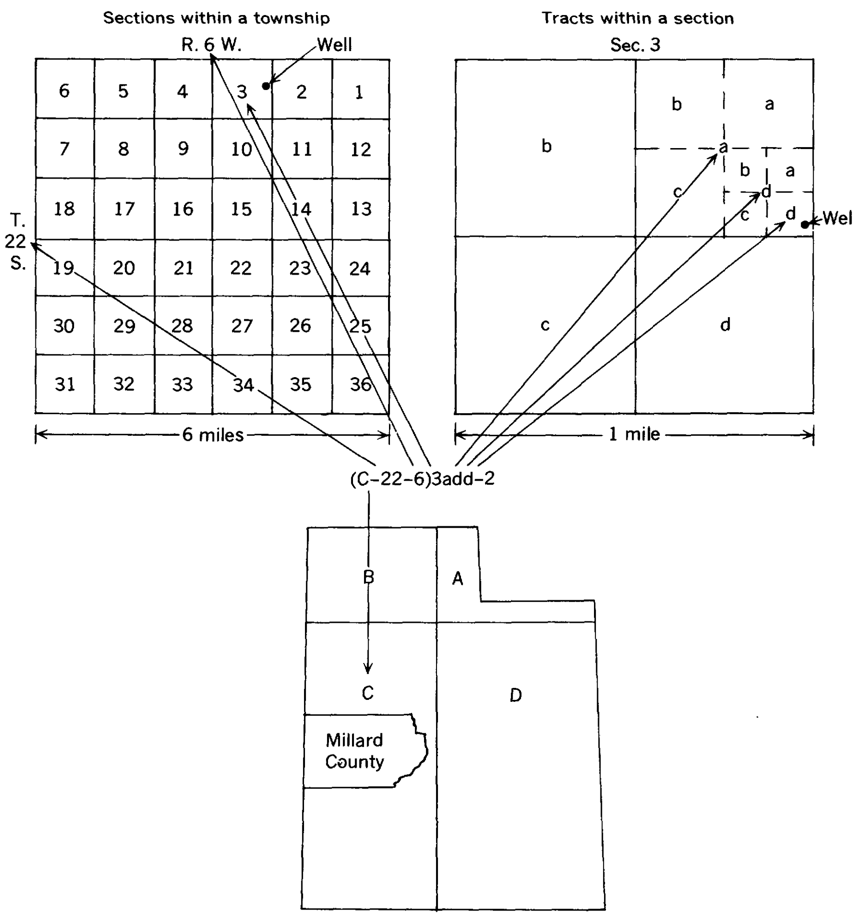


FIGURE 2.—Well-numbering system.

Lake Bonneville apparently stayed for a period of time), at an altitude of about 4,830 feet, is not as well defined as the Bonneville. Several other shorelines, both above and below the Provo shoreline, are visible on the slopes of Cedar Mountain, Bald Mountain, and West Mountain, which are low hills that project above the valley plain north and northwest of Fillmore.

Sand dunes cover a large area in the western part of the north half of Pavant Valley. Their surface is undulating, and the highest dunes rise as much as 40 feet above the interdune areas. Large rapidly moving sand dunes are encroaching on highways that cross the dune areas.

## DRAINAGE

Tributary drainage to Pavant Valley includes about 500 square miles, of which about 400 square miles are in the Pavant Range and about 100 square miles are in the Canyon Mountains. Chalk and Corn Creeks supply most of the surface water used for irrigation entering the valley from the Pavant Range; other lesser streams are, from north to south: Wild Goose Creek, Maple Hollow, and Pioneer, Pine, Meadow, Walker, and Cottonwood Creeks (pl. 1). Whiskey and Eightmile Creeks are the only streams diverted for irrigation in the Pavant Valley that enter the valley from the Canyon Mountains. Nearly all the flow of these two streams is snowmelt in early spring; occasionally prolonged rainstorms during the summer result in flow.

The south half of Pavant Valley is a basin that was closed by basalt flows—which formed a low, broad dam across the middle of the valley and created a small sink area northwest of Flowell in what had been the main drainageway of the valley. All surplus water south of Chalk Creek and some water from Chalk Creek drains into The Sink, where it infiltrates into the basalt or evaporates.

In the north half of Pavant Valley, before the Central Utah Canal was constructed in 1916, surplus flood water, including some water from Chalk Creek, had drained into a broad, shallow depression, Mud Lake, north of Pavant Butte. Since 1916 the canal has intercepted the flood water, and most of it has been used for irrigation. The water exceeding the irrigation requirements is discharged into The Sink. Occasionally, more water runs off from the uplands than the canal can carry. Overflow from the canal inundates several thousand acres of low-lying lands in the northern part of the valley; however, eventually part of it reaches Mud Lake.

The high permeability of the sand dunes in the northwest part of Pavant Valley permits infiltration of almost all the precipitation on them and thereby prevents much surface runoff; consequently, no integrated surface-drainage pattern has formed in the dune area. The shallow channel that meandered through the dune area before the surface water was diverted for irrigation has been nearly obliterated by the sand dunes. Only short remnants of the channel remain.

A gypsite playa west of Meadow and Hatton covers about 15 square miles. The playa is a collection basin for some surface drainage from the low basalt ridge to the west; the Pavant Range, where it forms the southeast boundary of the valley; and Devil's Ridge to the south. It also collects some shallow ground water that discharges in and along the east side of the playa. Other water is derived from upward leakage of artesian water and from local precipitation.

## CLIMATE

### PRECIPITATION

The climate of Pavant Valley ranges from semiarid on the valley plain to subhumid on the high mountains. The average total annual precipitation is estimated to range from 10 to 14 inches in the lowlands and from 14 to 35 inches on the upland slopes. Winters normally are moderate and wet. The average monthly precipitation at Fillmore is twice as much during the late winter and spring as it is during the summer. The annual precipitation varies widely from year to year and from the valley to the mountains. The average annual precipitation at Fillmore was 14.26 inches during the 69 years of record (1892–1960 inclusive), and it has ranged from 6.72 inches in 1934 to 21.28 inches in 1906. During the decade 1951–60, the average annual precipitation was 13.60 inches, 0.66 inches below the average for the period of record and 1.61 inches below the average for the previous decade, 1941–50, when it was 15.21 inches.

Snow-gaging stations are maintained in the Pavant Range near the head of Pine Creek, which is east of Meadow, and in Bear Canyon near the head of Chalk Creek, which is east of Fillmore. Precipitation as snow and estimated rainfall at the Pine Creek station during the period of record averaged 34 inches, while that at Bear Canyon averaged only 21 inches (table 1). The two records, however, are not comparable because the record for Pine Creek spans 31 years, whereas that for Bear Canyon spans 7 years. The two periods were not equivalent in precipitation. Precipitation at Bear Canyon, if represented by a longer period (31 years), would probably average about 26 inches.

The present period (1948–60) of deficient precipitation in the valley is one of three major droughts in Pavant Valley during the time that precipitation records have been kept at Fillmore. The curve in figure 3, which shows the cumulative departure from average precipitation 1892–1960, denotes periods of greater than average precipitation by

**Table 1.**—*Precipitation, as inches of water, in the Pavant Range east of Fillmore*

[From Soil Conserv. Service]

| Year | Snow course | | | | | | |
|---|---|---|---|---|---|---|---|
| | Pine Creek-Chalk Creek (Alt 8,500 ft) | | Pine Creek (Alt 8,700 ft) | | | Bear Canyon (Alt 7,200 ft) | |
| | April 1 snowpack measurement | Total annual precipitation (computed) | April 1 snowpack measurement | Total annual precipitation observed | Total annual precipitation (computed) | April 1 snowpack measurement | Total annual precipitation (computed) |
| 1930 | 11.1 | 32.7 | ---- | ---- | ---- | ---- | ---- |
| 1931 | 10.8 | 17.6 | ---- | ---- | ---- | ---- | ---- |
| 1932 | 14.8 | 25.8 | ---- | ---- | ---- | ---- | ---- |
| 1933 | 14.3 | 34.0 | ---- | ---- | ---- | ---- | ---- |
| 1934 | 7.2 | 10.1 | ---- | ---- | ---- | ---- | ---- |
| 1935 | 10.9 | 21.8 | ---- | ---- | ---- | ---- | ---- |
| 1936 | 10.7 | 30.6 | ---- | ---- | ---- | ---- | ---- |
| 1937 | 16.2 | 25.6 | ---- | ---- | ---- | ---- | ---- |
| 1938 | 15.7 | 30.5 | ---- | ---- | ---- | ---- | ---- |
| 1939 | 11.0 | 24.0 | ---- | ---- | ---- | ---- | ---- |
| 1940 | 15.3 | 23.2 | ---- | ---- | ---- | ---- | ---- |
| 1941 | 11.2 | 27.0 | ---- | ---- | ---- | ---- | ---- |
| 1942 | 13.1 | 23.8 | ---- | ---- | ---- | ---- | ---- |
| 1943 | 8.5 | 18.3 | ---- | ---- | ---- | ---- | ---- |
| 1944 | 15.2 | 27.6 | ---- | ---- | ---- | ---- | ---- |
| 1945 | 15.8 | 37.5 | ---- | ---- | ---- | ---- | ---- |
| 1946 | 7.0 | 19.8 | ---- | ---- | ---- | ---- | ---- |
| 1947 | 10.9 | 31.1 | ---- | ---- | ---- | ---- | ---- |
| 1948 | 17.2 | 25.9 | ---- | ---- | ---- | ---- | ---- |
| 1949 | ---- | 20.9 | 16.4 | 29.4 | 29.4 | ---- | ---- |
| 1950 | 9.2 | 15.6 | 11.3 | 19.2 | 19.2 | ---- | ---- |
| 1951 | 3.6 | 25.7 | 6.2 | ---- | 14.9 | ---- | ---- |
| 1952 | 21.4 | 31.5 | 28.4 | ---- | 41.9 | ---- | ---- |
| 1953 | 14.3 | 25.9 | 16.2 | ---- | 29.3 | ---- | ---- |
| 1954 | 12.5 | 22.3 | 12.9 | ---- | 23.0 | 9.1 | 16.3 |
| 1955 | 16.3 | 27.6 | 19.1 | ---- | 32.4 | 11.4 | 19.3 |
| 1956 | Discontinued | ---- | 12.3 | ---- | 20.2 | 5.4 | 8.9 |
| 1957 | ---- | ---- | 16.4 | 46.0 | 41.7 | 8.4 | 21.4 |
| 1958 | ---- | ---- | 19.7 | 30.9 | 25.6 | 12.4 | 16.1 |
| 1959 | ---- | ---- | 10.4 | 25.5 | 17.5 | 7.8 | 13.1 |
| 1960 | ---- | ---- | 16.1 | 38.8 | 26.7 | 12.1 | 20.1 |
| Average | 12.6 | 25.3 | 15.5 | 35.3 | 26.8 | 9.5 | 16.5 |
| Adjusted average | ---- | 32 | ---- | ---- | 34 | ---- | 21 |

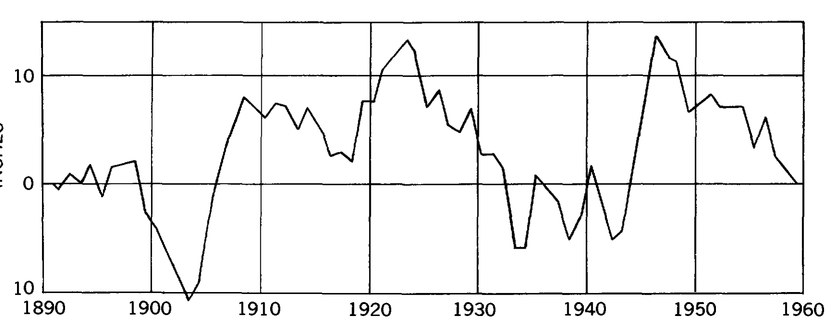


**Figure 3.**—Cumulative departure from average precipitation at Fillmore, 1892–1960. (Data from U.S. Weather Bur.)

an upward trend and periods of less than average precipitation by a downward trend. Thus, it can be seen by the general downward trend in the curve since 1948 that Pavant Valley is experiencing a pronounced drought.

The average annual precipitation figures used in this report are those computed for the entire period of record, except as indicated otherwise.

Climatological data were generally taken from official monthly and annual publications of the U.S. Weather Bureau; however, some precipitation data for stations in the Pavant Range were obtained from the Soil Conservation Service.

### TEMPERATURE AND EVAPORATION

Temperatures in Pavant Valley are moderate, seldom falling below 0°F or exceeding 100°F. The mean monthly temperature at Fillmore ranges from 29°F in January to 76°F in July. The mean-annual temperature, also at Fillmore, is 52°F and the average frost-free period is about 155 days. The average date for the last killing frost in spring is May 8; that date for the first killing frost is October 10.

Evaporation from a U.S. Weather Bureau class A land pan at Milford, about 30 miles south-southwest of Pavant Valley, averaged about 82 inches from April through October of each year during 1953–60. Some evaporation occurs during November through March; so, the annual total is probably at least 85 inches. Evaporation from open-water surfaces is less than that from land pans. Estimated adjustment factors of 0.70 for ponded water and 0.75 for open streams are applied to evaporation rates at Milford to obtain the amount of evaporation in Pavant Valley.

### VEGETATION

Native grasses and sagebrush grow throughout the noncultivated lowlands and contiguous foothills in Pavant Valley. There are a few small meadows supporting principally sedges and saltgrass in the bottom lands. However, greasewood, saltgrass, and rabbitbrush are the most abundant plants in the noncultivated bottom lands, where the water table is at or near the land surface. Saltcedar has recently entered the valley, and it is becoming a problem along some canals and in small irrigation reservoirs. It is also beginning to spread into the lowland pastures (1962).

In the undulating lowland part of the north half of the valley, the more stable sand dunes are covered with sagebrush and greasewood above an elevation of 5–10 feet above their bases. The lower 5–10 feet of the dunes are covered with greasewood, saltcedar, and sparse growths of phreatophytic grasses. The interdune areas contain dense growths of phreatophytic grasses.

Willow and wild rose grow thickly along stream channels and canal banks, especially on the alluvial fans, if their growth is not controlled artificially. Scrub oak, juniper, and large shrubs are abundant on upland slopes. Dense stands of pine, fir, and aspen grow at high altitudes.

## POPULATION, AGRICULTURE, AND INDUSTRY

The population of Pavant Valley in 1960 was about 3,500. Fillmore, the largest town, having half the population of the valley, is the county seat of Millard County. The economy is dependent upon agriculture, either directly or indirectly. During recent years, however, the tourist trade and the mining of volcanic cinders near Flowell have become important to the economy.

Irrigation farming, dryfarming, and stock raising are of about equal importance in the agricultural economy; however, the importance of dryfarming and stock raising depends largely on the success of irrigation farming. Cattle and sheep are grazed on mountain rangelands in the summer and desert rangelands on the valley plain all year. Winter wheat is the only dryland crop grown in the valley, and the areas where it can be grown successfully are small. Alfalfa, small grain, sugar beets, and potatoes are the principal irrigated crops. Some pasturelands are also irrigated, but usually they are in areas where irrigation water is relatively inexpensive and the land is of such poor quality that more remunerative cultivated crops cannot be grown successfully. Native meadow pastures in the bottom lands provide year-round forage for several thousand head of cattle, horses, and sheep.

An irrigated farm in Pavant Valley generally consists of 80–120 acres of cultivated land and some pasture. Farming is diversified, although the trend on many farms is toward one or two principal crops. In addition to the cultivated crops, most farmers maintain a small herd of beef or dairy cattle, or both. Most farmers reside in one of the four incorporated towns in the valley, where they maintain flocks of laying hens, a few pigs, vegetable gardens, and small orchards.

## WATER USE

Nearly all the surface water in the valley is diverted for irrigation; little is used for other purposes. The towns of Fillmore, Holden, Meadow, and Kanosh tap springs in nearby canyons for municipal water supplies. Fillmore, in addition, has two wells from which it obtains supplemental water. Stock and domestic water is obtained almost exclusively from wells, but during the winter streamflows are diverted for stock watering on farms near the mouths of the canyons.

Ground water is vital to the economy of eastern Millard County. Since 1915 some irrigation supplies have been obtained from the ground-water reservoir. Ground water provided about 10 percent of the total irrigation supply in Pavant Valley in 1920, about 15 percent in 1945, and about 45 percent in 1960. The use of ground water for irrigation will probably continue to increase for some time because not all irrigation wells for which permits have been granted have been completed, nor have all lands for which wells have been completed been brought into production. There may be a small reduction in the amount of irrigated land as a result of a pending water-rights adjudication, and as a result, at the completion of the adjudication, total annual ground-water withdrawal may decline. It is estimated that during future years of deficient precipitation as much as 60 percent of the irrigation water will be ground water; however, during years of normal to abnormally high precipitation, only about 30 percent of the total irrigation supply will be ground water.

Water in the valley is principally used for irrigation. In 1960 about 35.300 acres of land was irrigated, of which 13,400 acres was irrigated exclusively with surface water, 10,500 acres was irrigated with both surface and ground water, and 11,400 acres was irrigated exclusively with ground water (table 2). The ground-water districts given in table 2 are described on page 31.

Water is imported from the Sevier River for irrigation of land in the north half of Pavant Valley. The Central Utah Canal was constructed in 1916 for the purpose of diverting water to the valley. This canal heads on the Sevier River near the north end of the Canyon Mountains about 40 miles north of Fillmore.

TABLE 2.—*Irrigated lands, in acres, in Pavant Valley, 1960*

| Ground-water district | Surface water | Ground water | Surface and ground water | Total irrigated lands in district |
|---|---|---|---|---|
| McCornick | 50 | 1,750 | 400 | 2,200 |
| Greenwood | 1,700 | 850 | 850 | 3,400 |
| Pavant | 2,900 | 900 | 0 | 3,800 |
| Flowell | 4,200 | 3,950 | 3,950 | 12,100 |
| Meadow | 4,550 | 400 | 5,300 | 10,250 |
| Kanosh | 0 | 3,550 | 0 | 3,550 |
| Total in valley | 13,400 | 11,400 | 10,500 | 35,300 |

## GENERAL GEOLOGY

The direct and indirect influences of geologic factors on all phases of the hydrologic cycle are apparent throughout Pavant Valley. The landforms affect the amount and pattern of precipitation and runoff. The geologic materials and landforms control infiltration of precipitation and ground-water recharge. Subsurface geologic features control the occurrence and movement of ground water throughout the valley.

Only the geologic features that are most closely related to surface drainage and to ground-water conditions are outlined in this report. The geology has been described in greater detail by previous investigators, whose writings were freely drawn upon to compile the summary given herein. The reader may consult the references cited in the section titled "Previous investigations" if a more detailed geologic discussion is desired.

### SUMMARY OF GEOLOGIC HISTORY

Rocks dating from Precambrian time crop out in the Canyon Mountains, and rocks dating from Cambrian time crop out in the Pavant Range. Rocks of some time intervals are not present because no sediments were deposited during some periods of emergence and because some rocks have been removed by erosion.

The following discussion of the rocks in the Canyon Mountains is based on work done by Christiansen (1951). The Precambrian rocks consist of limestone in the lower part of the section and interbedded quartzite, shale, and conglomerate in the upper part; these rocks have an aggregate thickness of 7,955 feet. The basal beds are in thrust contact with younger rocks, indicating horizontal movement. The Cambrian rocks overlying the Precambrian rocks consist of 1,500 feet of coarse conglomerate and quartzite, 975 feet of limestone and shale, and 4,750 feet of limestone and dolomite—the upper part of which may be of Ordovician age. The next rocks are of Cretaceous age. They consist of coarse conglomerate in the lower part, which lies unconformably on the Cambrian rocks, and a thick sequence of sandstone, shale, and limestone. The Cretaceous rocks have a total thickness of 12,500 feet. A formation which totals 3,500 feet in thickness and consists of interbedded sandy limestone, calcareous sandstone, siltstone, and conglomerate lies unconformably on the Cretaceous rocks and is probably of Cretaceous age in the lower part and of Tertiary age in the upper part. Lying unconformably upon this formation is a bed of conglomerate which ranges in thickness from 0 to 1,800 feet and is of Tertiary age. Unconsolidated deposits of gravel, sand, and silt of Quaternary age, ranging from 0 to 1,000 feet in thickness, lie unconformably upon the conglomerate. Besides the major periods of orogeny suggested by the unconformities, there have been several other disturbances of lesser significance.

For practicable purposes, the foregoing discussion of rocks in the Canyon Mountains also applies to rocks in the Pavant Range; however, no Precambrian rocks are exposed in the Pavant Range. The kinds of rocks and their age groups are about the same, but the thicknesses of the formations may be slightly different.

The Sevier River(?) Formation of late Pliocene or early Pleistocene age is the oldest known rock unit of the valley fill. It is a fanglomerate composed of poorly sorted pebbles, cobbles, and boulders. Its aggregate thickness probably exceeds 800 feet. Most of the coarse material is angular and is derived from all older formations in the mountains.

Lake beds of Quaternary age predating Lake Bonneville overlie the Sevier River(?) Formation. They consist of 0 to nearly 800 feet of gravel, sand, silt, and clay. Basalt flows from two extinct volcanoes underlie some of these lake deposits to depths approaching 100 feet. The Black Rock Volcano is about 2 miles west of Kanosh in the south end of the valley. Most of the basalt is buried, and data are insufficient to map the extent of the flow; however, the flow extends at least 4 miles westward from the vent. The Pavant Flow (probably late Pliocene or early Pleistocene) is contemporaneous or slightly younger than the flow from Black Rock Volcano. It was extruded from Pavant Butte near the northwest corner of Pavant Valley, and it flowed mostly northward and southward. The Pavant Flow extends the full length of the valley and is 5 miles wide in some places.

The youngest sedimentary deposits in the valley were laid down by Lake Bonneville, an extinct lake that covered most of northwestern Utah, parts of northern Nevada, and southern Idaho during Pleistocene time. The deposits consist mostly of clay and sand and probably do not exceed 20 feet in thickness.

The alluvial fans were being deposited synchronously with the lake beds. As a result, coarse sediments in the lake deposits are generally contiguous with coarse fan deposits, and fine sediments in the lake deposits are contiguous with fine fan deposits.

Two small basalt flows along the west-central part of the valley are about the same age as the Lake Bonneville Group or younger. Deposits of clay and silt in the basalt vesicles below a line of equal altitude around the edge of Tabernacle Flow (late Pleistocene) indicates that it was extruded during the Provo time. The Ice Springs Craters Flow (Recent) occurred subsequent to the disappearance of Lake Bonneville from Pavant Valley.

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## GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES

In the mountains, some of the consolidated rocks are fractured in the upper few feet of their exposed surfaces, and they supply water to springs; most of them, however, are relatively impermeable and do not contain significant quantities of water. In general, little ground water moves from the mountains to the valley in the consolidated rocks. A small quantity of water moves to the valley in the upper few feet of the consolidated rocks through cracks, joints, and bedding planes, but the quantity probably does not exceed the base flow of the mountain streams. Most of the water in the consolidated formations emerges in the canyons at springs which maintain the base flow of several small creeks. Debris on the face of and at the foot of the mountains, especially the alluvial fans, affords the principal access conduits for recharge to aquifers in the valley.

The Sevier River(?) Formation is a generally impermeable commonly cemented fanglomerate composed of sediments ranging from boulders to clay. It forms the floor of the ground-water reservoir in Pavant Valley as well as the east and northeast walls. The surface of the Sevier River(?) Formation was eroded prior to the deposition of the lacustrine deposits, and the surface is very irregular. The formation forms the cores of several hills in the central part of the valley; Bald Mountain, Cedar Mountain, and West Mountain are the three most prominent. Buried hills of the Sevier River(?) Formation apparently exist also and, locally, may control the occurrence and movement of ground water. Locally the formation furnishes small quantities of water to wells. Material at these locations has probably been reworked, becoming less firmly cemented and having coarser and more uniform texture than the parent material.

The surface of the Sevier River(?) Formation is very irregular, and it is generally at shallower depths near the mountains than it is in the middle of the valley. The shallow depth of the Sevier River(?) Formation near the mountains is the principal reason that few successful irrigation wells have been completed along the east side of the valley. The few successful wells near the mountains are probably completed in re-entrants of valley fill, where ancient streams eroded channels in the Sevier River(?) Formation.

The lacustrine beds of gravel and sand constitute the artesian aquifers, which are the major sources of ground water in Pavant Valley. The aquifers are thicker, more extensive, and more permeable near the base of the mountains than they are away from the mountains (pl. 3). Artesian pressure occurs a short distance west of the mountains, where the aquifers become interbedded with lacustrine clay beds which confine the water. The several clay beds separate the valley fill into several interconnected aquifers that extend westward in finger-like projections. The well logs used to make the profiles on plate 3 are shown graphically in relation to sea-level datum, and the distances between the well logs are proportional to the distances between wells. The wells represented by the logs on profile *A–A′* are approximately on a north-south line through the most heavily developed parts of Pavant Valley. Profile *B–B′* is a west-east section through the Greenwood district, and profile *C–C′* is a west-east section through the Flowell district.

Close correlation of the individual strata shown in the logs of the several wells is questionable in alluvial sediments such as those in Pavant Valley, where deposition has been irregular and lenticular. Each well log in these profiles, however, shows zones in which coarse sediments predominate. These zones are thickest near the mountains and thinnest farther away. Coarse deposits lie at or near the land surface near the mountains, especially near the apex of the alluvial fans; at short distances away from the mountains however, the upper several feet of surface material is fine sand, silt, and clay.

The Pavant Flow is evident in the sections of the western two wells in profile *C–C′*. The other two profiles miss the flow by short distances; in fact, the basalt flow extends only one-fourth mile east of the line between wells (C–21–5) 5abd–1 and (C–21–5) 20 cca–2 in profile *A–A′*. The basalt is not shown on this profile because wells penetrating it were not selected for the profile.

Drillers' logs are available for 280 wells in Pavant Valley. Most of the well logs and construction data concerning wells have been obtained from notices of claims to underground waters and from well-drillers' reports filed with the Utah State Engineer. In these reports, well owners and drillers are required to give specific details about the history of the well and the well construction, including a log of the material drilled through, according to provisions of the State underground water law of March 1935. The information given on the claims for wells drilled before 1935 is probably not as accurate or complete as that for wells drilled since 1935 because the early data were mostly from memories of well owners, tenants, neighbors, and drillers.

Drillers generally distinguish the dominant material in logs such as gravel, sand, silt, and clay but do not report the degree of mixing. In outcrops, the unconsolidated sediments are seen to be poorly sorted, and they may be presumed to be equally poorly sorted at depths penetrated by wells. Thus, the terms used to describe the texture of the material penetrated are the driller's opinion. Examination of various drillers' logs of wells even within a radius of a very few feet, show

TABLE 3.—*Log of West Holden Irrigation Co. well (C-19-4)31dbb-1*

[Drilled in May 1960 by S. S. Stephenson. Pumped irrigation well near the center of the Greenwood district]

**Well log described in report of well driller**

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Topsoil | 5 | 5 |
| Hardpan | 3 | 8 |
| Gravel, cobbles, and boulders. | 7 | 15 |
| Clay, silt, and sand | 15 | 30 |
| Clay and gravel | 15 | 45 |
| Gravel, water-bearing | 5 | 50 |
| Clay and silt | 15 | 65 |
| Clay, silt, and sand; water-bearing. | 13 | 78 |
| Gravel, water-bearing | 7 | 85 |
| Clay, silt, and layers of small gravel. | 72 | 157 |
| Gravel, water-bearing | 5 | 162 |
| Clay and sand lenses | 10 | 172 |
| Gravel, cemented very hard. | 11 | 183 |
| Clay and gravel lenses | 40 | 223 |

**Well log described by R. D. Feltis, U.S. Geol. Survey, from well samples**

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| No sample | 5 | 5 |
| Gravel, fine to medium, and sand (70 percent); tan silt containing very fine basalt sand (30 percent). | 10 | 15 |
| Silt (50 percent) and clay (30 percent), reddish-tan; sand and gravel (20 percent). | 15 | 30 |
| Silt (70 percent), tan, and sand (30 percent). | 5 | 35 |
| Clay, tan; contains fine to coarse gravel. | 5 | 40 |
| Silt (80 percent); gravel, fine to medium, and sand (20 percent; tan. | 10 | 50 |
| Clay (90 percent) and silt (10 percent), tan; contains a few gravel particles. | 15 | 65 |
| Silt, tan; contains some gravel | 5 | 70 |
| Silt (60 percent), tan, and sand (40 percent.). | 5 | 75 |
| Clay (70 percent) and silt (30 percent), tan; contains a few gravel particles. | 5 | 80 |
| Clay (50 percent) and silt (50 percent), tan; contains fine to medium gravel. | 5 | 85 |
| Clay (50 percent) and silt (50 percent), tan. | 5 | 90 |
| Sand, fine to coarse, angular to rounded quartz, and fine gravel (90 percent); tan silt (10 percent). | 5 | 95 |
| do | 5 | 100 |
| Silt (70 percent), tan; sand and fine to medium gravel (30 percent). | 15 | 115 |
| Silt (40 percent) and clay (40 percent), tan; sand containing fine gravel (20 percent). | 5 | 120 |
| Silt (50 percent) and clay (50 percent), tan. | 10 | 130 |
| Silt (40 percent) and clay (40 percent). tan; sand (20 percent). | 5 | 135 |
| Silt (50 percent) and clay (20 percent), tan; sand and gravel (30 percent). | 10 | 145 |
| Silt (50 percent), tan, and sand (50 percent). | 5 | 150 |
| Sand, fine to coarse, and fine to medium gravel (80 percent); tan silt (20 percent). | 15 | 165 |
| Sand and fine gravel (40 percent), silt (40 percent), and tan clay (20 percent). | 5 | 170 |
| Gravel, fine to coarse, and sand (90 percent); tan silt (10 percent). | 10 | 180 |
| Sand and gravel (60 percent) and silt (40 percent). | 10 | 190 |
| Silt, tan, and fine to coarse gravel (80 percent); sand (20 percent). | 15 | 205 |
| Silt (50 percent) and clay (50 percent), tan; probably contains sparse thin layers of sand and gravel. | 35 | 240 |
| Silt, tan | 5 | 245 |
| Silt (70 percent), tan; fine sand (30 percent). | 20 | 265 |
| Silt (50 percent) and clay (20 percent), tan; fine sand (30 percent). | 10 | 275 |
| Silt (70 percent), tan; and sand (30 percent). | 5 | 280 |
| Silt (70 percent) and tan clay (30 percent). | 10 | 290 |
| Silt (70 percent), tan, and fine sand (30 percent). | 5 | 295 |

TABLE 3.—*Log of West Holden Irrigation Co. well (C-19-4)31dbb-1*—Continued

| Well log described in report of well driller | | | Well log described by R. D. Feltis, U.S. Geol. Survey, from well samples | | |
|---|---|---|---|---|---|
| | Thickness (feet) | Depth (feet) | | Thickness (feet) | Depth (feet) |
| Clay, gravel, and hardpan | 76 | 299 | Silt (50 percent) and clay (20 percent), tan; fine sand (30 percent). | 5 | 300 |
| Sand and mudstone | 6 | 305 | | | |
| Clay, sand, and conglomerate. | 23 | 328 | | | |
| Gravel, water-bearing | 3 | 331 | Silt (70 percent), tan; fine to coarse sand (30 percent); contains thin layers of fine to medium gravel in the intervals 300–310, 330–335, and 340–360 ft. | 60 | 360 |
| Clay, sand, and gravel | 9 | 340 | | | |
| Conglomerate | 8 | 348 | | | |
| Clay and sand | 14 | 362 | | | |
| | | | Silt (50 percent), tan; sand and fine to medium gravel (50 percent). | 5 | 365 |
| Conglomerate and cemented gravel. | 12 | 374 | Gr.vel (70 percent), fine to medium, and sand (30 percent). | 5 | 370 |
| Clay | 5 | 379 | Silt (50 percent), tan; and coarse sand (50 percent). | 5 | 375 |
| Conglomerate and cemented gravel. | 7 | 386 | Silt (70 percent), tan; and sand (30 percent). | 5 | 380 |
| Clay | 5 | 391 | | | |
| Gravel, water-bearing | 2 | 393 | Silt (50 percent), tan, and coarse sand (50 percent). | 15 | 395 |
| Clay | 5 | 398 | Silt (60 percent), tan; sand and fine to medium gravel, (40 percent). | 5 | 400 |
| | | | Gravel (40 percent), fine to medium; sand (30 percent); tan silt (30 percent). | 5 | 405 |
| Hardpan | 14 | 412 | | | |
| Clay | 2 | 414 | | | |
| Gravel | 2 | 416 | | | |
| | | | Sand (60 percent), fine to coarse, and tan silt (40 percent). | 15 | 420 |
| | | | Silt (60 percent), tan, and fine sand (40 percent). | 10 | 430 |
| Clay and gravel lenses | 22 | 438 | | | |
| | | | Sand (60 percent), fine to coarse, and tan silt (40 percent); contains thin layers of fine to medium gravel in the intervals 435–445 and 495–500 ft. | 70 | 500 |
| Clay, cemented gravel lenses, and hardpan. | 85 | 523 | No sample | 23 | 523 |

that a material described as clay by one driller may be described as silt or even sand by another. Two interpretations of the material penetrated in drilling irrigation well (C–19–4)31dbb–1—about in the center of the Greenwood district—are shown in table 3. The log of this well is also shown graphically in profile *A–A′* on plate 3. The poor sorting and heterogeneous nature of the material in the valley is evident in the logs and in the columnar sections.

All the basalt in Pavant Valley has approximately the same water-bearing properties. Although the basalt is highly vesicular, an unfractured unit is practically impermeable. The basalt is strongly jointed and creviced, however, and open joints and other fractures, brecciated layers, and blocky structure impart relatively high formational permeability to the basalt. Hence, it is copiously water bearing at many places; and wells completed in the basalt commonly yield large quantities of water.

## WATER RESOURCES

The water supply in Pavant Valley is derived partly from precipitation and partly from water from the Central Utah Canal. The amount of the precipitated water that can be used depends on its disposition and distribution. Much of the upland precipitation is snow, some of which disappears by sublimation. Some melt water and rainwater evaporates, some restores soil moisture, some runs off the mountain slopes at the surface; any that is left over becomes ground water which migrates toward the valley bottom by underflow.

Native vegetation consumes a large part of the soil moisture. Most surface water that is discharged by the upland streams during the growing season is diverted for irrigation, and much of the diverted water is consumed by crops. An undetermined, but large part, of the intermittent runoff from upland slopes enters the soil and replenishes soil moisture and ground water. All water that is not consumed in the uplands reaches Pavant Valley by surface runoff and underflow, except possibly a small amount of underflow from the uplands in the Corn Creek drainage. Water in the valley lowland is depleted by native and cultivated vegetation, and the unconsumed residual water moves as underflow westward from Pavant Valley to the Sevier Desert.

### VOLUME OF PRECIPITATION

Average annual precipitation on Pavant Valley and the contiguous uplands is estimated to be 730,000 acre-feet (table 4). About 180,000 acre-feet is concentrated on the valley plain (that part of the valley at an altitude below 4,800 feet); about 170,000 acre-feet, on the area between 4,800 and 6,000 feet; and about 380,000 acre-feet, on the uplands above 6,000 feet. The volume of precipitation, computed by the steps outlined below, is probably in the right order of magnitude.

The available precipitation data were plotted against station altitudes, and the trend of the relation between precipitation and altitude was defined. The contours on a topographic map having a scale of 1:250,000 were used as isohyetal lines. The area between each pair of isohyets (1,000-foot contour line) in each drainage was measured with a planimeter, and the volume of precipitation was computed from the average in that area (table 4).

In this report the period of annual precipitation on the uplands above 6,000 feet is from November of the preceding year through October of the given year. This period of time was selected because the snowpack measurement taken on April 1 is actually a measurement of all the snowfall from November to March minus snowmelt, sublimation, and evaporation. The amount of snowmelt, sublimation, and evaporation to April 1 is probably small compared with total

TABLE 4.—*Average annual precipitation by drainage basin and ground-water district in Pavant Valley and contiguous uplands, Utah*

| | Average annual precipitation (acre-feet) | | |
|---|---|---|---|
| | Between 4,800 and 6,000 ft | Above 6,000 ft | Total |
| *Drainage basin* | | | |
| Whiskey Creek | 14, 300 | 11, 200 | 25, 500 |
| Eightmile Creek | 13, 800 | 18, 600 | 32, 400 |
| Scipio Pass | 25, 200 | 17, 200 | 42, 400 |
| Wild Goose Canyon | 6, 700 | 14, 200 | 20, 900 |
| Wide Canyon | 6, 000 | 17, 300 | 23, 300 |
| Maple Hollow | 8, 200 | 11, 600 | 19, 800 |
| Pioneer Creek | 14, 200 | 22, 200 | 36, 400 |
| Between Pioneer and Chalk Creeks | 14, 800 | 7, 900 | 22, 700 |
| Chalk Creek | 4, 100 | 78, 700 | 82, 800 |
| Between Pine, Meadow, and Walker Creeks | 5, 000 | 4, 200 | 9, 200 |
| Pine Creek | 700 | 7, 400 | 8, 100 |
| Meadow Creek | 800 | 19, 500 | 0, 300 |
| Walker Creek | 1, 200 | 5, 800 | 27, 000 |
| Sunset Canyon | 5, 700 | 11, 600 | 17, 300 |
| Cottonwood Creek | 3, 000 | 5, 100 | 8, 100 |
| Below Corn Creek | 11, 600 | 5, 200 | 16, 800 |
| Corn Creek | 1, 600 | 100, 000 | 101, 600 |
| West of Corn Creek | 33, 000 | 21, 800 | 54, 800 |
| Total (rounded) | 170, 000 | 380, 000 | 550, 000 |
| *Ground-water districts* (below 4,800 ft) | | | |
| McCornick | | | 20, 000 |
| Greenwood | | | 44, 000 |
| Pavant | | | 14, 000 |
| Flowell | | | 45, 000 |
| Meadow | | | 31, 000 |
| Kanosh | | | 26, 000 |
| Total: | | | |
| In ground-water districts | | | 180, 000 |
| In valley and contiguous uplands | | | 730, 000 |

snowfall; however, it may be appreciable for years of mild winters or early springs. Measured precipitation for 4 years at the Pine Creek snow course indicate that about 20 percent of the precipitation during the period November to March becomes snowmelt or is lost by sublimation or evaporation. Thus the correction factor of +20 percent was used to adjust average annual precipitation in the mountains in computations used in this report to compensate for these factors.

## SURFACE WATER

The total surface-water inflow to Pavant Valley through natural channels—none of which leaves the valley as surface flow except during years of abnormal weather—is estimated at 104,000 acre-feet per year; an additional 17,700 acre-feet a year is brought into the valley from the Sevier River by the Central Utah Canal. The principal sources of the water in natural channels are Chalk Creek and Corn Creek, which contribute about 25,000 and 12,000 acre-feet per year, respectively. Pine and Meadow Creeks contribute about 2,000 and 5,000 acre-feet per year, respectively. All the other 14 streams are intermittent or have small discharge; however, they contribute an aggregate of about 59,000 acre-feet of surface water per year to Pavant Valley.

The volume of inflow of the aforementioned streams was estimated using streamflow measurements made since 1938 by the Geological Survey and the Office of the State Engineer. Chalk Creek was measured 21 times during 1938–43, and it has been measured continuously since 1944, when a recording gage was installed. Pine, Meadow, and Corn Creeks have been measured 9–44 times each at irregular intervals since 1938. Streamflow measurements of the other streams are unreliable or lacking.

To estimate the volume of inflow to Pavant Valley from the streams for which there are no streamflow records, certain physical, climatologic, and hydrologic data and characteristics of the individual drainage basins were compared to corresponding characteristics of the Chalk Creek, Pine Creek, Meadow Creek, and Corn Creek drainage basins and converted to a dimensionless number, described herein as runoff efficiency. Runoff efficiency is the yield of a drainage basin per unit area divided by the yield of the Chalk Creek drainage basin per unit area with equal precipitation in each of the drainage basins. In estimating runoff efficiency, the type and relative density of vegetal cover in each of the drainage basins was compared to that in the Chalk Creek drainage basin by field reconnaissance and from inspection of aerial photographs. The relative porosity and gradient of the surface materials and the geologic formations were taken from geologic reports, from topographic maps, and by cursory examination; these were then compared to the same factors in the Chalk Creek drainage basin. Runoff efficiency was estimated from these data.

### CHALK CREEK

Chalk Creek supplies more water, has a greater yield per acre of watershed, and has a more sustained flow than any other stream entering Pavant Valley. The average annual measured inflow from Chalk Creek during 1944–59 was 25,100 acre-feet, more than twice the inflow of the next largest stream (table 5). Annual inflow has ranged from 8,100 acre-feet in 1959 to 45,100 acre-feet in 1952. During the period 1944–59, its 36,000 acres of watershed yielded about 700 acre-feet per 1,000 acres from about 2,300 acre-feet of precipitation per 1,000 acres. The minimum recorded average daily flow was 4.4 cfs (cubic feet per second), and the minimum recorded average monthly flow was 6.6 cfs.

A recording gage has been maintained on Chalk Creek about 1 mile east of Fillmore since March 1944. The altitude of the gage is 5,180 feet. It is below all major tributaries, but there is one small irrigation diversion above the gage.

TABLE 5.—*Some physical characteristics of and computed inflow from watersheds tributary to Pavant Valley, Utah*

| Watershed | Average altitude (feet) | Size of area (acres) | Runoff efficiency (in relation to Chalk Creek) (percent) | Precipitation on watershed (percent of total) | Surface-water inflow | | Computed average annual surface-water inflow 1944-59 (acre-feet) |
|---|---|---|---|---|---|---|---|
| | | | | | Percent of Chalk Creek | Acre-feet per 1,000 acres | |
| Whiskey Creek | 6,060 | 17,200 | 60 | 3 | 19 | 280 | 4,800 |
| Eightmile Creek | 6,290 | 20,800 | 60 | 5 | 23 | 280 | 5,800 |
| Scipio Pass | 5,940 | 29,400 | 25 | 5 | 12 | 100 | 3,000 |
| Wild Goose Creek | 6,620 | 12,200 | 70 | 4 | 25 | 520 | 6,300 |
| Wide Canyon | 6,870 | 12,900 | 85 | 5 | 24 | 470 | 6,000 |
| Maple Hollow | 6,470 | 11,900 | 85 | 3 | 20 | 420 | 5,000 |
| Pioneer Creek | 6,720 | 20,500 | 90 | 6 | 40 | 490 | 10,000 |
| Between Pioneer and Chalk Creeks | 5,950 | 15,700 | 60 | 2 | 16 | 250 | 4,000 |
| Chalk Creek | 7,980 | 36,000 | 100 | 21 | 100 | 700 | 25,100 |
| Between Pine, Meadow, and Walker Creeks | 5,980 | 6,500 | 60 | 1 | 7 | 280 | 1,800 |
| Pine Creek | 7,650 | 3,800 | 83 | 2 | 8 | 530 | 2,000 |
| Meadow Creek | 8,130 | 8,700 | 93 | 5 | 23 | 670 | 5,800 |
| Walker Creek | 7,030 | 3,700 | 75 | 2 | 6 | 410 | 1,500 |
| Sunset Creek | 6,740 | 9,800 | 70 | 3 | 15 | 390 | 3,800 |
| Cottonwood Creek | 6,590 | 4,700 | 65 | 1 | 6 | 320 | 1,500 |
| Below Corn Creek | 5,820 | 12,200 | 35 | 1 | 7 | 150 | 1,800 |
| Corn Creek | 7,590 | 50,000 | 34 | 26 | 47 | 240 | 11,800 |
| West of Corn Creek | 5,950 | 38,000 | 25 | 6 | 16 | 100 | 4,000 |
| Total | | 314,000 | | | | | 104,000 |

## PINE CREEK

The average annual inflow to Pavant Valley from Pine Creek during 1944–59 was estimated to be 2,000 acre-feet. It ranged from 3,600 acre-feet in 1952 to 700 acre-feet in 1959. During this period, the contributing drainage area yielded about 530 acre-feet of surface water per 1,000 acres from 1,900 acre-feet of precipitation per 1,000 acres. The inflow of Pine Creek was estimated by comparing nine measurements of its flow to measurements of Chalk Creek made the same day or within 1 day when there were no effects from local recent precipitation. The comparison shows that inflow to Pavant Valley from Pine Creek is equivalent to about 8 percent of the total average annual inflow of Chalk Creek. The runoff efficiency of the Pine Creek drainage basin is calculated to be 83 percent of the runoff of the Chalk Creek drainage basin. This calculation means that a storm yielding 100 acre-feet of surface water per unit area in the Chalk Creek drainage basin would have yielded 83 acre-feet of surface water per unit area in the Pine Creek drainage basin.

## MEADOW CREEK

The average annual inflow to Pavant Valley from Meadow Creek during 1944–59 was estimated to be 5,800 acre-feet, and it ranged from 2,000 acre-feet in 1959 to 10,400 acre-feet in 1952. During this period the contributing area yielded about 670 acre-feet per 1,000 acres from

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about 2,200 acre-feet of precipitation per 1,000 acres. The total annual flow of Meadow Creek was estimated by comparing 38 discharge measurements made in it on comparable dates when the flow of Chalk Creek was measured. The average annual flow of Meadow Creek is 23 percent of the flow of Chalk Creek, and its runoff efficiency is 93 percent.

### CORN CREEK

The average annual inflow to Pavant Valley from Corn Creek during 1944–59 was estimated to be 12,000 acre-feet, and it ranged from 21,000 acre-feet in 1952 to 4,100 acre-feet in 1959. During this period, the contributing drainage area of 50,000 acres yielded about 240 acre-feet of surface water per 1,000 acres from 2,000 acre-feet of precipitation per 1,000 acres. The total annual flow of Corn Creek was estimated by comparing 44 discharge measurements made in it on comparable dates when the flow of Chalk Creek was measured. The runoff efficiency of the Corn Creek drainage basin is only 34 percent of that of the Chalk Creek basin, and the average annual inflow to Pavant Valley is 47 percent of the inflow of Chalk Creek, although the Corn Creek basin is 14,000 acres larger than the Chalk Creek basin.

The small runoff efficiency in the Corn Creek basin, compared with that in the Chalk Creek basin, is the result of more gentle slopes, more permeable surface materials, and denser vegetation, which all cause a greater percentage of the precipitation in the Corn Creek basin to be evaporated and transpired. Also, in the Corn Creek basin there is greater opportunity for ground water to flow out of the basin than in the Chalk Creek basin because of the dip of the geologic formations in the eastern and southern parts of Corn Creek basin.

### OTHER STREAMS

The total average annual volume of inflow from all the other streams contributing water to Pavant Valley was calculated to be 59,000 acre-feet, or 57 percent of the total natural inflow to the valley during 1944–59. During this period, inflow from these streams ranged from 190,000 acre-feet in 1952 to 36,000 acre-feet in 1959. The contributing drainage areas of individual streams yielded from about 100 acre-feet per 1,000 acres in Scipio Pass and the mountains west of Corn Creek to about 520 acre-feet per 1,000 acres in the Wild Goose Creek basin (table 5). The inflow from these streams was calculated as explained in a preceding section. Nearly all of these streams have small perennial flows in their upper reaches, but most of the inflow is snowmelt during the early spring freshet and runoff from summer thundershowers.

### CENTRAL UTAH CANAL

The average annual diversion from the Sevier River by the Central Utah Canal for use in Pavant Valley during 1934–60 was 17,700 acre-feet. Diversions ranged from 3,730 acre-feet in 1935 to 39,700 acre-feet in 1946 (table 6). Since 1955, annual diversions for Pavant Valley averaged 10,900 acre-feet, or only 62 percent of the average during 1934–60—and only 6,360 acre-feet were diverted during 1960.

TABLE 6.—*Summary of computed diversions, in acre-feet, from the Sevier River by the Central Utah Canal for use in Pavant Valley, Utah, 1934–60*

| Year | Number of days that water was in canal | Ground-water district | | | | Total [1] |
|---|---|---|---|---|---|---|
| | | McCornick | Greenwood | Pavant | Flowell | |
| 1934 | 35 | 1,770 | 580 | 2,520 | 660 | 5,530 |
| 1935 | 27 | 1,190 | 390 | 1,700 | 450 | 3,730 |
| 1936 | 59 | 2,030 | 670 | 2,890 | 750 | 6,340 |
| 1937 | 45 | 2,910 | 960 | 4,150 | 1,080 | 9,100 |
| 1938 | 79 | 4,000 | 1,320 | 5,690 | 1,480 | 12,490 |
| 1939 | 80 | 4,660 | 1,540 | 6,650 | 1,730 | 14,580 |
| 1940 | 69 | 3,640 | 1,200 | 5,180 | 1,340 | 11,360 |
| 1941 | 80 | 4,130 | 1,360 | 5,880 | 1,530 | 12,900 |
| 1942 | 150 | 12,000 | 3,960 | 17,120 | 4,440 | 37,520 |
| 1943 | 116 | 6,260 | 2,070 | 8,920 | 2,320 | 19,570 |
| 1944 | 133 | 7,240 | 2,390 | 10,310 | 2,680 | 22,620 |
| 1945 | 103 | 6,060 | 2,000 | 8,640 | 2,250 | 18,950 |
| 1946 | 201 | 12,700 | 4,200 | 18,100 | 4,700 | 39,700 |
| 1947 | 88 | 6,780 | 2,240 | 9,660 | 2,510 | 21,190 |
| 1948 | 131 | 11,640 | 3,850 | 16,600 | 4,310 | 36,400 |
| 1949 | 138 | 9,820 | 3,240 | 14,000 | 3,630 | 30,690 |
| 1950 | 115 | 7,340 | 2,420 | 10,450 | 2,720 | 22,930 |
| 1951 | 89 | 5,930 | 1,960 | 8,460 | 2,190 | 18,540 |
| 1952 | 157 | 6,270 | 2,070 | 8,930 | 2,320 | 19,590 |
| 1953 | 152 | 9,110 | 3,020 | 12,980 | 3,370 | 28,480 |
| 1954 | 119 | 6,380 | 2,110 | 9,100 | 2,360 | 19,950 |
| 1955 | 90 | 5,280 | 1,750 | 7,530 | 1,960 | 16,520 |
| 1956 | 58 | 3,120 | 1,030 | 4,450 | 1,150 | 9,750 |
| 1957 | 51 | 1,670 | 550 | 2,390 | 620 | 5,230 |
| 1958 | 69 | 5,320 | 1,760 | 7,580 | 1,970 | 16,630 |
| 1959 | 54 | 3,580 | 1,180 | 5,100 | 1,320 | 11,180 |
| 1960 | 43 | 2,040 | 670 | 2,900 | 750 | 6,360 |
| Average annual | 94 | 5,660 | 1,870 | 8,070 | 2,100 | 17,700 |

[1] Diversions taken from Sevier River Water Commissioner's annual reports. Totals are 60 percent of diversions shown in Commissioner's reports.

Annual diversions are regulated by court decree (Cox, 1936), which stipulates the quantity of water that may be diverted, and are based upon the volume of runoff in the Sevier River basin above Sevier Bridge Reservoir, about 30 miles north-northeast of Fillmore. Diversions are about 5 percent of the flow of the river when storage in the Sevier Bridge Reservoir is less than 104,000 acre-feet, but they are 57 percent of the flow when storage in the reservoir is greater than 104,000 acre-feet; thus there is a wide range in the annual diversions.

It was necessary to compute the average annual diversions listed in table 6 because flow in the canal is measured only near the diversion on the Sevier River, and water is withdrawn from the canal for irrigation of lands north of Pavant Valley. Of the 6,456 water-right shares of the Central Utah Water Co., 2,065 are in McCornick district, 682 are in Greenwood district, 2,944 are in Pavant district, and 765 are in Flowell district (Earl Greathouse, Secretary, Central Utah Water Co., written commun., April 14, 1961); 40 percent of the rights are north of Pavant Valley and 60 percent are in Pavant Valley. It was assumed that the deliveries from the canal would be at the ratio of these percentages. The ratio of deliveries may not have been exactly 60:40 because of trading, renting, and transferring of water from one area to another. (For example, in 1960, 56.9 percent of the water delivered by the canal was used in Pavant Valley, and 43.1 percent was used north of Pavant Valley.) The ratio 60:40 is used in this report because more accurate data are not available for earlier years, and this ratio is within the accuracy of other assumptions and the water measurements.

No data are available for the quantity of water delivered in each of the four districts in Pavant Valley using water from the canal; therefore, the canal water was apportioned to each of the districts at the ratio of the water-right shares owned in each of the districts. The computed amount of water delivered in each district since 1934 is listed in table 6.

Generally, several diversions of short duration are made at intermittent intervals during the irrigation season. The longest diversion is during the early part of the irrigation season, April to June; diversions of shorter duration are made at other times later in the year. Usually, the average rate of diversion is about 90 cfs for use in Pavant Valley, although the average annual rate of diversion has been as low as 60 cfs and as high as 120 cfs. The volume of water diverted each year is governed more by the length of time that water is being diverted than by the rate of diversion. During 1934–60, water was in the canal an average of 94 days a year, but it ranged from 27 days in 1935 to 201 days in 1946. Water was in the canal an average of 61 days per year during 1955–60 and only 43 days in 1960.

## GROUND WATER

In Pavant Valley, ground water is chiefly derived from the infiltration of precipitation and water used for irrigation. Some of the ground water eventually is discharged by wells or by evaporation; the residual moves westward out of the valley.

Generally, porous rocks below the water table are saturated. In the more permeable rocks, such as the beds of sand and gravel in the lake deposits, individual pore spaces are interconnected and are large enough that water moves freely through them under the force of gravity; however, in the less permeable rocks, such as the beds of clay and silt in the lake deposits and the poorly cemented mixture of clay, sand, gravel, and boulders of the Sevier River(?) Formation, the pores are so small that water moves through them slowly. In some areas, however, the Sevier River(?) Formation has probably been reworked, and the resulting deposits of coarse materials transmit some water. The basalt vesicles are not all interconnected, but in some areas the basalt has been fractured to such an extent that it freely transmits large quantities of water.

Ground-water discharge exceeded recharge by about 30,000 acre-feet during 1959, and the excess about equals the diminution in ground-water storage (table 7). Withdrawals through wells was about 6,000 acre-feet less than total recharge, and the total natural discharge was about 37,000 acre-feet.

TABLE 7.—*Ground-water budget (estimated), in acre-feet, in Pavant Valley, 1959*

[The discrepancy of 1,000 acre-feet in the budget is due to errors in estimating some of the factors used in the computations]

| Ground-water district | Recharge [1] | Discharge | | | | Change in storage (decrease) |
|---|---|---|---|---|---|---|
| | | Evapotranspiration [2] | Underflow (from valley) | Wells | Total | |
| McCornick | 7,100 | 0 | 3,500 | 6,600 | 10,100 | 4,000 |
| Greenwood | 17,300 | 11,000 | 3,500 | 4,100 | 18,600 | 500 |
| Pavant | 1,300 | 500 | 1,500 | 1,100 | 3,100 | 500 |
| Flowell | 20,000 | 4,000 | 5,000 | 26,300 | 35,300 | 10,000 |
| Meadow | 14,000 | 8,000 | 500 | 10,100 | 18,600 | 10,000 |
| Kanosh | 6,000 | 0 | 0 | 11,400 | 11,400 | 5,000 |
| Total (rounded) | 66,000 | 23,000 | 14,000 | 60,000 | 97,000 | 30,000 |

[1] Includes that part of the ground water discharged from wells which is not consumed.
[2] Evapotranspiration by native vegetation on nonirrigated lands.

## DELINEATION OF GROUND-WATER DISTRICTS

The valley was divided into six ground-water districts, designated from north to south: McCornick, Greenwood, Pavant, Flowell, Meadow, and Kanosh (pl. 4). The dividing lines between districts were established, generally, at places where geologic conditions formed hydrologic boundaries. The principal purpose of the division into districts was to delineate areas having like characteristics and common sources of recharge and areas of discharge. This delineation will assist in administering an orderly ground-water development. The ground water in the valley belongs to one hydrologic system, although in some respects ground-water conditions in one district are quite different from ground-water conditions in the other districts. There may be ground-water movement between districts, and ground-water development in a given district may cause effects in adjacent districts; nevertheless, each district may be considered as an entity for most purposes.

### OCCURRENCE

All water beneath the land surface is designated by the term "subsurface water" (Meinzer, 1923, p. 17–32). Ground water is that part of the subsurface water that is in the zone of saturation.

The upper surface of the zone of saturation is known as the water table, and it is approximated by the water level in water-table wells, except where the upper surface lies in material of low permeability. In material of low permeability, water will rise above the water table by capillary action. Artesian water is confined by material of lower permeability than the materials of the aquifer, and it has sufficient hydraulic pressure to rise above the bottom of the confining bed. The piezometric surface as used herein is an imaginary surface that coincides with the static water level in wells tapping an artesian aquifer. Water will flow from wells where the piezometric surface is above the land surface. Although both water-table and artesian conditions exist in Pavant Valley, no attempt is made to differentiate water on this basis, except for unconfined water in the basalt aquifer near Flowell, where the water table is generally continuous with the piezometric surface. The most readily accessible ground water of good quality occurs chiefly in unconsolidated permeable alluvium between Hatton and McCornick on the valley plain and in basalt west of Kanosh and west of Flowell. In these areas the water-bearing materials are thicker, more permeable, or nearer the land surface than they are in other parts of the valley.

Beneath the floor of Pavant Valley, ground water occurs in lake beds and in alluvial-fan deposits of gravel, sand, and silt. Interbedded lenses and tongues of clay and silt confine ground water in the lowest parts of the valley. The water-bearing materials become finer grained west of the mountains, and the deposits of clay and silt become thicker as the sand and gravel become thinner. The sand and gravel thin to the extent that the permeability is so reduced at about the latitude of the west edge of the valley that, in effect, a ground-water dam is formed, which confines the water in the permeable beds within the valley. Most of the beds of water-bearing materials are connected, and leakage from one to another is great enough that, for most purposes, they may be considered to be one aquifer within each of the six ground-water districts, although single permeable beds of gravel and sand may extend several miles in any given area.

Contiguous with the uppermost saturated bed of gravel and sand in the western part of the Flowell district is a bed of basalt that contains much unconfined ground water. The basalt underlying the area west of the Black Rock Volcano in the Kanosh district contains most of the ground water in that district. Shallow beds of sand and, locally, fine gravel underlie most of the area below an altitude of 4,800 feet; together with the basalt they compose the shallow unconfined aquifer.

Beneath the lake beds and the alluvial-fan deposits, the heterogeneous and fine-grained deposits of the Sevier River(?) Formation form the bottom of the ground-water reservoir, although, locally the formation may yield small quantities of water to wells.

### ABILITY OF AQUIFERS TO YIELD WATER

The quantity of water than an aquifer will yield to a well and the ability of the aquifer to transmit water depend on the physical and hydraulic properties of the materials that constitute the aquifer. Knowledge of these properties enables prediction of the hydraulic behavior of the aquifer under a given set of conditions. The terms used to denote the principal hydraulic properties are expressed mathematically as the coefficients of permeability, transmissibility, and storage and as the specific yield. Detailed geologic descriptions of materials discovered in drilling are useful in determining the hydraulic properties and thickness of aquifers, but more accurate quantitative estimates require more comprehensive laboratory or field tests.

The coefficient of permeability used in this report is the field coefficient of permeability ($P_f$) and is defined as the rate of flow of water, in gallons per day, through a cross-sectional area of 1 square foot of an aquifer under a hydraulic gradient of 100 percent at the prevailing water temperature. The coefficient of transmissibility ($T$) is the ability of the aquifer to transmit water under a given gradient. The coefficient of transmissibility may be expressed as the number of gallons of water transmitted per day, at the prevailing temperature, through a section of the aquifer 1 mile wide under a unit hydraulic gradient of 1 foot per mile. It is the average field coefficient of permeability multiplied by the thickness of the aquifer, in feet.

The amount of water releaased from or taken into storage in a saturated material depends upon the coefficient of storage of that material. The coefficient of storage of an aquifer is the volume of water yielded or taken into storage per unit surface area of the aquifer per unit change in component of head normal to that surface. For artesian conditions, the coefficient of storage represents compaction of the aquifer skeleton and expansion of the water itself as the head declines; thus, it is small, generally, being in the range of $10^{-3}$ to $10^{-4}$. The coefficient of storage under water-table conditions is much larger, generally being in the range of 0.01 to 0.3. Under water-table conditions, it includes the water that drains by gravity out of the material as the water table declines and the small quantity released by compaction of the aquifer and expansion of the water. The quantity of water that drains by gravity is called the specific yield, which is defined as the ratio of the volume of water that a saturated material will yield by gravity to the volume of the aquifer dewatered. The specific yield is generally several thousands of times larger than the small quantity released by compaction of the aquifer and expansion of the water; thus, for practical purposes, the specific yield can be considered equal to the coefficient of storage.

Not all the water in the interstices of an aquifer is drained by gravity; some is retained by capillary action. The ratio of the retained capillary water to the specific yield is related to the size and sorting of the aquifer materials. In general, the finer and the better sorted the material particles are, the smaller is the ratio of specific yield to the water held by capillary action. For example, a saturated clay contains more than 50 percent water by volume, but the amount of water that it will release by gravity is generally less than 0.1 percent. At the other extreme, a well-sorted gravel contains water equal to 25–35 percent of its volume; commonly the specific yield of such a gravel will be 20–30 percent, depending on the sorting and arrangement of the grains.

The coefficient of transmissibility for nonartesian aquifers can be expected to decrease as the water level declines. This relation is especially noticeable in thin aquifers, such as the basalt aquifer in the vicinity of Flowell, for, by definition, the coefficient of transmissibility is the field permeability multiplied by the saturated thickness of the aquifer.

### INTERFERENCE BETWEEN WELLS

The cones of depression around wells may overlap sufficiently (interfere) in areas where wells are closely spaced to cause a substantial increase of the pumping head. The amount of initerference depends upon the distance between wells, the rate and duration of pumping, and the hydrologic properties of the aquifer.

Under water-table conditions, as soon as a pump begins discharging water from a well, the water table in the vicinity of the well is lowered and a hyrdaulic gradient toward the well is established. The water table assumes a form comparable to that of an inverted cone, the apex of the cone being at the well. At first, most of the water pumped from the well is obtained by dewatering the saturated materials surrounding the well; but, as pumping continues, the material near the well is gradually dewatered, and water is transmitted to the well from an ever-increasing distance. Thus, the cone of depression continues to expand, and the water level declines gradually. The formation and shape of the cone may be altered if it reaches areas where the aquifer is being recharged or discharged.

Water continues to percolate toward a pumped well for a time after pumping is stopped, because the hydraulic gradient is in that direction. Water gradually fills the well and the material that was dewatered by pumping; as the material is refilled, the hydraulic gradient decreases, and the recovery of the water level in the well becomes progressively slower. Eventually the water table tends to assume its original form, although, in the absence of recharge, it may remain lower than before water was withdrawn.

In artesian aquifers, the cone of depression travels many times as fast as it does in water-table aquifers, because the artesian coefficient of storage is generally less than a hundredth as large as the water-table coefficient. Mutual interference between wells, therefore, occurs sooner and is more extensive under artesian conditions than it is under water-table conditions.

#### PUMPING TESTS TO DETERMINE AQUIFER CONSTANTS

Five pumping tests, each involving a pumped well and nearby observation wells, were made to determine the coefficients of transmissibility and storage of the aquifers in the alluvium; one test was made to determine those of the basalt aquifer. In addition, the coefficient of transmissibility was determined by five tests where only the rate of recovery of the pumped well was observed. The Theis nonequilibrium method (Theis, 1935, p. 519–524) of analyzing pumping-test data was used to determine the coefficients. In addition to those determined from pumping and recovery tests, coefficients of transmissibility were determined by using specific capacity data from 47 wells. The results are shown in table 8.

During each of the six pumping tests, an irrigation well was pumped at a constant rate for ½–3 days, and periodic measurements were made of the drawdown in as many as nine observation wells at distances ranging from 50 to 3,000 feet in different directions from the pumped well. Because of the relatively small size of the area of each test and because of considerable differences in composition and thickness of the aquifer in short distances, the coefficients of storage and of transmissibility listed in table 8 are approximate for the aquifer tested. Although useful as guides to esimate the effects of pumping, they should not be applied to large areas.

The coefficients of transmissibility of the alluvial aquifers tested ranged from 15,000 to 300,000 gpd per ft (gallons per day per foot). This range is from low to about average for aquifers consisting of sand and gravel. The lowest values were in those artesian aquifers which were thin and where the material was fine or poorly sorted. The one pumping test made in the basalt aquifer yielded a coefficient of transmissibility of 22,500,000 gpd per ft. This coefficient is ex-

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TABLE 8.—*Discharge, specific capacity, and coefficient of transmissibility of pumped irrigation wells in Pavant Valley, Utah, 1960*

[E, signifies the measurement is estimated or some doubt exists as to the accuracy]

| Well | Water right No. | Date of measurement | Aquifer material | Rate of discharge (gpm) | Volume pumped, 1960 (acre-feet) | Pumping lift (feet) | Specific capacity (gpm per foot of drawdown) | Approximate coefficient of transmissibility (gpd per ft) |
|---|---|---|---|---|---|---|---|---|
| **McCornick ground-water district** | | | | | | | | |
| (C-18-5)27bab-1 | A-22024 | 4-18-60 | Alluvium | 1,240 | 930 | 155 | 14 E | 30,000 |
| 27cba-1 | A-23141 | 4-19-60 | do | 1,170 | 775 | ---- | ---- | ---- |
| 27dba-1 | A-22437 | 4- 5-60 | do | 1,450 | 1,070 | 120 E | 35 E | 60,000 |
| 34adb-1 | A-22178 | 4-19-60 | do | 570 | 400 E | ---- | ---- | ---- |
| 34baa-1 | A-21744 | 4- 5-60 | do | 1,730 | 1,030 | 97 | 31 | 50,000 |
| 34bba-1 | A-21476 | 4- 5-60 | do | 1,320 | 1,040 | 103 | 23 | 40,000 |
| 34bca-1 | A-21612 | 4- 5-60 | do | 975 | 565 | ---- | ---- | ---- |
| (C-19-5)3aaa-1 | A-28301 | 4-19-60 | do | 2,160 | 1,320 | 113 | 35 | 60,000 |
| Total pumped in district (rounded) | ---- | ---- | ---- | ---- | 7,100 | ---- | ---- | ---- |
| **Greenwood ground-water district** | | | | | | | | |
| (C-19-4)30dab-1 | A-21772 | 4- 6-60 | Alluvium | 1,440 | 1,425 | 94 | 32 | 50,000 |
| 31dbb-1 | A-31647 | 7-14-60 | do | 2,410 | 655 | 126 | 27 | 60,000 |
| (C-19-5)36baa-1 | A-21452<br>A-22238 | 4-19-60 | do | 1,200 | 480 E | 88 | 16 E | 35,000 |
| (C-20-4)5cbd-1 | A-28398 | 5-10-60 | do | 2,060 | 1,400 E | 100 | 38 | 60,000 |
| (C-20-5)11baa-1 | A-3527<br>A-21628 | 8-30-60 | do | 860 | 400 E | ---- | ---- | ---- |
| Total pumped in district (rounded) | ---- | ---- | ---- | ---- | 4,400 | ---- | ---- | ---- |
| **Pavant ground-water district** | | | | | | | | |
| (C-20-5)24bac-2 | A-21937 | 7- 7-60 | Alluvium | 540 | 145 | 96 E | 10 E | 15,000 |
| 26add-1 | A-21928 | 5-10-60 | do | 500 | 220 | ---- | ---- | ---- |
| 26ddd-1 | A-21915 | 5-10-60 | do | 640 | 375 | 140 E | 10 E | 15,000 |
| Total pumped in district (rounded) | ---- | ---- | ---- | ---- | 700 | ---- | ---- | ---- |
| **Flowell ground-water district** | | | | | | | | |
| (C-21-5)5abd-1 | A-31117 | 7-12-60 | Alluvium | 900 E | 20 E | 120 E | 10 E | 15,000 |
| 6cac-1 | A-28069 | 6-28-60 | Basalt | 3,370 | 1,500 | ---- | ---- | ---- |
| (C-21-5)7cdd-2 [1] | A-24648 | 7-20-60 | do | 790 | 40 | 57 | 2,900 E | 22,500,000 |
| 7cdd-3 | a-3221 | 4- 7-60 | do | 3,380 | 1,440 | 49 | 2,900 | 22,500,000 |
| 7ddc-3 | A-24509 | 4- 7-60 | do | 2,050 | 725 | 56 | 1,075 | 10,000,000 |
| 8bdc-2 | A-22038 | 4-20-60 | Alluvium | 1,630 | 945 | ---- | ---- | ---- |
| 8cdd-2 | "R"A-21865 | 4-20-60 | do | 730 | 300 | 132 | 11 | 15,000 |
| 8dbb-2 | A-21884 | 4- 6-60 | do | 1,900 | 585 | 105 | 30 E | 50,000 |
| 16bcc-2 | C-15150 | 4-20-60 | do | 375 | 150 | ---- | ---- | ---- |
| 17add-3 | "R"C-8775 | 5-13-60 | do | 1,950 | 835 | ---- | ---- | ---- |
| 17bdd-3 [2] | "R"C-4716 | 5- 2-60 | do | 960 | 655 | ---- | ---- | 105,000 |
| 17cab-1 | C-2663 | 5- 2-60 | do | 375 | 90 | ---- | ---- | ---- |
| 17cdd-2 | "R"C-1376 | 4-20-60 | do | 730 | 425 | ---- | ---- | ---- |
| 17dad-1 | C-3332 | 6-28-60 | do | 350 | 155 | 47 | 15 E | 25,000 |
| 17ddd-1 | C-4616 | 8- 5-60 | do | 150 | 185 | ---- | ---- | ---- |
| 18aba-1 | A-27255 | 7-20-60 | Basalt | 2,920 | 1,200 E | 68 | 635 | 5,000,000 |
| 18ada-2 | A-24715 | 4- 7-60 | Basalt and alluvium. | 1,210 | 545 | 67 | 140 | 220,000 |
| 18dda-1 | C-4714 | 6-28-60 | Alluvium | 420 | 270 | ---- | ---- | ---- |
| 19add-1 | "R"C-13525 | 5- 2-60 | do | 1,040 | 765 | ---- | ---- | ---- |

See footnotes at end of table.

**Table 8.**—*Discharge, specific capacity, and coefficient of transmissibility of pumped irrigation wells in Pavant Valley, Utah, 1960*—Continued

| Well | Water right No. | Date of measurement | Aquifer material | Rate of discharge (gpm) | Volume pumped, 1960 (acre-feet) | Pumping lift (feet) | Specific capacity (gpm per foot of drawdown) | Approximate coefficient of transmissibility (gpd per ft) |
|---|---|---|---|---|---|---|---|---|
| **Flowell ground-water district—Continued** | | | | | | | | |
| (C-21-5)19ccd-3 | A-29943 | 4-20-60 | Basalt | 1,220 | 475 | | | |
| 20aad-2 [3] | "R"C-149 | 5- 2-60 | Alluvium | 2,480 | 1,190 | 37 | 80 E | 155,000 |
| 20aba-1 | C-2219 | 9- 3-60 | do | 240 | 190 | | | |
| 20bab-2 | "R"C-6333 | 5- 2-60 | do | 730 | 570 | | | |
| 20bdd-2 | "R"C-6622 | 5- 2-60 | do | 960 | 540 | | | |
| 20cca-2 [4] | "R"C-1377 | 4-20-60 | do | 600 | 360 | | | 142,000 |
| 20dad-1 | C-6992 | 5-13-60 | do | 275 | 205 | | | |
| 20dda-1 [5] | C-3808 | 5- 2-60 | do | 440 | 440 | | | 300,000 |
| 21cba-3 | "R"C-7685 | 5-24-60 | do | 3,040 | 1,100 E | | | |
| 28aaa-1 | A-29390 | 5-24-60 | do | 2,080 | 1,040 | 80 E | 25 E | 60,000 |
| 29aaa-3 | "R"C-6223 | 5- 3-60 | do | 1,820 | 1,350 | | | |
| 29bdd-2 | "R"2670 | 7-13-60 | do | 1,780 | 385 | | | |
| 29cdd-2 | "R"C-3334 | 4- 1-60 | do | 2,090 | 1,195 | | | 152,000 |
| 29cdd-3 | A-29946 | 5-31-60 | do | 980 | 275 | 81 | 13 | 30,000 |
| 30dad-2 | a-3868 | 7- 7-60 | do | 1,700 | 480 | | | |
| 30dbc-2 | A-18002 | 5-24-60 | do | 300 | 245 | 58 | 6 E | 15,000 |
| 31cdd-2 | "R"C-6236 | 8- 5-60 | do | 1,150 | 395 | | | |
| 32bba-1 [6] | "R"C-2959 | 5- 2-60 | do | 1,160 | 460 | 29 | 38 E | 150,000 |
| 33bcc-3 | a-3756 | 5- 3-60 | do | 1,950 | 845 | 66 | 30E | 80,000 |
| 33ccd-1 | "R" C-6335<br>A-25916 | 5- 3-60 | do | 1,910 | 500E | 56E | 48E | 170,000 |
| 33dcc-2 | "R" C-71 | 5- 3-60 | do | 1,880 | 250E | 52 | 80E | 220,000 |
| (C-21-6)1dcb-1 | A-26601 | 4- 6-60 | Basalt | 3,420 | 1,425 | 55 | 1,760 | 20,000,000 |
| (C-22-5)2ada-1 | A-22141 | 5-12-60 | Alluvium | 1,170 | 300E | | | |
| 4bbd-1 | A-25647 | 7-13-60 | do | 1,810 | 590 | 68 | 50E | 170,000 |
| 4cdb-1 | A-22355 | 5-24-60 | do | 850 | 260 | 53 | 35E | 130,000 |
| 4dca-1 | A-15376 | 5- 3-60 | do | 1,310 | 750 | 68 | 40E | 170,000 |
| 9bba-1 | A-26974 | 5- 3-60 | do | 2,040 | 625 | 84 | 32E | 120,000 |
| (C-22-6)3add-2 | A-21831 | 6-14-60 | Basalt and alluvium. | 690 | 390 | 115 | | |
| Total pumped in district (rounded). | | | | | 27,700 | | | |
| **Meadow ground-water district** | | | | | | | | |
| (C-22-5)8cdd-1 | C-10473 | 6-11-60 | Alluvium | 320 | 275 | | | |
| 9cad-2 | A-21941 | 4- 8-60 | do | 1,590 | 575 | 104 | 20 | 60,000 |
| 17abd-1 | C-2220<br>C-13520 | 6-11-60 | do | 290 | 90 | | | |
| 17bdd-2 | C-3295<br>C-8202 | 7- 8-60 | do | 430 | 115 | | | |
| 17cda-1 | C-15317<br>C-15866 | 1960 | do | 400E | 170E | | | |
| 17dad-1 | a-3585 | 1960 | do | 1,800 | 40 E | | | |
| 17dbd-2 | "R"C-12170<br>A-29114 | 5- 3-60 | do | 1,450 | 200 E | | | |
| 20aad-1 | C-11970 | 1960 | do | 400 E | 95 E | | | |
| 20aba-1 | C-12113 | 5- 3-60 | do | 550 | 280 | | | |
| 20bdd-1 | C-13531 | 6-11-60 | do | 130 | 50 | | | |
| 20dbc-1 | C-6332 | 8- 5-60 | do | 420 | 50 | | | |
| 21acd-2 | "R"A-21718 | 5- 3-60 | do | 650 | 310 | 99 | 14 | 30,000 |
| 21dda-1 | A-21758 | 5- 3-60 | do | 620 | 245 | | | |
| 22dac-1 | A-31096 | 7-13-60 | do | 400 | 255 | 165 E | 10 E | 25,000 |
| 28aad-1 | A-22766 | 7-13-60 | do | 640 | 110 | 93 | 15 E | 30,000 |
| 29cdd-1 | A-13159 | 5-24-60 | do | 610 | 210 | 75 | 11 E | 25,000 |
| 32cdd-1 | A-27254 | 5-24-60 | do | 2,220 | 750 E | | | |
| 32dbd-1 | A-12492 | 1960 | do | 900 E | 180 E | | 15 E | 30,000 |
| 32dbd-2 | A-22210 | 1960 | do | 2,000 E | 400 E | | | |
| 33abc-1 | A-18018 | 4-22-60 | do | 1,180 E | 450 | | | |
| 33ccd-1 | A-21746 | 5-12-60 | do | 1,890 | 760 | 82 | | |
| 33cdd-2 | "R"A-13367 | 5-12-60 | do | 1,630 | 200 E | 109 | 50 E | 170,000 |

See footnotes at end of table.

TABLE 8.—*Discharge, specific capacity, and coefficient of transmissibility of pumped irrigation wells in Pavant Valley, Utah, 1960*—Continued

| Well | Water right No. | Date of measurement | Aquifer material | Rate of discharge (gpm) | Volume pumped, 1960 (acre-feet) | Pumping lift (feet) | Specific capacity (gpm per foot of drawdown) | Approximate coefficient of transmissibility (gpd per ft) |
|---|---|---|---|---|---|---|---|---|
| **Meadow ground-water district—Continued** | | | | | | | | |
| (C-23-5)5acd-1 | A-30068 | 5-12-60 | Alluvium | 2,840 | 1,190 | 110 | 80 | 220,000 |
| 5adc-1 | A-21483 | 7-13-60 | do | 900 | 30E | | | |
| 5cba-1 | A-23484 | 5-12-60 | do | 1,820 | 620 | 84 | 100E | 150,000 |
| 6daa-1 | C-8201 | 5-12-60 | do | 640 | 285 | | | |
| 6dcd-1 | A-23646 | 5-12-60 | do | 1,620 | 810 | 98 | 90E | 140,000 |
| 7aaa-1 | A-22898 | 5-12-60 | do | 1,680 | 855 | 104 | 80 | 120,000 |
| Total pumped in district (rounded) | | | | | 9,600 | | | |
| **Kanosh ground-water district** | | | | | | | | |
| (C-22-6)20bbb-1 | A-29593 | 1960 | Basalt | | 70E | | | |
| 32ccc-1 | A-26617 | 5-12-60 | do | 2,330 | 800 | 46E | 500E | 2,000,000 |
| 32dcc-1 | "R" A-22151 | 5-12-60 | do | 2,620 | 670 | | | |
| (C-23-6)5cbc-1 | A-24533 | 5-17-60 | do | 1,770 | 150E | 48 | 160E | 230,000 |
| 8abd-1 | A-24463 | 5-24-60 | do | 2,600 | 425E | | | |
| 9bca-1 | A-28699 | 5- 9-60 | do | 3,450 | 1,260 | 63 | 125E | 180,000 |
| 9ccd-1 | A-14592 | 5- 9-60 | do | 1,810 | 810 | 48 | 180 | 250,000 |
| 10ccc-1 | A-19930 | 5- 9-60 | do | 2,550 | 745 | 50 | 700E | 6,000,000 |
| 15baa 1 | a-3444 | 4-22-60 | do | 2,570 | 535 | | | |
| 15bdd-2 | "R" A-20809 | 7-13-60 | do | 3,120 | 1,600 | 65E | 400E | 800,000 |
| 16bad-1 | A-18458 | 5- 9-60 | do | 2,350 | 1,070 | 53 | 300E | 500,000 |
| 16cad-1 | "R" A-22139 | 5- 9-60 | do | 1,140 | 260 | 62 | 90E | 180,000 |
| 17cdc-1 | A-24871 | 5-12-60 | Alluvium | 1,660 | 750E | 125E | 25E | 70,000 |
| 20caa-1 | A-19929 | 5-12-60 | do | 1,500E | 900E | 97 | 50E | 80,000 |
| 21add-1 | a-3716#1 | 5- 9-60 | do | 1,060 | 620 | 138 | 30 | 80,000 |
| 21bdd-1 | a-3716#2 | 5- 9-60 | do | 1,550 | 780E | | | |
| 28bbb-1 | A-21511 | 1960 | do | 900 | 420E | | | |
| Total pumped in district (rounded) | | | | | 11,900 | | | |

1 Approximate coefficient of storage, $6.0 \times 10^{-2}$.
2 Approximate coefficient of storage, $4.6 \times 10^{-4}$.
3 Approximate coefficient of storage, $2.8 \times 10^{-3}$.
4 Coefficient of storage, $1.6 \times 10^{-3}$.
5 Coefficient of storage, $9.5 \times 10^{-4}$.
6 Coefficient of storage, $2.5 \times 10^{-4}$.

tremely high, even higher than the famed Snake River Group in Idaho, which, as reported by Crosthwaite and Scott (1956, p. 14), has a maximum coefficient of transmissibility of several million gallons per day per foot. The basalt in the area of the test in the Pavant Valley is highly fractured. Although the vesicles have remained open, probably little water moves through them; most of it moves through the fractures.

The observed coefficient of storage of the artesian alluvial aquifers range from $1.6 \times 10^{-3}$ to $2.5 \times 10^{-4}$, the usual range for aquifers consisting of sand and gravel. The coefficient of storage was 0.06 for the one test made in the basalt aquifer. This coefficient indicates that water in the basalt is unconfined and that the water-bearing openings are sparse although large; thus the basalt has a low average porosity. Well logs suggest that the coefficient of storage of the water-table aquifers in the alluvium ranges from 0.1 to 0.25, which is about normal for water-table conditions elsewhere in similar sediments.

### SPECIFIC CAPACITY OF WELLS

The highest specific capacities in Pavant Valley are in irrigation wells tapping the basalt. Data for 13 of these wells indicate that the specific capacities range from 90 to 2,900 gpm (gallons per minute) per foot of drawdown and average 900 gpm per foot of drawdown (table 8), and data for 41 irrigation wells tapping the alluvium give specific capacities that range from 6 to 100 gpm per foot of drawdown and average 34 gpm per foot of drawdown. The specific capacity of one well that tapped both the basalt and alluvium is 140 gpm per foot of drawdown. The specific capacity of a well, as used in this report, is the quantity of water yielded by the well, in gallons per minute per foot of drawdown after pumping for 24 hours. Under artesian conditions this relation is approximately constant for any drawdown where the pumping level is above the bottom of the confining bed. For water-table conditions, the specific capacity is approximately constant only when the drawdown is a small fraction of the saturated thickness; when the drawdown exceeds a small fractiion of the saturated thickness, the specific capacity decreases in direct response to the drawdown.

The specific capacity of a well and the coefficient of transmissibility of the aquifer are related. The specific capacity also depends upon the construction and development of wells, which include the following factors: The depth of penetration of the well into the aquifer; the diameter of the well; the type, size, and amount of perforations in the casing; and the type and amount of development that the well has had. Notwithstanding these factors, specific capacity is useful in estimating the coefficient of transmissibility; and a comparison of specific capacities is useful in estimating the relative efficiency of wells.

Effects of nearby pumping wells and the water-level trend cause erroneous specific capacities unless corrections are applied. Declining water levels and effects from nearby pumping wells cause the apparent specific capacity to be smaller than the true value, and rising water levels cause the apparent specific capacity to be larger.

Nearly all the irrigation wells in Pavant Valley that were constructed with the intent of equipping them with pumps are 12 inches or larger in diameter, and they were constructed and developed with reasonable care; therefore, the apparent specific capacities can be used in computing approximate transmissibility. The values of the coefficients of transmissibility computed by use of specific capacity, however, seemed to be too low. The values of the coefficients of transmissibility in table 8 that were computed from specific capacity were increased after comparing them with more accurate coefficients obtained from pumping tests.

Differences in specific capacity of wells in different parts of the valley generally indicate differences in permeability of the aquifer materials. The basalt is many times more permeable than the alluvium, and this relation is reflected in the very high specific capacity of some wells in the basalt as compared to that of wells in the alluvium. Usually, the smaller specific capacities of wells in the basalt are in areas where the basalt is thin and where alluvium has partly filled the voids in the basalt, decreasing the permeability. Wells in the basalt that have a very large specific capacity undoubtedly intersect cracks or crevices that extend many feet into the aquifer. These cracks, in effect, act as large conduits which convey water readily to the well from relatively long distances.

Commonly, wells tapping the upper parts of the alluvial fans have a specific capacity ranging from 50 to 100 gpm per foot of drawdown, the specific capacity of wells tapping the lower parts of the fans range from 25 to 50 gpm per foot of drawdown, and the specific capacities of wells on the valley floor and in the Pavant district range from 6 to 25 gpm per foot of drawdown. Well logs show that the aquifer materials grade from well-sorted coarse gravel in the upper parts of the fans through fine gravel and coarse sand in the lower parts of the fans to principally fine to coarse lacustrine sand on the valley floor. This gradation accounts for the decreasing specific capacity westward away from the mountains.

### SHAPE AND SLOPE OF THE WATER TABLE AND PIEZOMETRIC SURFACE

The water table and the piezometric surface are not level or uniform, but are warped, sloping surfaces. Irregularities in the amount and direction of slope are caused by unequal additions or withdrawals of water and by differences in thickness or permeability of the aquifer. Water moves in the general direction of the slope of the water table. The rate of movement, assuming a uniform cross section, is proportional to the slope (hydraulic gradient) and to the permeability of the water-bearing material. The configuration of the water table and of the piezometric surface is shown on a map by contour lines along which all points have the same altitude. The direction of ground-water movement is at right angles to the contour lines. The ground-water contour map (pl. 4) is based on water-level measurements made during the late winter of 1960. The general direction of movement of the ground water in Pavant Valley is shown by the use of arrows on plate 2.

As the slope of the water table depends on the permeability and thickness of the water-bearing materials and on the amount of water being transmitted, the slope is considerably different in different parts of the valley and in the various formations. Although the unconsolidated material of the valley fill near the mountains along the east side of the valley is much more permeable than the material in the bottom of the valley, the water table is steeper near the mountains because the saturated material is much thinner, except possibly in the alluvial fans of the two principal streams. The ground-water mounds in the alluvial fans of Chalk Creek and Corn Creek (pl. 4) indicate areas of appreciable recharge. The average slope of the water table in these fans is 70 and 40 feet per mile, respectively. Through the center of the valley, where permeability is relatively high, the slope is more gentle; but along the west side, where permeability is low, the slope steepens. The large relatively flat area on the piezometic surface in the Flowell district is in an area of large withdrawal and is the result of the piezometric surface not fully recovering its original position after cessation of pumping. The broad, gently sloping water table in the Kanosh district is in an area where the aquifer is highly permeable basalt.

At no place in Pavant Valley are permeable beds in the Sevier River(?) Formation extensive enough to contain large quantities of water. Although the material in the hills northwest of Fillmore is Sevier River(?) Formation, the hills are "islands" in more permeable lake deposits; therefore, ground water in the lake beds flows around them rather than through them, and they have little effect on the configuration of the water table.

### WATER-LEVEL FLUCTUATIONS

The ground-water surface is not stationary but fluctuates as water is added to or withdrawn from the ground-water reservoir. The stage of the water table is a measure of the quantity of ground water in storage in the ground-water reservoir, and it can be likened to the water level in a surface reservoir. Thus, water-level fluctuations in wells indicate changes in storage resulting from recharge to or discharge from a ground-water reservoir during a specified period. They do not, however, reflect small fluctuations caused by barometric changes, passing vehicles, earthquakes, and moon, earth, and ocean tides. The major water-level fluctuations in aquifers in Pavant Valley are attributed to discharge from wells, evapotranspiration, and recharge of the ground-water reservoir by infiltration of water from stream channels, irrigation ditches, irrigated fields, and precipitation. Water levels in artesian wells also fluctuate in response to barometric changes, earthquakes, moving vehicles, and earth and moon tides; but these do not affect the amount of water in storage; and the magnitude and (or) the period of fluctuation is small.

Fluctuations of the water level or pressure in a well may be represented graphically. The term "hydrograph" is used to designate the resulting graph. A hydrograph shows the composite effect of all forces acting on the ground-water reservoir. By the proper selection of observation wells and periods of observation, hydrographs may show one predominant force causing water-level fluctuations. Detailed data are obtained from recording gages, of which five were maintained in Pavant Valley. Less detailed water-level data were obtained from about 200 wells.

Four distinct cyclic fluctuation periods of ground-water levels in the Pavant Valley are related to recharge or withdrawals of water from the ground-water reservoir. The shortest period is the daily cycle, and the longest period is of several years duration; in between are weekly and seasonal cycles. The daily cycle is particularly noticeable in artesian wells and results from more water being withdrawn in the day than in the night. The daily cyclic amplitude has been noted to exceed 5 feet in observation well (C–21–5)21aba–1, in which water levels show effects of pumping in wells nearly three-quarters of a mile away. Most of the irrigation wells are pumped 24 hours a day; but some, principally wells equipped with engines, are pumped only 10–15 hours a day. The daily cyclic fluctuations of water levels in wells in the artesian aquifers are mainly the result of the pumping of artesian wells equipped with engines.

Closely akin to the daily cyclic fluctuations is the weekly cycle. During the irrigation season, water levels decline, in general, from Monday through Saturday (in addition to the daily fluctuations), but from Saturday evening until Monday morning water levels rise in response to the cessation of pumping. The hydrograph for well (C–21–5)21aba–1 in figure 4 shows that water levels rise several feet every seventh day, on Sundays.

The seasonal cycle coincides with the irrigation season. Water levels begin to decline about April 1—the beginning of the irrigation season—and continue to decline until about July 1. During July and August, the water levels remain about the same. During September they rise slowly; then, more rapidly in early October. And then the rate of rise diminishes, as the piezometric head in the aquifer tends to assume a plane surface (fig. 4). The demand for irrigation water generally begins to diminish by the first part of July, when crops begin to mature, and it continues to diminish until about October 1, the end of the irrigation season. The average water level in well (C–21–5)21aba–1 remained at about 55 feet below the land surface

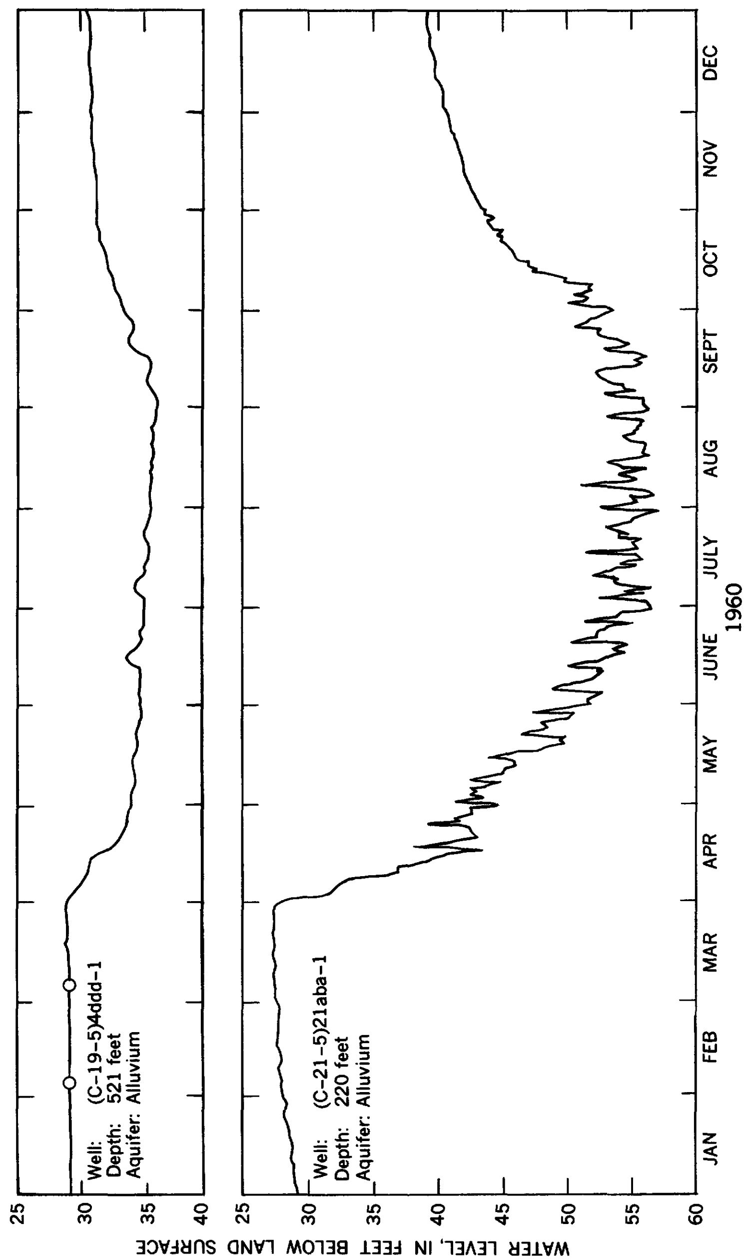



FIGURE 4.—Hydrographs of two observation wells near heavily pumped areas in Pavant Valley, 1960.

during July and August in 1960, during which time water moving into the pumped area equaled total discharge. Water levels began to rise soon after September 1—an indication that the quantity of ground water moving into the pumped area was exceeding withdrawal—and they continued to rise until the beginning of the following irrigation season. From March to September 1960, water levels declined an average of 7 feet in all of Pavant Valley and an average of 16 feet in the pumped areas.

A decline in water level in Pavant Valley during the 1960 irrigation season is shown on plate 5 by the differences in water levels, as measured in 160 wells in March and September. The largest declines are in the areas of greatest withdrawal, and, in general, the amount of decline indicates the magnitude of withdrawal. Observed seasonal declines ranged from 0 along the extreme west side of the Greenwood district to more than 60 feet near the center of the Flowell district. During the 1959 irrigation season, water levels declined an average of 2 feet throughout the valley and nearly 4 feet in the pumped area; the largest declines from March 1959 to March 1960 were in the centers of greatest pumpage (pl. 6).

Most of the annual decline is due to discharge of ground water rather than to decrease in recharge. The fact that the centers of greatest declines coincide with the centers of greatest withdrawal and that the relation between amounts of decline and withdrawal is definite confirm that this is true. Declines were relatively small in the principal recharge areas near the mountains along the east side of the valley. Plate 5 shows the same general pattern of water-level declines as plate 6, thus corroborating the theory that most of the declines are due to pumping. There were at least small declines throughout the valley, however, even where there was no withdrawal; this indicates that recharge in the valley was probably below normal. Thus, part of the water-level decline during 1959 can be attributed to below-normal recharge.

The long-term cyclic ground-water fluctuations coincide with long-term cyclic precipitation fluctuations. Usually water levels rise during periods of greater than normal precipitation and decline during periods of less than normal precipitation. Hydrographs of 11 selected observation wells are shown on plate 7; at least one observation well is in each ground-water district and in each principal aquifer in Pavant Valley. The hydrographs show that water levels in observation wells decline during periods of below-normal precipitation and rise during periods of above-normal precipitation. (Compare the hydrograph for well (C–21–5)21aba–1 on plate 7 with the curve showing cumulative departure from average precipitation 1892–1960 in figure 3.)

The average water-level decline was 8 feet beneath the entire valley and 16 feet beneath the pumped area during the 10-year period 1950–60 (pl. 8). These 10 years include the period during which most of the pumped irrigation wells were put in operation. It can be seen that the centers of water-level declines are also the centers of greatest withdrawal and that the largest declines are in the Flowell district, which, since 1915 when the first irrigation wells were drilled, has been the center of greatest withdrawal. Declines in the intervening areas indicate that recharge since 1950 has been below normal, but the amount of decline that can be attributed to below-normal recharge is less than 5 feet in most of the area. The decline due to below-normal recharge in the area from Fillmore northwestward for about 6 miles is an exception. Here the declines have been much greater than 5 feet, even though withdrawal has been small.

In March 1960 the area of artesian flow included more than 90 square miles (pl. 9). In this area, water in the artesian aquifer had sufficient head to flow from wells at the surface. The head was reduced during the 1960 irrigation season, and so the area of artesian flow decreased by 13 square miles. The largest part of the area in which wells ceased flowing was in the Flowell district. If the 1960 rates of pumping and recharge are maintained, wells will cease flowing in all but the very lowest areas along the west side of the valley by 1965.

## RECHARGE

During 1959, recharge to the Pavant Valley from all sources was estimated to be 66,000 acre-feet. The source of most of the recharge in Pavant Valley is direct penetration of precipitation, some of which percolates downward to the ground-water reservoir; infiltration from streams; and unconsumed irrigation water. The estimated recharge from each source in each of the ground-water districts is given in table 9. The methods and data used to compute recharge are discussed in the following subsections.

TABLE 9.—*Recharge (estimated), in acre-feet, from various sources in each ground-water district in Pavant Valley during 1959*

| Ground-water district | Infiltration of precipitation | Seepage from streams | Deep percolation of irrigation water | | Underflow from other districts (not additional recharge to the valley) | Total recharge in district |
|---|---|---|---|---|---|---|
| | | | Surface water | Ground water | | |
| McCornick | 1,500 | 1,000 | 3,300 | 1,300 | 0 | 7,100 |
| Greenwood | 2,000 | 6,000 | 8,500 | 800 | 500 | 17,800 |
| Pavant | 100 | 0 | 1,000 | 200 | 2,500 | 3,800 |
| Flowell | 1,000 | 5,000 | 8,500 | 5,500 | 7,500 | 27,500 |
| Meadow | 1,500 | 5,000 | 5,500 | 2,000 | 0 | 14,000 |
| Kanosh | 2,000 | 1,500 | 0 | 2,500 | 500 | 6,500 |
| Total in valley (rounded) | 8,000 | 18,000 | 27,000 | 12,000 | | 65,000 |

#### INFILTRATION OF PRECIPITATION

Seepage from precipitation is one of the principal sources of recharge in the nonirrigated sections of the valley. Precipitation may reach the ground-water reservoir after satisfying the soil-moisture deficiency in the root zone. The proportion of available water that becomes recharge is controlled largely by the physical character and moisture content of the soil and the amount and intensity of precipitation. Most of the recharge from summer storms is from runoff that collects in ephemeral streams and flows onto alluvial fans, for the thundershowers and most intense storms are usually of such short duration that the soil in other places is left dry below a depth of a few inches.

The several small retarding dams built across gullies and ravines on the alluvial fans intercept runoff from summer thundershowers and snowmelt and facilitate recharge to the ground-water reservoir. Winter storms usually result in the accumulation of snow several inches deep over the valley. When the snow melts, the ground-water reservoir may be recharged over much of the upland part of the valley between altitudes of 4,800 and 6,000 feet—by deep percolation. The average annual precipitation in this part of the valley is about 14 inches, of which 5 percent may percolate to the ground-water reservoir. On this basis, the direct infiltration of precipitation on the principal intake area during years of average recharge is about 8,000 acre-feet.

#### SEEPAGE FROM STREAMS

About 18,000 acre-feet of recharge per year is derived from streams in Pavant Valley. Chalk and Corn Creeks contribute most of this recharge, but all streams contribute some. Streams, after entering Pavant Valley, are above the water table and commonly lose water rapidly; they are called influent streams. Undoubtedly part of this loss is due to evapotranspiration, but most of it is due to seepage into the permeable materials underlying streambeds where they cross alluvial fans. Ordinarily the base flow of the smaller streams disappears within a mile or two of the mountains. Seepage is also appreciable in the narrow belt of alluvium that forms the floor of the canyons above the canyon mouths, and this seepage enters the valley as underflow beneath the stream channels and recharges the ground-water reservoir.

Much of the mountainous area surrounding Pavant Valley is drained by three perennial streams and by many small canyons and draws in which there may be small perennial streams or streamflow only for a few days or weeks each year. Except for runoff in the larger canyons, whose generally dependable flows during the spring freshet are diverted for irrigation, the runoff ordinarily infiltrates into the ground soon after it enters the valley and makes a major contribution to the ground-water reservoir. In the smaller canyons, probably the greater part of the water moves as underflow through the alluvium and upper few feet of the bedrock of the canyon until it enters the ground-water reservoir in the valley. Many streams flow only in direct response to precipitation, but, because of the permeable material in the streambeds, they absorb water readily and contribute much recharge to the ground-water reservoir.

Seepage is greatest where streams flow over the upper part of the alluvial fans, ordinarily where sediments are coarsest and most permeable. Residents who have dug disposal holes near the channel of Chalk Creek in Fillmore report that water levels coincide with altitude of the streambed during late spring and early summer but that the water levels in disposal holes are much lower than the streambed at slighty greater distances from the stream. They also report that no water is observed near the stream channel during late summer and fall unless the stream had been unusually high for several days. Rises of water levels in wells tapping the Chalk Creek alluvial fan were correlated with the high spring runoff in Chalk Creek, when seepage is probably greatest, and they seem to support the conclusion that recharge to the ground-water reservoir is appreciable during high runoff. Seepage from other streams in Pavant Valley is probably comparable to that of Chalk Creek.

Sources of recharge by seepage to the ground-water reservoir in Pavant Valley are as numerous as the canyons and streams themselves. The relative importance of these sources is clearly indicated on the ground-water contour map (pl. 4). Ground water moves approximately in the direction of the slope of the water table, and the rate varies with the steepness of the water table, other factors remaining equal. The water table near Chalk and Corn Creeks slopes steeply away from them. This indicates that the streams are important sources of recharge. It was not possible to accurately determine the shape of the water table near the mountains because of the lack of water-level data in the vicinity of the alluvial fans; however, other sources of seepage recharge of lesser importance indicated on plate 4 are Wild Goose Creek, Maple Hollow, Pioneer Creek near Holden, and Meadow Creek near Meadow.

The contours on plate 4 indicate that the movement of water throughout the reservoir is evidently outward from the mountains but that water entering the valley from the ephemeral streams and from the face of the mountains is probably a small quantity compared with that from the two major perennial streams. However, although recharge other than that from the major streams is small compared with that from the major streams, it is a significant part of the total recharge to the valley.

Man has altered the natural recharge pattern by diverting, for irrigation, water that under natural conditions would have recharged the basalt ground-water reservoir along the western part of the valley. Much of the surface water from Chalk Creek southward formerly flowed to The Sink, where appreciable quantities percolated into the underlying permeable basalt.

#### DEEP PERCOLATION OF IRRIGATION WATER

Total recharge from deep percolation of irrigation water was estimated to be about 39,000 acre-feet in 1959—27,000 acre-feet from unconsumed surface water and 12,000 acre-feet from unconsumed ground water (table 9). Recharge from irrigation, in this report, is regarded as the aggregate of seepage from reservoirs, ditches, and irrigated fields. When irrigation water is applied in sufficient quantities so that some infiltrates below the root zone, the excess may continue downward to the ground-water reservoir. The term "deep percolation," as used herein, refers to water that infiltrates below the root zone. Recharge derived from deep-percolation losses of irrigation water may be from water diverted from streams or pumped from wells.

Streams that have a flow sufficient for irrigation are generally diverted near the apex of the alluvial fans into ditches constructed with a gradient less than that of the natural stream channel; the diversion works are built so that the flow in the ditches is nearly constant, regardless of great variations in flow of the stream. The beds of the ditches, therefore, become more impermeable by deposition of silt and clay than the streambeds; thus, loss by seepage from the ditches is less than that from a stream of comparable size. Some of the silt and clay is removed during the annual ditch cleaning, however; so, the ditch never becomes completely impermeable. Several miles of concrete ditches have been built to convey water across some of the more permeable parts of the alluvial fans, and nearly all seepage losses have been eliminated in those reaches.

Most of the irrigated lands supplied by streams are distributed rather widely over the alluvial fans, and some lands require unduly long and sometimes wasteful ditches to convey water to them. For example, some land is irrigated on the Chalk Creek fan near the head of the fan east of Fillmore, but some water is diverted as much as 6 miles from the mouth of the canyon to the Pavant district and more than 6 miles to fields south of Flowell (pl. 10). A stream of water estimated at 75 gpm in the ditch supplying the area south of Flowell was observed to disappear into the ground in a distance of about 1 mile during a cool spring day when evaporation was small. The observed stream covered only about half of the ditch bed at the head of the reach, and it diminished in width downstream; thus, seepage from that reach of the ditch may exceed 200 gpm. Seepage losses from other reaches of this ditch and from other ditches are probably comparable.

Most of the recharge derived from deep percolation of irrigation water on the alluvial fans is from the irrigated fields. The surface material is commonly thin and relatively permeable on the alluvial fans, and it overlies coarse, very permeable material. Surface material of this type is very susceptible to large seepage losses. Available data indicate that recharge derived from deep-percolation losses constitutes about one-fourth of the water used above the altitude of 4,800 feet. Most of the seepage losses above this altitude percolate to the artesian aquifer.

The irrigated lands below an altitude of 4,800 feet lie above the artesian aquifers, but are separated from them by confining beds of clay and silt. Deep-percolation losses of irrigation water diverted from streams and pumped from wells below this altitude percolate to relatively shallow unconfined alluvial deposits, from which some of the water migrates into contiguous basalt flows. The deep-percolation losses of water applied to the land from ditches and reservoirs below an altitude of 4,800 feet is estimated to be one-fifth of the water diverted from streams or pumped from wells. The deep-percolation losses represent only part of the water not consumed by the crops. Some additional water is evaporated from reservoirs, ditches, and the soil surface in the fields; some is consumed by ditch- and reservoir-bank vegetation; some migrates laterally at shallow depths to adjacent noncultivated lands and is consumed by native vegetation, especially where the soil is underlain by shallow beds of clay; and some flows on the surface off the lower ends of irrigated fields onto noncultivated lands, where much of it is consumed by native vegetation. Other factors of lesser importance also take their toll; thus, only a part of the water not consumed by the irrigated crops ever reaches the water table.

In the computation of irrigation efficiencies for the Pavant Valley, one should consider not only deep percolation but also all the other losses previously discussed. Mr. L. S. Willardson (oral commun., April 2, 1963) found that during 1959–62 irrigation efficiencies ranged from 50 to 60 percent for about 100 farms in the vicinity of Milford. During 1960 the amount of water pumped per acre in Pavant Valley was about 15 percent less on six farms containing 2,150 acres than the amount pumped in the area studied by Willardson. This difference is an indication that irrigation practices may be more efficient in Pavant Valley than in the vicinity of Milford. It is beyond the scope of this report, however, to determine irrigation efficiencies for Pavant Valley.

Conveyance losses of seepage, evaporation, and transpiration by canal-bank vegetation from the Central Utah Canal have not been measured directly; however, they are large. Estimates indicate that losses probably range from less than 40 percent of the total diversion during years of large diversions to more than 70 percent during years of small diversions. For purposes of the present study, losses are assumed arbitrarily, and probably conservatively, to be as follows: About 40 percent when diversions exceed 25,000 acre-feet; 50 percent when diversions range from 15,000 to 25,000 acre-feet; and 60 percent when diversions are less than 15,000 acre-feet, except for 1960, when measured losses were about 70 percent. Mr. T. C. Callister, president of the Central Utah Water Co., reported (oral commun., April 26, 1961) that 1,820 acre-feet of water was delivered to Pavant Valley by the canal during 1960, but 6,120 acre-feet was diverted into the canal at the intake for delivery to Pavant Valley.

About 97 percent of the water lost from the Central Utah Canal is seepage into the bottom and banks of the canal. Although the surface materials consist chiefly of sand, the canal is unlined; however, for part of its length, the bottom of the canal is in clay or marl. Some of the seepage is eventually lost by evapotranspiration soon after the cessation of diversion to the canal, but these losses are probably small compared with the total. Most of the seepage losses eventually percolate to underlying aquifers; thus, locally, the canal plays a major role in the ground-water regimen. About 60 percent (table 10) of the seepage losses occurs upstream from McCornick; thus, the seepage losses do not recharge aquifers in Pavant Valley. Only the losses from McCornick southward need be considered with regard to recharge in Pavant Valley. The average annual seepage losses during 1934–60 are given in table 10.

TABLE 10.—*Some dimensions of the Central Utah Canal and percentage of water loss in selected reaches, 1934–60*

| | Average width (feet) | Length (miles) | Loss (percent of total loss) | Average annual loss (acre-feet) |
|---|---|---|---|---|
| Above McCornick | 22 | 23 | 60.7 | 5,100 |
| McCornick | 20 | 5 | 12.0 | 1,000 |
| Greenwood | 18 | 7 | 15.1 | 1,300 |
| Pavant | 13 | 4 | 6.2 | 500 |
| Flowell | 10 | 5 | 6.0 | 500 |

North of Flowell, the Central Utah Canal intercepts all surface water that flows that far out into the valley. Most of the water is diverted for irrigation, or it seeps from the canal. The excess canal water is discharged from the lower end of the canal to flow into The Sink.

### QUANTITY OF WATER IN STORAGE

Virtually all the ground water in Pavant Valley is in the unconsolidated lake beds and alluvial-fan deposits and in the basalt in the western and southern parts of the valley. Much of the water (possibly as much as 90 percent) is unrecoverable because the fine-grained materials, especially clay and silt, will not readily release the water to wells. Most of the recoverable ground water is in the sand and gravel deposits and the basalt.

The approximate quantity of ground water in storage was determined by multiplying the volume of saturated material by average coefficients of storage of 0.25 for the alluvium, 0.12 for the combined alluvium and basalt aquifer in the Kanosh district, and 0.06 for the basalt in the Flowell district; all coefficients were determined on the basis of pumping tests. The extent of these deposits and their saturated thicknesses were determined by interpretation of 280 well logs. The extent and average thickness of saturated material in each of the six ground-water districts are given in table 11. The volume of ground water in storage in March 1960 computed from these figures is about 11,000,000 acre-feet. The volume of ground water in storage (estimated) in each of the ground-water districts is given in table 11.

TABLE 11.—*Volume of saturated material and quantity of ground water estimated to be in storage in Pavant Valley, Utah, March 1960*

| Ground-water district | Coefficient of storage | Average saturated thickness (feet) | Extent of district (acres) | Volume of saturated material (acre-feet) | Quantity of ground water in storage (acre-feet) | Quantity removed from ground-water storage during 1959 (acre-feet) | Predicted decrease in ground-water storage resulting from a decline in water level of 50 feet below the March 1960 level (acre-feet) |
|---|---|---|---|---|---|---|---|
| McCornick | 0.25 | 275 | 17,500 | 4,800,000 | 1,200,000 | 4,000 | 70,000 |
| Greenwood | .25 | 300 | 31,000 | 9,300,000 | 2,300,000 | 500 | 60,000 |
| Pavant | .25 | 200 | 9,500 | 1,900,000 | 480,000 | 500 | 20,000 |
| Flowell: | | | | | | | |
| Alluvium | .25 | 500 | 34,500 | 17,200,000 | 4,300,000 | 9,500 | 50,000 |
| Basalt | .06 | 50 | 6,500 | 320,000 | 20,000 | 500 | 20,000 |
| Meadow | .25 | 350 | 24,500 | 8,600,000 | 2,200,000 | 10,000 | 50,000 |
| Kanosh | .12 | 300 | 14,000 | 4,200,000 | 500,000 | 5,000 | 80,000 |
| Total for valley | | | 137,500 | 46,320,000 | 11,000,000 | 30,000 | 350,000 |

The predicted decrease in ground-water storage resulting from a decline in water levels of 50 feet below the March 1960 levels is given in the last column of table 11. The predicted decreases, except for the Flowell (basalt) district, are not derived directly from the data in columns 2–4, because if water levels were to decline 50 feet the water would still be under artesian conditions throughout much of the valley. Values for the artesian coefficient of storage in the Pavant Valley range from $10^{-3}$ to $10^{-4}$; therefore, a decline in artesian head of 50 feet would result in very small changes in storage. Nearly all the water obtained from storage would come from the relatively narrow zone of unconfined water in the eastern part of the valley. The coefficient of storage in the zone of unconfined water is approximately the same as that given in column 2 of table 11. The values given in the last column of table 11, therefore, represent principally the change in storage in the relatively narrow zone of unconfined water.

Probably less than 1 million acre-feet of the water in storage is recoverable by present-day means and methods of extracting water. Most of the water not recoverable is held in fine sand, silt, and clay or in aquifers which are so thin that they will not yield sufficient water for irrigation. The economics of seeking and pumping water would preclude pumping water below some undetermined depth for crops normally grown in Pavant Valley.

## DISCHARGE

Ground water is discharged from the valley by evapotranspiration, by underflow, and from wells. The rate at which it is discharged depends on many factors, such as the depth to the water table, the nature of the vegetal cover, and the season of the year. More ground water is discharged from some parts of the valley than from others. Large quantities of water are withdrawn by plants from the zone of saturation where the water table is at or close to the land surface. Only small quantities, if any, are withdrawn by plants where the water table is more than 25 feet below the land surface, but in such areas the vegetation indirectly affects ground-water recharge and discharge by consuming water before it can become ground-water recharge. In a natural regimen the average annual discharge during a long period of years equals the average annual recharge. Ground-water discharge through wells increases recharge or reduces the natural discharge by a like amount. In addition to recharge or a reduction of natural discharge, it may also be partly or wholly derived from storage.

During 1959 the total ground-water discharge in the Pavant Valley was estimated to be 98,000 acre-feet (table 12). The underflow moving between districts does not affect ground-water discharge from the valley, but the amount is given in table 12 to show the relation of ground water in adjacent districts.

TABLE 12.—*Discharge (estimated), in acre-feet, in each ground-water district in Pavant Valley during 1959*

| Ground-water district | Evapo-transpiration [1] | Withdrawn from wells | Underflow | | Removed from storage | Total discharge in district |
|---|---|---|---|---|---|---|
| | | | From valley | To other districts | | |
| McCornick | 0 | 6,600 | 3,500 | 500 | 4,000 | 10,600 |
| Greenwood | 11,000 | 4,100 | 3,500 | 500 | 500 | 19,100 |
| Pavant | 500 | 1,100 | 1,500 | 500 | 500 | 3,600 |
| Flowell | 4,000 | 26,300 | 5,000 | 2,000 | 10,000 | 37,300 |
| Meadow | 8,000 | 10,100 | 500 | 7,500 | 10,000 | 26,100 |
| Kanosh | 0 | 11,400 | 0 | 0 | 5,000 | 11,400 |
| Total ground-water discharge in valley (rounded) | 24,000 | 60,000 | 14,000 | ------------ | 30,000 | 98,000 |

[1] Evapotranspiration by native vegetation on nonirrigated lands.

## EVAPOTRANSPIRATION

Water evaporates from open-water surfaces and from the soil. Plant roots get water from the soil, from the capillary fringe above the water table, and directly from the zone of saturation. Plants store some water, but they discharge most of it to the atmosphere by transpiration. The depths from which plants lift water differs greatly with different types of plants and with different soils and soil conditions. Transpiration usually cannot be measured separately from evaporation; so, the two processes are referred to by the collective term "evapotranspiration."

In Pavant Valley, evapotranspiration is especially rapid in the bottom lands, where the water table is at or near the land surface and where native and cultivated water-loving vegetation abounds. No data on the rate at which ground water is evaporated and transpired in Pavant Valley were obtained during this investigation. In Malad Valley, Idaho, about 250 miles north of Pavant Valley, in which the climate, soil conditions, and types of plants are comparable to those of Pavant Valley, evapotranspiration from the zone of saturation in areas where the depth to the water table was shallow was estimated by Mower and Nace (1957) to be as much as 4 feet a year, the average for grasslands being about 1½ feet a year.

Where the water table is close enough to the land surface to cause discharge of ground water by evaporation, a residue of water-soluble minerals is left at the land surface. The depth from which water may be brought to the land surface by capillarity depends upon the texture of the material above the water table—the finer grained the material, is the greater the capillary rise. Probably little water is brought to the land surface where the depth to the water table exceeds 10 feet. The amount of water evaporated directly from the soil surface depends upon the depth to the water table, the type of soil, and the extent and type of vegetal cover. Through passage of time, salts gradually accumulate at the land surface, and the vegetal cover becomes restricted to the more salt-tolerant varieties.

The water table beneath 35,000 acres of the valley lies sufficiently close to the land surface that evapotranspiration is operative (pl. 9). If one assumes that an average of 4 inches of water is transpired and evaporated each year from the shallow-water zone of saturation in the Meadow district where the valley is mostly devoid of vegetation, and that an average of 12 inches a year is transpired and evaporated from the zone of saturation in other parts of the valley, the annual evapotranspiration by native vegetation on nonirrigated lands from the ground-water reservoir is about 24,000 acre-feet (table 12).

### SUBSURFACE OUTFLOW

About 14,000 acre-feet of ground water moves westward yearly to other parts of the Sevier Desert from Pavant Valley. The amount of annual subsurface outflow is diminishing because withdrawal of water through wells lowers the ground-water levels in the valley, thus reducing the hydraulic gradient of the outflow. The quantity of water moving through an aquifer varies with the cross-sectional area of the aquifer and the hydraulic gradient, if one assumes no change in transmissibility. The transmissibility of aquifers was estimated on the basis of pumping tests, the cross-sectional areas were determined from well logs, and the hydraulic gradient was taken from a map of the configuration of the water table and piezometric surface. The average value for each of these factors used in estimating the subsurface outflow from the valley is given in table 13.

TABLE 13.—*Subsurface outflow and controlling factors in Pavant Valley, 1959 (estimated)*

| | Width of aquifer section (miles) | Average hydraulic gradient along western edge of valley during 1959 (feet per mile) | Estimated average coefficient of transmissibility (gpd per ft) | Estimated outflow during 1959 (acre-feet) |
|---|---|---|---|---|
| McCornick | 5 | 19 | 35,000 | 3,500 |
| Greenwood | 7 | 22 | 20,000 | 3,500 |
| Pavant | 3 | 15 | 30,000 | 1,500 |
| Flowell: | | | | |
| Alluvium | 7 | 9 | 30,000 | 2,000 |
| Basalt | 3 | 0.2 | 5,000,000 | 3,000 |
| Meadow | 5 | 3 | 30,000 | 500 |
| Kanosh | 7 | 0 | 500,000 | 0 |
| Total subsurface outflow from valley | | | | 14,000 |

**WELLS**

About 57,500 acre-feet of water was withdrawn through wells for irrigation; 2,000 acre-feet, for domestic and stock uses; and 75 acre-feet, for municipal uses during 1959. About 48,000 acre-feet of the water withdrawn through wells was consumed, and the remainder returned to the ground-water reservoir. Before 1950, most of the discharge from wells was from flowing wells but by 1959 flowing wells contributed only about 10 percent of the total discharge from wells. Total annual ground-water withdrawal (estimated) increased from 17,700 acre-feet in 1946 to a maximum of 67,300 acre-feet in 1960 (table 14), and the number of pumped irrigation wells increased from 3 to 110 during the same period of time. Figure 5 shows that as the number of pumped irrigation wells, and consequently pumpage, increased, the quantity of discharge from flowing wells decreased.

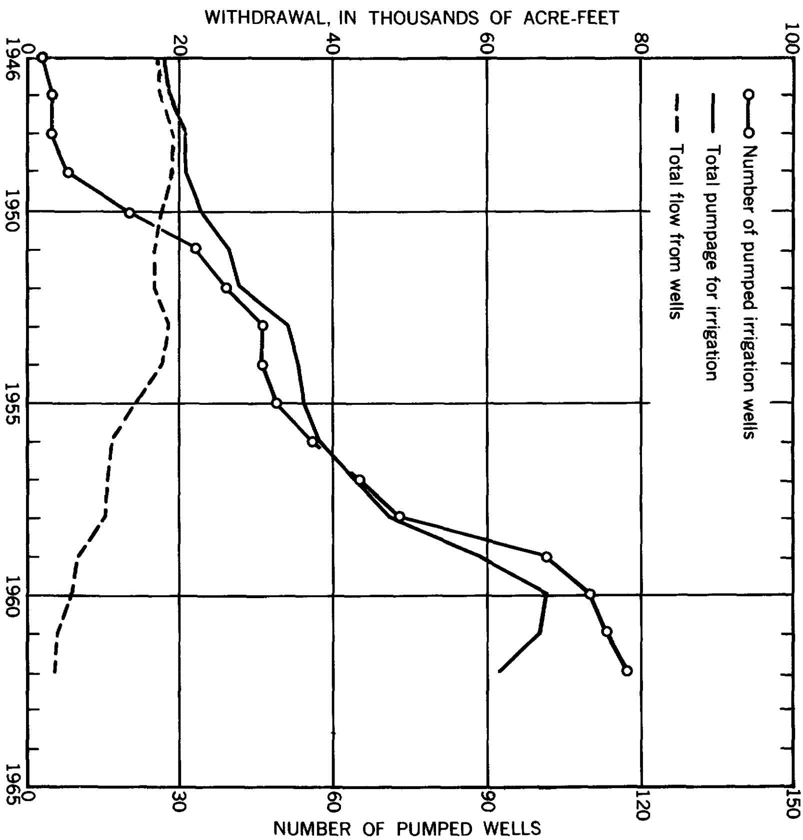



FIGURE 5.—Relation of number of pumped irrigation wells and total pumpage to total discharge from flowing wells in Pavant Valley, 1946–62.

TABLE 14.—*Discharge from wells (estimated), in acre-feet,*

| Year | McCormick | | | Greenwood | | | Pavant | | |
|---|---|---|---|---|---|---|---|---|---|
| | Flowed | Pumped | Total | Flowed | Pumped | Total | Flowed | Pumped | Total |
| 1946 | 0 | 0 | 0 | 1,000 | 0 | 1,000 | 300 | 0 | 300 |
| 1947 | 0 | 0 | 0 | 1,000 | 0 | 1,000 | 300 | 0 | 300 |
| 1948 | 0 | 0 | 0 | 1,000 | 0 | 1,000 | 300 | 0 | 300 |
| 1949 | 0 | 0 | 0 | 1,100 | 0 | 1,100 | 300 | 0 | 300 |
| 1950 | 0 | 800 | 800 | 1,200 | 500 | 1,700 | 300 | 100 | 400 |
| 1951 | 0 | 3,100 | 3,100 | 1,200 | 800 | 2,000 | 300 | 400 | 700 |
| 1952 | 0 | 4,200 | 4,200 | 1,300 | 1,000 | 2,300 | 400 | 600 | 1,000 |
| 1953 | 0 | 3,600 | 3,600 | 1,300 | 1,100 | 2,400 | 400 | 700 | 1,100 |
| 1954 | 0 | 4,500 | 4,500 | 1,300 | 1,200 | 2,500 | 400 | 700 | 1,100 |
| 1955 | 0 | 4,600 | 4,600 | 1,300 | 1,300 | 2,600 | 400 | 700 | 1,100 |
| 1956 | 0 | 4,800 | 4,800 | 1,300 | 1,400 | 2,700 | 300 | 700 | 1,000 |
| 1957 | 0 | 4,900 | 4,900 | 1,300 | 2,200 | 3,500 | 300 | 700 | 1,000 |
| 1958 | 0 | 4,600 | 4,600 | 1,200 | 2,500 | 3,700 | 300 | 700 | 1,000 |
| 1959 | 0 | 6,600 | 6,600 | 1,200 | 2,900 | 4,100 | 300 | 800 | 1,100 |
| 1960 | 0 | 7,100 | 7,100 | 1,200 | 4,400 | 5,600 | 300 | 700 | 1,000 |
| 1961 | 0 | 7,500 | 7,500 | 900 | 5,500 | 6,400 | 200 | 800 | 1,000 |
| 1962 | 0 | 6,600 | 6,600 | 700 | 5,900 | 6,600 | 100 | 1,200 | 1,300 |

*Flowing wells.*—Flowing wells were first constructed in the valley in 1915, and they provided the only ground water used for irrigation for the next 20 years and most of the ground water used for irrigation during the following 15 years. At first most of the water was used to supplement surface water, but it was the only source of irrigation water on a few small farms. In time, additional wells were drilled to obtain supplemental irrigation water, especially during drought, when flowing wells may have provided half the irrigation water used on the valley plain.

The largest quantity of ground-water discharge from flowing wells for any year was estimated to be 19,400 acre-feet in both 1948 and 1949. Since that time, discharge from flowing wells has generally diminished, partly as a result of drought and partly as a result of lower artesian pressures caused by pumping. Before 1959 most of the water from flowing wells was used for irrigation, and use for stock and domestic supplies was incidental; however, since 1959 most of the water from flowing wells has been used for stock and domestic supplies, and any irrigation use has been incidental.

A summation of withdrawal from the Pavant Valley ground-water reservoir by district during the period 1946–62, inclusive, is given in table 14. The increase in the discharge from flowing wells in the Greenwood district from 1946 to 1952 was caused by an increase in the number of irrigation and stock wells. Because few new wells were drilled in that district during 1952–57, annual discharge remained at about 1,300 acre-feet. Since 1957, annual discharge has been slightly less, only about 1,200 acre-feet a year during 1958–60.

In the Pavant district available hydrologic data suggest that the greatest annual discharge from flowing wells was in 1953 and that total *by ground-water district, Pavant Valley, Utah, 1946–62*

| Flowell | | | Meadow | | | Kanosh | | | Total in Pavant Valley | Number of pumped irrigation wells | Total number of wells in valley |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Flowed | Pumped | Total | Flowed | Pumped | Total | Flowed | Pumped | Total | | | |
| 14,000 | 0 | 14,000 | 2,000 | 200 | 2,200 | 0 | 200 | 200 | 17,700 | 3 | 343 |
| 14,000 | 0 | 14,000 | 2,100 | 500 | 2,600 | 0 | 500 | 500 | 18,400 | 5 | 349 |
| 16,000 | 0 | 16,000 | 2,100 | 600 | 2,700 | 0 | 600 | 600 | 20,600 | 5 | 351 |
| 15,000 | 100 | 15,100 | 2,200 | 1,100 | 3,300 | 0 | 1,000 | 1,000 | 20,800 | 8 | 367 |
| 14,000 | 700 | 14,700 | 2,100 | 1,700 | 3,800 | 0 | 1,300 | 1,300 | 22,700 | 20 | 400 |
| 13,000 | 1,400 | 14,400 | 2,000 | 3,300 | 5,300 | 0 | 800 | 800 | 26,300 | 33 | 413 |
| 13,000 | 1,400 | 14,400 | 1,900 | 2,000 | 3,900 | 0 | 1,600 | 1,600 | 27,400 | 39 | 424 |
| 15,000 | 2,800 | 17,800 | 2,000 | 4,600 | 6,600 | 0 | 2,300 | 2,300 | 33,800 | 46 | 445 |
| 14,000 | 3,400 | 17,400 | 1,800 | 5,200 | 7,000 | 0 | 2,900 | 2,900 | 35,400 | 45 | 451 |
| 11,000 | 5,700 | 16,700 | 1,700 | 5,400 | 7,100 | 0 | 3,900 | 3,900 | 36,000 | 49 | 466 |
| 8,000 | 9,100 | 17,100 | 1,400 | 5,600 | 7,000 | 0 | 5,400 | 5,400 | 38,000 | 56 | 485 |
| 7,000 | 10,200 | 17,200 | 1,600 | 6,000 | 7,600 | 0 | 8,300 | 8,300 | 42,500 | 65 | 498 |
| 7,000 | 13,400 | 20,400 | 1,500 | 5,900 | 7,400 | 0 | 9,900 | 9,900 | 47,000 | 73 | 507 |
| 3,800 | 22,500 | 26,300 | 1,000 | 9,100 | 10,100 | 0 | 11,400 | 11,400 | 59,600 | 101 | 522 |
| 3,700 | 27,700 | 31,400 | 700 | 9,600 | 10,300 | 0 | 11,900 | 11,900 | 67,300 | 110 | 532 |
| 3,000 | 27,000 | 30,000 | 400 | 11,000 | 11,400 | 0 | 10,000 | 10,000 | 66,300 | 113 | 535 |
| 2,500 | 24,500 | 27,000 | 300 | 8,000 | 8,300 | 0 | 12,000 | 12,000 | 61,800 | 117 | 540 |

discharge has diminished annually since 1953 because artesian pressures declined as a result of the current drought.

In the Meadow and Flowell districts, from 1946 through 1953 and 1954, respectively, the total annual discharge from flowing wells remained nearly constant and during these periods the annual variations of discharge were probably related to changes in recharge. Beginning in 1954 and 1955, respectively, and continuing through 1960, however, the total annual discharge from flowing wells diminished rapidly, as a result of reduced artesian pressure caused by pumping other irrigation wells. In fact, the effects of pumping were so great during 1959 and 1960 that most of the discharge from flowing wells occurred during the nonirrigation season. Effects of pumping are discussed further in a subsequent section.

Some water discharged from flowing wells during the winter is used for stock watering and some for irrigation, but much seems to be wasted. At least 3,500 acre-feet, and perhaps as much as 5,000 acre-feet of the 6,000 acre-feet of water discharged by uncontrolled or poorly controlled flowing wells is estimated to have been wasted during the winter of 1959–60. Thus, more than 50 percent of the 1959–60 winter discharge from flowing wells was probably wasted; this is equivalent to 5 percent of all ground water withdrawn from wells during 1960 (table 15).

To determine the amount of water discharged from each of the flowing wells during 1960, the rate of flow per foot of head was determined in at least one nearby representative observation well. The 1960 data were extrapolated to each of the years 1946–59 by using the water levels in the same observation wells to obtain the average rate of flow

TABLE 15.—*Discharge (estimated), in acre-feet, from flowing wells in Pavant Valley during the winter of 1959–60*

| Ground-water district | Beneficial use | Nonbeneficial use | Total |
|---|---|---|---|
| McCornick | 0 | 0 | 0 |
| Greenwood | 650 | 500 | 1,150 |
| Pavant | 80 | 180 | 260 |
| Flowell | 1,800 | 2,000 | 3,800 |
| Meadow | 180 | 700 | 880 |
| Kanosh | 0 | 0 | 0 |
| Totals (rounded) | 2,500 | 3,500 | 6,000 |

for each year. From this extrapolation, it was possible to compute the annual discharge from each of the flowing wells. Except for computations involving a few wells for which additional information was available, it was necessary to make the following assumptions: (1) The same methods of capping the wells that were observed to be in use during the winter 1959–60 were employed during each of the years 1946–59, (2) the rate of leakage through faulty or partly open valves and around defective caps varied only in direct response to change in artesian pressure, (3) the wells for which specific information was not available were opened April 1 and closed September 30 each year, and (4) wells uncapped during 1959–60 were assumed to have been uncapped since 1946. Although these assumptions may result in erroneous discharge for some wells, they are applicable to the valley as a whole. The annual discharge of flowing wells in the valley computed by this method compares favorably with the discharges estimated by Dennis, Maxey, and Thomas (1946, p. 75). They did not include the discharge from flowing wells in the Greenwood district and that from a part of the wells in the Pavant district, but this discharge would have been a small part of the total in the valley.

*Pumped irrigation wells.*—Most of the ground-water discharged in Pavant Valley is pumped from wells. About 61,400 acre-feet of water was pumped from 110 wells in 1960 (table 14). The first well pumped for irrigation in Pavant Valley was drilled by the Drought Relief Administration in 1934 in the village of Hatton. The number of pumped irrigation wells increased slowly until 1950, when 20 wells were pumped. The availability of electricity for irrigation pumps in the McCornick district in 1952 and in other districts in 1958 was a big factor in the increased number of pumped irrigation wells. There were 117 pumped wells in 1962, and the number will probably range between 125 and 135 in succeeding years.

Table 8 includes the discharge, in gallons per minute, and the volume of water pumped during 1960, in acre-feet, for each pumped irrigation well in use in Pavant Valley. The discharge of wells ranged from

130 to 3,450 gpm, and the volume of water pumped ranged from 20 to 1,600 acre-feet. The smallest discharge and volumes of water pumped were from the older small-diameter artesian wells. The largest discharge and volumes of water pumped were from wells finished in the basalt aquifer.

Pumping for irrigation in the McCornick district started in 1950, when 800 acre-feet of water was pumped; by 1961 pumpage had increased to 7,500 acre-feet, although it declined slightly in 1962. Pumping for irrigation also started in the Greenwood district in 1950, when 500 acre-feet was pumped, and it reached 5,900 acre-feet in 1962. The Pavant district has the least ground-water withdrawal of the six districts. The first pumping was in 1950, when 100 acre-feet was pumped; in 1962 pumpage was only 1,200 acre-feet. Flowing wells had been used in the Flowell district for many years when the first pump was used in 1949. Pumpage in the Flowell district increased from 100 acre-feet in 1949 to 27,700 acre-feet in 1960, but it declined in 1961 and 1962 (table 14). In the Meadow district, there were two pumped wells in 1946 that pumped about 200 acre-feet of water; by 1961, pumpage had increased to 11,000 acre-feet, although it declined slightly in 1962. The first irrigation well in the Kanosh district pumped 200 acre-feet in 1946; by 1962, 12,000 acre-feet was pumped from 16 wells.

Although it is more expensive to pump water from artesian aquifers than to obtain water by natural flow, the savings in time and efficiency that can accrue from having a greater supply of water available when needed may more than offset the cost of water obtained solely from flowing wells. Nearly all the pumped irrigation wells discharge at a rate several times that of a flowing well, making it possible to irrigate a farm in a much shorter time than was possible with flowing wells and with a smaller percentage of evaporation and seepage losses from reservoirs and ditches. Larger irrigation streams enable more even distribution of water over the fields and thus help to prevent excessive percolation losses at the head of the field and insufficient irrigation at the bottom and to increase crop yield. Also, crops having a higher market value can be grown as a result of the more dependable water supply available by pumping. All these factors increase the farmer's incentive to improve his distribution systems and irrigation practices.

## CHEMICAL QUALITY OF WATER

Problems of the quality of ground water are closely related to those of quantity. An insufficient supply or the overdevelopment of ground water in an area is sometimes associated with undesirable chemical characteristics of the water, such as excessive amounts of total dissolved solids or of a single element such as sodium. These problems may be related to the geology and hydrology or to the reuse of irrigation, municipal, and industrial water, whereby the quality of water deteriorates owing to concentration of minerals by evapotranspiration, by re-solution from the soil, or by addition of contaminates. Ultimately, reuse of irrigation water may adversely affect the user of downgradient water, as this concentrated irrigation water mixes with ground water of better quality downgradient.

The chemical quality of ground water in Pavant Valley was studied to determine its general usability and the possibility of future changes in quality. Also, knowledge of the chemical characteristics of irrigation water can be helpful in determining irrigation practices.

Most of the chemical analyses were made of water samples collected in 1943–44 and in 1956–60. Samples of ground water were collected from representative wells in the alluvium and the basalt. Selected chemical analyses of water samples from 41 wells are listed in table 16, and chemical analyses of all water samples from wells in Pavant Valley analyzed by the Geological Survey through 1962 were compiled by Mower (1963). Water samples are collected once or twice a year from several selected wells to monitor changes in quality. A total of 196 water samples from 127 wells were analyzed during 1943–62. The chemical characteristics of ground water from 10 wells is shown in figure 6.

The discussion of water quality in this report pertains only to the chemical quality of the water and does not relate to the sanitary quality of the individual supplies, except that a high nitrate content may be an indication of pollution.

## PRINCIPAL CHEMICAL CHARACTERISTICS AFFECTING WATER USED FOR IRRIGATION

All natural waters contain chemical substances in solution. Water dissolves some of the rocks and soils through which it passes. The amount and character of the mineral matter taken into solution depend chiefly on the chemical and physical composition of the rocks through which the water passes, the length of time the water is in contact with the soil or rocks, and other factors such as temperature and pressure. Ground water, in general, is usually more mineralized than direct surface runoff because it remains in contact with the soil and rocks for a longer time. The concentration and character of the minerals in solution—particularly the total amount of dissolved solids, the amount of boron, and the percentage of sodium relative to other cations—determine the quality of the water for irrigation.

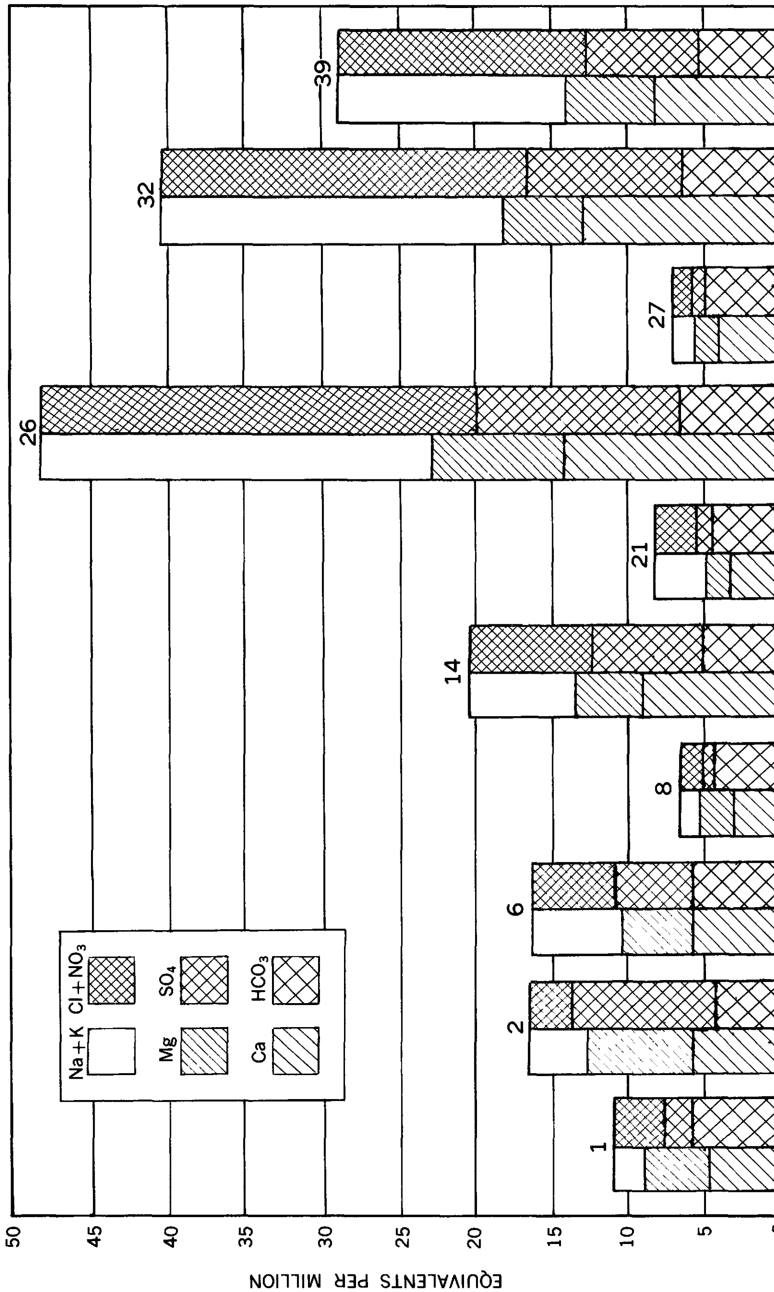



FIGURE 6.—Chemical character of representative ground waters in Pavant Valley. Numbers refer to analyses in table 16.

**TABLE 16.—*Chemical analyses of water from 41 selected wells in Pavant Valley, Utah***

[Character of water-bearing material: B, basalt; G, gravel; K, conglomerate; S, sand]

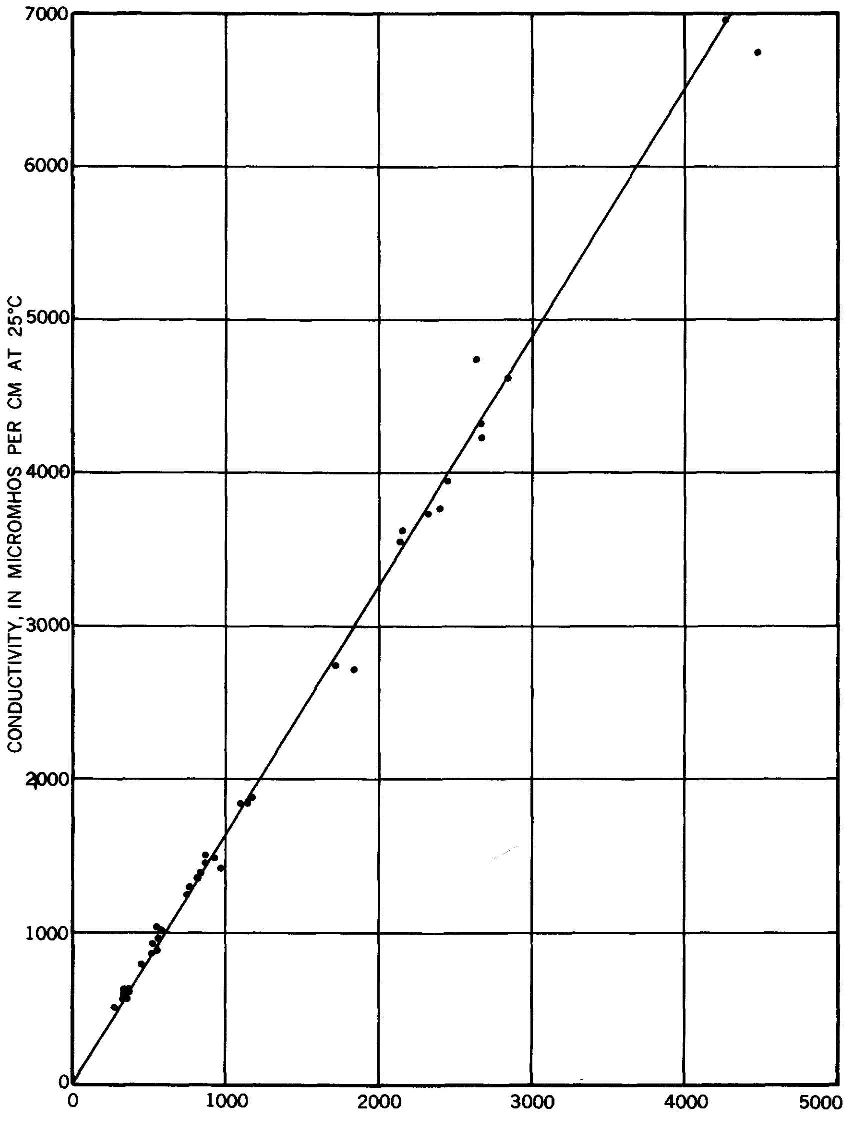
| Analysis | Well | Owner | Date of collection | Depth of well (ft) | Character of water-bearing material | Temperature (°F) | Parts per million | | | | | | | | | | | Percent sodium | Sodium-adsorption-ratio (SAR) | Specific conductance (micromhos per cm at 25° C) | pH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Silica ($SiO_2$) | Calcium (Ca) | Magnesium (Mg) | Sodium and potassium (Na+K) | Bicarbonate ($HCO_3$) | Sulfate ($SO_4$) | Chloride (Cl) | Nitrate ($NO_3$) | Dissolved solids | Hardness as $CaCO_3$ | Noncarbonate hardness as $CaCO_3$ | | | | |
| 1 | (C-18-5)34baa-1 | L. C. Callister | 5-23-60 | 667 | S, G | 62 | 25 | 92 | 51 | 48 | 348 | 80 | 120 | 6.6 | 594 | 438 | 153 | 19 | 1.0 | 1,010 | 7.6 |
| 2 | (C-20-5)22bcc-1 | J. C. Rowley | do | 400 | do | 63 | 26 | 111 | 84 | 91 | 251 | 450 | 102 | 1.7 | 989 | 622 | 416 | 24 | 1.6 | 1,410 | 7.7 |
| 3 | (C-21-4)7bbc-1 | A. W. Brunson | 11-17-44 | 73 | do | ---- | ---- | 84 | 33 | 4.4 | 397 | 13 | 10 | 2.0 | 342 | 345 | 20 | 3 | .1 | 628 | ---- |
| 4 | (C-21-5)6cac-1 | A. R. Swallow | 5-7-57 | 90 | B | 55 | 30 | 151 | 54 | 78 | 309 | 150 | 238 | 31 | 884 | 600 | 347 | 22 | 1.4 | 1,500 | ---- |
| 5 | 6dba-1 | Jarold Robison | 10-23-57 | 400 | S, G | ---- | 18 | 48 | 23 | 21 | 233 | 24 | 32 | 2.9 | 284 | 217 | 26 | 18 | .6 | 506 | 7.3 |
| 6 | 7cdd-3 | Christensen Brothers | 5-24-60 | ---- | B | 54 | 28 | 111 | 56 | 136 | 344 | 238 | 186 | 16 | 940 | 510 | 228 | 37 | 2.6 | 1,490 | 7.7 |
| 7 | 7ddc-3 | A. P. Robison | 8-26-58 | 96 | do | 54 | 21 | 92 | 32 | 68 | 352 | 89 | 81 | 15 | 571 | 360 | 71 | 29 | 1.5 | 967 | 7.6 |
| 8 | 8bdc-2 | Swallow and Robison | 5-31-60 | 407 | S, G, B | 63 | 21 | 61 | 26 | 30 | 256 | 39 | 48 | 4.8 | 356 | 257 | 47 | 20 | .8 | 602 | 7.7 |
| 9 | 8cdd-1 | F. W. Johnson | 8-26-58 | 246 | G, B | 56 | 20 | 70 | 26 | 26 | 264 | 38 | 53 | 7.7 | 371 | 280 | 64 | 17 | .7 | 629 | 7.8 |
| 10 | 18aba-1 | Robison and Brinkerhoff | do | 150 | B | 55 | 22 | 114 | 44 | 96 | 348 | 186 | 131 | 13 | 777 | 464 | 179 | 31 | 2.0 | 1,250 | 7.6 |
| 11 | 18ada-2 | F. G. Johnson | 6-24-58 | 135 | B, G, S | 55 | 24 | 76 | 40 | 63 | 332 | 132 | 51 | 13 | 562 | 356 | 84 | 28 | 1.4 | 890 | 7.6 |
| 12 | 20dad-1 | J. D. Ivie | 10-11-57 | 293 | S, G | 57 | 17 | 67 | 24 | 17 | 319 | 2.0 | 18 | 18 | 320 | 267 | 5 | 12 | .4 | 575 | 7.1 |
| 13 | 28aaa-1 | Charles Owen | 8-28-58 | 510 | G, K | 59 | 15 | 71 | 25 | 16 | 318 | 16 | 17 | 16 | 332 | 280 | 19 | 11 | .4 | 578 | 7.2 |
| 14 | 29bdd-2 | Lawrance Rasmussen | do | 632 | G, S | 65 | 16 | 177 | 53 | 162 | 302 | 348 | 282 | 6.2 | 1,190 | 660 | 412 | 35 | 2.7 | 1,890 | 7.4 |
| 15 | 30dbc-3 | Christensen Brothers | [1] 5-27-60 | 787 | S, G | ---- | 16 | 141 | 67 | 164 | 229 | 344 | 311 | 1.0 | 1,160 | 628 | 440 | 36 | 2.8 | 1,860 | 7.6 |
| 16 | 31cdd-2 | J. N. Rogers | 3-24-59 | 800 | G, K | 66 | 15 | 79 | 23 | 75 | 305 | 80 | 85 | 3.1 | 510 | 292 | 42 | 36 | 1.9 | 873 | 7.5 |
| 17 | 33ccd-1 | L. V. Barnes | 5-8-57 | 250 | G, S | 58 | 13 | 96 | 23 | 76 | 242 | 64 | 165 | 5.8 | 562 | 336 | 138 | 33 | 1.8 | 1,030 | 7.8 |
| 18 | (C-21-6)1ddb-1 | Clyde Larsen | 6-23-58 | 105 | B | 55 | 30 | 130 | 55 | 83 | 325 | 151 | 210 | 16 | 835 | 552 | 286 | 25 | 1.5 | 1,390 | 7.4 |
| 19 | (C-22-5)4bbd-1 | Olaf George | 8-28-58 | 250 | G | 59 | 13 | 128 | 27 | 126 | 262 | 188 | 208 | 4.0 | 823 | 432 | 217 | 39 | 2.6 | 1,360 | 7.2 |
| 20 | 9cad-2 | W. A. Paxton | 10-2-58 | 527 | S, G | 69 | 15 | 263 | 73 | 261 | 311 | 652 | 415 | 5.1 | 1,840 | 955 | 700 | 37 | 3.7 | 2,720 | 7.2 |
| 21 | 17bdd-1 | William Blake | 5-24-60 | 375 | do | 58 | 20 | 64 | 20 | 78 | 266 | 48 | 97 | 4.5 | 462 | 240 | 22 | 41 | 2.2 | 803 | 7.8 |
| 22 | 21acd-2 | Mrs. L. Stott and others | 8-27-58 | 340 | G | 57 | 13 | 85 | 21 | 84 | 312 | 52 | 116 | 8.4 | 532 | 298 | 42 | 38 | 2.1 | 936 | 7.5 |
| 23 | 33abc-1 | Grant Beckstrand | do | 250 | S, G | 55 | 14 | 75 | 11 | 34 | 199 | 34 | 72 | 7.7 | 346 | 232 | 69 | 24 | 1.0 | 595 | 7.7 |
| 24 | (C-22-6)3add-2 | Edwards and Harding | 7-10-57 | 339 | B | ---- | 48 | 114 | 41 | 134 | 276 | 148 | 258 | 2.3 | 881 | 454 | 228 | 39 | 2.7 | 1,460 | 7.3 |
| 25 | 32ccc-1 | A. L. Kimball | 10-8-58 | 115 | do | 58 | 37 | 281 | 126 | 478 | 344 | 538 | 1,000 | 9.0 | 2,640 | 1,220 | 938 | 46 | 6.0 | 4,760 | 7.3 |

| | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 26 | 32dcc-1 | W. B. Bushnell | do | 115 | do | 60 | 38 | 281 | 105 | 589 | 398 | 630 | 1,010 | 6.3 | 2,860 | 1,130 | 804 | 53 | 7.6 | 4,620 | 7.2 |
| 27 | (C-23-5) 5adc-1 | F. T. Paxton | 8-27-58 | 180 | G | 55 | 19 | 78 | 19 | 32 | 293 | 40 | 40 | 7.8 | 380 | 274 | 34 | 20 | .9 | 635 | 7.6 |
| 28 | (C-23-6) 8abd-1 | B. P. and M. Watts | 5-24-60 | 200 | B | 58 | 47 | 317 | 88 | 516 | 352 | 517 | 1,020 | 7.8 | 2,690 | 1,150 | 861 | 49 | 6.6 | 4,230 | 7.4 |
| 29 | 9bca-1 | Keith Pace | 8-27-58 | 170 | do | 62 | 54 | 405 | 114 | 1,050 | 486 | 924 | 1,700 | 5.4 | 4,490 | 1,480 | 1,080 | 61 | 12 | 6,750 | 6.9 |
| 30 | 9ccd-1 | do | 5-8-57 | 136 | B, G | 60 | 40 | 257 | 62 | 434 | 372 | 406 | 785 | 6.7 | 2,170 | 896 | 591 | 51 | 6.3 | 3,620 | 7.8 |
| 31 | 10ccc-1 | C. A. Kimball | 6-5-58 | 96 | B | 60 | 38 | 265 | 69 | 523 | 379 | 495 | 885 | 10 | 2,470 | 945 | 634 | 55 | 7.4 | 3,940 | 7.3 |
| 32 | 15bbd-2 | G. D. Staples, and others | 5-17-60 | 141 | do | 59 | 40 | 257 | 63 | 514 | 380 | 495 | 840 | 7.7 | 2,400 | 900 | 588 | 55 | 7.4 | 3,780 | 7.3 |
| 33 | 16bad-1 | Keith Pace | do | 130 | do | 58 | 45 | 313 | 92 | 515 | 366 | 541 | 1,000 | 7.6 | 2,690 | 1,160 | 860 | 49 | 6.6 | 4,310 | 7.2 |
| 34 | 16cda-1 | Alvin Englestead | 5-10-58 | 205 | do | 58 | 40 | 253 | 71 | 474 | 370 | 466 | 820 | 8.9 | 2,310 | 920 | 617 | 53 | 6.8 | 3,740 | 7.4 |
| 35 | 17cdc-1 | LaVal Bradshaw | 6-4-58 | 440 | G, S | 61 | 37 | 146 | 74 | 525 | 287 | 314 | 880 | 11 | 2,130 | 670 | 435 | 63 | 8.8 | 3,560 | 7.5 |
| 36 | 20caa-1 | N. L. Nielson | 10-8-58 | 307 | S, G | 57 | 33 | 88 | 69 | 200 | 239 | 234 | 352 | 4.8 | 1,100 | 505 | 309 | 46 | 3.9 | 1,860 | 7.7 |
| 37 | 20cbb-1 | do | 8-27-58 | 430 | do | 61 | 37 | 257 | 136 | 1,140 | 362 | 533 | 2,000 | 7.8 | 4,290 | 1,200 | 903 | 67 | 14 | 6,970 | 7.2 |
| 38 | 21add-1 | Victor McCanon | 5-10-58 | 445 | B | 57 | 31 | 55 | 36 | 74 | 221 | 108 | 104 | 11 | 528 | 288 | 107 | 36 | 1.9 | 880 | 7.8 |
| 39 | 21bdd-1 | Ronald Bradshaw | 5-24-60 | 415 | B, G | 56 | 44 | 162 | 71 | 343 | 322 | 353 | 570 | 9.3 | 1,710 | 696 | 432 | 52 | 5.7 | 2,750 | 7.6 |
| 40 | 21cdd-1 | D. H. Moore | 5-13-58 | 630 | | | 22 | 26 | 17 | 138 | 218 | 101 | 104 | 10 | 525 | 137 | 0 | 69 | 5.1 | 876 | 7.4 |
| 41 | 28bbb-1 | J. C. Moore | 5-10-58 | 194 | G, S | | 31 | 57 | 44 | 147 | 198 | 166 | 210 | 13 | 765 | 322 | 160 | 50 | 3.6 | 1,300 | 8.0 |

[1] Contains 0.47 ppm boron (B).

### SPECIFIC CONDUCTANCE

Specific conductance is useful in the evaluation of irrigation water because it is an index of the concentration of dissolved solids or the salinity of the water. The higher the concentration of dissolved solids, the greater conductivity of the water. In Pavant Valley, the average ratio of specific conductance to dissolved solids is 0.61 (fig. 7).




GURE 7.—Relation of specific conductance to dissolved solids of ground water in Pavant Valley.

Specific conductance is used as a general index of suitability in some systems of classifying irrigation water. Also, water having high specific conductance speeds the corrosion of metals in which it is in contact, including well casings, pumps, and pipelines. The specific conductance of water from 122 wells in Pavant Valley has been measured, and the values are plotted in figure 2; the results from 41 wells are plotted in figure 18.

Saline soils tend to be flocculated if the sodium hazard (see the following subsection, "Sodium hazard") of irrigation water is low; as a result, the soils are friable and granular and consequently permeable. Water of high salinity can be used with varying degrees of success in Pavant Valley, depending on the soil drainage.

### SODIUM HAZARD

In Pavant Valley the suitability of water for irrigation is largely determined by the amount of dissolved sodium in proportion to the amount of dissolved calcium and magnesium. A high proportion of sodium in irrigation water tends to break down the friable, granular nature of soil and thus causes the soil to become impermeable. In contrast, water containing high proportions of dissolved calcium and magnesium to dissolved sodium maintains good tilth and texture in soil.

The sodium hazard of irrigation water is generally reported as percent sodium. The classification of irrigation water according to percent sodium is not wholly satisfactory because it does not directly measure the potential for ion-exchange adsorption of sodium by the soil. The sodium-adsorption-ratio (SAR) has been used more during recent years to evaluate waters for irrigation use than the percent sodium because it is more nearly a direct measure of that potential.

Classifying water according to the amount of harm that its sodium content will do to soil is not simple because the suitability of water for irrigation is influenced by soil drainage, water management, and application of soil amendments. Also, gypsum and calcium in the soil tend to counteract the effects of sodium. The Department of Agriculture method of classifying waters for irrigation is used in this report (fig. 8). The method relates the specific conductance of water to the sodium or alkali hazard and thereby determines the suitability of water for irrigation.

In general, the poorest quality ground water in the valley is the shallow ground water in the western and southern parts of the valley. Ground water in these areas has traveled farthest from the recharge areas and may be return flow from previous irrigation. The result of both factors is that the sodium hazard is increased.

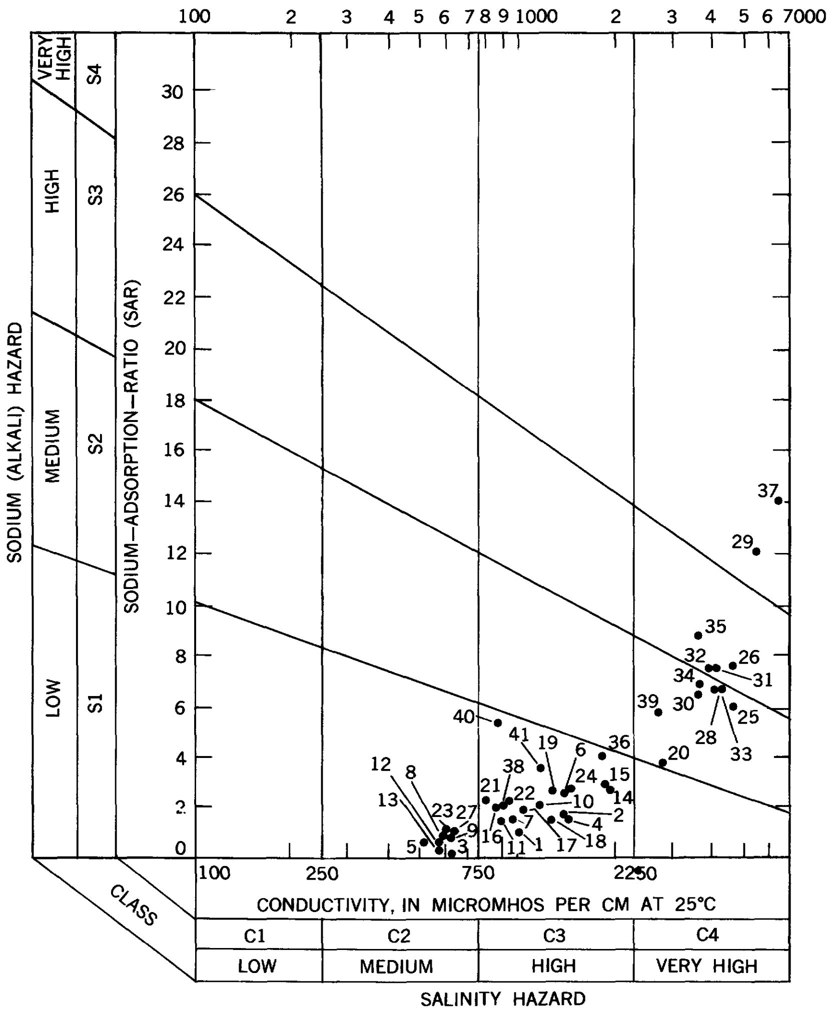



FIGURE 8.—Interpreting the analysis of irrigation water in Pavant Valley (method of U.S. Salinity Lab. Staff, 1954). Numbers refer to analyses in table 16.

## BORON

Boron is essential to plant growth, but it is extremely toxic at concentrations slightly above optimum. The concentration of boron in some irrigation waters in Pavant Valley approaches the maximum tolerable for the least sensitive plants. According to the U.S. Salinity Laboratory Staff (1954), the permissible limits of boron ranges from 0.33 to 1.25 ppm (parts per million) for sensitive crops and from 1.00 to 3.75 ppm for tolerant crops. In Pavant Valley the concentration of boron in ground water ranges from 0.1 to 2.5 ppm. Additional comments on boron are made in the following subsections, where the chemical quality of ground water in the various ground-water districts is discussed.

### CLASSIFICATION OF WATER FOR IRRIGATION

The classification of irrigation water in Pavant Valley ranges from excellent to undesirable. The SAR and the specific conductance of water from 122 wells are shown on plate 1, and SAR was plotted against specific conductance on a diagram (fig. 8) to classify the water with respect to sodium and salinity hazard. Figure 8 shows that the salinity hazard of ground water used for irrigation in Pavant Valley ranges from medium to very high, but the sodium hazard ranges from low to medium for most of the water.

The U.S. Salinity Laboratory Staff (1954, p. 79–81) defines the different classes of saline and alkaline waters as follows:

Low-salinity water (C1) can be used for irrigation with most crops on most soils with little likelihood that soil salinity will develop. Some leaching is required, but this occurs under normal irrigation practices except in soils of extremely low permeability.

Medium-salinity water (C2) can be used if a moderate amount of leaching occurs. Plants with moderate salt tolerance can be grown in most cases without special practices for salinity control.

High-salinity water (C3) cannot be used on soils with restricted drainage. Even with adequate drainage, special management for salinity control may be required and plants with good salt tolerance should be selected.

Very high salinity water (C4) is not suitable for irrigation under ordinary conditions, but may be used occasionally under very special circumstances. The soils must be permeable, drainage must be adequate, irrigation water must be applied in excess to provide considerable leaching, and very salt-tolerant crops should be selected.

Low-sodium water (S1) can be used for irrigation on almost all soils with little danger of the development of harmful levels of exchangeable sodium. However, sodium-sensitive crops such as stone-fruit trees and avocados may accumulate injurious concentrations of sodium.

Medium-sodium water (S2) will present an appreciable sodium hazard in fine-textured soils having high cation-exchange-capacity, especially under low-leaching conditions, unless gypsum is present in the soil. This water may be used on coarse-textured or organic soils with good permeability.

High-sodium water (S3) may produce harmful levels of exchangeable sodium in most soils and will require special soil management—good drainage, high leaching, and organic matter additions. Gypsiferous soils may not develop harmful levels of exchangeable sodium from such waters. Chemical amendments may be required for replacement of exchangeable sodium, except that amendments may not be feasible with waters of very high salinity.

Very high sodium water (S4) is generally unsatisfactory for irrigation purposes except at low and perhaps medium salinity, where the solution of calcium from the soil or use of gypsum or other amendments may make the use of these waters feasible.

The chemical quality of water as it pertains to use for irrigation in each of the six ground-water districts is discussed in detail in the following subsections.

### McCORNICK GROUND-WATER DISTRICT

Dissolved solids are low in the one analysis of ground water available for the McCornick district (table 16, anal. 1), but as shown in figure 8 this water has a high-salinity hazard and a low-sodium hazard. Use of this water provides little, if any, danger of the accumulation of harmful amounts of sodium; however, the salinity level is such that the water should be used on well-drained soils and for plants having good salt tolerance. The soil in the district has high quality and good drainage and therefore is suitable for irrigation by water of chemical quality similar to that indicated by the analysis in analysis 1 of table 16, providing that reasonably good irrigation practices are followed.

The amount of boron in ground water in the McCornick district was not determined, but the concentration of boron does probably not exceed 1 ppm, which is a safe concentration for crops normally grown in the district.

### GREENWOOD GROUND-WATER DISTRICT

Water was analyzed from one well in the Greenwood district. The quality of water and the soil conditions in the eastern part (east of the railroad) of the Greenwood district, however, are about the same as they are in the McCornick district. The quality of the water and the soil conditions in the western part of the Greenwood district are probably about the same as they are in the western part of the Pavant district. Thus, quality problems should not arise in the irrigated parts of the Greenwood district, providing reasonably good irrigation practices are followed.

### PAVANT GROUND-WATER DISTRICT

The chemical quality of ground water in the Pavant district is represented by analysis 2 in table 16, and water moving into the southeast corner of the district is represented by analysis 3. Analyses of water from nine other wells in the Pavant district are available but are not included in table 16; however, they are evaluated in the following discussion.

Water within the district has a high-salinity hazard and a low-sodium hazard according to the classification in figure 8. This water can probably be used safely on lands east of the paved county highway running north-south through the middle of the district. Special precautions and expert management of the water may be required in irrigating lands with ground water west of this highway because of the apparent high-sodium and high-salinity content of the soils and the relatively poor local drainage.

Water moving into the southeast corner of the district has a medium-salinity hazard and a low-sodium hazard; this fact indicates that the quality of the water deteriorates from east to west.

Most of the ground water used for irrigation is used in the eastern part of the district; thus, there should be few, if any, quality problems if reasonably good irrigation practices are followed.

The amount of boron in two samples was 0.2 and 0.4 ppm, a concentration that is probably below the maximum that can be tolerated by the most sensitive plants.

### FLOWELL GROUND-WATER DISTRICT

The quality of water in the Flowell district is represented by analyses 4–19 and by analysis 24, all in table 16. Water in this district has a low-sodium hazard and a medium- to high-salinity hazard. The water of poorest quality is in the southwestern part of the district. The water-level contours on plate 4 show that the poor-quality water in the southwestern part of the district originates in the Meadow district, where the water apparently flows through rock material for longer periods of time than the other water and thus has more opportunity to dissolve minerals.

Some of the ground water of poorest quality in the Flowell district is in the basalt aquifer. Much of this water is derived from upward leakage from underlying artesian aquifers and from deep-percolation losses of irrigation water withdrawn from the underlying artesian aquifers. The water in the basalt, therefore, has more opportunity to become charged with dissolved solids than does water in the artesian aquifers. For example, water from an artesian well, (C–21–5) 6dba–1, has less than one-third as many dissolved solids as water from a nearby well in the basalt, (C–21–5) 6cac–1.

The southwestern quarter of the Flowell district is the only area where the quality of ground water need be of much concern. Soils in the southwestern part of the district have a relatively high concentration of sodium chloride and alkali, and drainage characteristics are poor. The present (1962) quality of the soil in other parts of the district can be maintained and possibly improved through proper irrigation practices and by the application of soil amendments. Enough water must be applied during each irrigation, however, to leach some of the detrimental elements in the soil and excessive dissolved constituents in some of the ground water.

The quality of ground water in the southwestern part of the district is not likely to improve with use. In fact, it may deteriorate because pumping during the irrigation season causes the direction of flow of the ground water to the west to be reversed and thus the more highly mineralized water along the west side of the district flows into the pumped area.

The concentration of boron in the Flowell district ranges from 0.2 to 2.5 ppm. The highest concentration, which is in the southwestern part, would be toxic to the most sensitive plants but is probably not toxic to the crops commonly grown in Pavant Valley.

The relatively high concentrations of nitrate in the ground water pumped from the basalt aquifer indicates contamination from decaying organic materials or deep-percolation losses of irrigation water from fields fertilized with nitrogen fertilizer. Water from wells in the shallow lacustrine deposits also has high nitrate content. The nitrate content of these waters is 2–10 times the concentration of the deeper artesian water. The nitrate is not harmful in irrigation water and may even be beneficial.

### MEADOW GROUND-WATER DISTRICT

Five water analyses in table 16 (anals. 20–23, 27) are representative of ground water in the Meadow district. Except for one sample (anal. 20), which has a medium-sodium hazard and a very high salinity hazard, water in this district has a low-sodium hazard and a medium- to high-salinity hazard. A large part of the ground water used for irrigation in the district is supplemental to surface water; thus, surface water of better quality flushes out some of the undesirable elements deposited by the ground water. In most areas in this district, ground water can probably be used safely in this manner without any danger of the soil becoming too highly mineralized for irrigation. In the western part of the district, where drainage is poor, the saline water and soil and, locally, the sodium hazard cause small crop yields.

Analyses of boron were made of ground water from two wells in the northwestern part of the district. They contained 0.2 and 0.4 ppm boron, which is below the toxic limits for even the most sensitive plants. Ground water west of the sampled wells may contain higher concentrations of boron, but these concentrations are still probably less than the toxic limits for most crops.

### KANOSH GROUND-WATER DISTRICT

Only the Kanosh district has serious quality-of-water problems. Analyses 25, 26, and 28–41 in table 16 are representative of ground water in the district. The dissolved-solids content of ground water in the district is several times that in the other districts, and the bicarbonate content is of the same order of magnitude. Nearly all the water has a very high salinity hazard and a medium- to high-sodium hazard. Samples represented by analyses 29 and 37 in table 16, however, have a very high salinity hazard and a very high sodium hazard. Water from wells nearest the principal recharge area, represented bv analyses 36, 38, 40, and 41 in figure 7 and in table 16, are of slightly better quality than other ground water in the district.

The concentration of boron in water from one well (anal. 31, table 16) was 1.5 ppm. This concentration is less than the toxic limit of most semitolerant and tolerant plants and there is probably no place in the district where the concentration of boron exceeds the toxic limits for plants normally grown in Pavant Valley.

Fortunately, most of the soil in the district has good texture and is well drained, otherwise it would not be possible to use the available ground water for irrigation. Some of the soils contain appreciable quantities of gypsum, which helps to alleviate the sodium hazard.

Chemical data indicate that ground water in the district is from three sources; from Devil's Ridge, from near Kanosh around or through Black Rock Volcano, and from the mountains across the south end of the valley. Plate 2 shows the general sources or paths of the ground water. The water mixes as it moves through the district, and by the time that the water reaches the northwestern part of the district it has been thoroughly mixed.

Water moving westward from Devil's Ridge is of a different chemical character than that moving westward from Black Rock Volcano; this water is, in turn, chemically different from the water moving north and northwestward from the mountains across the south end of the district. The waters mix as they move downgradient, and additional minerals are taken into solution as the water moves through the district. Also, return flow of irrigation water percolates to the aquifer and carries with it higher concentration of dissolved solids than the original water had contained. The final result is that the ground water near the northwestern part of the district is chemically different from the parent waters. It is not possible to determine the relative quantities of water from each of the sources because of the additional minerals taken into solution as the water flows through the district.

The chemical quality of the ground water is deteriorating with time because of deep percolation by excess irrigation water and encroachment of more highly mineralized water from the west. The irrigation water that percolates to the water table is more highly mineralized than the applied water because it contains much of the mineral matter left behind by water that evaporates from the soil or is transpired by the plants.

As previously stated, ground water becomes more highly mineralized with time as it moves through rock material; thus, water that had flowed through a certain well in the past is more highly mineralized than the water presently at the well. One reason that the ground water in the district becomes more highly mineralized with time is that water flowing beyond the pumped area reverses direction of flow during the irrigation season and returns to the pumped area. Thus the rate of deterioration of the quality of ground water in the Kanosh district will increase as water levels decline.

## TEMPERATURE

The temperature of water from 178 wells in Pavant Valley ranged from 52° to 85° F. The temperature of the shallowest water is about the same as the mean annual air temperature of 52° F. Ground-water temperature increases an average of 1°F for each 80 feet of depth in the sediments in the valley. The temperature also increases westward from the mountains toward areas of recent volcanic activity. Near the mountains along the east side of the valley, the temperature of the ground water ranges from 52° to 57° F; along the west side of the valley, the temperature ranges from about 60° to 85° F, except that the temperature of water from wells in the basalt aquifer ranges from 54° to 57° F. A temperature of 143° F was measured for springs along Devil's Ridge west of Hatton, but the rate of flow is only 1 or 2 gpm. Wells in Pavant Valley have not been known to tap water warmer than 85° F.

The temperature of ground water, in general, increases 1°–3° F through the irrigation season. This temperature rise is caused principally by excess irrigation water that has been warmed at the land surface and has returned to the aquifer and by upward migration of warmer water from lower depths.

## PHREATOPHYTES

The infestation of the bottom lands by phreatophytes of little or no economic value, principally saltcedar, is one of the greatest threats to agriculture in Pavant Valley. These plants use water that could be used more beneficially by plants of greater economic value, and generally their demand for water equals and commonly exceeds that of crops. Most of the indigenous phreatophytes in the valley have a low to fair economic value as forage, but saltcedar has no value.

Phreatophytes habitually send their roots down to the water table or to the capillary fringe above it; thus, they grow in areas of shallow ground water, along stream channels, canal banks, flood plains, and reservoirs. Indigenous phreatophytes grow on about 35,000 acres in Pavant Valley, and they range from sparse growths of greasewood and pickleweed to dense growths of meadow grasses. The locations and extent of the phreatophyte areas are shown on plate 9, but no attempt was made to determine or show density of growth.

Sedges, wirerush, and saltgrass are the most desirable indigenous phreatophytes in Pavant Valley, and they compose nearly all the native bottom-land pastures. The most common undesirable indigenous phreatophytes in the bottom lands are greasewood, rabbitbrush, and pickleweed. Cottonwood, willow, wild rose, and rabbitbrush are the predominant indigenous phreatophytes along ditch banks and creek channels above the bottom lands. Alfalfa is an imported phreatophyte, and it is one of the major crops grown in the valley.

Saltcedar, or tamarisk, as it is sometimes called, presents a real threat to the economy of Pavant Valley because of its voracious use of water and, under favorable conditions, its ability to rapidly infest wet areas and areas of shallow ground water. It has been in the valley only a few years, and at present (1962) there are a relatively few saltcedar plants growing throughout the valley. The greatest concentration is along the banks of the Central Utah Canal, but there are scattered plants in the meadow pastures, along ditch banks and laterals leading from wells and streams and along the shores of overnight-storage reservoirs. Most of the saltcedars have grown from seed, probably carried into Pavant Valley by the Central Utah Canal; some seeds may have been windborne, and some plants have been imported for ornamental shrubbery. The fact that saltcedar plants have established themselves in all parts of the bottom lands, although very sparsely, is a serious threat to the entire bottom lands and to the stream channels tributary to the valley.

## SUMMARY

Although water levels in the Flowell and Meadow districts are declining at an apparently alarming rate, a serious depletion problem will probably not arise if the 1962 rate of pumpage is continued because the quantity of natural discharge is still large. As water levels decline, an increasing quantity of natural discharge will be intercepted by wells, thus the total ground-water discharge will be reduced. This condition will, in turn, cause a dimunition in the rate of water-level decline. Eventually, total ground-water discharge will equal recharge if withdrawal by wells does not exceed recharge; at this time average annual water levels will again be in equilibrium.

The Greenwood ground-water district is the only district in which more ground-water development is possible. The wells should have optimum spacing to minimize mutual interference and to intercept the maximum practical quantity of natural discharge, which would entail drilling several wells in the northern and western parts of the district. Further development of ground water equaling or exceeding total natural discharge from the district will cause the small flowing irrigation and stock wells in the western part of the district to cease flowing and will eventually intercept ground water now being discharged by evapotranspiration.

The Kanosh district is the only place where a quality-of-water problem is serious. The gradual increase in concentration of chemical constitutents in the ground water will continue as long as pumpage exceeds recharge. Salt concentration in the soil from the use of ground water will also continue to increase.

The concentration of boron is below the toxic limit for tolerant plants in all well waters for which boron was determined. It seems reasonable to assume that the toxic limit of boron is not exceeded in any of the ground waters now being used, and probably the toxic limit of boron is not exceeded in any of the ground water in Pavant Valley.

Consumptive waste of ground water by useless vegetation is not serious, but the spread of saltcedar into native meadow pastures with an attending increase in consumptive waste of ground water is very threatening. The saltcedar plants now present in the valley should be eradicated completely, at once, while the cost is relatively small and before they form dense thickets which make them nearly impossible to eradicate.

Ground water is being wasted from flowing wells each winter. Of the 6,000 acre-feet of water that flowed from wells during the winter 1959–60, more than 50 percent, and possibly as much as 80 percent, was wasted. Most of the waste could be eliminated by installation of better control devices. This would help alleviate the general decline of water levels in the valley.

There is no or little rejected recharge in Pavant Valley; thus, the amount of recharge cannot be increased by lowering water levels. However, some of the water that has flowed beyond the pumped areas will return and in effect act as additional recharge when water levels in the pumped areas decline sufficiently to reverse the hydraulic gradient in the natural discharge areas.

Ground-water withdrawal by wells in Pavant Valley increased from 23,000 acre-feet in 1950 to 67,000 acre-feet in 1960, and the number of pumped irrigation wells increased from 20 to 110 in the same length of time. Artesian pressures declined from about 5 feet in areas of small withdrawal to more than 35 feet in the Flowell district during the period 1950–60. Withdrawal in 1960 was only slightly less than the average annual recharge of 70,000 acre-feet. Natural discharge was about 45,000 acre-feet; thus, more than 40,000 acre-feet of ground water was taken from storage.

## REFERENCES CITED

Christiansen, F. W., 1951, A summary of the structure and stratigraphy of the Canyon Range, *in* Utah Geol. Soc. Guidebook to the geology of Utah: No. 6, p. 5–18.

Connor, J. G., and others, 1958, A compilation of chemical quality data for ground and surface waters in Utah: Utah State Engr. Tech. Pub. 10, 276 p.

Cox, LeRoy H., 1936, Cox decree adjudicating the Sevier River system: Fillmore, Utah, The Progress Printing Co., 232 p.

Crosthwait, E. G., and Scott, R. C., 1956, Ground water in the North Side Pumping Division Minidoka Project, Minidoka County, Idaho: U.S. Geol. Survey Circ. 371, 20 p.

Dennis, P. E., Maxey, G. B., and Thomas, H. E., 1946, Ground water in Pavant Valley, Millard County, Utah: Utah State Engr. Tech. Pub. 3, 96 p.

Fenneman, N. M., 1931, Physiography of western United States: New York, McGraw-Hill Book Co., 510 p.

Gilbert, G. K., 1890, Lake Bonneville: U.S. Geol. Survey Mon. 1, 438 p.

Livingston, Penn, and Maxey, G. B., 1944, Underground leakage from artesian wells in the Flowell area near Fillmore, Utah: Utah State Engr. Tech. Pub. 1, 37 p.

Maxey, G. B., 1946, Geology of part of the Pavant Range, Utah: Am. Jour. Sci., v. 224, p. 324–356.

——— 1911, Ground water in Juab, Millard, and Iron Counties, Utah: U.S. Geol. Survey Water-Supply Paper 277, p. 86–94.

Meinzer, O. E., 1923, Outline of ground-water hydrology, with definitions: U.S. Geol. Survey Water-Supply Paper 494, 71 p.

Mower, R. W., 1963, Selected hydrologic data, Pavant Valley, Millard County, Utah: U.S. Geol. Survey open-file rept. (duplicated as Utah Basic-Data Rept. No. 5), 20 p.

Mower, R. W., and Nace, R. L., 1957, Water consumption by water-loving plants in the Malad Valley, Oneida County, Idaho: U.S. Geol. Survey Water-Supply Paper 1412, 33 p.

Theis, C. V., 1935, The relation between the lowering of piezometric surface and the rate and duration of discharge of a well using ground-water storage: Am. Geophys. Union Trans., v. 16, pt. 2, p. 519–524.

U.S. Salinity Laboratory Staff, 1954, Diagnosis and improvement of saline and alkali soils: U.S. Dept. Agriculture Handb. 60, 160 p.

# INDEX

[Italic page numbers indicate major references]

U.S. GOVERNMENT PRINTING OFFICE: 1965 O—747-562


Hydrology by R. W. Mower

Base map from AMS
1:250,000 scale maps

## EXPLANATION

FLOWING WELLS
*(FLOWED AT LEAST DURING MARCH 1960)*

Irrigation

Domestic and stock

NONFLOWING WELLS

Irrigation or public supply

Domestic and stock

Test well

$\frac{1.9}{673}$

Upper figure is sodium-adsorption-ratio (SAR); lower figure is specific conductance (micromhos per cm at 25°C)

W, water-level measurement in basic data report (Mower, 1963 table 2)
L, driller's log of well in basic data report (Mower, 1963, table 3)
C, chemical analysis in basic data report (Mower, 1963, table 1)

Spring

Tick on well symbol indicates project observation well

Triangle enclosing well symbol indicates recording-gage record is available

Cross through well symbol indicates well has been plugged or water level has declined below bottom of well

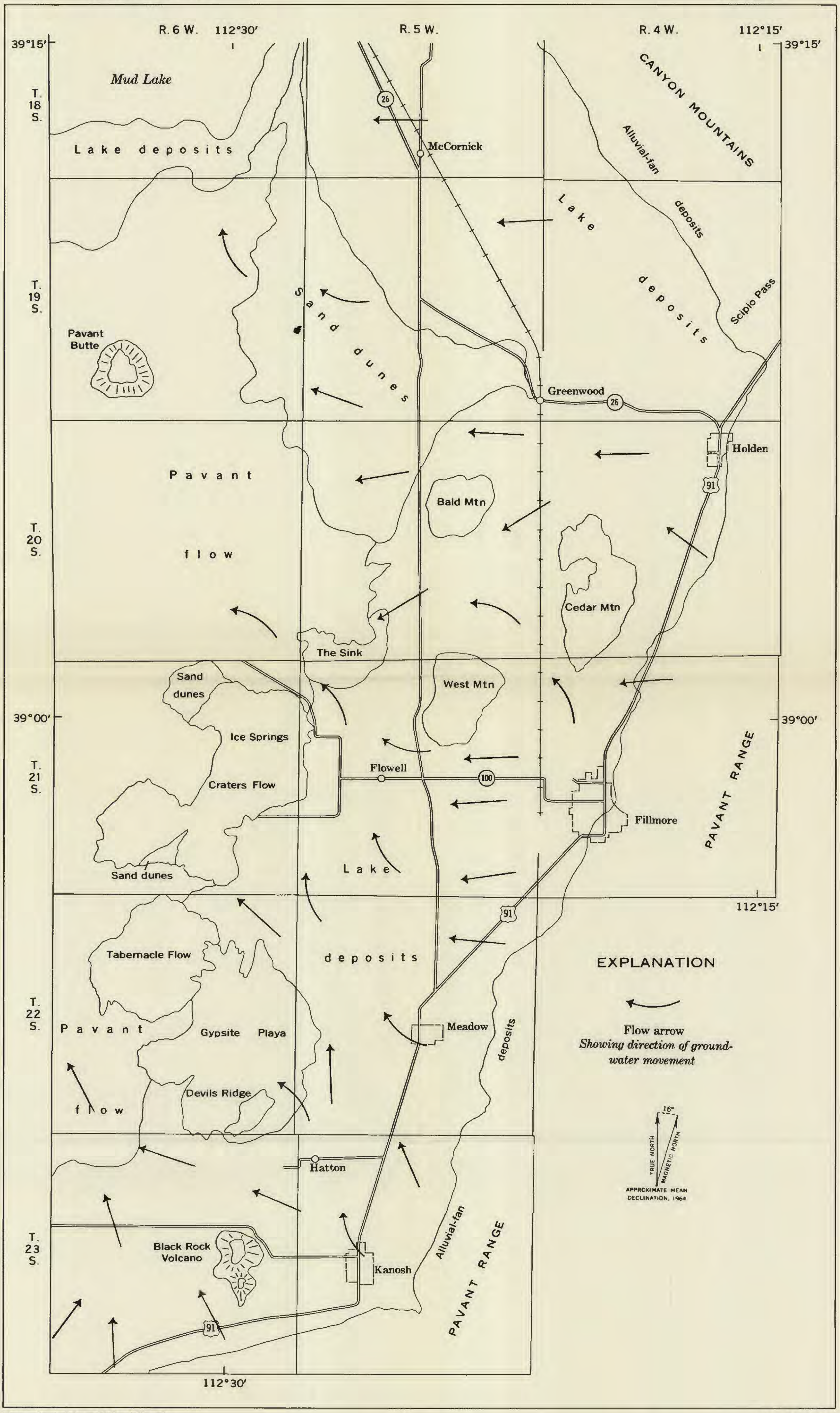
# MAP OF PAVANT VALLEY, UTAH, SHOWING LOCATION OF SELECTED WELLS AND HYDROGEOCHEMICAL DATA

SCALE 1:62 500

1 ½ 0 1 2 3 4 5 MILES

1 5 0 1 2 3 4 5 KILOMETERS

CONTOUR INTERVAL 200 FEET
WITH SUPPLEMENTARY CONTOURS AT 100 FOOT INTERVALS
DATUM IS MEAN SEA LEVEL




Base adapted from Millard County General Highway Map

By R. W. Mower

# GENERALIZED GEOLOGIC MAP OF PAVANT VALLEY, UTAH

1 0 1 2 3 4 5 MILES

747-562 O - 65 (In pocket) No. 2


# STRIP LOGS FROM DRILLERS' LOGS OF WELLS IN PAVANT VALLEY, UTAH

747-563 O - 65 (In pocket) No. 3

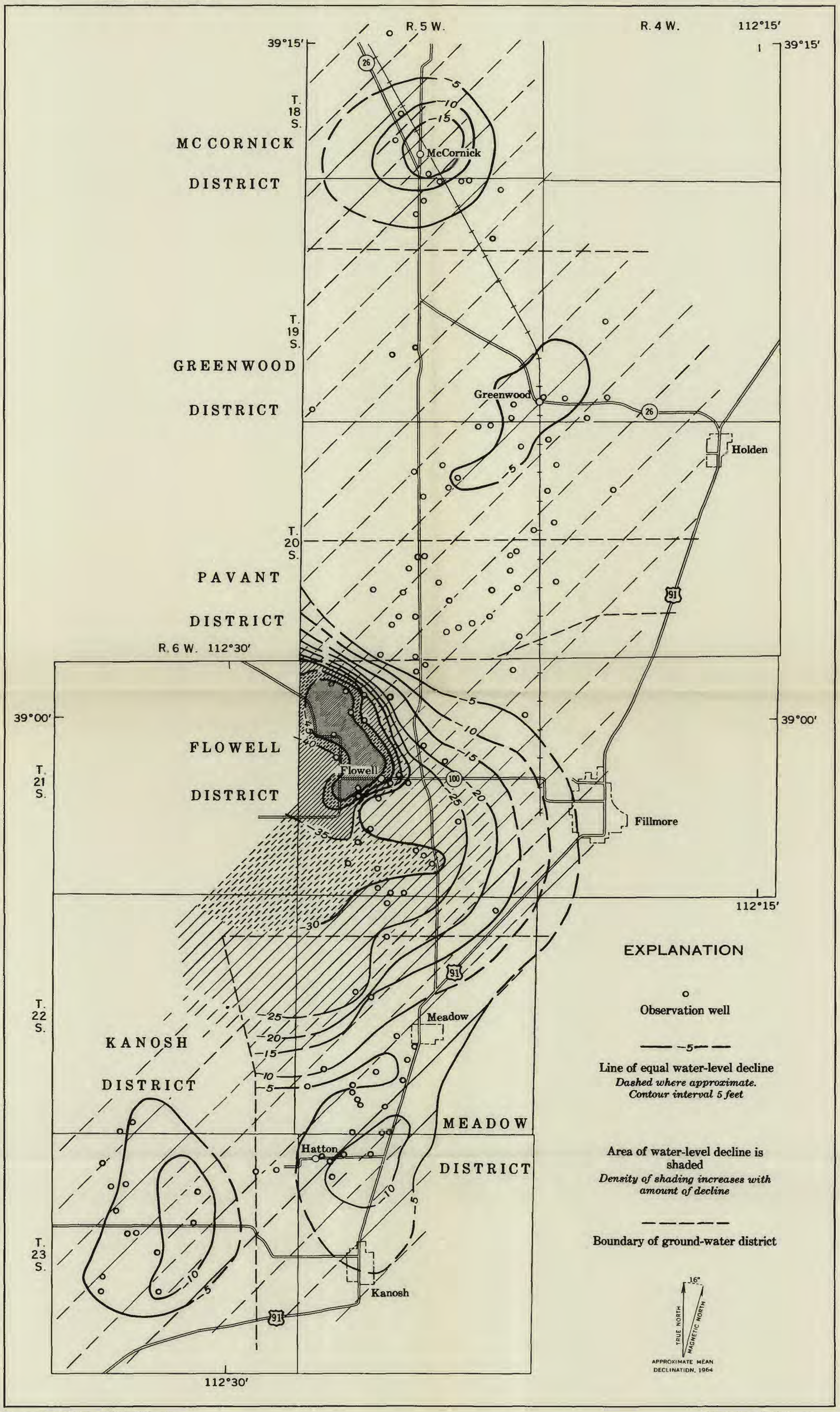

# MAP OF PAVANT VALLEY, UTAH, SHOWING GROUND-WATER CONTOURS, MARCH 1960

SCALE 1:62 500

1 ½ 0 1 2 3 4 5 MILES

1 .5 0 1 2 3 4 5 KILOMETERS

CONTOUR INTERVAL 200 FEET
WITH SUPPLEMENTARY CONTOURS AT 100 FOOT INTERVALS
DATUM IS MEAN SEA LEVEL



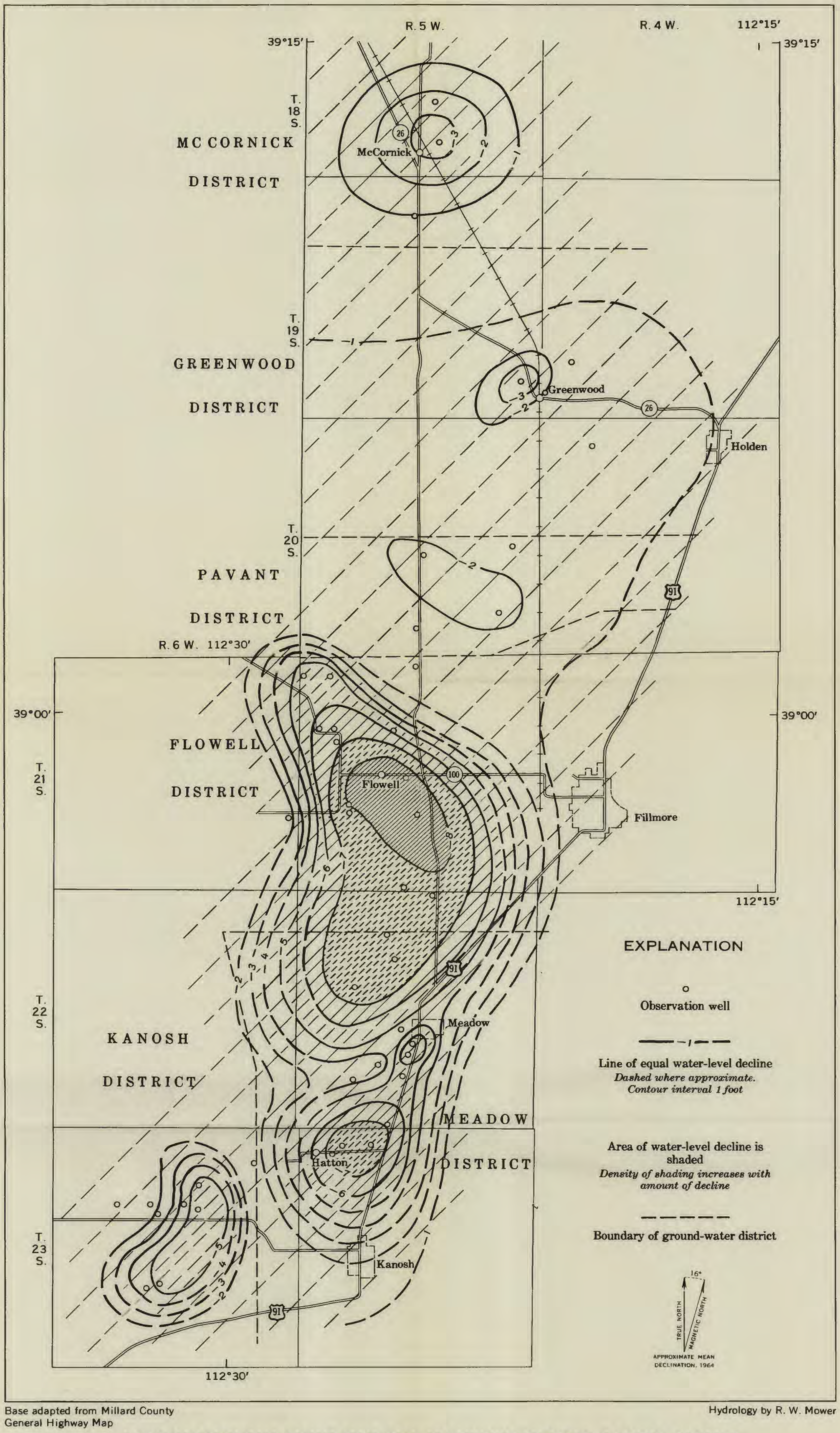

Base adapted from Millard County General Highway Map

Hydrology by R. W. Mower

# MAP SHOWING DECLINE OF GROUND-WATER LEVEL FROM MARCH TO SEPTEMBER 1960 IN PAVANT VALLEY, UTAH

1 0 1 2 3 4 5 MILES

747-562 O - 65 (In pocket) No. 5



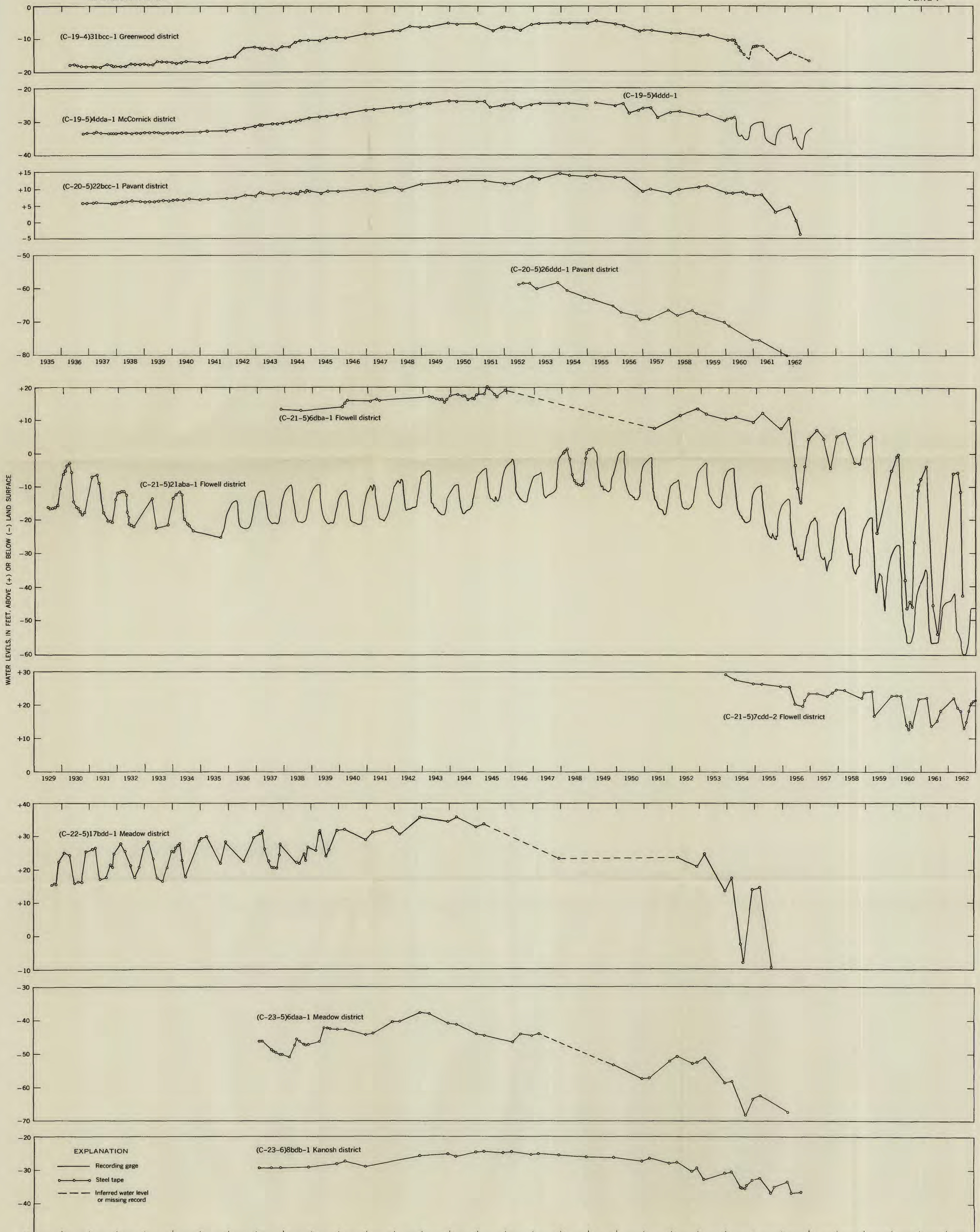

Base adapted from Millard County General Highway Map

Hydrology by R. W. Mower

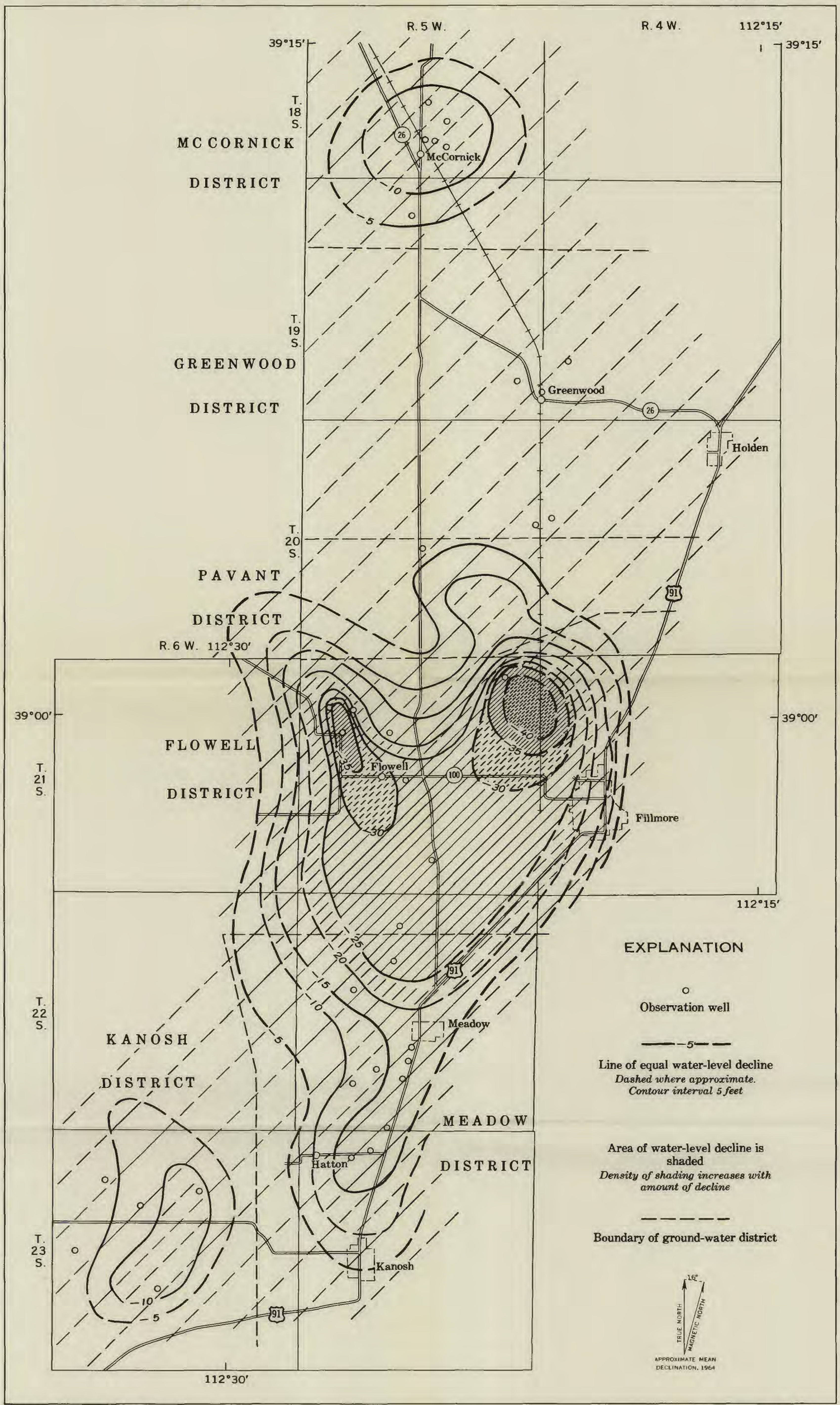
# MAP SHOWING DECLINE OF GROUND-WATER LEVEL FROM MARCH 1959 TO MARCH 1960 IN PAVANT VALLEY, UTAH

1 0 1 2 3 4 5 MILES

747-562 O - 65 (In pocket) No. 6




# HYDROGRAPHS OF SELECTED OBSERVATION WELLS IN PAVANT VALLEY, UTAH, 1929–62




Base adapted from Millard County General Highway Map

Hydrology by R. W. Mower

# MAP SHOWING DECLINE OF GROUND-WATER LEVEL FROM MARCH 1950 TO MARCH 1960 IN PAVANT VALLEY, UTAH

1 0 1 2 3 4 5 MILES

747-562 O - 65 (In pocket) No. 8


Base map from AMS
1:250,000 scale maps

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D. C.—1965—W64222

# MAP SHOWING AREAS OF ARTESIAN FLOW AND PHREATOPHYTE OCCUPATION DURING 1960 IN PAVANT VALLEY, UTAH

SCALE 1:62 500

1 ½ 0 1 2 3 4 5 MILES

1 .5 0 1 2 3 4 5 KILOMETERS

CONTOUR INTERVAL 200 FEET
WITH SUPPLEMENTARY CONTOURS AT 100 FOOT INTERVALS
DATUM IS MEAN SEA LEVEL

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

WATER-SUPPLY PAPER 1794
PLATE 10


Base map from AMS
1:250,000 scale maps

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D. C.—1965—W64222

# MAP SHOWING LAND IRRIGATED DURING 1960 IN PAVANT VALLEY, UTAH

SCALE 1:62 500

1 ½ 0 1 2 3 4 5 MILES

1 .5 0 1 2 3 4 5 KILOMETERS

CONTOUR INTERVAL 200 FEET
WITH SUPPLEMENTARY CONTOURS AT 100 FOOT INTERVALS
DATUM IS MEAN SEA LEVEL