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GROUND-WATER CONDITIONS IN SOUTHERN UTAH VALLEY AND GOSHEN VALLEY, UTAH

by

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ABSTRACT

Southern Utah Valley and Goshen Valley are in the southern part of Utah Lake Valley, which is in the Great Basin physiographic province. Unconsolidated deposits fill the valleys to generally unknown depths and include four main aquifers—a water-table aquifer and three artesian aquifers. The water needs of southern Utah Valley and Goshen Valley are supplied mainly by (1) streams and springs in the Wasatch Range and other bordering mountains, (2) imported surface water from the Colorado River Basin and Juab Valley, and (3) wells, drains, and springs in the valley fill.

Recharge to the ground-water reservoir underlying the two valleys is by (1) seepage from waterways and irrigated land, (2) infiltration of precipitation, and (3) subsurface inflow from the bordering mountains. The estimated minimum recharge in 1966 was 150,000 acre-feet. This estimate is a minimum because neither seepage from ephemeral and intermittent streams nor subsurface inflow could be determined. Both items are therefore excluded from the estimate, but either could be of significant magnitude.

Discharge from the ground-water reservoir is by (1) drains and springs, (2) wells, (3) seepage into waterways, (4) evapotranspiration, (5) infiltration into municipal sewer systems, and (6) discharge into Utah Lake. The estimated minimum discharge in 1966 was 220,000 acre-feet, of which about 29,000 acre-feet was withdrawn from storage in the aquifer. The estimate is a minimum because the amount of discharge into Utah Lake could not be completely determined, but the undetermined discharge is considered to be small.

The estimated discharge, after adjusting for the change in storage, exceeds the estimated recharge by 41,000 acre-feet. This discrepency probably is due to excluding from the recharge estimate the two items of subsurface inflow and seepage from ephemeral and intermittent streams; it is believed the amount of recharge from these two sources is large enough to account for the discrepency.

Water-level records indicate that long-term discharge and recharge probably are in equilibrium in southern Utah Valley. Water-level records from Goshen Valley show that annual discharge exceeds annual recharge, and water is being withdrawn from storage in the aquifer.

The maximum practicable withdrawal of ground water through wells in southern Utah Valley without mining of ground water is estimated to be 80,000 acre-feet per year. Withdrawal of 80,000 acre-feet per year through wells, however, would lower water levels and would diminish the amount of natural discharge.

The amount of recoverable water in storage in the upper 400 feet of saturated valley fill is estimated to be 3 million acre-feet in southern Utah Valley and 3 million acre-feet in Goshen Valley.

The importation of additional surface water into southern Utah Valley and Goshen Valley and the salvage of water now lost to evapotranspiration by the Central Utah Project will increase the amount of recharge to the ground-water reservoir by about 25 percent of the amount imported and salvaged.

Artesian conditions occur in most of southern Utah Valley, but only locally in Goshen Valley. Effects of the pumping of artesian wells spread rapidly and contribute to a general lowering of water levels, and pumping from wells that tap one aquifer may cause a lowering of water levels in a different aquifer.

The development of the ground-water reservoir by wells began at least as early as 1879 in southern Utah Valley and 1886 in Goshen Valley. By the end of 1966 there were about 1,600 wells in southern Utah Valley and about 80 in Goshen Valley. Most wells are used for stock or combined domestic, irrigation, and stock purposes; are less than 200 feet deep; are 8 inches or less in diameter; and flowed when drilled.

Yields of wells in southern Utah Valley and Goshen Valley range from less than 1 to 4,100 gpm (gallons per minute). The average yield of wells with diameters of 8 inches or less, based on well-drillers' records, is about 40 gpm in southern Utah Valley and 16 gpm in Goshen Valley. Excluding uncommonly high yields, the average is 20 and 10 gpm, respectively. The average yield of wells with diameters exceeding 8 inches, based on well-drillers' records, is about 1,200 gpm in southern Utah Valley and 1,500 gpm in Goshen Valley. Most of the large-diameter wells are in the highlands where the average yield of wells is greater than that from wells of similar size in the lake plain.

The dissolved-solids concentration of ground water in southern Utah Valley generally decreases with depth. The average concentration of dissolved solids is greater in ground water in Goshen Valley than in southern Utah Valley. Ground water in southern Utah Valley is generally of the bicarbonate type. In the northwestern and eastern parts of Goshen Valley the ground water is of the chloride type, but in the southwestern part of the valley, it is of the bicarbonate type. Most ground water in southern Utah Valley contains less than 500 mg/l (milligrams per liter) of dissolved solids, but in Goshen Valley most of the ground water contains more than 500 mg/l. The ground water in southern Utah Valley is generally suitable for irrigation without special management practices; but in Goshen Valley special management practices may be required for most of the water.

Important factors that should be considered in managing the ground-water reservoir include increased withdrawal of water from wells, wastage of water from flowing wells, saltcedar infestation, sewage disposal, and the Central Utah Project.

INTRODUCTION

Location of the area

Southern Utah Valley and Goshen Valley together form the southern part of most of the land area around Utah Lake, in Utah Lake Valley, Utah County, Utah (fig. 1). Utah Lake Valley is in north-central Utah on the eastern side of the Great Basin physiographic province.

The area investigated covers approximately 400 square miles and includes southern Utah Valley, Goshen Valley, West Mountain, and the southern part of Utah Lake. (See fig. 1.) The area is arbitrarily bounded on the north by an east-west line through the middle of T. 7 S., and is naturally bounded by the Wasatch Range on the east and south, by Long Ridge on the south, and by the East Tintic Mountains, Selma Hills, Mosida Hills, and the southern tip of the Lake Mountains on the west. Goshen Valley is separated from southern Utah Valley by West Mountain, the northern tip of Long Ridge, and Utah Lake.

The ground-water investigation was devoted mainly to the valleys, but data were collected in the bordering mountains if they had a direct bearing on ground-water conditions in the valleys.

Purpose and Scope of Investigation

The investigation of ground-water conditions in southern Utah Valley and Goshen Valley, Utah, was made by the U. S. Geological Survey as part of a cooperative program with the Utah Department of Natural Resources, Division of Water Rights, to investigate the water resources of the State. The purposes of the investigation were to (1) determine the occurrence, recharge, discharge, movement, storage, chemical quality, and availability of ground water; (2) appraise the effects of increased withdrawal of water from wells; and (3) evaluate the effect of the Central Utah Project on the ground-water reservoir and the water supply of Utah Lake.

This report presents a description of the aquifer system in the two valleys, a detailed description of the ground-water resources, and conclusions about potential development and its effect on the hydrologic conditions in the valleys. Two supplementary reports are products of the investigation. A basic-data release (Cordova, 1969) contains most of the basic data collected for the investigation, including well characteristics, drillers' logs, water levels, pumpage from wells, chemical analyses of ground and surface waters, and discharge of selected springs, drains, and streams. An interpretive report (Cordova and Mower, 1967) contains the results of a large-scale aquifer test in southern Utah Valley.

History and methods of investigation

The investigation was started in July 1964 by C. H. Carpenter and R. M. Cordova. Mr. Carpenter left the investigation in July 1965 and was replaced by J. D. Gillespie in February 1966. Mr. Gillespie left the investigation in May 1967. E. L. Bolke and G. E. Pyper assisted in the field during the summer and fall of 1967. Fieldwork for the investigations was completed in December 1967.

Much of the effort of the investigation was expended in the following ways: (1) inventorying about 800 wells, including all the large-discharge pumped wells (discharges

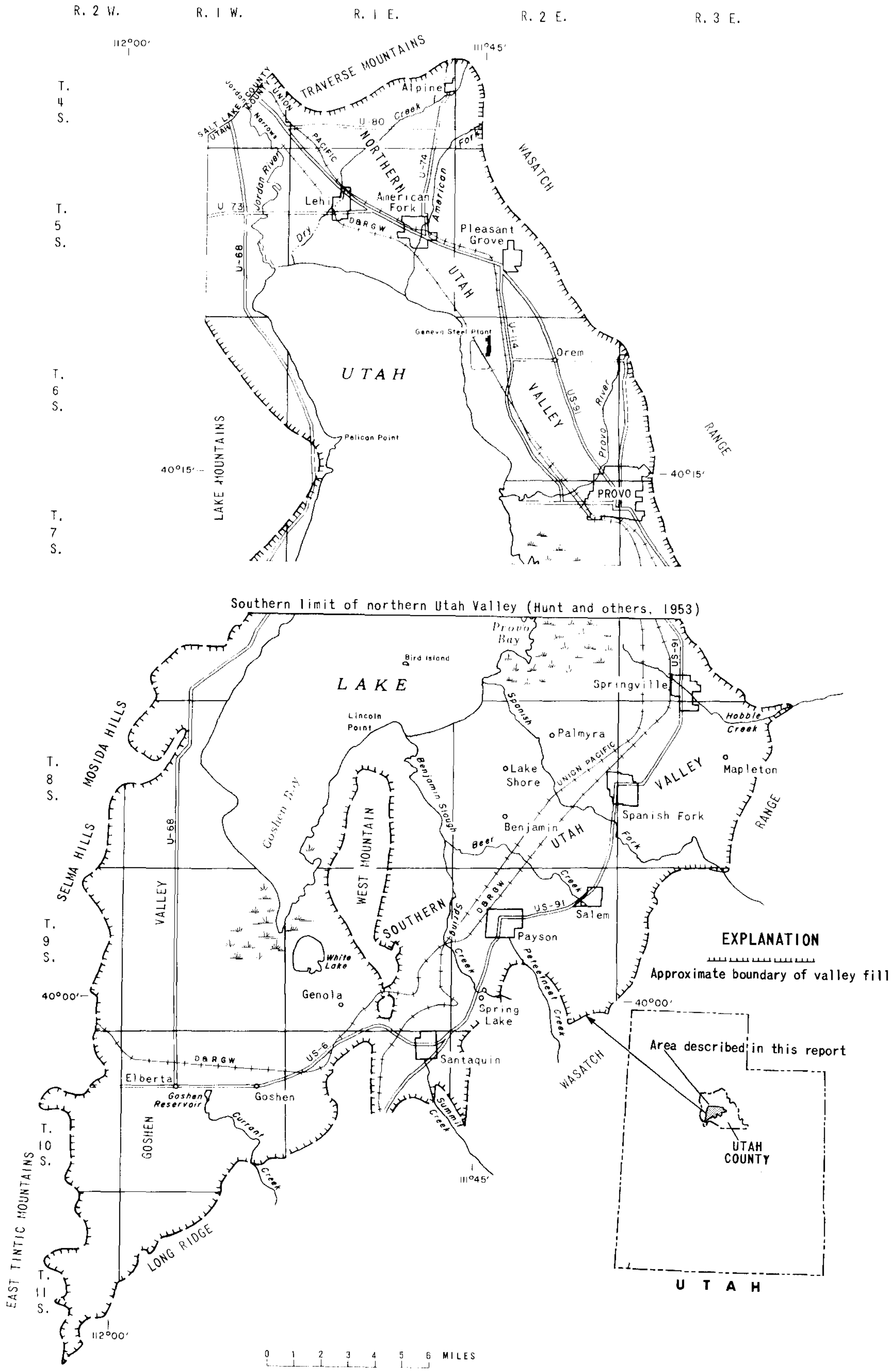


Figure 1.—Map of Utah Lake Valley showing location and extent of northern Utah Valley, southern Utah Valley, and Goshen Valley.

exceeding 200 gallons per minute); (2) measuring the discharge of the large-discharge pumped wells several times; (3) measuring water levels periodically in 60 wells and maintaining recording gages on 4 of these wells; (4) measuring the discharge of all the major springs several times and of many minor ones at least once; (5) making three seepage runs on the major natural and manmade waterways; (6) making a field reconnaissance of areas of phreatophytes with the aid of aerial photographs; (7) comparing about 400 chemical analyses of water from wells, springs, drains, and streams; (8) analyzing records of municipal water use and sewage effluent to determine ground-water infiltration; (9) making a geologic reconnaissance of areas of discharge, areas of probable intervalley subsurface flow, and areas of probable recharge.

Aquifer characteristics were determined from (1) 28 recovery tests, (2) 4 local interference tests using a discharging well and from 1 to 5 observation wells in each test, and (3) a large-scale interference test using 5 pumped wells and 74 observation wells.

A total of 92 gamma-ray logs were obtained in wells to help in identification of the aquifers in the ground-water reservoir. Gamma-ray logs of 4 wells in northern Utah Valley, of 26 wells in southern Utah Valley, and of 6 wells in Goshen Valley along with 3 descriptive logs by well drillers were used to construct 8 geologic sections (figs. 4-11). Gamma-ray logs were used to correlate aquifers in northern Utah Valley (Hunt, Varnes, and Thomas, 1953) with those in southern Utah Valley.

In order to facilitate discussion of ground-water conditions in the various parts of southern Utah Valley and Goshen Valley, each valley was divided, largely on the basis of physiographic expression, into a highlands unit and a lake plain unit.

Previous investigations

The geology of the surficial unconsolidated rocks (valley fill) in southern Utah Valley and Goshen Valley was studied in detail by H. J. Bissell (1963). Studies of the consolidated rocks in the drainage area tributary to the valleys are reported in numerous publications, among which are those by Lindgren and Loughlin (1919) and Hintze (1962). The latter is a useful reference to the geology of the Wasatch Range and nearby mountains and contains a fairly complete bibliography of geological publications on the same area. Geophysical studies were made by Cook and Berg (1961) and Mabey and others (1964).

Richardson (1906) made a general descriptive study of the occurrence and development of ground water in Utah Lake Valley. Since 1935 the U. S. Geological Survey in cooperation with the Utah State Engineer has measured water levels periodically in observation wells in the valley. During the period 1938-40 the Utah State Engineer (1940) made diversion-and-use surveys in Utah County to determine the quantity of water discharged from wells according to type of use. The geology and water resources of northern Utah Valley were studied in some detail by Hunt, Varnes, and Thomas (1953).

Physiography

Terminology

Southern Utah Valley and Goshen Valley are parts of a larger area that is called Utah Lake Valley (Richardson, 1906). Also included in Utah Lake Valley is Utah Lake and an area called northern Utah Valley, which is the northern continuation of southern Utah Valley and Goshen Valley. The boundary separating northern Utah Valley from southern Utah Valley and

Goshen Valley is an arbitrary line through the middle of T. 7 S. This line was chosen by Hunt (*in* Hunt, Varnes, and Thomas, 1953), who studied the valley fill in the northern part of Utah Lake Valley. Bissell (1963), who studied the valley fill of the southern part of Utah Lake Valley, called the area (including Goshen Valley) southern Utah Valley. For purposes of this investigation, the name "southern Utah Valley" is confined to the part of Utah Lake Valley that is south of Hunt's northern Utah Valley but east of West Mountain and Long Ridge. The name "Goshen Valley" is used for that part of Utah Lake Valley west of West Mountain.

The valley floor

The floors of southern Utah Valley and Goshen Valley consist of sediments deposited in ancient Lake Bonneville, in modern Utah Lake, and in alluvial fans and stream channels. Currents in Lake Bonneville reworked and redeposited the material that streams carried into the lake. The present valley floors have spits, bars, deltas, and other deposits formed in Lake Bonneville, and these deposits cover most of the valley floors up to an altitude of 5,135 feet. Above this altitude are ancient alluvial fans, recent alluvial fans, and stream-channel deposits. The ancient alluvial fans locally are covered by younger alluvial fans and recent stream-channel deposits. Below an altitude of 5,135 feet the Lake Bonneville deposits locally are covered by alluvial fans and recent deposits of Utah Lake and streams.

The floors of the valleys can be divided into two main physiographic units—the highlands and the lake plain (pl.1). The highlands comprise the deltas of Spanish Fork and Currant Creek and the alluvial fans that extend from the mountains. The lake plain extends from the shoreline of Utah Lake, which is at an altitude of about 4,490 feet, to the highlands. The boundary between the highlands and the lake plain is generally not sharp except at the deltas of Spanish Fork and Currant Creek. The boundary for purposes of this report is placed at the 4,600-foot contour in southern Utah Valley and at the 4,520-foot contour in Goshen Valley, the altitudes below which most wells flow. The lake plain has gradients of less than 15 feet per mile, and the highlands have gradients of 15 feet to several hundred feet per mile.

Surface streams

Surface water flows into southern Utah Valley and Goshen Valley in several perennial streams and in numerous ephemeral and intermittent streams. The three main perennial streams are Spanish Fork, Hobble Creek, and Currant Creek (pl. 1), and their average annual inflow is as follows:

	Average annual flow (acre-ft)	Length of record (years)
Spanish Fork at Castilla	152,800	42
Hobble Creek, 1½ miles upstream from mouth of canyon	34,900	33
Currant Creek, 3 miles upstream from mouth of canyon	15,780	7

Spanish Fork at Castilla receives about 60 percent of its flow from approximately 670 square miles in the Wasatch Range and about 40 percent by transmountain diversion from the Colorado River Basin. An estimated 40 percent, or 60,000 acre-feet, of the average annual flow in

Spanish Fork reaches Utah Lake in the natural channel, and an unknown amount reaches the lake in drains. Most of the streamflow entering the lake during the irrigation season is unconsumed overland flow from irrigation because practically all the inflow to the valley is diverted during the irrigation season and most of the water in the lower reaches of the stream channels enters them where they cross the lake plain. Part of the diverted water is conducted into the drainage areas of Benjamin Slough and White Lake, where some is consumed, some infiltrates to the water table, and the rest flows to Utah Lake. During the nonirrigation season most of the water in Spanish Fork flows directly to Utah Lake. Part of the flow into the lake includes ground-water seepage and runoff from precipitation on the valley floor.

Hobble Creek drains 105 square miles in the Wasatch Range. An estimated 30-50 percent of the average annual inflow in Hobble Creek reaches Utah Lake in the stream channel and an unknown amount reaches the lake in drains. Most of the streamflow entering the lake during the irrigation season is unconsumed overland flow from irrigation because practically all the inflow is diverted for irrigation. During the nonirrigation season most of the inflow goes directly to Utah Lake. Part of the flow into the lake includes ground-water seepage and runoff from precipitation on the valley floor.

Currant Creek carries water from northern Juab Valley into Goshen Valley, where the water is diverted or is dissipated in the marshy area south of Utah Lake. Some of the water eventually reaches Utah Lake as return flow from irrigation, together with runoff from precipitation on the valley floor and ground-water seepage.

Much of southern Utah Valley and Goshen Valley drains to Utah Lake through sloughs and manmade drains. Benjamin Slough and its tributaries drain most of the area south and west of the Spanish Fork channel in southern Utah Valley. Most of the water in Benjamin Slough originates as ground-water seepage and as unconsumed overland flow from irrigation; some of the flow is contributed by small perennial streams draining the Wasatch Range and by sewage effluent from Salem and Payson. Based on a 12-year intermittent record collected from 1937 to 1966, the average annual discharge of Benjamin Slough measured at stations 2½-3 miles upstream from Utah Lake is 16,000 acre-feet.

Many miles of closed and open drains empty water directly into Utah Lake or into natural waterways which drain to Utah Lake. These drains make farming possible in the lower parts of the lake plain, where waterlogging formerly was a major problem.

Utah Lake

Utah Lake receives its water supply from natural streams and manmade drains, ground water that enters the lake through the bottom sediments in springs or as diffuse seepage, and precipitation on the surface of the lake.

Utah Lake has an area of about 150 square miles where the lake level is a compromise level (the legal level at which water can be held in the lake without liability action by landowners on the lakeshore); compromise level is about 4,489 feet above mean sea level. The deepest point in the lake below the compromise level is about 13 feet. The capacity of the lake at the compromise level is 898,000 acre-feet of water according to capacity tables prepared in 1963 by the U. S. Bureau of Reclamation.

The lake has been operated as a reservoir since 1884 when the first dam was built on the Jordan River (Hunt, Varnes, and Thomas, 1953, p. 69), and water entering the lake is stored for use in the Jordan Valley to the north. Water from the lake leaves Utah Lake Valley in the Jordan River, which flows northward through a gap in the Traverse Mountains into the Jordan Valley. At low lake stages it is necessary to lift the water by pump from the lake into the Jordan River channel.

Evaporation from the lake surface is high because the lake is so broad and shallow (Hunt, Varnes, and Thomas, 1953, p. 71). The computed amount of annual evaporation from Utah Lake is generally significantly larger than the amount of water annually diverted by man for beneficial use (Hunt, Varnes, and Thomas, 1953, table 21). Gardner (1967, p. 27 and 29) reported that in the dry year 1961, the evaporation amounted to about 264,700 acre-feet of water compared to the annual outflow of about 112,100 acre-feet; in the wet year 1965, the evaporation amounted to 275,300 acre-feet and the outflow to about 191,200 acre-feet. The average annual evaporation for the period 1914-66 was more than 300,000 acre-feet. In addition to the large loss of water by evaporation a significant loss probably occurs by transpiration by water-loving vegetation which inhabits much of the marginal area of the lake.

The Central Utah Project

The Central Utah Project is part of the Colorado River Storage Project, which was authorized by Congress in 1956 to provide maximum beneficial use of the waters of the Colorado River. The Central Utah Project, which is directed by the U. S. Bureau of Reclamation, is designed to divert most of Utah's remaining undeveloped share of Colorado River water to those parts of the State where it is most needed. The initial phase of the Central Utah Project includes four units, the largest and most complex of which is the Bonneville Unit. The construction phase of that unit began in 1967 and was expected to be completed in 10 years. As part of plans for operation of the Bonneville Unit, it is proposed that 45,500 acre-feet of water will be brought into Utah Lake Valley annually and 39,200 acre-feet of additional water will be developed annually for beneficial use in Utah Lake Valley (U. S. Bur. Reclamation, oral commun., 1969). The additional water is to be developed largely by salvaging water lost by evaporation from Utah Lake and transpiration by phreatophytes growing at the lakeshore. This salvage is to be accomplished mostly by separating Provo and Goshen Bays from Utah Lake with dikes, thus reducing the area of the lake by about one-third. The general effects of the Central Utah Project on ground-water conditions in southern Utah and Goshen Valleys are discussed in the last section of this report.

Acknowledgments

Special acknowledgment is due to personnel of the U. S. Bureau of Reclamation, who greatly facilitated the investigation and were cooperative in furnishing information and in the discussion of problems. They provided most of the chemical analyses and much of the water-level data used in the preparation of this report.

Thanks are due to all the residents of southern Utah Valley and Goshen Valley who allowed their springs and wells to be studied and who otherwise contributed information useful to the investigation.

Well- and spring-numbering system

The system of numbering wells and springs in Utah is based on the cadastral land-survey system of the U. S. Government. The number, in addition to designating the well or spring, locates its position to the nearest 10-acre tract in the land net. By this system, the State is divided into four quadrants by the Salt Lake Base Line and Meridian, and these quadrants are designated by the uppercase letters A, B, C, and D, thus: A, for the northeast quadrant; B, for the northwest; C, for the southwest; and D, for the southeast quadrant. Numbers designating the township and range, respectively, follow the quadrant letter, and the three are enclosed in parentheses. The number after the parentheses designates the section, and the lowercase letters give the location 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. The serial number that follows the letters indicates the number of the well or spring within the 10-acre tract. Thus, well (D-8-2)24bdd-1, in southern Utah County, is in the SE¼SE¼NW¼ sec. 24, T. 8 S., R. 2 E., and is the first well constructed or visited in that tract. (See fig. 2,) springs are identified by the letter "S" preceding the serial number. The numbering system is used without serial numbers in this report to designate locations of surface-water and other data-collection sites.

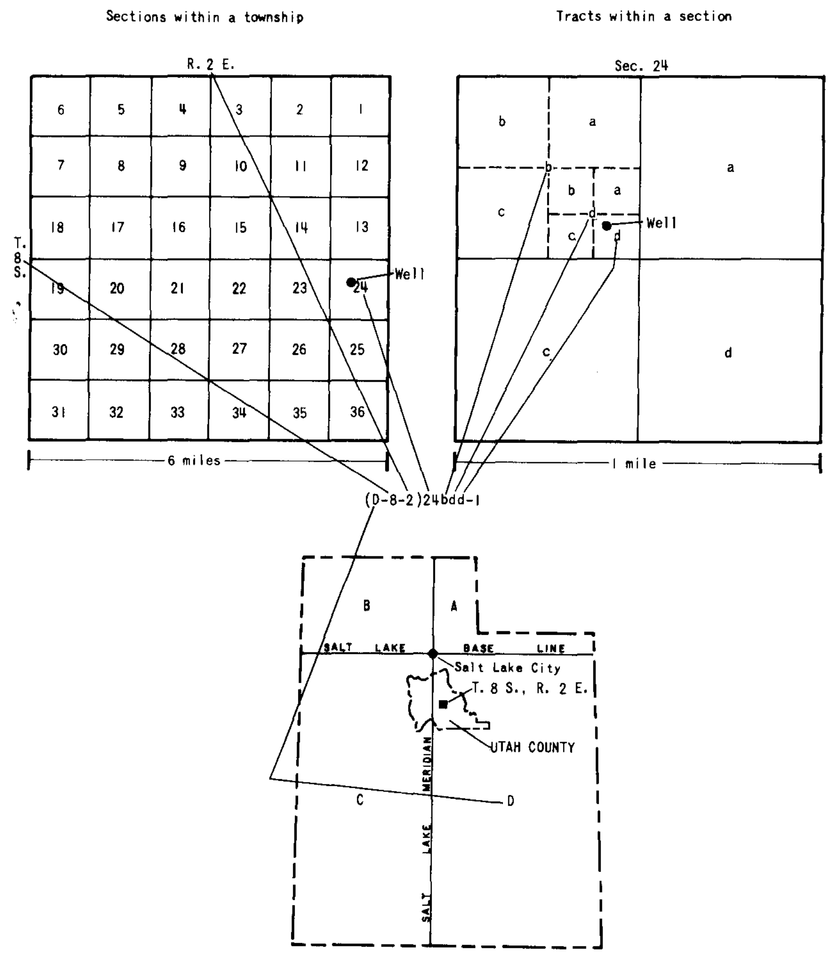


Figure 2.—Well- and spring-numbering system used in Utah.

Use of metric units

In this report, the units which indicate concentrations of dissolved solids and individual ions determined by chemical analysis and the temperatures are metric units. This change from reporting in "English units" has been made as a part of a gradual change to the metric system that is underway within the scientific community. The change is intended to promote greater uniformity in reporting of data. Chemical data for concentrations are reported in milligrams per liter (mg/l) rather than in parts per million (ppm), the units used in earlier reports in this series. For concentrations less than 7,000 mg/l, the number reported is about the same as for concentrations in parts per million.

Water temperature is reported in degrees Celsius (centigrade of °C), but the customary English unit of degrees Fahrenheit (°F) follows in parentheses in the text. The reporting of temperatures in both metric and English units is done to assist those readers who are not familiar with the Celsius temperature scale. The following conversion table will also help to clarify the relation between degrees Fahrenheit and degrees Celsius:

TEMPERATURE-CONVERSION TABLE

For conversion of temperature in degrees Celsius (°C) to degrees Fahrenheit (°F). Conversions are based on the equation, °F = 1.8°C + 32; Temperatures in °F are rounded to nearest degree. Underscored equivalent temperatures are exact equivalents. For temperature conversions beyond the limits of the table, use the equation given, and for converting from °F to °C, use °C = 0.5556 (°F - 32). The equations say, in effect, that from the freezing point (0°C, 32°F) the temperature rises (or falls) 5°C for every rise (or fall) of 9°F.

°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F
-20	-4	-10	14	0	32	10	50	20	68	30	86	40	104
-19	-2	-9	16	+1	34	11	52	21	70	31	88	41	106
-18	0	-8	18	2	36	12	54	22	72	32	90	42	108
-17	+1	-7	19	3	37	13	55	23	73	33	91	43	109
-16	3	-6	21	4	39	14	57	24	75	34	93	44	111
-15	5	-5	23	5	41	15	59	25	77	35	95	45	113
-14	7	-4	25	6	43	16	61	26	79	36	97	46	115
-13	9	-3	27	7	45	17	63	27	81	37	99	47	117
-12	10	-2	28	8	46	18	64	28	82	38	100	48	118
-11	12	-1	30	9	48	19	66	29	84	39	102	49	120

GEOLOGY OF THE GROUND-WATER RESERVOIR

General features

Southern Utah Valley

The ground-water reservoir in southern Utah Valley consists of an undetermined thickness of valley fill. The valley is a structural valley that was formed as a block of the earth's crust dropped between faults. The Wasatch fault zone, which bounds the eastern and part of the southern sides of the structural valley, is traceable on the surface by visible displacement of the rocks. A concealed fault zone, which bounds the western side of the structural valley, is indicated by a gravity survey (Cook and Berg, 1961, p. 82) of the subsurface and the presence of thermal springs at the surface. The fault zone extends from near Santaquin northward paralleling the east side of West Mountain.

The valley fill was derived by weathering of the bordering mountains during Tertiary and Quaternary time. The fill consists generally of coarse-grained fan deposits and fine-grained lake deposits, and the amount of coarse-grained material in relation to the amount of fine-grained material is a rough indication of the water-yielding ability of the fill. The amount of coarse-grained material, in terms of gravel and coarser materials, was determined as a percentage of borehole material recorded in drillers' logs to a depth of 400 feet. The percentages are plotted in figure 3 to show the distribution of gravel and coarser materials according to several percentage categories.

In most of southern Utah Valley, the upper 400 feet of valley fill contains 25 percent or less of gravel and coarser materials. Gravel and coarser materials exceed 25 percent in the northeastern and southern parts of the valley and in a narrow area extending from the mouth of Spanish Fork Canyon to Lake Shore. This distribution indicates that Hobble, Peteetneet, and Summit Creeks were major contributors of coarse-grained materials to the valley, but that Spanish Fork did not contribute large quantities of these coarser materials during the time when the upper 400 feet of deposits were laid down.

The range in thickness of the valley fill is unknown because the maximum thickness is not known. The deepest well in the valley, (D-8-3)19bbb-1, which was drilled to a depth of 1,003 feet, bottomed in unconsolidated deposits, but rocks of Paleozoic and Tertiary age crop out near Benjamin Cemetery (sec. 32, T. 8 S., R. 2 E.) and Payson Station (sec. 7, T. 9 S., R. 2 E.) (Bissell, 1963, pl. 5), indicating that the valley fill does have a considerable range in thickness.

Goshen Valley

The ground-water reservoir in Goshen Valley is formed by a considerable thickness of valley fill which was derived from the bordering mountains, as a result of weathering, during Tertiary and Quaternary time. The valley is not known to be a structural valley bounded by faults, but faulting is evidenced along parts of the west sides of Long Ridge and West Mountain by faceted spurs, warm mineralized springs, and fault breccia. The fill consists generally of coarse-grained fan material and fine-grained lake deposits. In most of the western half of Goshen Valley the upper 400 feet of fill contains more than 50 percent of gravel and coarser materials. (See fig. 4.) Most of the eastern half of the valley contains only shallow wells, and the percentage of gravel in the fill is unknown.

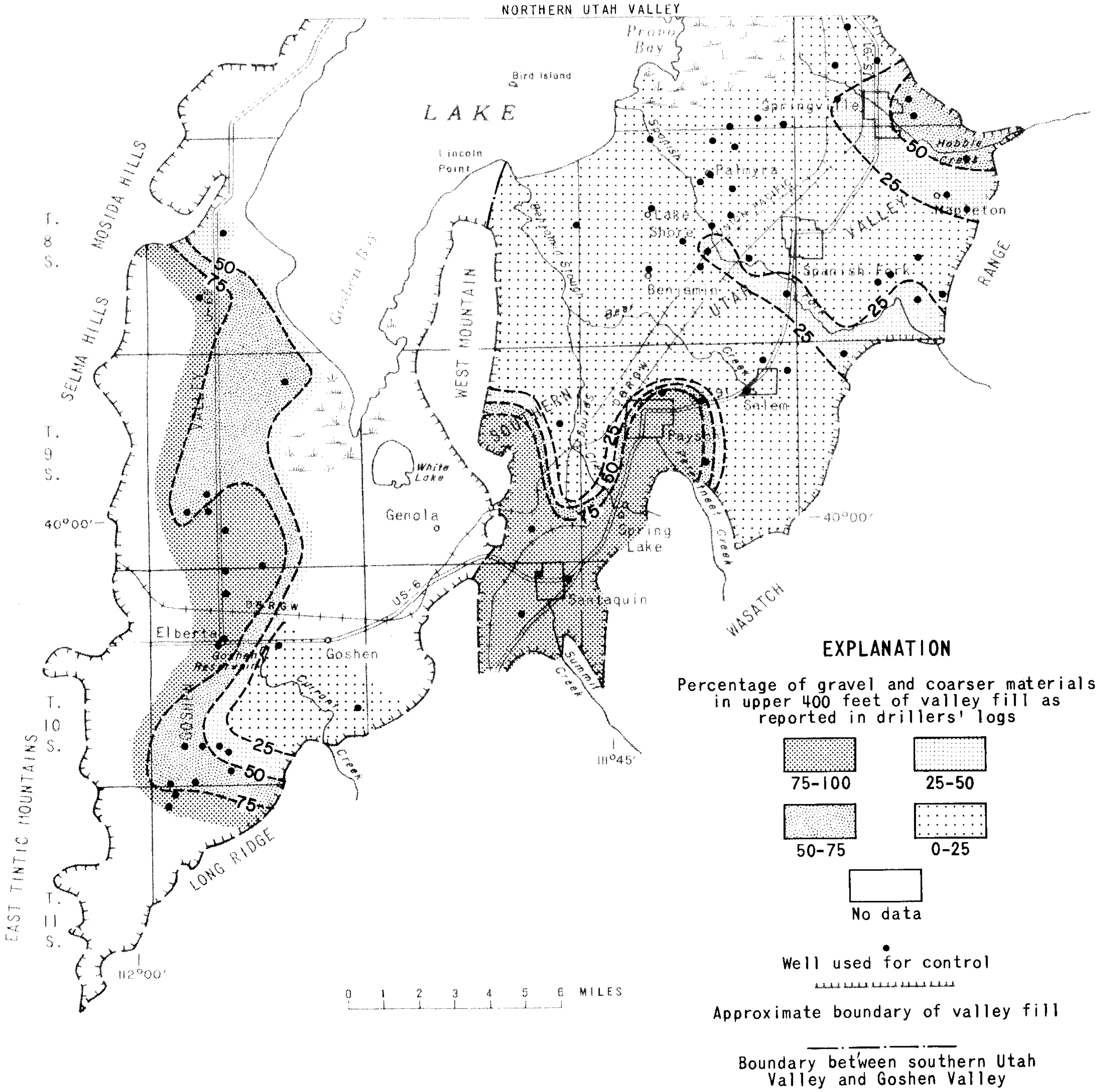


Figure 3.—Map of southern Utah Valley and Goshen Valley showing distribution by percentage of gravel and coarser materials in the upper 400 feet of valley fill.

Few wells in Goshen Valley have reached the base of the valley fill. In the northern part of the valley, however, three wells were drilled into limestone and shale of probable Paleozoic age. Well (C-8-1)16cbb-1, at an altitude of about 4,545 feet, reached the base of the valley fill at a depth of 300 feet; well (C-8-1)29bdc-1, at an altitude of about 4,635 feet, reached the base of the fill at a depth of 350 feet; and well (D-8-1)20cdb-2, at an altitude of 4,620 feet, reached the base of the fill at 227 feet. Deep wells elsewhere in the valley which did not reach the base of the fill are well (C-9-1)4ddc-1, at an altitude of 4,570 feet and with a depth of 690 feet; well (C-10-1)4cbb-1, at an altitude of 4,680 feet and with a depth of 1,218 feet; and well (C-10-1)29cdd-1, at an altitude of 4,680 feet and with a depth of 862 feet.

Aquifers in southern Utah Valley and Goshen Valley

Hunt, Varnes, and Thomas (1953) described four main aquifers in northern Utah Valley, and these aquifers have been traced into southern Utah and Goshen Valleys. In descending order from the surface they are the Lake Bonneville Group of Pleistocene age, the shallow artesian aquifer of Pleistocene age, the deep artesian aquifer of Pleistocene age, and the artesian aquifer of Tertiary age.

The Lake Bonneville Group is the source of water for most springs and a few wells in southern Utah Valley and Goshen Valley. The Lake Bonneville Group consists of coarse- and fine-grained materials, but at the base it is mainly fine grained. The fine-grained basal zone has relatively low permeability and forms a confining bed above the artesian part of the ground-water reservoir.

The Lake Bonneville Group contains water that is mainly under water-table conditions. However, local artesian conditions in the Lake Bonneville Group result in flowing wells in small areas east of Spring Lake, near Holladay Springs and Lincoln Point, and 5 miles south of Elberta. Perched ground water occurs in the Lake Bonneville Group under the highlands where water levels in shallow wells may be as much as 100 feet above the regional water table. The greatest difference between the level of the perched ground water and the level of the regional water table in the Lake Bonneville Group is at higher altitudes near the mountains. As the distance from the mountains increases, the difference diminishes and the perched water table merges with the regional water table near the boundary between the highlands and the lake plains.

The artesian aquifers, and their extensions into areas where they are unconfined, are the principal sources of water for wells in southern Utah Valley and Goshen Valley. The aquifers consist of coarse- and fine-grained materials that vary widely in permeability from place to place, but each aquifer is separated from the underlying aquifer by a zone of less permeable deposits.

The artesisn aquifers in southern Utah Valley extend beneath the lake plain and the highlands, but wells in these aquifers flow only where land-surface altitudes are below about 4,600 feet. Thus, in southern Utah Valley the lake plain is the main area of flowing wells and the highlands are the main areas of nonflowing wells. The artesian aquifers in Goshen Valley are mainly in the eastern part of the valley between Goshen and the shores of Utah Lake. Wells in these aquifers flow only where land-surface altitudes are below about 4,520 feet. The absence of extensive artesian aquifers in the western half of Goshen Valley suggests that the valley fill in that area consists mainly of permeable sand and coarser grained materials with no extensive confining beds that would divide the reservoir into separate artesian aquifers.

Eight geologic sections (figs. 4-11) were constructed to show the continuity of the aquifers southward from northern Utah Valley and the altitudes and thicknesses of the aquifers in southern Utah and Goshen Valleys. The sections were based mainly on gamma-ray and drillers' logs of wells. The sections are shown in figures 4-11 and their locations are shown on plate 1.

The geologic sections show only the gross relationships of the major aquifers. They do not show local perched water bodies or local departures from regional artesian conditions. Deposits of Holocene age, which overlie the Lake Bonneville Group, are not differentiated from the latter in the sections.

Section A-A' in figure 4 shows that the aquifers of northern Utah Valley (Hunt, Varnes, and Thomas, 1953) continue into southern Utah Valley. The section extends from a point near Payson in southern Utah Valley to a point 3 miles north of Provo in northern Utah Valley and crosses the deltas of the Provo River, Hobble Creek, and Spanish Fork—features formed in late Pleistocene time. The tops of the aquifers are higher in altitude near the deltas of the Provo River and Hobble Creek than they are between these two areas and near the delta of Spanish Fork and the city of Salem. The deep Pleistocene artesian aquifer is thicker than the shallow Pleistocene artesian aquifer in the central part of section A-A', but the relationship is reversed north of Provo and south of the delta of Spanish Fork.

Geologic section B-B' (fig. 5) shows the altitudes and thicknesses of the aquifers from near Utah Lake to Mapleton, near the Wasatch Range. The deep Pleistocene artesian aquifer is generally thicker than the shallow Pleistocene artesian aquifer. Both aquifers are thickest near Springville, where the section passes through the delta of Hobble Creek, and they thin toward Utah Lake and the Wasatch Range.

Geologic section B-B'' (fig. 6) shows the altitudes and thicknesses of the aquifers from near Utah Lake to the Wasatch Range, near the mouth of Spanish Fork Canyon. The most significant feature shown in this section is the decided thickening of the shallow Pleistocene artesian aquifer where the section crosses the delta of Spanish Fork between the west edge of the city of Spanish Fork and Lake Shore.

Geologic section C-C' (fig. 7) shows the altitudes and thicknesses of the aquifers between Utah Lake and Salem. The shallow Pleistocene artesian aquifer is thickest south of Benjamin where the section crosses the delta of Peteetneet Creek.

Geologic section D-D' (fig. 8) shows the altitudes and thicknesses of the aquifers from near Utah Lake to the Wasatch Range, near Payson. Little data are available along this section below the shallow Pleistocene artesian aquifer, which is thickest north of Payson where the section crosses the delta of Peteetneet Creek.

Geologic section E-E' (fig. 9) shows the altitudes and thicknesses of the aquifers from near Goshen in Goshen Valley to Palmyra in southern Utah Valley. The section shows two aquifers in Goshen Valley, which can be correlated with the upper two aquifers in southern Utah Valley, even though the sequence of unconsolidated rocks is interrupted by Long Ridge. The section shows that the Lake Bonneville Group thickens considerably from Palmyra to Goshen. The shallow Pleistocene artesian aquifer is thickest between Palmyra and Benjamin, where the section crosses the delta of Spanish Fork, and near Santaquin where the section crosses the delta of Summit Creek. The deep Pleistocene artesian aquifer is apparently thickest in the Palmyra area and fairly constant in thickness along the rest of the section south of Palmyra. Aquifer tests in the southern part of southern Utah Valley and in Goshen Valley indicate that most of the ground water is unconfined, so the term "artesian" is not used in part of the section or in section F-F'. The beds between the aquifers are permeable and do not appreciably confine the ground water.

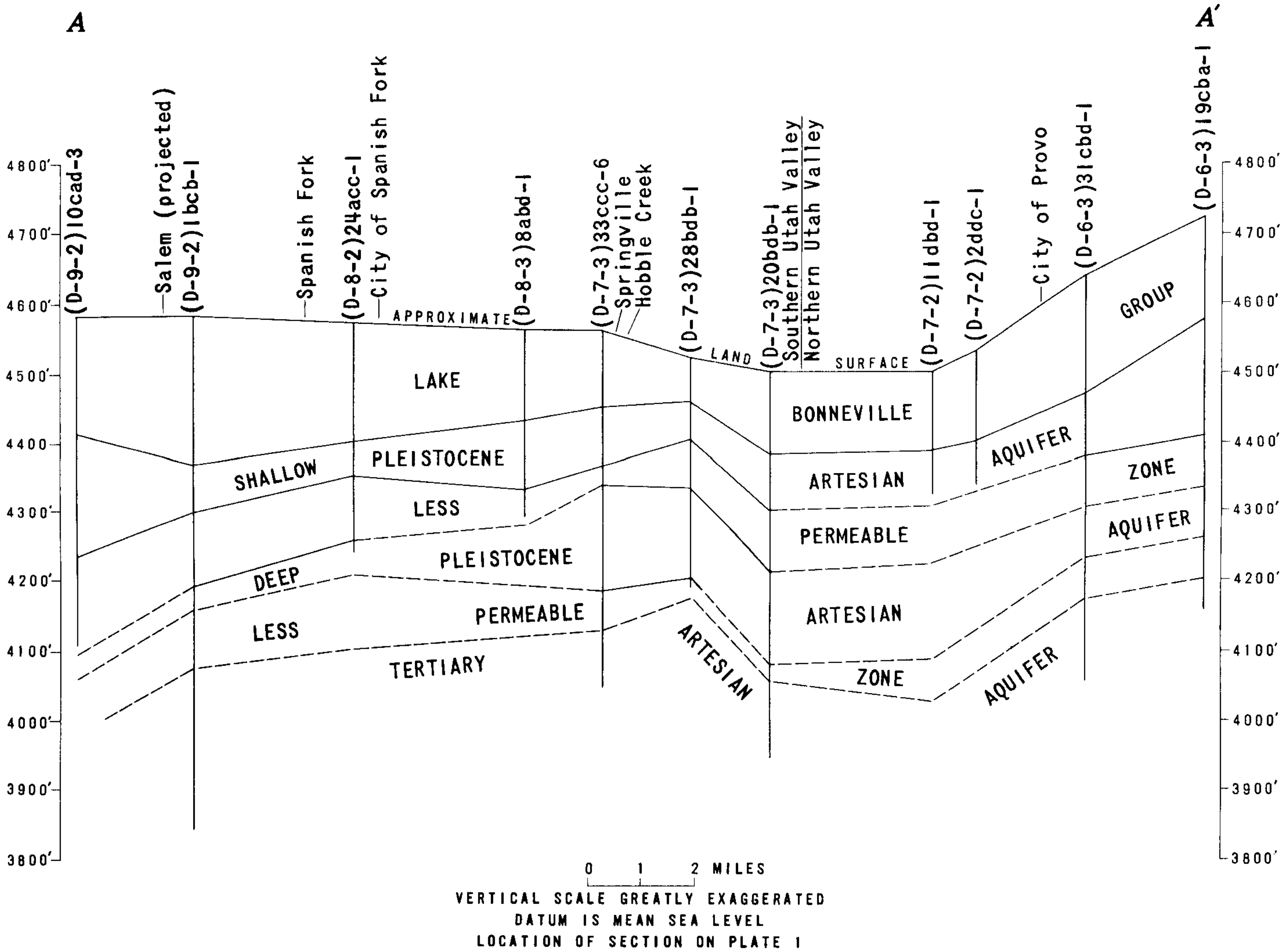


Figure 4.—Geologic section A-A′, from near Payson in southern Utah Valley to 3 miles north of Provo in northern Utah Valley.

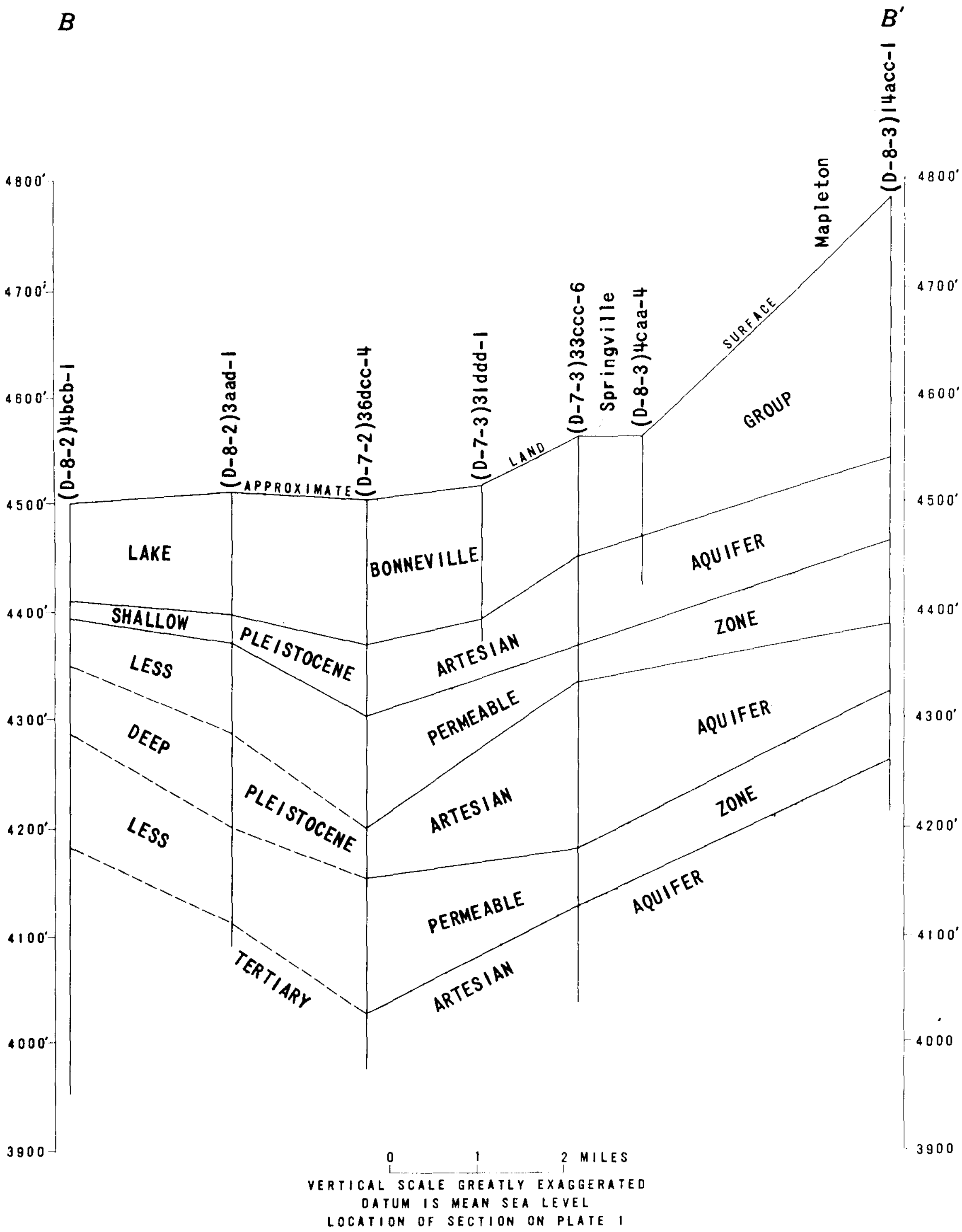


Figure 5.—Geologic section B-B′, from near Utah Lake to Mapleton, near the Wasatch Range.

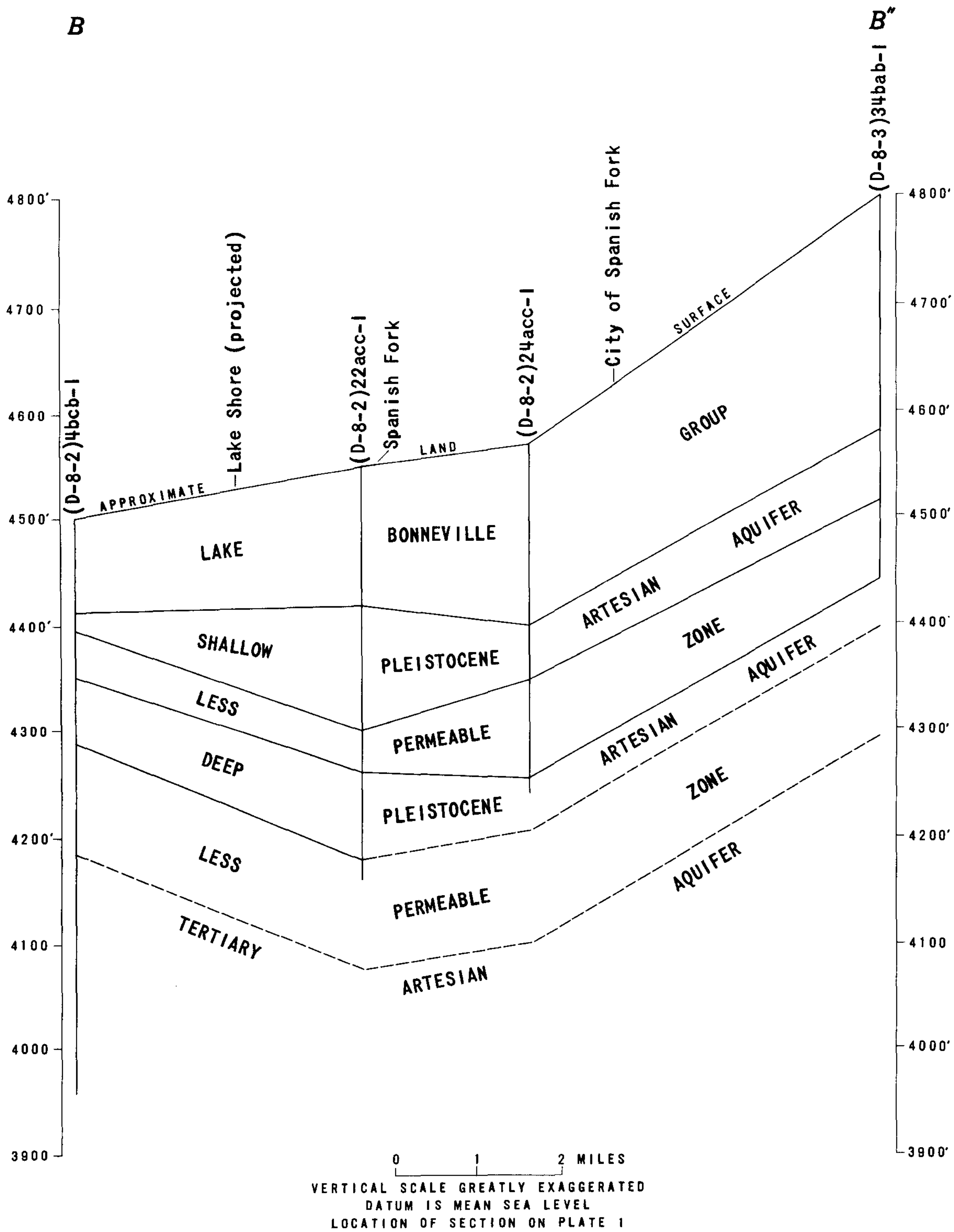


Figure 6.—Geologic section B-B″, from near Utah Lake to the Wasatch Range, near the mouth of Spanish Fork Canyon.

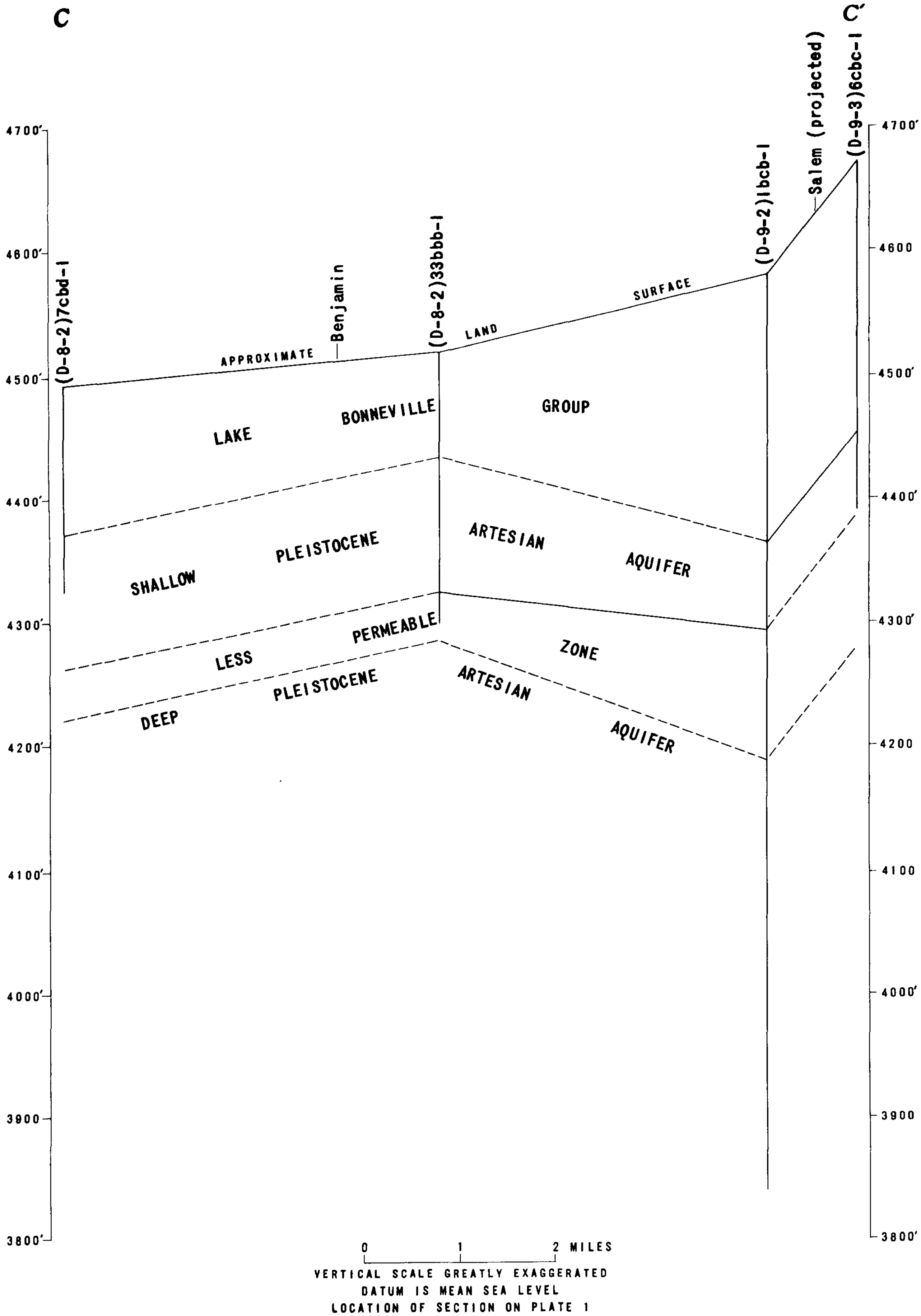


Figure 7.—Geologic section C-C′, from near Utah Lake to Salem.

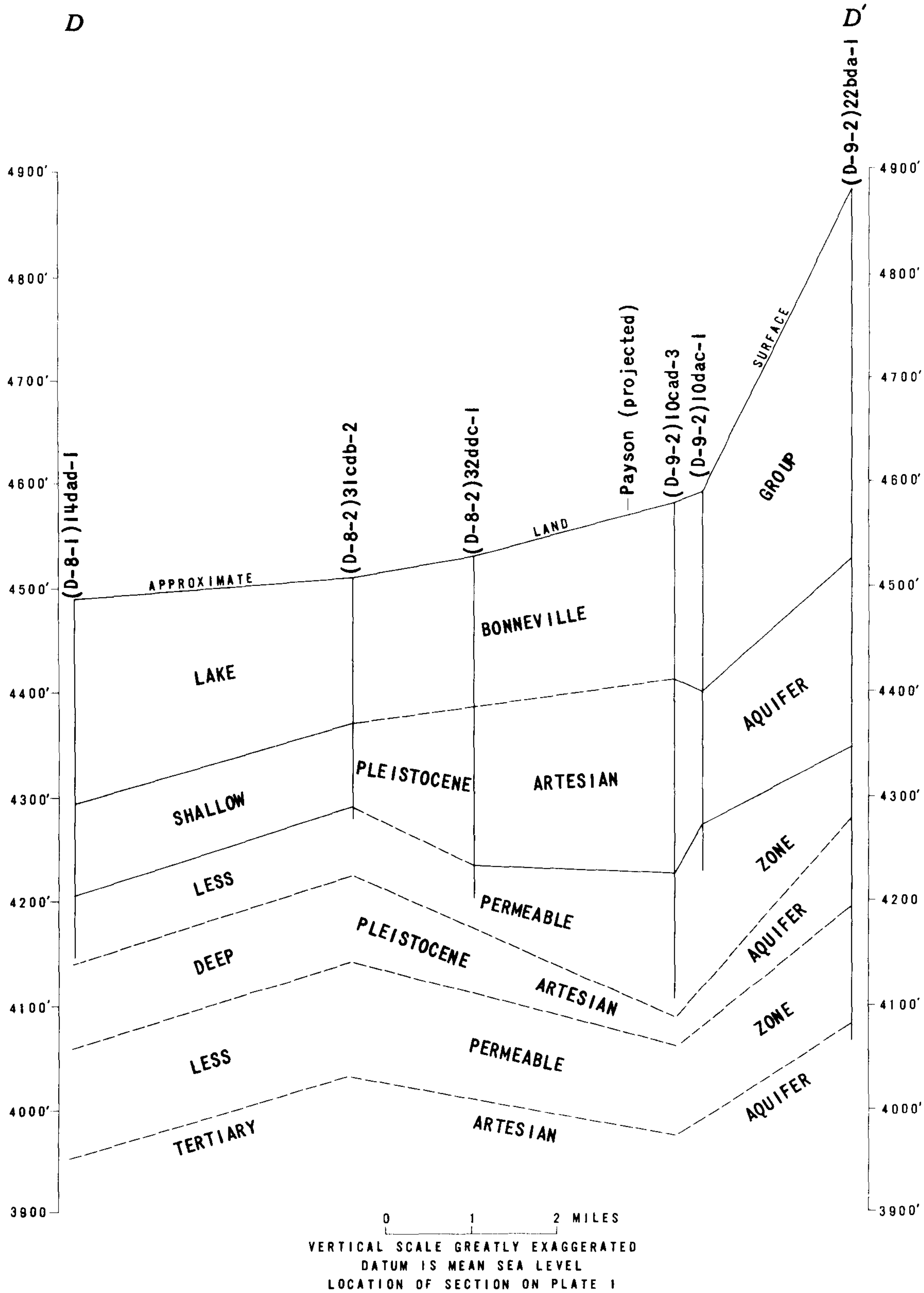


Figure 8.—Geologic section D-D′, from near Utah Lake to the Wasatch Range, near Payson.

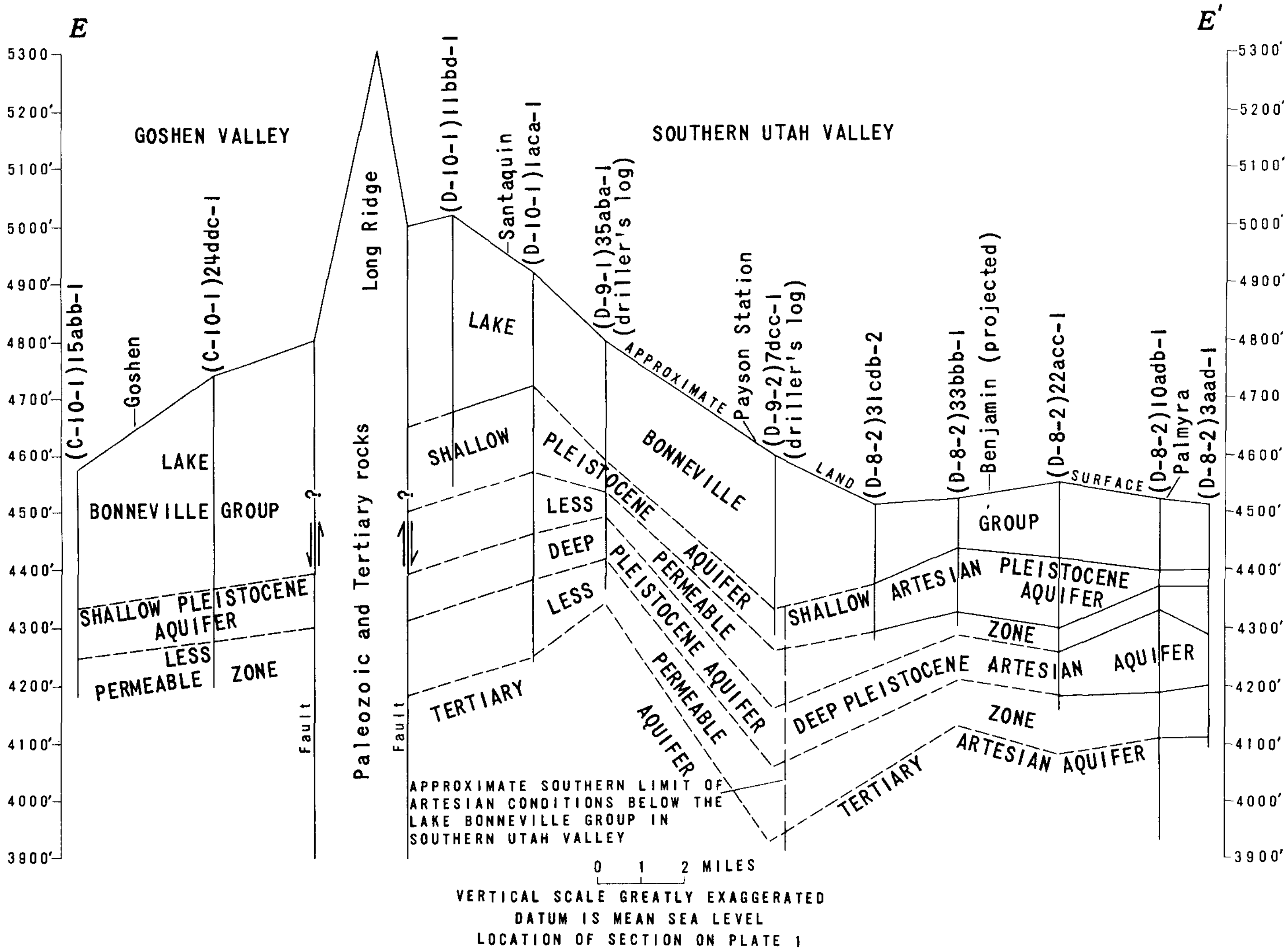


Figure 9.—Geologic section E-E', from near Goshen in Goshen Valley to Palmyra in southern Utah Valley.

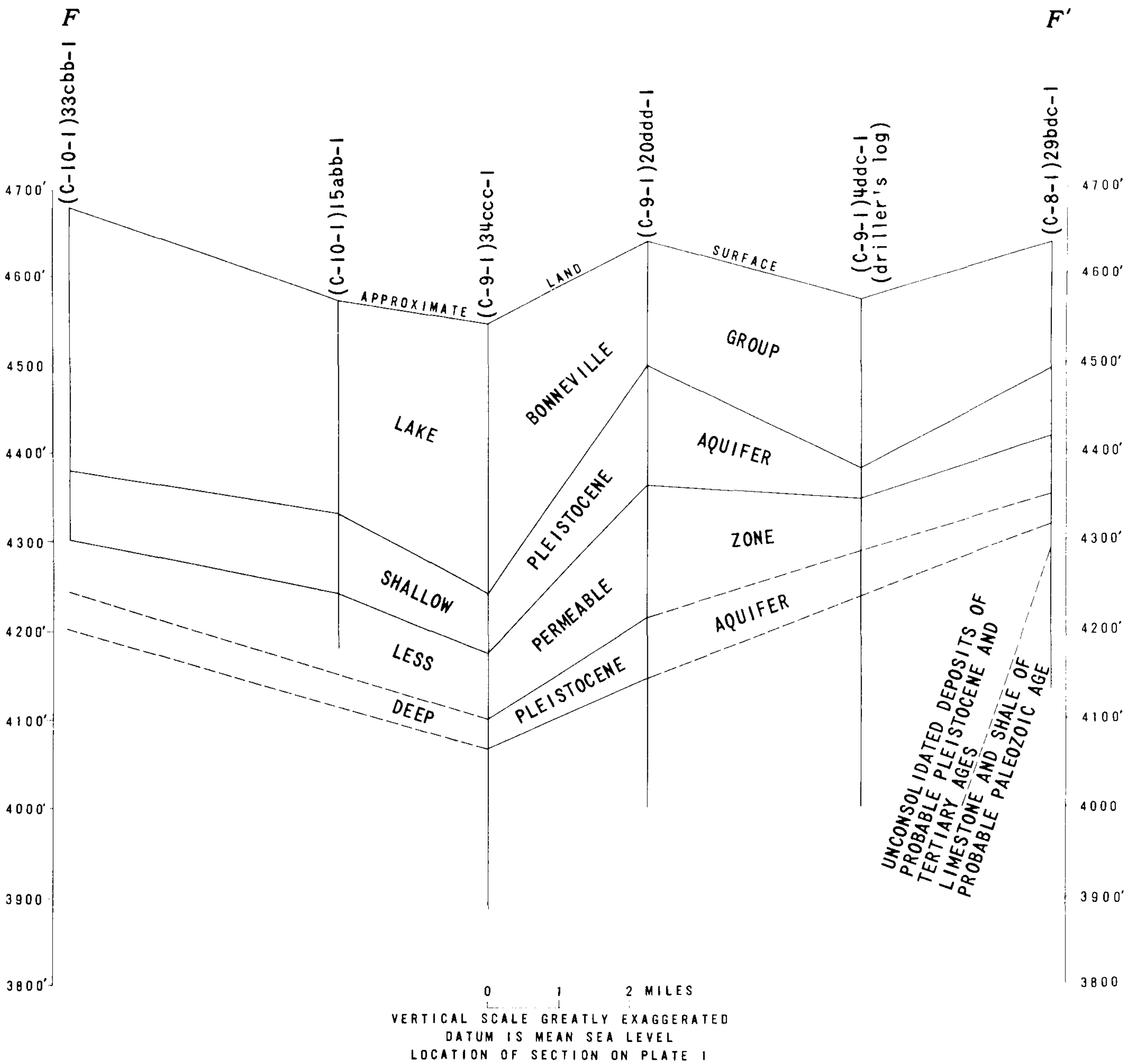


Figure 10.—Geologic section F-F', from near the south end of Goshen Valley to near the Mosida Hills.

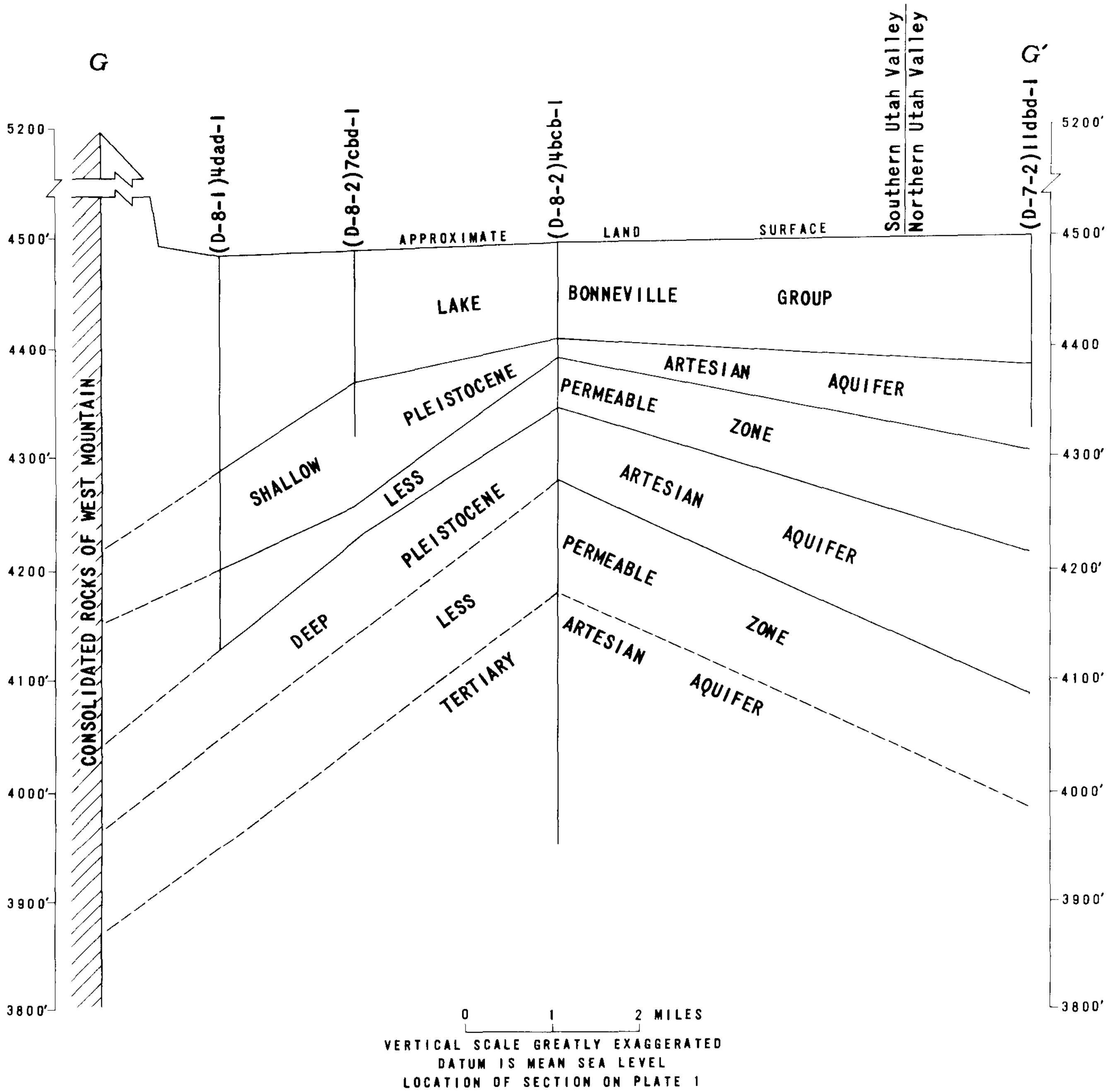


Figure 11.—Geologic section G-G′, from Provo in northern Utah Valley to West Mountain in southern Utah Valley.

Section F-F′ (fig. 10) shows the altitudes and thicknesses of three unconfined aquifers in Goshen Valley. A significant feature shown in the section is the shelf or pediment of rocks of probable Paleozoic age southeast of the Mosida Hills. Within 3 miles to the south of well (C-8-1)29bdc-1, which penetrated the shelf at 350 feet, well (C-9-1)4ddc-1 was drilled to 690 feet without encountering the shelf. A fault, with its downthrown side on the south, probably crosses the valley between the two wells.

Geologic section G-G′ (fig. 11) shows the altitudes and thicknesses of the aquifers from West Mountain to Provo. The most significant feature shown in this section is the rise in altitude of the artesian aquifers and less permeable zones from the Provo and West Mountain areas to the vicinity of Palmyra. The shallow Pleistocene artesian aquifer thins considerably in the Palmyra area.

The geologic sections were used to make maps of the depths to the tops of the lower three aquifers in southern Utah Valley (pl. 2 and fig. 12). Such maps are useful in determining the depths to the main water-yielding zones. However, the user of the maps should keep in mind that yields to wells vary from place to place in the same aquifer, that in any locality one aquifer may yield significantly more water than the other aquifers, and that locally the less permeable zones between the aquifers may contain thin water-bearing zones that yield sufficient water for stock or domestic purposes.

GROUND WATER

Recharge

Recharge to the ground-water reservoir in southern Utah Valley and Goshen Valley is by (1) seepage from waterways (streams and canals and ditches distributing water from the streams) and irrigated land, (2) infiltration of precipitation on the unconsolidated rocks of the valley, and (3) subsurface flow from the bordering mountains. The minimum total recharge in 1966 was estimated to be 150,000 acre-feet of water (table 1).

Table 1.—Ground-water recharge, in acre-feet, in 1966

	Southern Utah Valley	Goshen Valley
(1) Seepage from waterways and irrigated land	106,000	17,000
(2) Infiltration of precipitation	15,000	14,000
(3) subsurface flow	Unknown	Unknown
Minimum subtotals (rounded)	120,000	30,000
Minimum total	150,000	

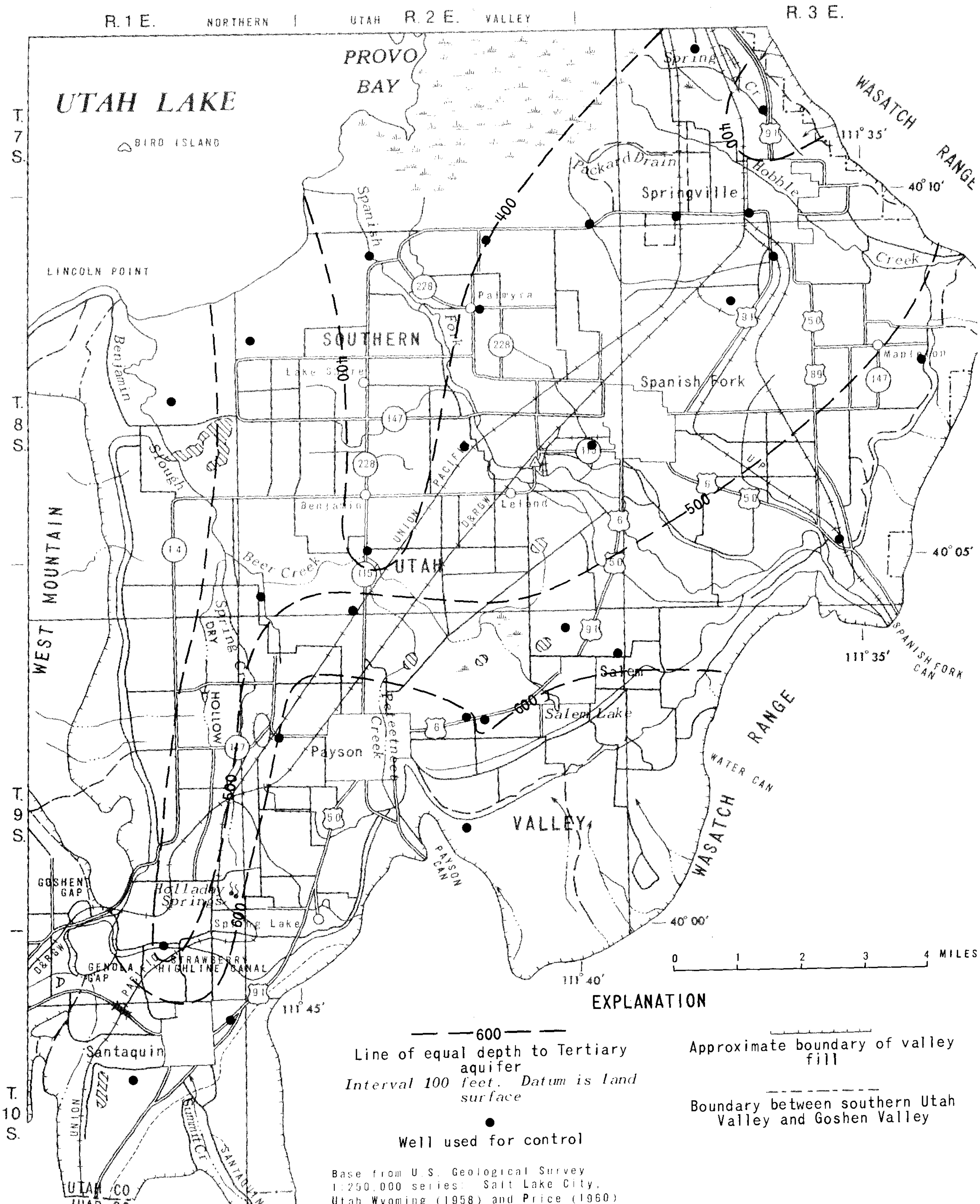


Figure 12.—Map showing depth to top of the Tertiary artesian aquifer and its unconfined extensions.

The estimated minimum seepage to the ground-water reservoir from waterways and irrigated land was 120,000 acre-feet (see table 2).

Table 2.—Minimum seepage, in acre-feet, to the ground-water reservoir from waterways and irrigated land

	Southern Utah Valley	Goshen Valley
Waterways:		
Water from perennial streams	38,000	600
Water from springs and drains in unconsolidated rocks	13,600	800
Water from wells	1,200	0
Water from springs, tunnels, and mines in bordering mountains	900	900
Water from ephemeral and intermittent streams	Unknown	0
Water from Utah Lake	0	0
Irrigated land:		
Water from perennial streams, canals, and ditches	32,000	4,000
Water from springs and drains in unconsolidated rocks	16,300	2,100
Water from wells	3,300	5,600
Water from springs, tunnels, and mines in the bordering mountains	1,000	2,000
Water from ephemeral and intermittent streams	Unknown	0
Water from Utah Lake	0	900
Minimum subtotals (rounded)	106,000	17,000
Minimum total (rounded)	120,000	

Seepage of water from perennial streams, canals, and ditches was estimated by making seepage runs on three major perennial streams—Hobble Creek, Spanish Fork, and Currant Creek—as well as on the major canals and ditches diverting water from these streams.

Table 3 summarizes the results of seepage runs made in 1965 and 1966 on selected reaches of the main waterways. The accuracy of the percentage losses is probably in the general range of plus or minus 10 percent. Instrumental error accounts for about half of the total error and variable field conditions account for the other half.

Table 3.—Summary of results of seepage runs made in 1965 and 1966 on selected reaches of the main waterways

Main stream and its irrigation distribution system	Net loss in percent			
		1966		Average
	1965	May-June	Sept.-Oct.	(rounded)
Hobble Creek system:				
Hobble Creek (Lake Plain Reach)	27 (Sept.)	-	-	30
Springville Highline Canal	14 (June-July)	-	-	10
Springville Upper Canal	-	8	32	20
Fullmer Ditch	-	7	31	20
Average	20	8	32	20
Spanish Fork system:				
Spanish Fork	13 (Sept. Oct.)	5	10	10
Strawberry Highline Canal	10 (Aug.-Oct.)	11	-	10
Mill Race Canal	4 (Aug.)	2	18	10
Salem Canal	15 (Sept.)	35	50	30
East Bench Canal	13 (Aug.)	-	10	10
South Ditch	-	5	12	10
Average	11	16	20	20
Currant Creek system:				
Currant Creek	-	8	-	10
Currant Creek Canal	-	10	-	10
Average	-	9	-	10

The percentage of seepage loss increased generally during the 1966 irrigation season, so that the highest percentages of loss are probably in the last half of the irrigation season. This percentage increase is largely the cumulative result of the scouring action in the channels of the waterways caused by sand carried in the water. The scouring action of the sand removes the clay and silt which have caked on the bottom and sides of the channels. Thus, water more readily seeps out of the channels in localities where they are constructed in coarse-grained permeable materials.

The loss of water in 1966 from the perennial streams and the irrigation waterways diverting water from them was 20 percent in southern Utah Valley and 10 percent in Goshen Valley. Both of these numbers are rounded averages based on the 1966 loss determinations. The average seepage rates determined were then applied to those perennial streams, canals, and ditches where seepage runs were not made.

Seepage from irrigated land was determined by using a factor of 30 percent suggested by the U. S. Soil Conservation Service (G. A. Lawrence and Waldo Potter, oral commun., 1967). The total amount of seepage thus estimated is shown in table 4.

Seepage of water from waterways which distributed water from springs and drains originating in the unconsolidated rocks and seepage from land that was irrigated with water from such springs and drains was estimated by using data in tables 3 and 4. The percentages shown in columns 3, 6, and 8 in table 4 for seepage from waterways and irrigated land were applied to the 1966 figures of total discharge from springs and drains. (See table 3.)

Table 4.—Seepage from perennial streams and from land irrigated with water from perennial streams in 1966.

Perennial stream diverted for irrigation (1)	Seepage during nonirrigation season (November-March): Total inflow, in acre-feet (rounded) (2)	Seepage from perennial streams: Percent (3)	Seepage from perennial streams: Acre-feet (rounded) (4)	Seepage during irrigation season 1/ (April-October): Total inflow, in acre-feet (rounded) (5)	Seepage from waterways: Percent (6)	Seepage from waterways: Acre-feet (rounded) (7)	Seepage from irrigated land 2/: Percent (8)	Seepage from irrigated land 2/: Acre-feet (rounded) (9)	Total seepage, in acre-feet (rounded) (10)
SOUTHERN UTAH VALLEY									
Spanish Fork 3/	4/26,700	20	5,300	5/110,200	20	6/23,700	30	26,000	55,000
Hobble Creek 7/	8/7,800	20	1,600	9/16,400	20	3,300	30	3,900	9,000
Peteetneet Creek 10/	1,400	20	300	6,200	20	1,200	30	1,500	3,000
Summit Creek 10/	1,600	20	300	2,700	20	500	30	700	2,000
Maple Creek 10/	300	20	60	800	20	200	30	200	500
Totals (rounded)	38,000		8,000	136,000		30,000		32,000	70,000
GOSHEN VALLEY									
Spanish Fork	0	0	0	8,400	0	0	30	2,500	2,000
Currant Creek 10/	11/800	0	0	11/6,200	10	600	30	2,000	3,000
Totals (rounded)	1,000		0	15,000		1,000		4,000	5,000
Grand totals (rounded)	39,000		8,000	151,000		31,000		36,000	75,000

1/ It is assumed that diversions from the perennial streams are made only during the irrigation season.
2/ Percentages are based on data from the U.S. Soil Conservation Service (G. A. Lawrence and Waldo Potter, oral commun., 1967). Except for Spanish Fork, percentage is applied to water remaining after deducting seepage loss from waterways, assuming all streamflow is diverted for irrigation. Percentage for Spanish Fork is applied to water remaining after deducting seepage loss from waterways and the amount of water diverted for irrigation in Goshen Valley (8,400 acre-feet).
3/ Inflow of Spanish Fork was measured at a stream-gaging station at Castilla in (D-9-4)12bad, about 4 miles upstream from the mouth of Spanish Fork Canyon.
4/ Includes 900 acre-feet of ground-water inflow in the reach extending 1 mile upstream from the canyon mouth and 1,700 acre-feet from Cold Springs.
5/ Includes 4,300 acre-feet of ground-water inflow, 1,500 acre-feet from Cold Springs, and 500 acre-feet from Malcolm Springs, which is in the stream channel in (D-8-3)34d, but does not include 8,400 acre-feet delivered to Goshen Valley via the Highline Canal.
6/ Determined by applying the percentage to the sum of 110,200 acre-feet and 8,400 acre-feet which is the total amount of inflow of Spanish Fork conducted in waterways in southern Utah Valley.
7/ Inflow of Hobble Creek was measured at a stream-gaging station in (D-8-4)6abb, about 1½ miles upstream from the mouth of Hobble Creek Canyon, and includes 1,765 acre-feet of water from Bartholomew Springs, (D-7-4)7-S and 8-S.
8/ Includes 1,500 acre-feet of ground-water inflow in the reach crossing the highlands and 600 acre-feet diverted from Cox Spring in the stream channel at the canyon mouth.
9/ Includes 4,300 acre-feet of ground-water inflow and 900 acre-feet diverted from Cox Spring.
10/ Inflow determined from measurements at the canyon mouth.
11/ Includes springflow in Goshen Canyon.

Seepage from waterways which distributed water from wells and seepage from land which was irrigated with water from wells was determined as follows: In southern Utah Valley about 50 percent of the water from pumped and flowing irrigation wells was conveyed to fields in unlined waterways in 1966; but in Goshen Valley nearly all the water from irrigation wells was conveyed by lined waterways. The seepage of well water from waterways in southern Utah Valley was determined by applying the seepage factor of 20 percent for waterways (col. 6, table 4) to 50 percent of the 12,300 acre-feet of water from wells used for irrigation in 1966. In Goshen Valley the seepage from waterways was negligible. The seepage factor of 30 percent (col. 8, table 4) for irrigated land was applied to the difference between all water from wells used for irrigation and the seepage from waterways in southern Utah Valley and to all water from wells used for irrigation in Goshen Valley in 1966.

Seepage of water from waterways which distributed water coming directly from mines, springs, and tunnels in the bordering mountains (table 5) and seepage from land irrigated with such water was estimated as follows: In southern Utah Valley, seepage of this water from waterways was estimated by multiplying the amount of water diverted for irrigation (table 5) by the seepage factor of 20 percent for waterways (col. 6, table 4). Seepage from irrigated land was estimated by applying the factor of 30 percent for irrigated land (col. 8, table 4) to the difference between the amount of water diverted for irrigation and the amount of seepage from waterways. Water enters Goshen Valley from the Burgin Mine, about 2 miles to the west in the East Tintic Mountains, in a ditch system which carries the water into ponds. The estimated flow in the ditches in 1966 was 4,300 acre-feet, and the seepage was estimated by applying the seepage factor of 20 percent for waterways (col. 6, table 4). The amount of seepage from the ponds was estimated to be 60 percent of the difference between the total inflow and the seepage from waterways, giving 2,000 acre-feet for seepage from irrigated land.

Seepage from the channels of ephemeral and intermittent streams may be significant in years when runoff is high. Little, if any, of this water is used for irrigation, however, because its undependable availability does not warrant the construction of irrigation facilities. In southern Utah Valley, data are not available for 1966 to determine the amount of flow in the ephemeral and intermittent streams and, therefore, the amount of seepage. In Goshen Valley, data from crest-stage partial-record stations in the channels of two ephemeral streams draining the East Tintic Mountains indicated no flow in 1966. It is assumed, therefore, that there was no seepage from intermittent and ephemeral streams in 1966.

Seepage from land in Goshen Valley irrigated by water pumped from Utah Lake was 900 acre-feet, estimated by applying the seepage factor of 30 percent for irrigated land (col. 8, table 4) to the 3,058 acre-feet of water applied for irrigation. The water is piped to the irrigated land so there is no seepage from waterways.

Infiltration of precipitation

Recharge by the direct infiltration of precipitation in 1966 on the valley fill of southern Utah Valley and Goshen Valley was estimated to be about 15,000 and 14,000 acre-feet, respectively. The amount of infiltration of precipitation depends on several complex factors, including among others, intensity and amount of precipitation, soil conditions and characteristics, vegetal cover, and rates of evapotranspiration. No data bearing on these factors were collected during this investigation.

The amount of infiltration during 1966 was estimated by making the following assumptions: (1) That the precipitation at Payson and Elberta is representative of precipitation in southern Utah Valley and Goshen Valley, respectively; and (2) that 30 percent of the precipitation that falls on the highlands and 10 percent that falls on the lake plain during the

Table 5.—Ground water from mines, springs, and tunnels in the bordering mountains which flowed into southern Utah Valley in 1966

Source of water	Location of measurement site	Discharge: Average measured rate (cfs)	Discharge: Total for year (acre-ft)	Discharge: Estimated diversion for irrigation (acre-ft)
Unnamed spring and Konold tunnel	(D-7-3)35cca	5.7 [1]	4,100	2,100
Osler Spring	(D-8-3)2acb	.2 [2]	140	90
Mapleton City Springs	12cda	.7 [3]	500	0
Unnamed tunnel	23dbc	.1 [2]	70	40
Cold Springs	(D-8-3)34bad (D-9-3)11aaa 12bad	2.7 [4]	1,950	0
Bartholomew Springs	(D-8-4)6aba	2.9 [1]	2,100	1,765[5]
Payson City Springs	(D-9-2)21bdd	1.2 [6]	900	0
Unnamed springs	29cbb	.03[7]	20	0
Unnamed spring	(D-9-3)8acb 8cab	.15[2]	100	60
Dream Mine	8cab	.1 [2]	70	40
Salem City Springs	17bdd	.6 [8]	400	0
Unnamed springs	18dda	.4 [2]	300	200
Santaquin City Springs	(D-10-1)12cdc	1.1 [2]	800	0
Totals (rounded)		15.9	11,000	4,300

[1]Based on total-flow meter records of city of Springville.

[2]Based on measurements by the U. S. Geological Survey.

[3]Based on total-flow meter records of city of Mapleton.

[4]Based on total-flow meter records of city of Spanish Fork.

[5]Measured.

[6]Based on total-flow meter records of city of Payson.

[7]Based on metered use by residents of Spring Lake.

[8]Based on several monthly volumetric measurements by city of Salem employees.

months of January-April and October-December infiltrates to the water table and that none of the precipitation during May-September infiltrates.

The precipitation during the periods January-April and October-December 1966 was 10.16 inches at Payson and 6.98 inches at Elberta (U. S. Environmental Sci. Services Adm., 1967). The area of the highlands is about 43,000 acres in southern Utah Valley and 73,000 acres in Goshen Valley. The area of the lake plain is about 52,000 acres in southern Utah Valley and 20,000 acres in Goshen Valley. The precipitation during the period January-April and October-December 1966 thus was 80,000 and 54,000 acre-feet on southern Utah Valley and Goshen Valley, respectively; but the amount that recharged the ground-water reservoir was about 15,000 and 14,000 acre-feet, respectively.

Subsurface flow

Part of the recharge to the ground-water reservoir is by subsurface flow directly from the consolidated rocks of the bordering mountains. The large areas of soluble and fractured rock in the mountains absorb a large amount of precipitation. Part of the absorbed water is consumed by evapotranspiration, part seeps into surface streams in the mountains, and part remains in the subsurface until it eventually percolates directly into the valley fill. The quantity of water that recharges the ground-water reservoir in southern Utah Valley and Goshen Valley in this manner is not known.

Discharge

Water is discharged from the ground-water reservoir in southern Utah Valley and Goshen Valley by (1) drains and springs, (2) wells, (3) evapotranspiration, (4) seepage into municipal sewer systems, and (5) ground-water discharge directly into Utah Lake. The minimum total discharge in 1966 was estimated to be 220,000 acre-feet (table 6).

Table 6.—Ground-water discharge, in acre-feet, in 1966

	Southern Utah Valley		Goshen Valley
(1) Drains and springs	79,000		7,800
(2) Wells	24,000		19,000
(3) Evapotranspiration	55,000		27,000
(4) Seepage into municipal sewer systems	3,000		0
(5) Ground-water discharge directly into Utah Lake (minimum)	4,000		4,000
Minimum subtotals (rounded)	160,000		60,000
Minimum grand total		220,000	

Drains and springs

Discharge of ground water by drains and springs in the valley fill was estimated to be 79,000 acre-feet in southern Utah Valley and 7,800 acre-feet in Goshen Valley (table 7). The amount of ground water that discharges into drains was determined by measuring the discharge of the drains near their mouths during the nonirrigation season and assuming that (1) the difference between this amount and the measured surface inflow was ground water and (2) the ground-water discharge during the nonirrigation season represented the average annual discharge. It was also assumed that the ground water in the drains discharges from the Lake Bonneville Group.

The volume of water discharged from springs was determined by using the mean of the maximum and minimum amounts of each spring measured during 1966. The springs listed in table 7 are considered to be discharging from the water-table aquifer in the Lake Bonneville Group.

Wells

The discharge from wells in 1966 was about 24,000 acre-feet in southern Utah Valley and about 19,000 acre-feet in Goshen Valley (table 8).

The discharge for irrigation was determined separately for flowing wells and for pumped wells on a well-by-well basis. The average discharge rate of most flowing irrigation wells was estimated from measurements of discharge at the well. (See section on yields of wells.) The average discharge from some wells that were not measured was estimated by comparison to wells of similar diameter. Some discharge measurements at flowing wells were made by the U. S. Geological Survey during the period of well inventory (July 1964 to April 1965), some were made by the Utah State Engineer in cooperation with the Federal Works Progress Administration in 1938-40, and some were reported. Reported yields were used only if direct measurements were not available. A comparison of measurements made in 1964-65 with measurements made in prior years at the same wells indicated that in general, no significant changes in rates of discharge had taken place; therefore, the earlier measurements are considered adequate after making appropriate adjustments for change in water level between the earlier period and 1966. The total discharge for 1966 of each flowing well was determined by multiplying the estimated average discharge rate of the well by the estimated number of days that the well was allowed to flow.

The total annual discharge of pumped irrigation wells equipped with electric motors was computed on the basis of the total quantity of electricity consumed and the rate of water discharge per unit of electricity used. A similar method was used for wells equipped with engines powered by natural gas. The total annual discharge at two wells equipped with diesel engines was determined by measuring the well discharge and estimating the length of the pumping period.

The total annual discharge of industrial wells was based on reported average discharge rates and lengths of pumping periods.

The total annual discharge of some public-supply wells was measured with total-flow meters and reported by city officials. The discharge of others was estimated from a reported discharge rate, which was assumed to be constant during the period of use, and a reported length of pumping period.

The total annual discharge of wells used for combined domestic, stock, and irrigation purposes was determined for each well from average discharge rates and length of period of use. The average discharge rate was determined from measurements and estimates in the same way as for flowing irrigation wells.

Table 7.—Ground-water discharge from the Lake Bonneville Group by the major springs and drains in 1966

Name or location of spring or drain	Location of measurement site	Discharge: Average measured rate (cfs)	Discharge: Total for year (acre-ft, rounded)
SOUTHERN UTAH VALLEY			
Dry Creek (lower part)[1]	(D-7-2)36dcc	7.5	5,400
Spring Creek Spring	(D-7-3)28bca	15.5	11,200
Spring Creek (lower part)[1]	29aab	4.8	3,500
Little Spring Creek[1]	29daa	2.4	1,700
Springville's 4th North Drain	29dda	2.9	2,100
Packard Drain	30cdd	5.9	4,300
Wood Spring	31add	4.4	3,200
Matson Spring	32cda	2.4	1,700
Wheeler Springs	34cdc (D-8-3)3abb	4.7	3,400
Benjamin Slough[1]	(D-8-1)25abd	21.2	15,300
Bradford Spring	(D-8-2)36aad	1.5	1,100
Springs in Hobble Creek	(D-8-3)1,2,3	8.1	5,800
Burt Spring	(D-8-3)1cab	4.0[2]	2,900
Dry Creek (upper part)[3]	4cac	4.7	3,400
Spring area of Big Hollow	9dab	3.2	2,300
Springs in Spanish Fork	34	7.2	5,200
Holladay Springs	(D-9-1)24ddc 25ada	1.5	1,100
Salem Lake Springs	(D-9-2)11abd	5.0	3,600
Spring Lake Springs	29cbb	2.1	1,500
Totals (rounded)		109.0	79,000
GOSHEN VALLEY			
Warm Springs	(D-10-1)8cab 8cdb 17bab	10.8	7,800
Grand totals (rounded)		120.0	87,000

[1]Natural drain.

[2]Estimated from records of previous years.

[3]A spring area. The discharge includes flow of Clyde and Fullmer Springs.

Table 8.—Discharge from wells, in acre-feet, in 1966

	Southern Utah Valley			Goshen Valley		
	Flowing wells	Pumped wells	Total annual	Flowing wells	Pumped wells	Total annual
Irrigation	2,900	9,400	12,300	0	18,800	18,800
Industry	400	140	540	0	186	186
Public supply	0	900	900	0	19	19
Domestic, stock, and irrigation combined	9,500	600	10,100	100	40	140
Totals (rounded)	13,000	11,000	24,000	100	19,000	19,000

Evapotranspiration

Discharge of ground water by evapotranspiration was estimated to be 55,000 acre-feet of water in southern Utah Valley and 27,000 acre-feet in Goshen Valley. Evapotranspiration of ground water takes place mainly in areas of phreatophytes, which are plants that obtain part or all their water supply from the ground-water reservoir. Most of the phreatophytes are concentrated in the lake plain where the water table is within 10 feet of the land surface. Some phreatophytes grow where the depth to water exceeds 10 feet, but for the purposes of this report, the amount they use is considered negligible.

In uncultivated areas, the dominant phreatophytes include saltcedar (*Tamarix gallica*), which is concentrated near the lakeshore, and saltgrass (*Distichlis stricta*). Also found are small tracts of greasewood (*Sarcobatus vermiculatus*), rabbitbrush (*Chrysothamnus* sp.), alkali sacaton (*Sporobolus airoides*), and pickleweed (*Allenrolfea occidentalis*). In cultivated areas and pastures, alfalfa (*Medicago sativa*) and meadowgrass (various assemblages of water-loving grasses, sedges, and rushes) are the dominant phreatophytes replacing some saltgrass and the otherphyreatophytes named above.

The general areas of phyreatophyte growth are shown on plate 1. The areas were determined with the aid of aerial photographs taken in July 1965, from field observations, and from information provided by the U. S. Soil Conservation Service (W. Potter, oral commun., 1968), the U. S. Bureau of Reclamation (O. Mohlman, oral commun., 1968) and the Utah Water Research Laboratory (1968). An estimated 30 percent of the alfalfa, saltgrass, and meadowgrass area shown on plate 1 includes tracts of nonphreatophytic plants that use little or no ground water.

The amount of ground water used by phreatophytes was estimated by separating these plants into three association groups and by multiplying the number of acres of each group by an estimated annual use (see table 9). The three groups were chosen on the basis of the dominant phreatophytes for which the consumptive use of ground water, and the number of acres could be estimated. The consumptive use of water was calculated from a formula developed by Blaney and Criddle (1962) which assumes that there is optimum soil moisture available at all times. The water used by the phreatophytes was assumed to be all ground water except for fields of alfalfa and meadowgrass, which are irrigated when surface-water supplies are plentiful. The consumption of ground water by alfalfa was estimated by subtracting from the total consumptive use (2.2 feet per year) the estimated amount of water supplied by irrigation (0.9 foot per year).

Table 9.—Evapotranspiration of ground water by phreatophytes

Dominant phreatophyte	Acres	Use of ground water (ft per year)	Total use of ground water (acre-ft, rounded)
	Southern Utah Valley		
Alfalfa	6,700	1.3	8,700
Saltgrass and meadowgrass	21,000	2.0	42,000
Saltcedar	1,300	3.3	4,300
Subtotals (rounded)	29,000	-	55,000
	Goshen Valley		
Alfalfa	1,100	1.3	1,400
Saltgrass and meadowgrass	8,200	2.0	16,000
Saltcedar	2,900	3.3	9,600
Subtotals (rounded)	12,000	-	27,000
Grand total (rounded)	41,000		82,000

The amount of water supplied by irrigation was calculated using an average field irrigation efficiency of 50 percent and an annual irrigation-water application of 21 inches (1.75 feet). The average field irrigation efficiency of 50 percent is reported as probable by the U. S. Bureau of Reclamation (R. Johnston, oral commun., 1969) for the lake plain; the depth of irrigation water is reported by the U. S. Bureau of Reclamation (written commun., 1964).

The calculated use of 2.2 feet per year for saltgrass and meadowgrass was adjusted arbitrarily downward to 2.0 to account for a small amount of irrigation water which is applied to the meadowgrass.

During severe storms, winds may raise the stage of Utah Lake so that low land adjacent to the lake is inundated. At such times, lake water may seep into the ground and supply part of the water used by phreatophytes. The amount of lake water so used is considered to be negligible in terms of the total quantity of water used annually by the phreatophytes.

Infiltration into municipal sewer systems

Of the 8,600 acre-feet of sewage effluent from municipal sewer systems in southern Utah Valley during 1966, about 3,000 acre-feet or 35 percent is estimated to be ground-water infiltration (table 10). There are no municipal sewer systems in Goshen Valley.

For Payson, the amount of infiltration was estimated from low-flow measurements made by the Call Engineering Co., using weirs at the sewage plant, at the time of day when the use of public supply water was negligible. Measurements made on November 25 and 26 and on December 21 and 22, 1966, indicated that about 0.3 cfs (cubic feet per second) of water was

Table 10.—Municipal use of water and infiltration of ground water into municipal sewer systems, in acre-feet, in southern Utah Valley in 1966

Estimated infiltration: See text for explanation of method used to estimate infiltration.

	Municipalities with sewer systems in 1966							
	Payson		Salem		Spanish Fork		Springville	
Month	Use[1]	Estimated infiltration	Use[2]	Estimated infiltration	Use[3]	Estimated infiltration	Use[4]	Estimated infiltration
January	46.0	20	40	4	85.5	59	-	100
February	46.5	20	40	3	71.5	66	-	90
March	65.2	20	40	4	135.0	60	-	130
April	92.6	40	40	4	190.0	60	-	150
May	107.0	40	40	4	229.0	60	-	160
June	129.0	40	40	4	274.0	60	-	170
July	98.1	40	40	4	310.0	60	-	150
August	73.3	40	40	4	259.0	60	-	150
September	74.9	40	40	4	151.0	60	-	140
October	79.3	40	40	4	97.3	72	-	120
November	49.6	20	40	4	78.3	60	-	100
December	59.5	20	40	4	72.0	92	-	100
Total (rounded)	900.0	400	500	50	2,000.0	800	2,300	1,600

[1] Monthly totals are measured springflow, except for January which is assumed to be about the same as February. Monthly totals during the irrigation season do not include pumpage from two wells.

[2] Estimated from springflow measurements made by city employees during part of the year. Use estimated to be the same during the remainder of the year.

[3] Measured springflow. Monthly totals during irrigation season do not include a small amount of pumpage from a well.

[4] Springflow partially measured monthly; annual total estimated from measurements.

flowing in the sewer system. This amount was considered by the Call Engineering Co. (oral commun., 1967) to be wholly ground-water discharge. The total annual infiltration was estimated by assuming that the daily average rate of infiltration was 0.3 cfs during the period November-March and 0.6 cfs during the remaining months of the year. The larger daily average figure was used for the period April-October because the average flow in the sewer system nearly doubles during the irrigation season. This increase of flow is in part the result of the increased use of water within the municipality but mostly the result of the infiltration of water used for irrigation on coarse fan deposits at elevations at and above Payson.

For Salem, the amount of infiltration was estimated from three low-flow measurements made by city employees during the time of day when the use of water was negligible. The infiltration so determined was assumed to be all ground-water discharge, and the rate determined was assumed to be constant for the entire year.

For Spanish Fork, the amount of infiltration was estimated from records of the amounts of water entering the city water-supply system and leaving the sewage-treatment plant.

For Springville, the amount of infiltration was estimated from low-flow measurements of sewage effluent recorded at the city sewage-treatment plant. The low flow is considered by city water officials to be ground-water infiltration. The lowest recorded flow for each month of 1966 was assumed to be the average rate for the month.

Discharge into Utah Lake

Ground water in southern Utah Valley and Goshen Valley moves toward Utah Lake but most of it is discharged above the lake and only a small part discharges into the lake. Discharge into the lake in the project area occurs by diffuse seepage and springflow through the lake-bottom sediments from the confined and unconfined aquifers. The amount of ground water that enters the lake varies according to the hydraulic gradients in the aquifers and the stage of the lake. The minimum amount of ground water moving toward the lake from southern Utah Valley in 1966, an estimated 4,000 acre-feet, was calculated as flow through a section of the valley fill.

The basis for estimating the amount of ground water moving toward the lake is a variation of Darcy's Law:

$$Q = 0.212 \, P \, I \, A$$

in which Q is the estimated annual discharge through a selected cross section of the aquifer, in acre-feet per year; 0.212 is a units-conversion factor for obtaining acre-feet per year, P is the field coefficient of permeability (the rate of flow of water through a cross-sectional area of 1 square foot under a hydraulic gradient of 100 percent at the prevailing water temperature expressed in gallons per day per square foot); I is the hydraulic gradient across the section in feet per mile; and A is the area of the cross section in millions of square feet. Values for P, I, and A, for the four aquifers used in the computation and the calculated minimum ground-water discharge to Utah Lake from southern Utah Valley are shown in the following table:

Aquifer	P (gpd/ft^2)	I (ft/mi)	A (million sq ft)	Q (acre-ft per yr, rounded)
Lake Bonneville Group	10	5	5.0	50
Shallow Pleistocene	24	13	2.3	150
Deep Pleistocene	50	16	3.3	560
Tertiary	50	16	18.5	3,100
Total (rounded)				4,000

The cross section used for the estimate is about 7 miles long, and it is coincident with the lakeshore from the northeastern boundary of the project area to West Mountain. The section includes the Lake Bonneville Group, the shallow and deep Pleistocene artesian aquifers, and the upper 500 feet of the Tertiary artesian aquifer. The total thickness of the Tertiary artesian aquifer is not known and for this reason the estimated amount moving through the entire section is a minimum amount. Aquifer tests and drillers' descriptions of aquifer materials were the basis for estimating the coefficients of permeability. The hydraulic gradients were extrapolated from data shown on the water-table and potentiometric-surface maps for March 1965 (pl. 1 and figs. 17-19); and these gradients were assumed to hold true for 1966. The areas of saturated aquifer materials were planimetered from geologic section G-G' and extrapolated to the lakeshore.

The amount of ground water discharged from Goshen Valley to Utah Lake may be about the same as for southern Utah Valley, but the available subsurface data near the lakeshore are insufficient to justify more than an assumption. Although the length of the section at the lakeshore is longer, the water-table gradient is lower than in southern Utah Valley, and permeabilities probably are generally lower or the same as those in southern Utah Valley.

The total minimum ground-water discharge from southern Utah Valley and Goshen Valley to Utah Lake in 1966, therefore, is estimated to have been about 8,000 acre-feet.

Imbalance between recharge and discharge

Recharge to the aquifers in southern Utah Valley and Goshen Valley in 1966 was an estimated minimum of 150,000 acre-feet of water, and discharge was an estimated mimimum of 220,000 acre-feet. The relation between recharge and discharge can be expressed by the equation,

$$R = D \pm \Delta S,$$

in which R is the amount of recharge, D is the amount of discharge, and ΔS is the change in storage. The estimated change in storage in 1966 was a decrease of 29,000 acre-feet (8,000 acre-feet in southern Utah Valley and 21,000 acre-feet in Goshen Valley). These amounts were estimated using the water-level change map for the period March 1966 to March 1967 (fig. 13) and the storage coefficients of 2×10^{-1} and 1×10^{-3} for the water-table and artesian aquifers, respectively. The storage coefficient for artesian conditions is based on aquifer tests, and the storage coefficient for water-table conditions is an estimate based on the lithology of the aquifer materials.

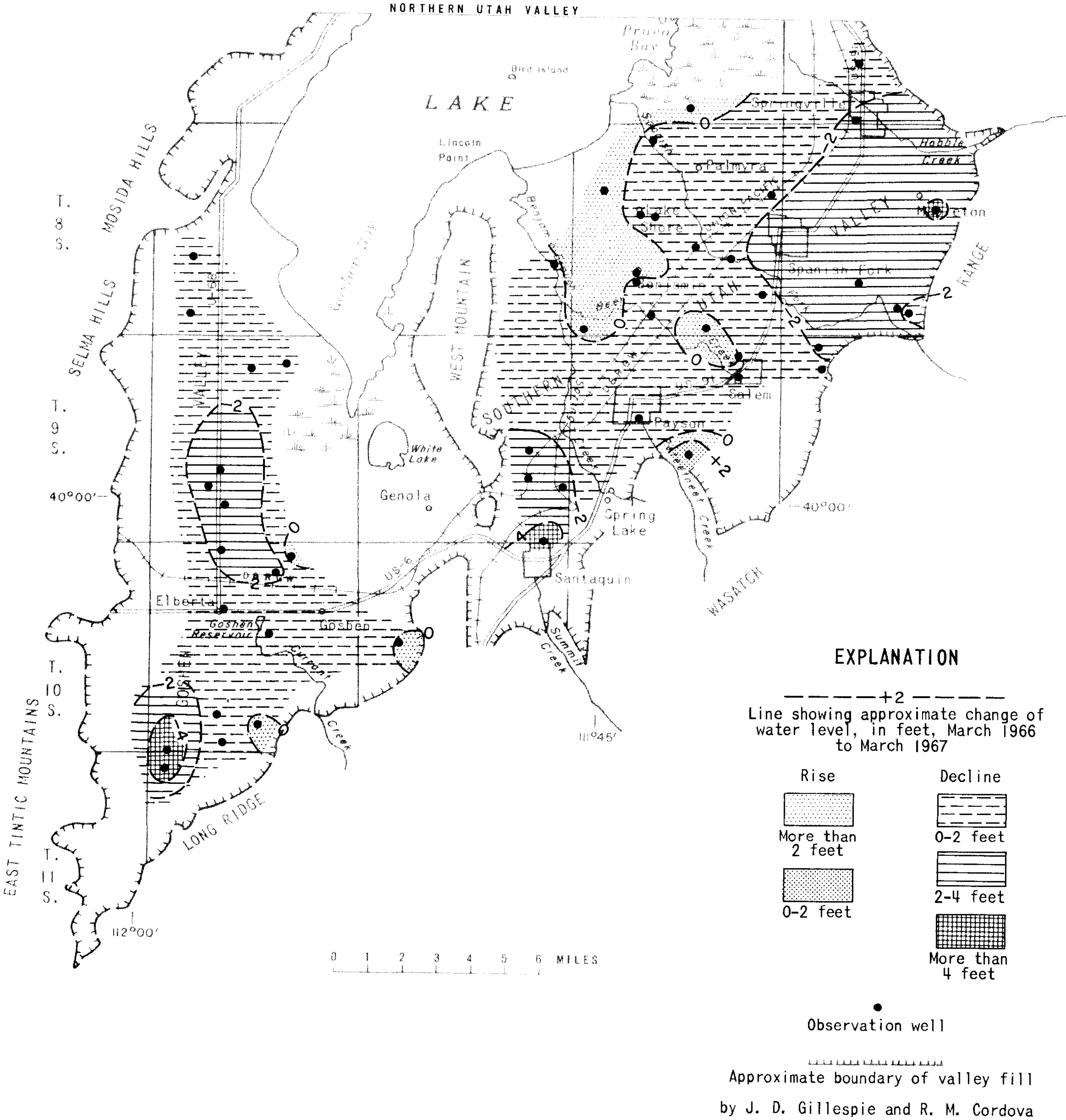


Figure 13.—Map of southern Utah Valley and Goshen Valley showing change of water levels from March 1966 to March 1967.

Inserting the values for recharge, discharge, and change in storage into the formula results in a difference of 41,000 acre-feet. The difference results from equating discharge for which one item could not be completely estimated, with recharge for which two items could not be estimated. The actual total amount of discharge probably would not be significantly changed if the incompletely estimated item, discharge into Utah Lake, could be determined completely. However, the unestimated items of recharge, subsurface flow from the bordering mountains, and seepage from ephemeral and intermittent streams, probably are significant sources of recharge, and could probably account for the 41,000 acre-feet.

Water-level fluctuations

Water levels in southern Utah Valley and Goshen Valley are changing continually for many reasons. They rise with a net addition of water to the ground-water reservoir, and they decline with a net subtraction. They fluctuate in response to earthquakes, barometric changes, temporary loading of the aquifers, and other causes. The various influences may operate singly or in combination and may be brief, daily, seasonal, or long term. Only seasonal and long-term fluctuations are discussed further in this report.

Seasonal fluctuations of water levels in southern Utah Valley are shown by the hydrographs in figure 14.

Well (D-8-2)36bbb-1, which is 15 feet deep, taps the water-table aquifer in the lake plain. The water level is highest in this well in the late spring because of recharge from winter and spring precipitation. The water level declines during the summer mainly because of heavy evapotranspiration in the vicinity of the well. The water level rises again during the fall and winter when evapotranspiration slackens.

Well (D-8-3)8abd-1, which is 270 feet deep, taps the artesian part of the ground-water reservoir in the lake plain. Although the seasonal water-level fluctuations in this well have almost the same pattern as in well (D-8-2)36bbb-1, the causes are different. The slight rise of water level during late winter and spring resulted from recharge from winter and spring precipitation. The decline of water level during the summer resulted from the withdrawal of water from wells for irrigation, and the water levels rose again during the fall and early winter after the irrigation wells were closed.

Water levels in Goshen Valley fluctuate seasonally (fig. 15). The water levels in wells (C-9-1)28ccb-1, (C-9-1)29acc-1, and (C-10-1)29cdd-1, all of which are pumped, decline during the pumping season and rise when pumping ceases. Seasonal pumping of these wells caused water levels in them to be drawn down about 35 to 80 feet during the period of record. At well (C-9-1)34ccc-1, which is not pumped but which is near a pumping well field, the water level declined about 2 feet during the irrigation seasons in 1964 and 1966.

The long-term fluctuations of water levels in southern Utah Valley are illustrated in figure 16. The annual precipitation during 13 of the 18 years from 1940 to 1957 exceeded the annual normal for the period 1931-60. Water levels generally were higher during this period compared to the following 5-year period, 1958-62, when the precipitation was less than normal. During the following 4 years, 1963-66, normal precipitation was nearly equaled or exceeded. A year after precipitation increased (1964) the downward water-level trend was reversed. The continued fluctuation of water levels in response to variations of precipitation in southern Utah Valley indicates that on a long-term basis total discharge does not exceed recharge.

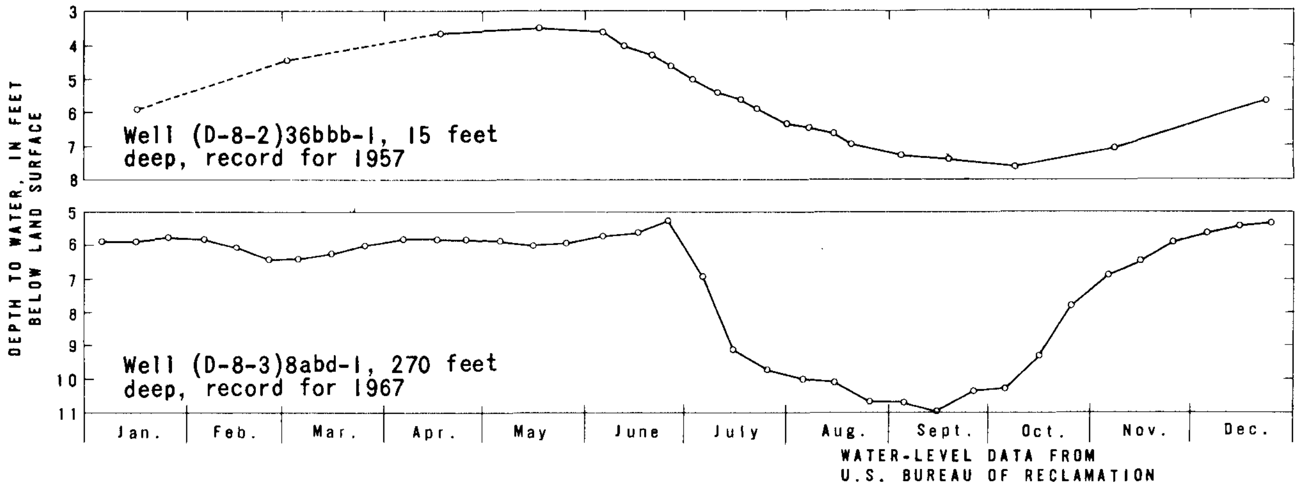


Figure 14.—Hydrographs of water levels in a deep and a shallow well in southern Utah Valley.

In Goshen Valley long-term records of water levels are not available. However, the overall short-term water-level trend shown by the five hydrographs in figure 15 is downward during the period of record 1961-67. In wells (C-10-1)29cdd-1 and (C-10-1)33cbb-1, the downward trend apparently started after 1962 or during the period when most of the large-discharge irrigation wells were constructed. During the period 1961-67 precipitation was above normal for 5 years and only slightly below normal for 2 years. Thus, water levels would have been expected to rise. The decline of water levels during this period in the western part of Goshen Valley indicates, therefore, that discharge has exceeded recharge.

Movement

Southern Utah Valley

Contours of the water table (pl. 1) indicate that the general slope and therefore the direction of flow of the unconfined ground water is from the Wasatch Range and the highlands toward Utah Lake.

The slope of the water table is generally greatest near the mountains and least near Utah Lake. The maximum gradient is about 100 feet per mile near Salem; the minimum measured gradient is about 10 feet per mile northwest of Salem.

Contours of the potentiometric surfaces for the three artesian aquifers (figs. 17-19) indicate that the general slope and therefore the direction of movement of the confined ground water is from the Wasatch Range toward Utah Lake. The measured slope of the potentiometric surface of the shallow Pleistocene artesian aquifer ranges from about 15 feet per mile at Spanish Fork to about 60 feet per mile at Springville, and of the deep Pleistocene artesian aquifer from less than 10 feet per mile at Spanish Fork to more than 30 feet per mile at Springville, and of the Tertiary artesian aquifer from about 3 feet per mile east of Leland to about 13 feet per mile west of Leland.

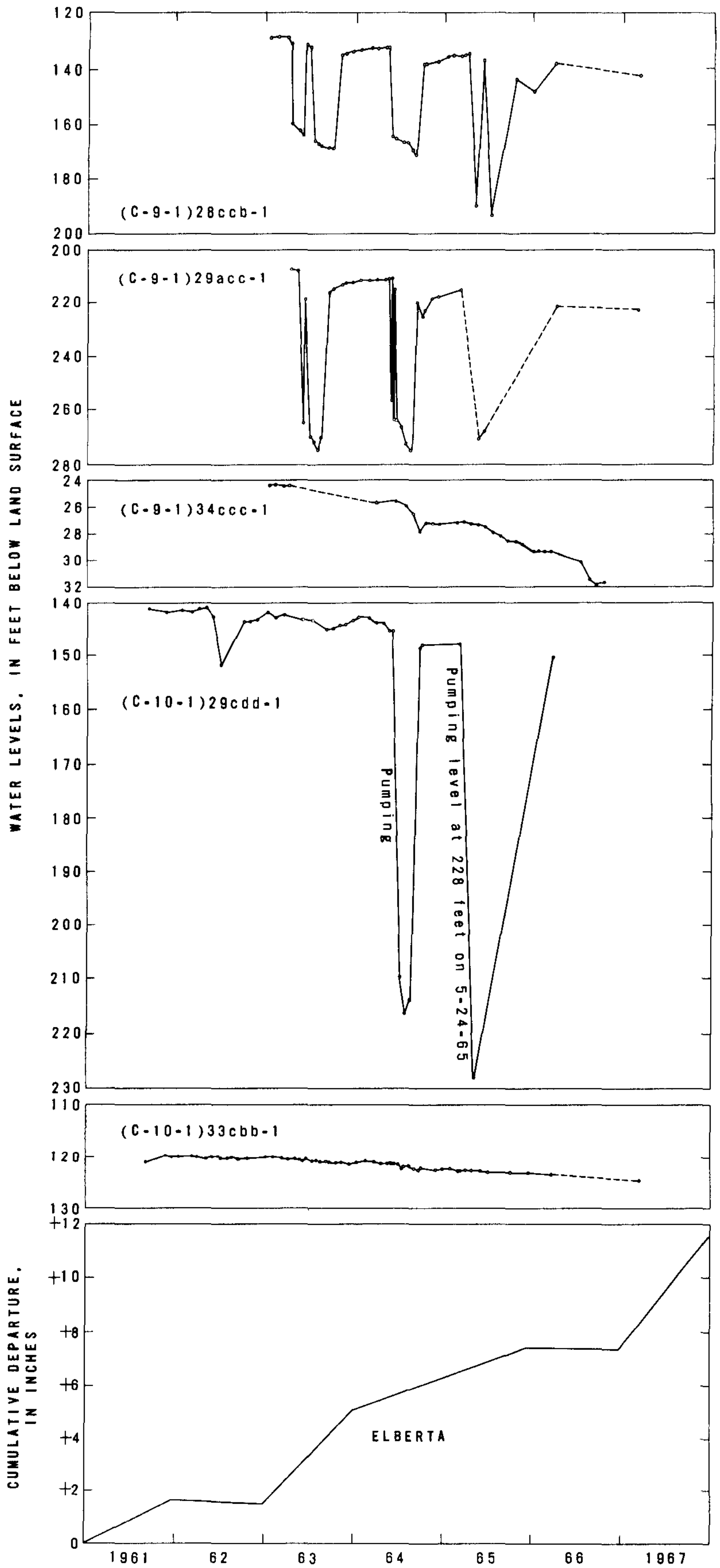


Figure 15.—Hydrographs of water levels in five selected wells in Goshen Valley and cumulative departure from the 1931-60 normal annual precipitation at Elberta.

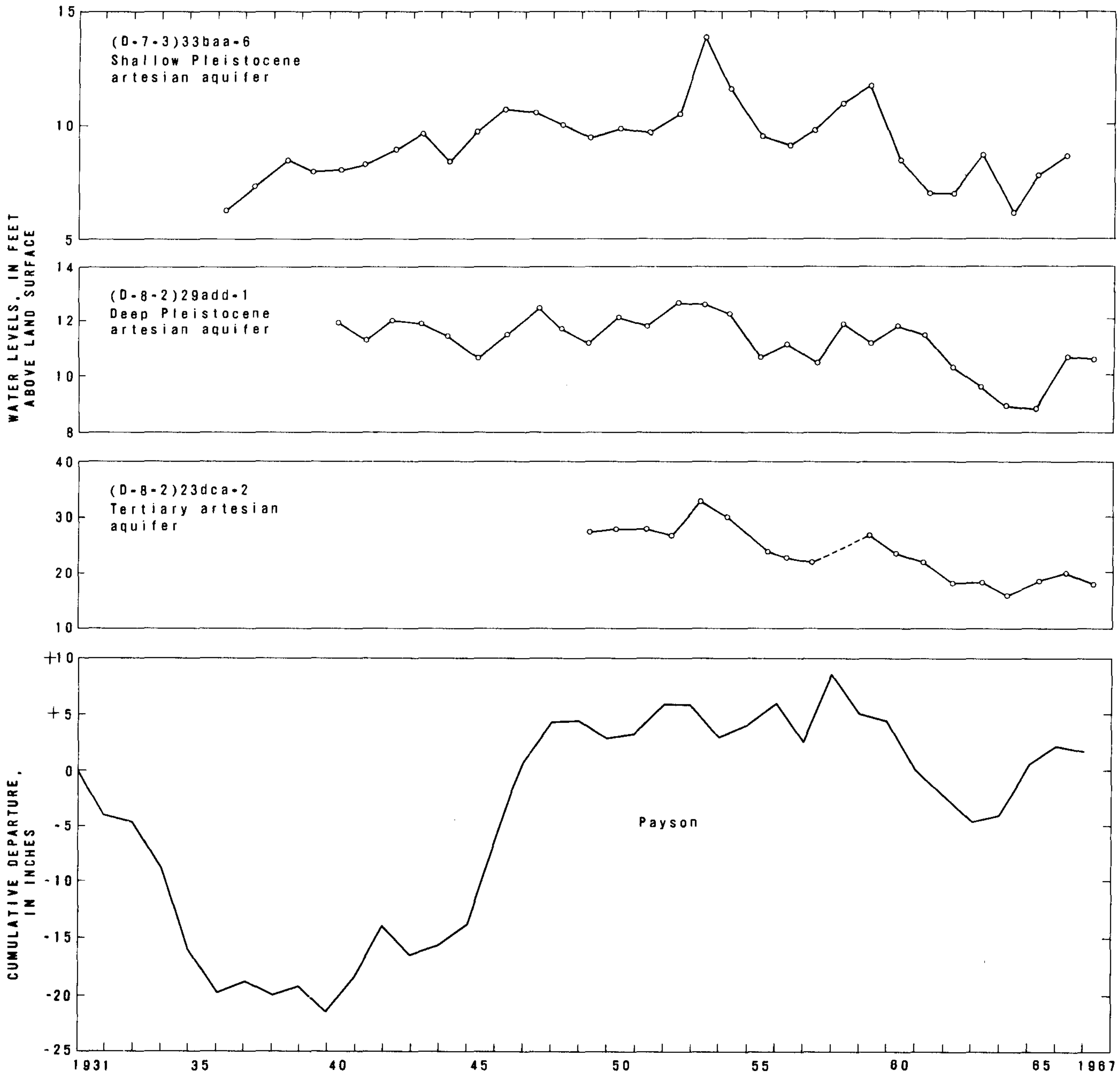


Figure 16.—Relation of water levels in the three artesian aquifers in southern Utah Valley to the cumulative departure from the 1931-60 normal annual precipitation at Payson.

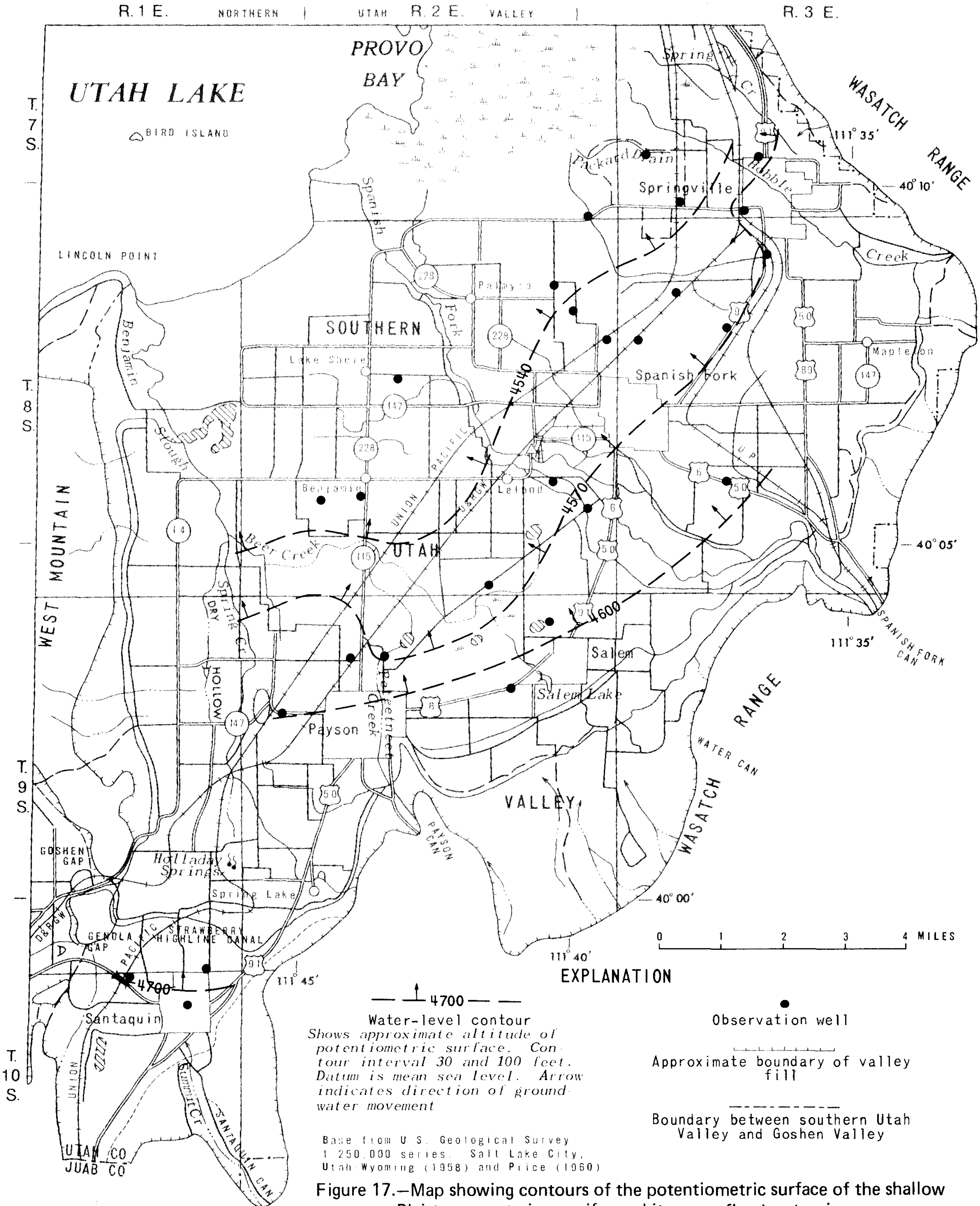


Figure 17.—Map showing contours of the potentiometric surface of the shallow Pleistocene artesian aquifer and its unconfined extensions, March 1965.

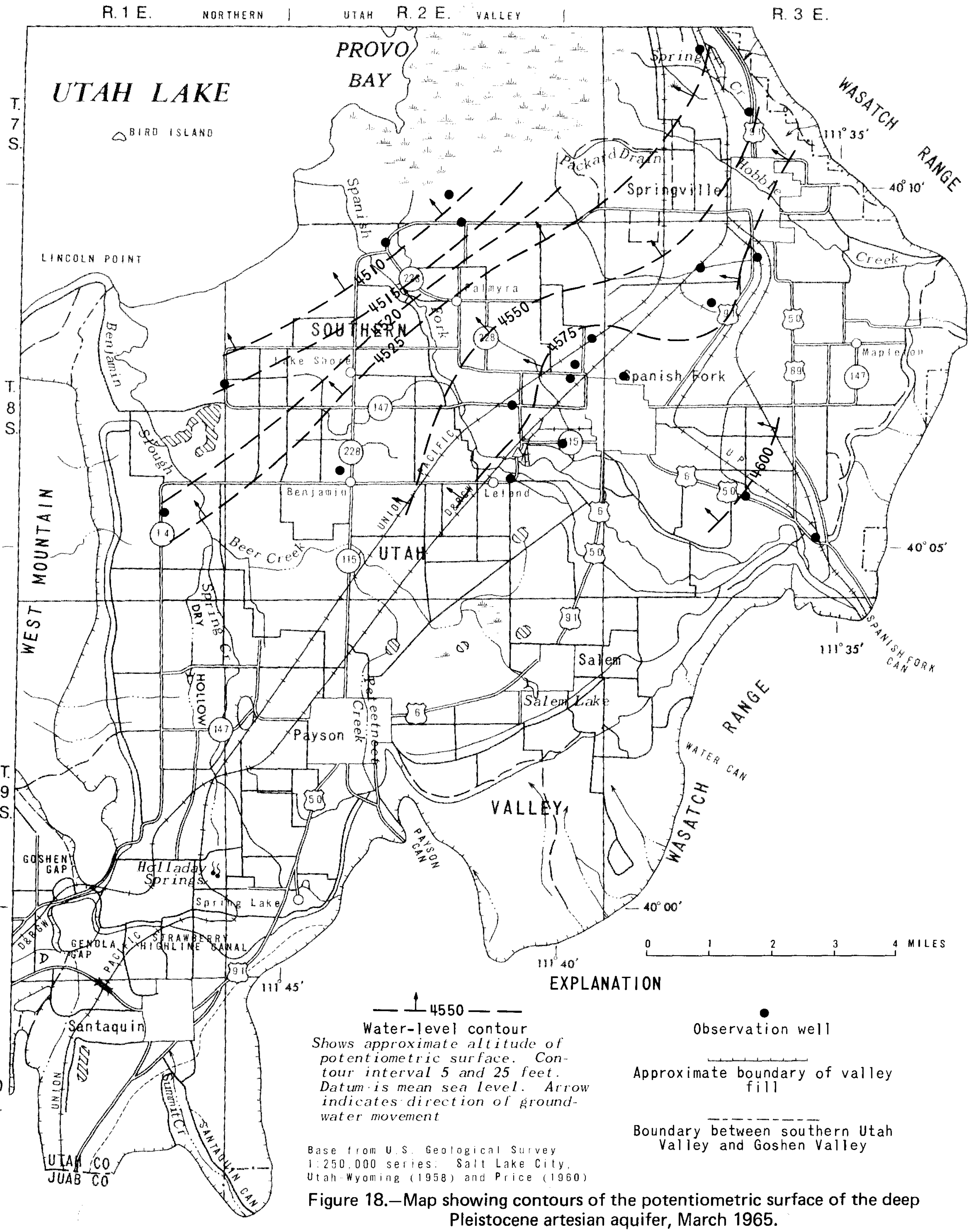


Figure 18.—Map showing contours of the potentiometric surface of the deep Pleistocene artesian aquifer, March 1965.

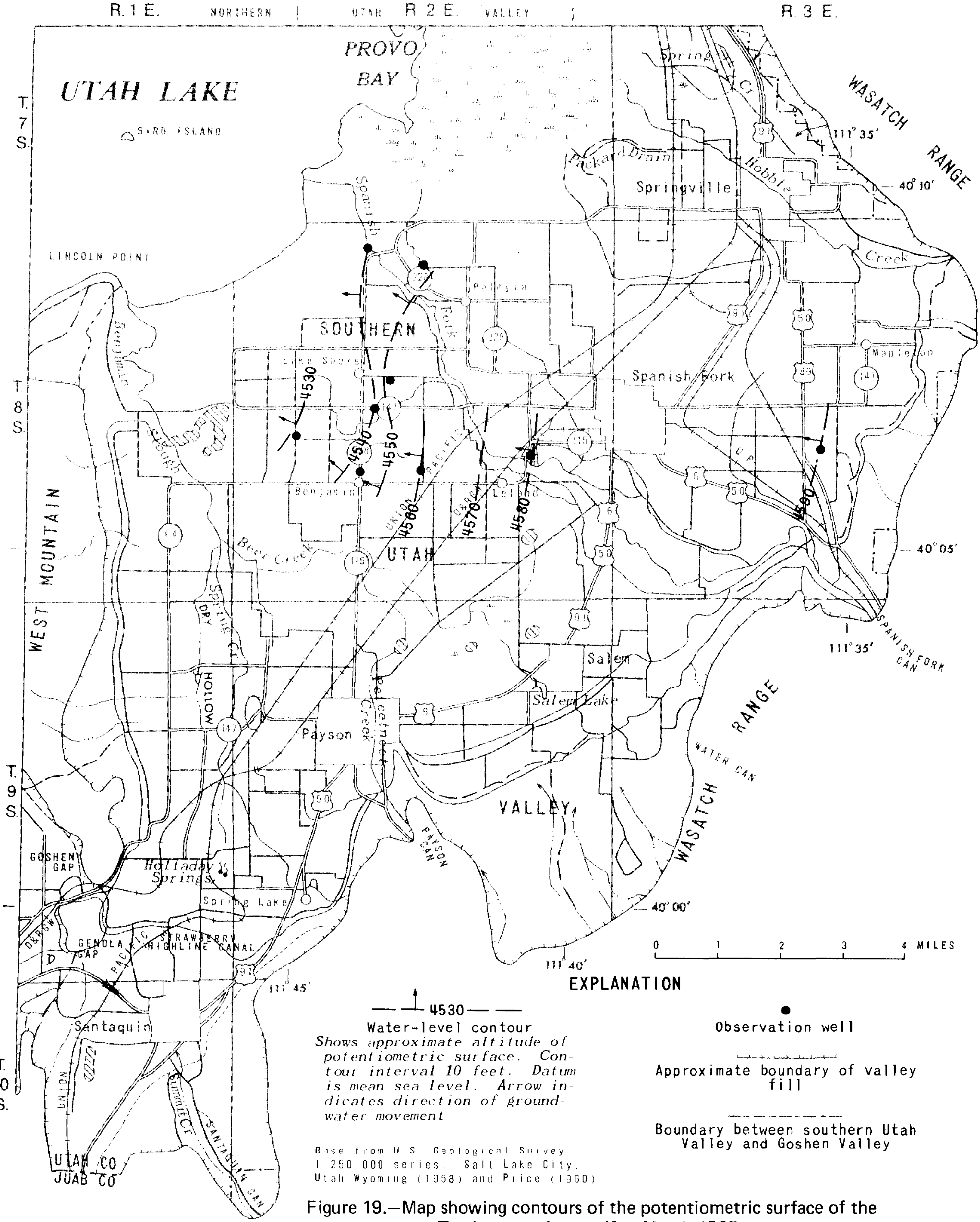


Figure 19.—Map showing contours of the potentiometric surface of the Tertiary artesian aquifer, March 1965.

In most of southern Utah Valley the potentiometric surface of each artesian aquifer is higher in altitude than that of the overlying aquifer. Where this phenomenon occurs water moves upward from the lower aquifers through the confining beds to the overlying aquifers. Locally, when large quantities of water are discharged from wells finished in the deeper aquifers, the altitude of water levels in the artesian aquifers may be nearly the same or the gradient may even be reversed.

Goshen Valley

Contours of the water table in Goshen Valley indicate that the general slope and therefore the direction of movement of ground water is away from the bounding mountains toward Utah Lake (pl. 1).

The slope of the water table ranges from about 5 feet per mile near Utah Lake to more than 20 feet per mile east of Goshen.

West Mountain area

Ground water in the water-table aquifer may move a distance of about 1 mile in the subsurface through the southern end of West Mountain from southern Utah Valley to Goshen Valley. Water levels on the east side of West Mountain are at least 100 feet higher than water levels on the west side. The difference in water levels is shown on plate 1 and in two profiles of the water table through Goshen and Genola Gaps in West Mountain (fig. 20). Wells (D-9-1)27aca-1 and (D-9-1)34bdb-1 tap unconfined water in consolidated rock; the other wells shown in figure 20 tap water in valley fill, and White Lake is an area of natural discharge from the water-table aquifer.

West Mountain possibly is a recharge area, and ground water may move east and west from the upland area into the valleys, and not from one valley to another. Water-level data available at this time are not sufficient to define the situation.

AQUIFER TESTS

Aquifer tests in both southern Utah Valley and Goshen Valley were conducted to obtain data about the hydraulic characteristics of aquifers in both valleys and to determine whether pumping large-diameter wells decreased artesian pressures and resulting flow from the numerous small-diameter flowing wells. Selected test-well data and aquifer-test evaluations are given in table 11, and locations of wells used in aquifer tests in southern Utah Valley are shown in figure 21.

The test data were analyzed by the modified leaky aquifer formula (Hantush, 1960, p. 3713-3725) and by the Theis nonequilibrium method and the Theis recovery method (see Ferris and others, 1962) to determine the coefficient of transmissibility and the coefficient of storage of the aquifers. The coefficient of transmissibility indicates the ability of an aquifer to transmit water and is defined as the rate of flow of water, in gallons per day, through a verticial strip of the aquifer 1-foot wide and extending the full saturated thickness under a hydraulic gradient of 1 foot per foot. The coefficient of storage is defined as the volume of water that the aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface.

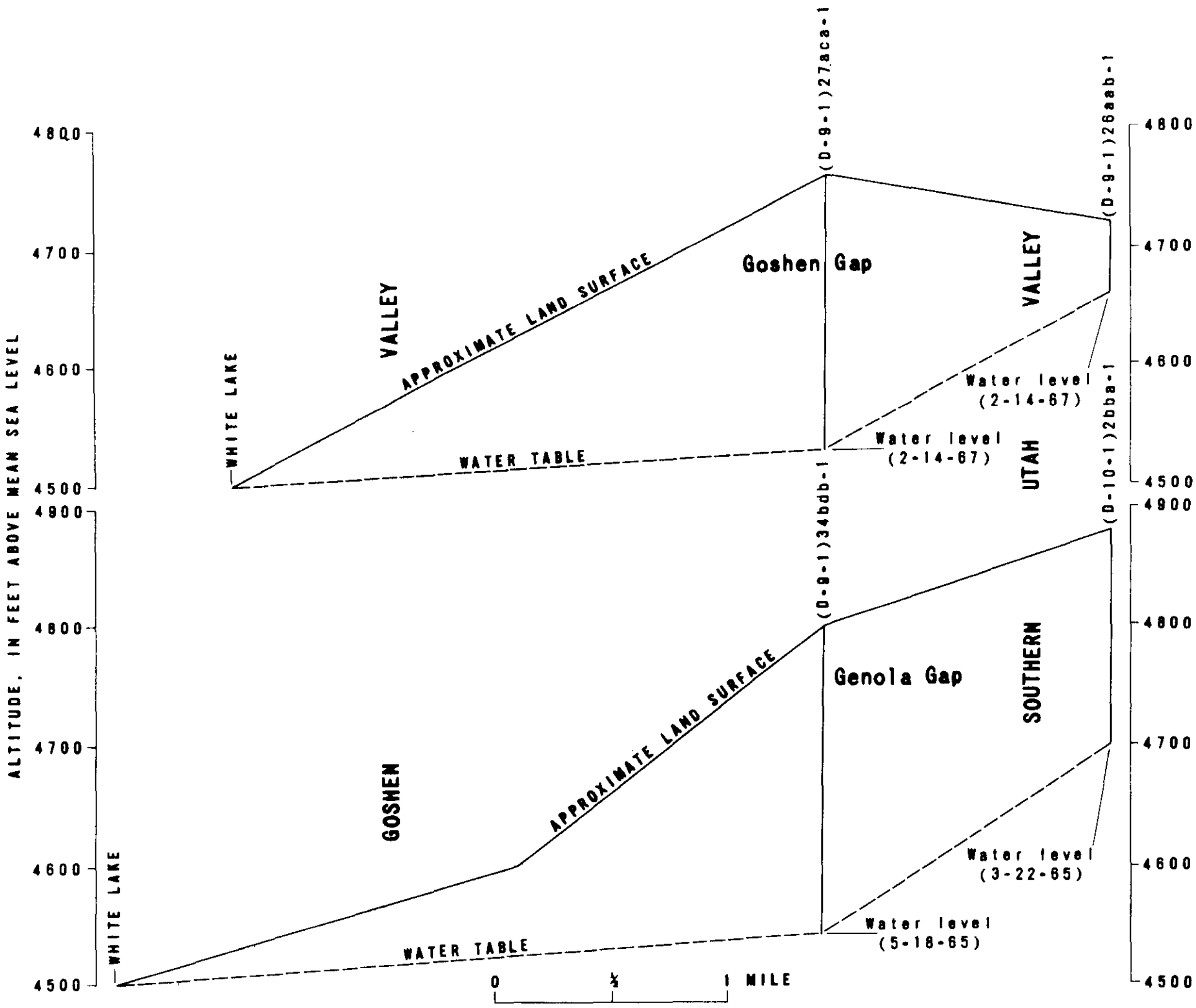


Figure 20.—Profiles of the water table in the Goshen Gap and Genola Gap areas.

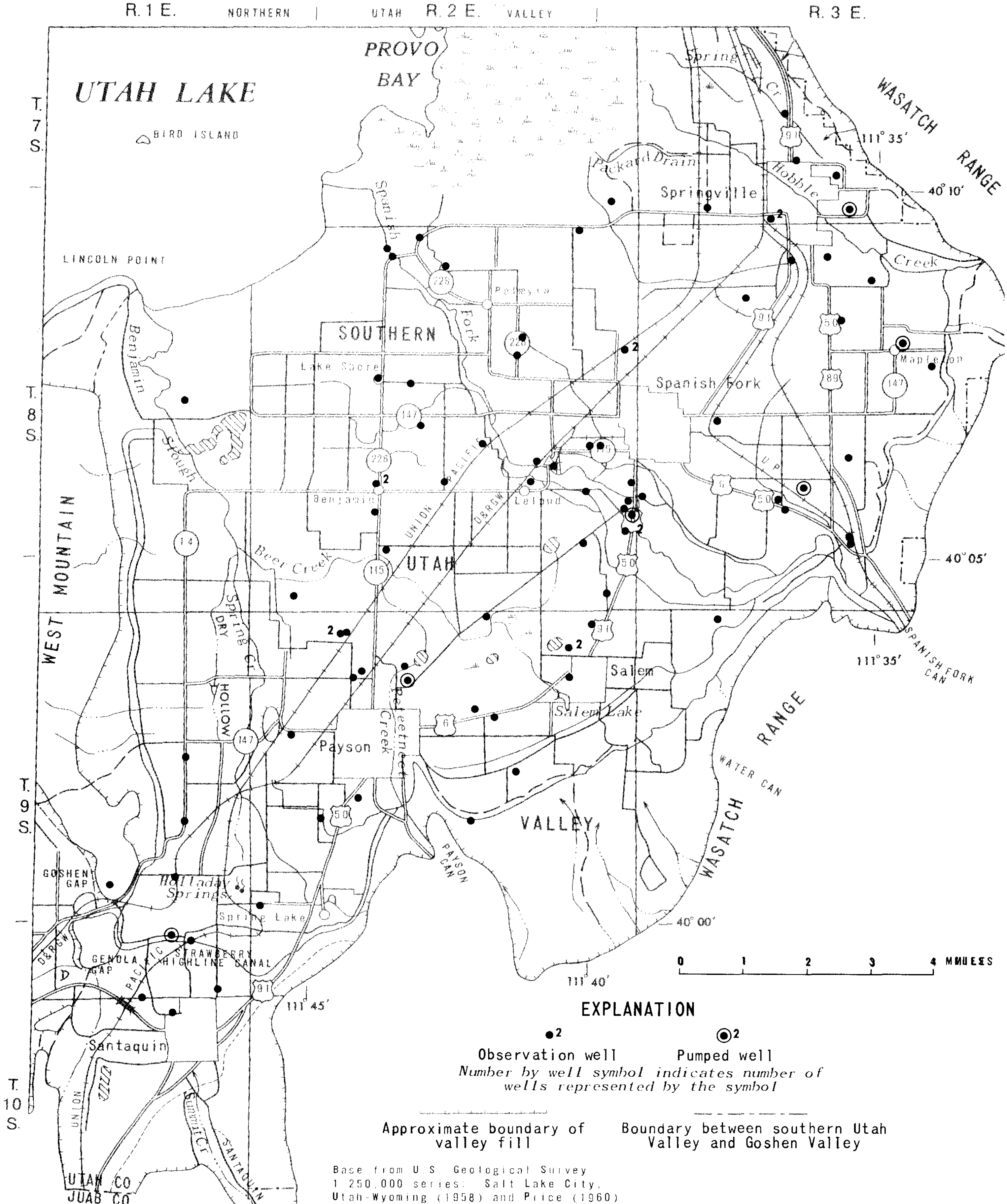


Figure 21.—Map of southern Utah Valley showing locations of pumped wells and observation wells used in an extensive aquifer test, January-March 1967.

The methods of analysis require certain restrictive assumptions that describe an ideal aquifer. These assumptions are that the aquifer is homogeneous, isotropic, constant in thickness, and infinite in areal extent; that the discharging well is perforated through the entire thickness of the aquifer, and has an infinitesimal diameter; that the coefficient of transmissibility is constant at all places and all times; and that water taken from storage by the decline in water level is discharged instantaneously with the decline in head. In parts of southern Utah Valley and Goshen Valley the actual physical conditions in and bounding the aquifers deviate from the ideal. The main deviation results from the heterogeneous bedding of the aquifer materials and the resulting changes in physical and hydraulic properties in relatively short distances. Most of the coefficients reported herein were determined from tests ranging in length from 5 to 27 days and for most purposes the aquifer coefficients are satisfactory.

Another assumption that the aquifers do not fully satisfy is equal vertical and horizontal permeability. The many beds of clay and silt in the aquifers cause the vertical permeability to be very small in comparison to the horizontal permeability. For this reason, the drawdown is less in an observation well finished at a level in the aquifer other than the level at which the pumped well is finished, than it would be if the observation will were finished at the same level as the pumped well. This difference in drawdown in wells finished at different levels in the aquifer diminishes with increased pumping time; and after pumping for several months to several years, the difference in drawdown may become negligible.

Still another assumption that is not fully satisfied by the aquifers is that points of recharge and discharge must be at infinite distances from the pumped well. Most recharge areas are sufficiently distant to satisfy this assumption; however, most areas of natural discharge are not. Natural discharge to the water-table aquifer in the Lake Bonneville Group by upward leakage through the confining beds occurs throughout the year in the lake plain where artesian heads are above the water table. When the cone of depression from a pumped well intercepts a point or area of natural discharge, the cone is modified because the water that would otherwise become natural discharge is shunted to the well. Both the drawdown and the distance from the pumped well to which the cone extends are less than they would be if the natural discharge were not intercepted.

Description of an extensive aquifer test

An extensive aquifer test in southern Utah Valley was made during January-March 1967. Aquifer coefficients were determined for several areas in southern Utah Valley. A discussion of the testing procedures, findings, and reliability of the data for each area is given in a report by Cordova and Mower (1967). The locations of the wells used in the extensive test are shown in figures 21-25; selected well and aquifer data are given in table 11; and water-level hydrographs of selected observation wells are shown in figure 26.

The principal test consisted of pumping five wells and observing water-level drawdowns in these and 74 observation wells. The test was conducted during January-March when withdrawals from wells and evapotranspiration were at a minimum, and after water levels had essentially stabilized following the season of heavy pumping. The pumped wells were turned on one at a time at intervals of from 4 to 7 days beginning January 30, until pumping of the fifth well was begun on February 21. Once pumping of a well was begun, it was continued at a constant uninterrupted rate until February 27, when all five pumping wells were turned off simultaneously. Water-level declines and recoveries were measured in most of the observation wells and all the pumped wells until March 27.

Pumping from well (D-8-2)25dac-3 near Spanish Fork resulted in water-level declines in observation wells nearly 3 miles away (see hydrograph of well (D-8-2)12ddc-2 and fig. 22). The pumped well is perforated from 505 to 605 feet, and water levels declined in an observation well perforated from 540 to 730 feet, in approximately the same zone as the pumped well (see hydrograph of well (D-9-2)1bcb-1). Water-level drawdowns were less in wells (D-8-2)24bdd-1 and (D-8-2)24bdc-2 finished at 180 feet and 327-352 feet, respectively.

Pumping from well (D-7-3)34cdb-1 near Springville resulted in water-level declines in observation wells within 3 miles of the pumped well (fig. 23). Water levels declined in wells tapping one or more of the beds tapped by well (D-7-3)34cdb-1. (See hydrographs of wells (D-7-3)33ccc-5 and (D-7-3)33ccc-6.) Pumping from well (D-8-3)11ccc-1 near Mapleton resulted in drawdowns in observation wells in both the Mapleton and Springville areas. Drawdowns of water levels in most wells observed in the Springville-Mapleton area resulted from pumping at both the Springville and the Mapleton wells.

Pumping from well (D-9-2)9bac-1 near Payson caused a large sudden drawdown of water level in well (D-9-2)4cdc-1, a quarter of a mile north of the pumped well (fig. 24). This is the only observation well in the Payson area that showed such a sudden and marked response to pumping. Pumping from well (D-9-2)9bac-1 caused only moderate to small water-level declines in some of the other observation wells in the Payson area.

Pumping from well (D-9-1)35aba-1 near Santaquin drew down water levels in observation wells within 1.2 miles to the south and east of the pumped well (fig. 25). However, little or no drawdown was observed in observation wells (D-9-1)26aab-1, 1.1 miles to the north of the pumped well, (D-9-2)30cbb-2, 1.5 miles to the northeast, or in (D-9-1)27aca-1, 1.4 miles to the northwest. Well (D-9-1)27aca-1 is the only well in the observation-well network that is completed in the consolidated rock of West Mountain.

Description of local aquifer tests

An aquifer test using pumped well (D-8-2)25dad-2, in the Spanish Fork area, was conducted on March 21, 1967. The well is 401 feet deep, and the 10-inch casing is perforated between 384 and 400 feet. The well was pumped for 4½ hours at an average rate of 223 gpm (gallons per minute) and the drawdown was 10.4 feet. Interpretation of the test data for the coefficients of transmissibility and storage of the developed aquifer between observation well (D-8-2)25ddb-2, which is 0.12 mile south, and observation well (D-8-2)25dbd-2, 0.2 mile west of the pumped well, are given in table 11.

An aquifer test was made in November 1965 near the mouth of Spanish Fork Canyon by pumping well (D-8-3)28abc-1 and observing water levels in four other wells. Interpretation of the test data indicate that the coefficient of transmissibility ranges from about 100,000 to about 1,000,000 gpd per foot, and that the coefficient of storage is about 0.0003 (see table 11).

Interference tests using small-yield flowing wells were conducted in Salem and 1 mile north of Payson. In the Salem test, well (D-9-2)2dad-2 was allowed to flow for 1 hour at an average rate of 32 gpm, and it produced a drawdown of 1.4 feet in observation well (D-9-2)2dad-1, 45 feet away. In the test north of Payson, well (D-9-2)5bdd-4 was allowed to flow for about 5 hours at an average rate of 90 gpm, and it produced a drawdown of 0.85 foot in observation well (D-9-2)5bdd-2, 48 feet away.

Other local aquifer tests were made in the lake plain in 28 flowing wells by shutting them in and measuring the recovery of the shut-in pressure. Interpretation of the test data suggests that the coefficient of transmissibility in the area of flowing wells is on the order of 100,000 gpd per foot.

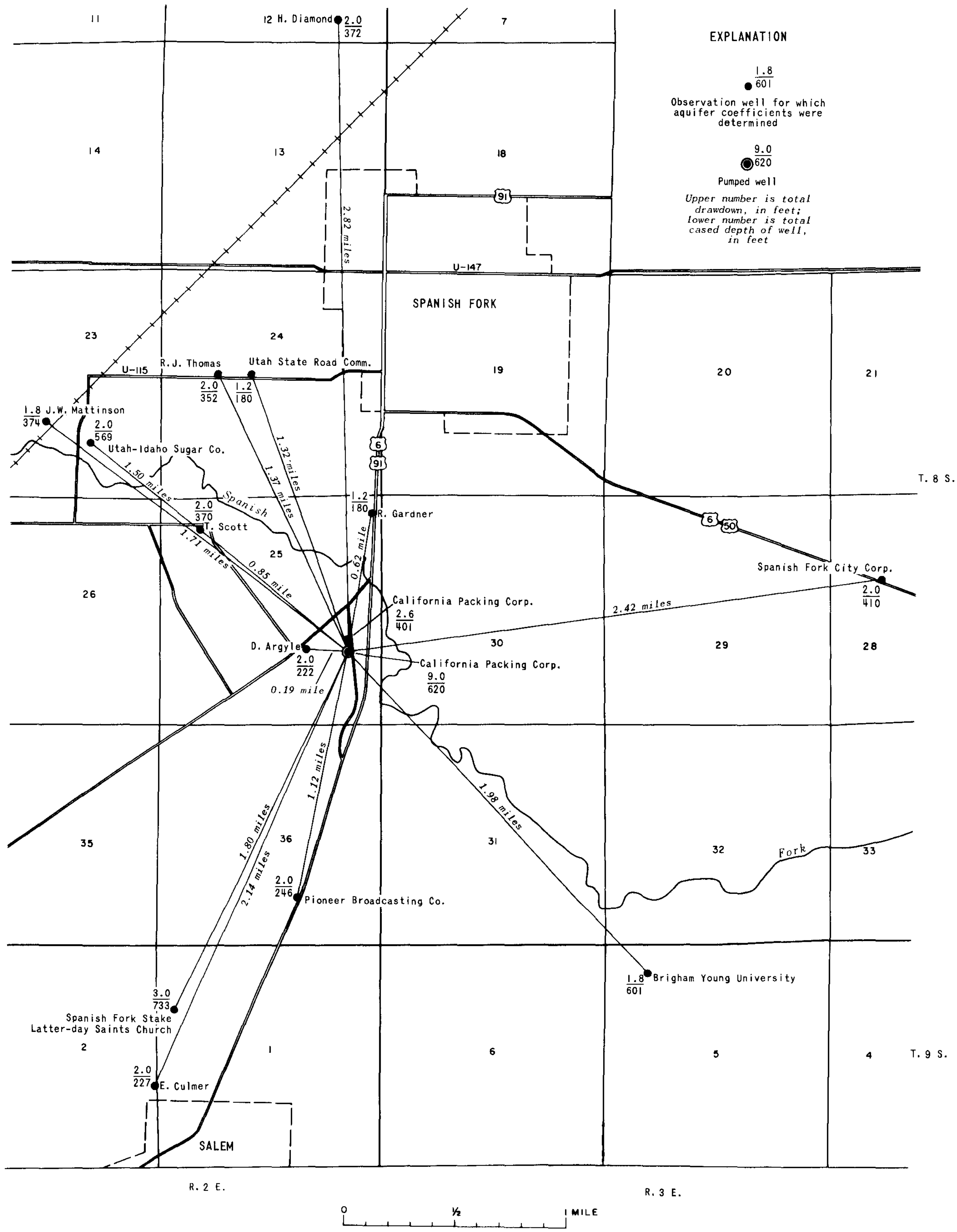


Figure 22.—Map showing locations of wells, depths of wells, distances from pumped well to observation wells, and observed drawdown in the vicinity of Spanish Fork.

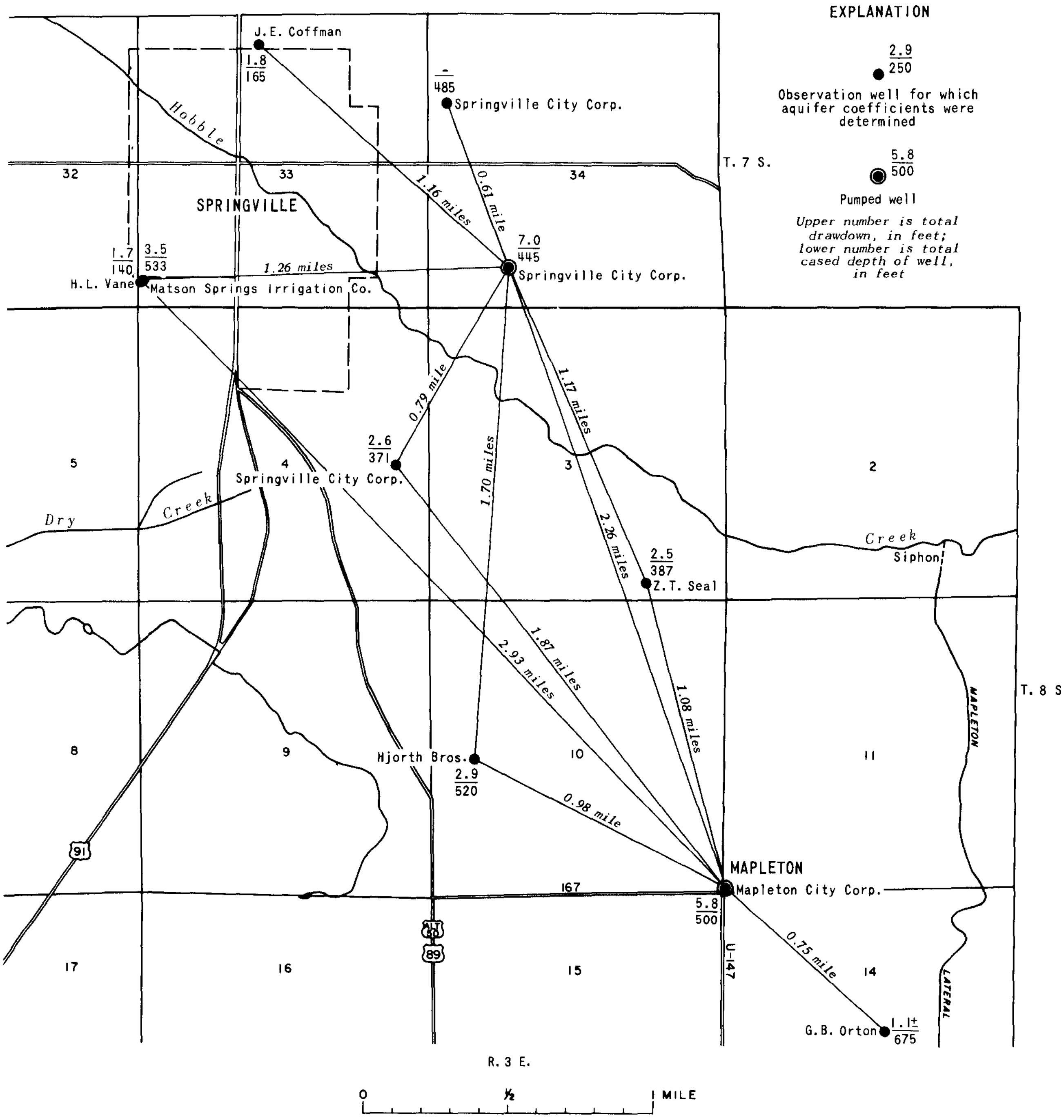


Figure 23.—Map showing locations of wells, depths of wells, distances from pumped wells to observation wells, and observed drawdown in the vicinity of Springville and Mapleton.

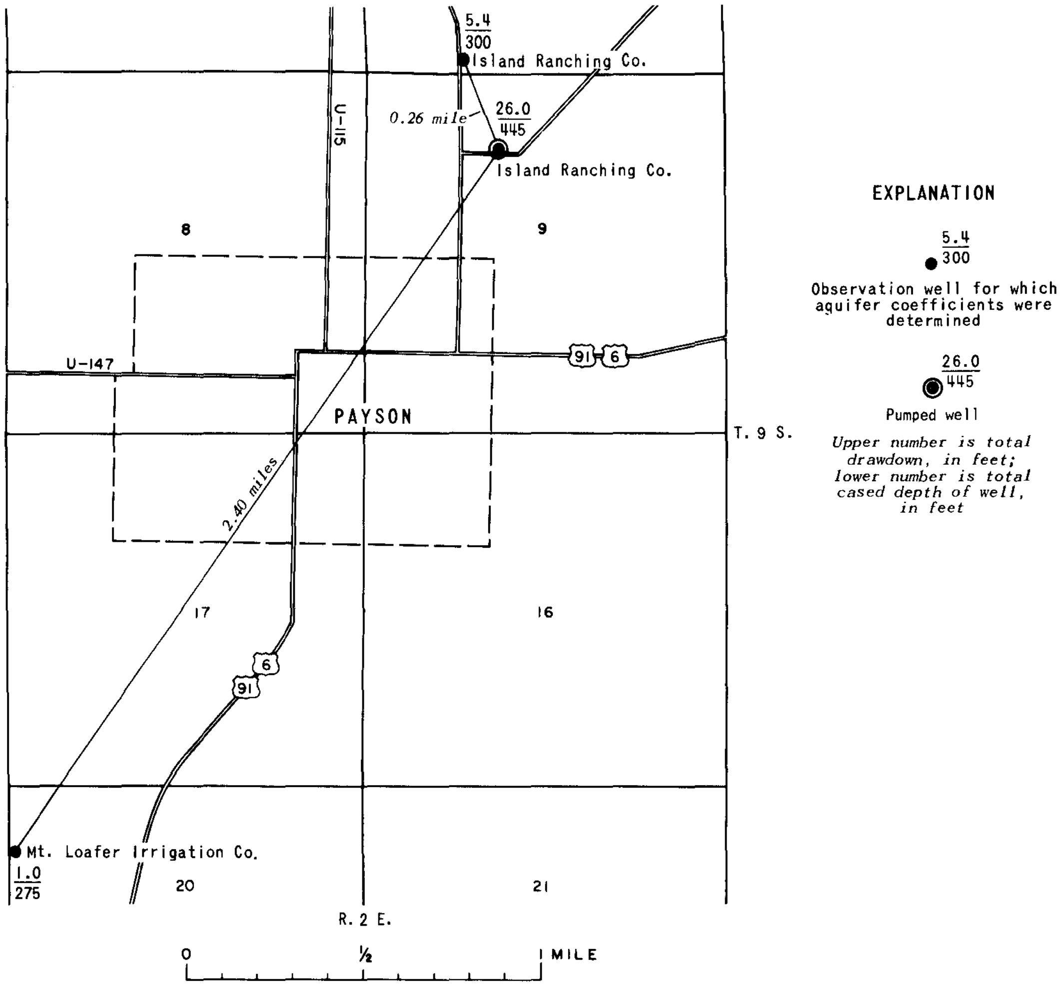


Figure 24.—Map showing locations of wells, depths of wells, distances from pumped well to observation wells, and observed drawdown in the vicinity of Payson.

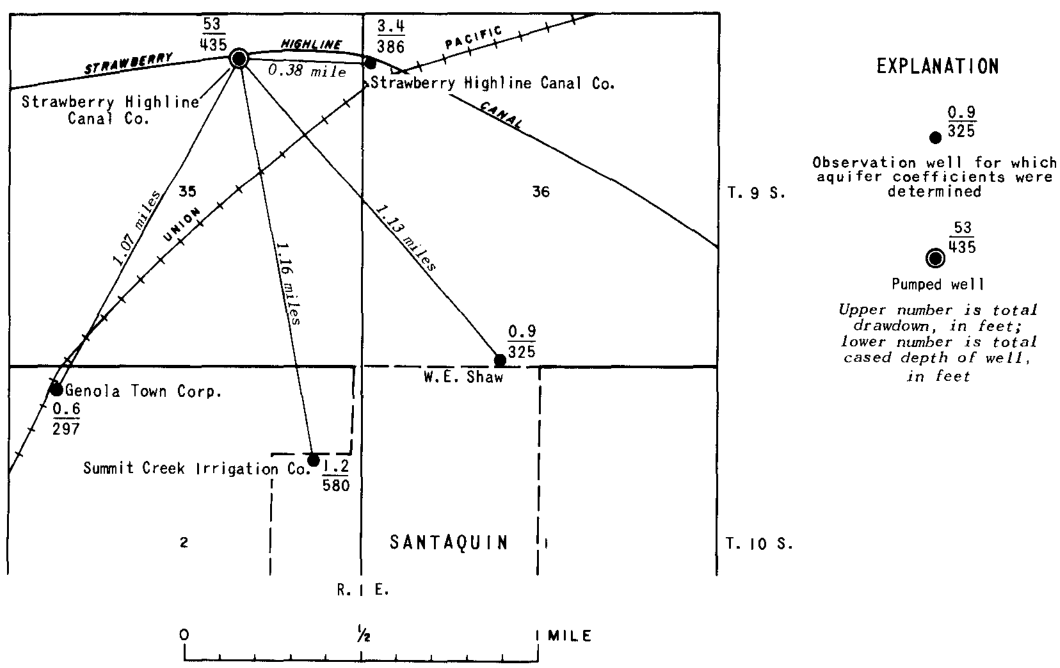


Figure 25.—Map showing locations of wells, depths of wells, distances from pumped well to observation wells, and observed drawdown in the vincinity of Santaquin.

Table 11.—Summary of selected test-well data and aquifer-test evaluations.

Wells tested: Aquifer - B, Lake Bonneville Group; D, Deep Pleistocene artesian aquifer; L, less permeable zone between aquifers; S, shallow Pleistocene artesian aquifer; T, Tertiary artesian aquifer; designations like D-T indicate the well is finished in and between the aquifers cited. Use during test - P, pumped well; O, observation well. Finish - O, open end; P, perforated; S, screen; U, unknown.

Area of aquifer test (see figs. 21-25)	Wells tested and their construction						Aquifer coefficients	
	Well-location number	Aquifer	Use during test	Depth (ft)	Diameter (in)	Finish	Storage	Transmissibility (gpd per ft)
SOUTHERN UTAH VALLEY								
Springville	(D-7-3)33baa-7	S	O	165	2	U	0.002	330,000
	33ccc-5	S	O	140	2	O	.0004	470,000
	33ccc-6	D-T	O	533	16	P230-533	.0002	420,000
	34bcb-1	L-T	O	485	16	P410-475	.0007	230,000
	34cdb-1	B-D	P	445	16	P158-230, 294-395, 402-442	-	380,000
	(D-8-3)4daa-1	S-D	O	371	16	P145-255, 280-370	.007	230,000
Mapleton	(D-8-3)3dcd-1	B-S	O	387	16	P215-385	.0005	700,000
	10cba-1	D-T	O	520	10	P395-520	.0005	550,000
	11ccc-1	D, L	P	500	16	P383-495	-	350,000
	14acc-1	B, L, T	O	675	10	P189-200, 372-395, 507-675	.004	500,000
Spanish Fork	(D-8-2)23cad-2	L	O	374	4	O	.003	63,000
	23dca-2	T	O	569	8	P475-500	.0009	72,000
	24bdc-2	D	O	352	6	P327-352	.003	72,000
	24bdd-1	S	O	180	2½	O	.004	50,000
	25aaa-1	S	O	180	2	O	.007	140,000
	25bbd-1	D	O	370	6	O	.004	59,000
	25dab-2	L	O, P	401	10	P384-400	.0009	100,000
	25dac-3	T	P	620	16	P505-605	-	130,000
	25dbd-2	S	O	222	4	O	.002	130,000
	25ddb-2	S	O	233	4	O	.001	220,000
	36dcb-2	S	O	246	4	O	.003	63,000
	(D-8-3)28bcd-1	D	O	410	12½	U	.0005	125,000
	(D-9-2)1bcb-1	T	O	733	16	P540-730	.0007	140,000
	2dad-2	S	O	196	4	O	.000003	200,000
	(D-9-3)5bbd-1	S-D	O	601	20	P300-586	.0001	145,000
Payson	(D-9-2)4cdc-1	S	O	300	8	O	.003	350,000
	9bac-1	B, S, L	P	445	16	P50-169, 202-252, 288-337, 377-427	-	200,000
	20bbc-2	B, S	O	275	16	P85-265	.003	140,000
Santaquin	(D-9-1)35aba-1	B-D	P	435	16	P145-430	-	100,000
	36bbc-1	B-D	O	386	16	P80-370	.02	200,000
	36cdd-1	B-D	O	325	12	P192-325	.02	370,000
	(D-10-1)2adb-1	S-D	O	580	16	P259-548	.009	400,000
	2bba-1	B-S	O	297	16	P189-297	.02	580,000
Mouth of Spanish Fork Canyon	(D-8-3)22cad-1	L, T	O	541	16	P485-535	.0002	950,000
	27cdc-1	B, T	O	630	16	P220-589	.0005	530,000
	28abc-1	S, D	P	470	12	P264-284, 425-465	-	100,000
	28bcd-1	D	O	410	12½	U	.0005	120,000
	28bdc-1	S	O	395	12	P240-285	.0002	110,000
GOSHEN VALLEY								
North of Elberta	(C-9-1)3ddb-1	S-D, T?	P	575	20, 18	P190-205, 225-338, 365-565	-	160,000
	4ddc-1	-	P	690	18	P200-683	-	50,000
	(C-10-1)4cbb-1	S-D, T?	P	1,218	30, 16, 12	S406-550, 640-680, P700-850	-	1/38,000
South of Elberta	(C-11-1)6abc-1	B-T	O	682	18	P315-322, 330-335, 390-488, 495-532, 545-675	0.001	300,000

1/ Determined by W. F. Guyton and Associates.

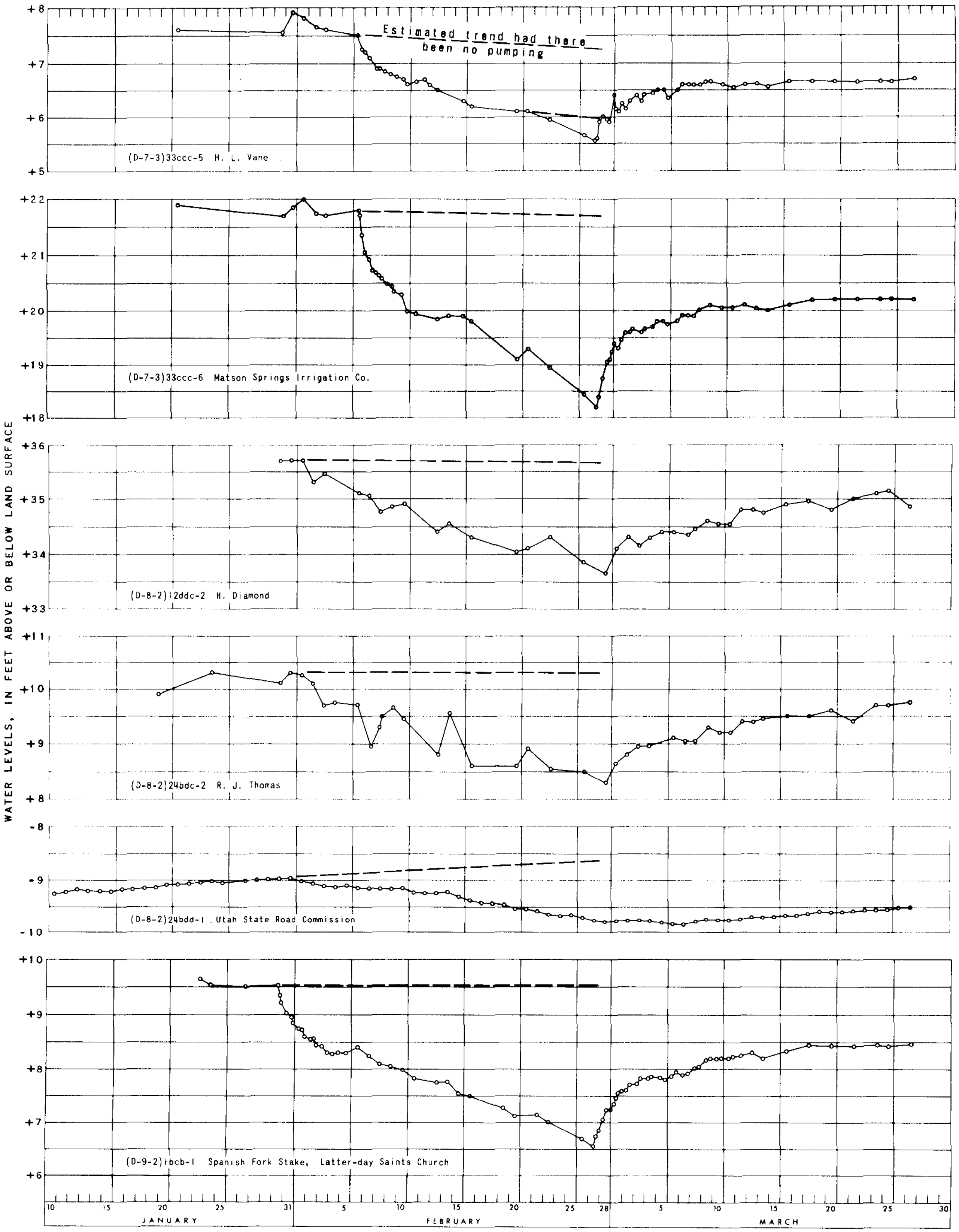


Figure 26.—Water-level hydrographs of selected observation wells used in an extensive aquifer test in southern Utah Valley, 1967.

In the area of pumped irrigation wells north of Elberta in Goshen Valley, several tests during April 5-14, 1967, showed no interference between pumped wells discharging 1,800 to 2,700 gpm and observation wells about 1 mile away after pumping 24 hours. Recovery tests on three pumped wells in the area north of Elberta showed the coefficient of transmissibility of the upper 400 feet of saturated materials to range from about 22,000 gpd per foot in well (C-10-1)4cbb-1 to 120,000 gpd per foot in well (C-9-1)3ddb-1. In the area of pumped irrigation wells south of Elberta, a 7-hour aquifer test on April 11, 1967, indicated artesian conditions between the pumped well (C-10-1)31cdd-1 and wells (C-11-1)6abc-1 and (C-11-1)6bdd-1 about a half a mile to the south. Interference effects were noted almost immediately among these wells but were not noted in observation wells about 1 mile north of the pumped well, indicating unconfined conditions north of the pumped wells. The coefficient of transmissibility between wells (C-10-1)31cdd-1 and (C-11-1)6abc-1 is about 270,000 gpd per foot and the coefficient of storage is 0.001 in the upper 400 feet of saturated materials.

Storage

The amount of ground water recoverable by wells from storage in the upper 400 feet of saturated materials of the ground-water reservoir is estimated to be 3 million acre-feet in southern Utah Valley and 3 million acre-feet in Goshen Valley. The upper 400 feet of saturated materials in southern Utah Valley was chosen for detailed study because most of the wells in southern Utah Valley are developed in this zone and because most of the geologic data available pertains to this zone. The upper 400 feet was chosen in Goshen Valley to allow comparison with southern Utah Valley.

The total amount of water in storage was estimated by determining the volume of saturated materials in the upper 400 feet of the ground-water reservoir. The amount of water recoverable by wells was then estimated by applying percentages for specific yield to six classes of saturated sediments. The specific yield is the ratio of the volume of water the sediment will yield (by gravity) to the total volume of the sediment. Some water is also released from storage in artesian aquifers by compression of the aquifer materials and expansion of the water when water levels are lowered. This quantity of water is small, however, and was estimated to be 30,000 acre-feet using a coefficient of storage of 10^{-3} and 400 feet of lowering over an area of about 78,000 acres where artesian conditions prevail.

To simplify the assignment of specific yields, the sediments described by well drillers were grouped into six classes. From laboratory and field studies in other areas (Johnson, 1967) and from personal judgment based on field experience in southern Utah Valley and Goshen Valley, estimated values of specific yield were assigned to the six classes as follows:

Description	Specific yield
Class 1 - Gravel and coarser material, sand may be present	0.25
Class 2 - Gravel and coarser material with clay and silt	.05
Class 3 - Sand	.25
Class 4 - Sand, clay, and silt	.05
Class 5 - Clay and silt	.03
Class 6 - Cemented materials mainly, including hardpan, conglomerate, and consolidated rock	.01

The volume of saturated materials was determined for each township from the percentage of each class of sediment in a representative log chosen for the township. The representative log was chosen by comparing the logs available in each township or in nearby townships. A total of 483 logs in southern Utah Valley and 41 logs in Goshen Valley were classified and compared.

The amount of water recoverable by wells was determined by multiplying the volume of the saturated sediments of the class by the specific yield assigned to the class. The amount of recoverable water in each township and data used in the computations are shown in table 12.

Ground-water development by wells

History of development

Development of the ground-water reservoir by wells began at least as early as 1879 in southern Utah Valley and 1886 in Goshen Valley according to the records of the Utah Division of Water Rights; by the end of 1966 about 1,700 wells were reported to be in these valleys (table 13). Of the total number, about 1,600 wells were in southern Utah Valley and about 80 in Goshen Valley.

The records of the Utah Division of Water Rights indicate that the average rates of well construction in southern Utah Valley from 1900 to 1932 and from 1937 to 1966 were 13 and 20 wells per year, respectively, compared to 125 wells per year, in the 4 years 1933 to 1936. The accelerated rate of well construction during the period 1933-36 may have been partly due to several years of below-normal precipitation but is mostly an increase that apparently resulted from the necessity for filing claims as required by enactment of the State ground-water law in 1935. About 66 percent of the large-discharge pumped wells used for irrigation and public supply in the valley at the end of 1966 were constructed from 1961 to 1963. These wells were drilled after a period of low springflow and streamflow from 1959 to 1961 to ensure stable irrigation and public water supplies. The average rates of well construction in Goshen Valley from 1900 to 1932 was one well each 3 years, from 1943 to 1966 was two wells per year compared to six wells per year from 1933 to 1936. The number of large-discharge pumped wells used for irrigation increased by 72 percent during the period 1961-66. These wells were drilled to supply water for land which previously had not been irrigated.

Table 13 shows a classification of wells as of the year 1966 by use, depth, and diameter. The numbers of wells shown in table 13 are based upon detailed study of the records of the Utah Division of Water Rights.

The distribution of selected wells by area and type of use is shown on plate 3. Most of the large-diameter wells used for irrigation, public supply, or industry are in the highlands, whereas most of the small-diameter wells used for household purposes, stock, and some irrigation are in the lake plain.

Well yields

The yield of a well in the project area is generally larger when the well is first constructed than after several years of use. The decline in yield may result from several causes but a chief cause in southern Utah Valley is the filling of the casing with fine-grained sediments. Yields measured, therefore, fairly soon after construction are most representative of an aquifer's ability

Table 12.—Ground water recoverable by wells from storage in the upper 400 feet of the ground-water reservoir.

(All products and totals rounded; volume and recoverable water given in thousands of acre-feet)

Township and range	Area (acres)	Volume of upper 400 feet of saturated sediments	Class 1			Class 2			Class 3			Class 4			Class 5			Class 6			Total recoverable water
			Percent	Volume	Recoverable water	Percent	Volume	Recoverable water	Percent	Volume	Recoverable water	Percent	Volume	Recoverable water	Percent	Volume	Recoverable water	Percent	Volume	Recoverable water	
SOUTHERN UTAH VALLEY																					
7S - 2E	7,000	3,000	6	200	50	0	0	0	9	300	80	18	500	20	67	2,000	60	0	0	0	200
7S - 3E	6,000	2,000	28	600	200	0	0	0	8	200	50	12	200	10	52	1,000	30	0	0	0	300
8S - 1E	6,000	2,000	0	0	0	11	200	10	8	200	50	46	900	50	35	700	20	0	0	0	100
8S - 2E	23,000	9,200	8	700	200	0	0	0	13	1,200	300	11	1,000	50	68	6,300	200	0	0	0	800
8S - 3E	19,000	7,600	1	80	20	67	5,100	300	16	1,200	300	15	1,100	60	0	0	0	1	80	.8	700
9S - 1E	8,000	3,000	10	300	80	5	200	10	6	200	50	4	100	50	62	2,000	60	13	400	4	200
9S - 2E	19,000	7,600	30	2,300	580	45	3,400	200	0	0	0	0	0	0	25	1,900	60	0	0	0	800
9S - 3E	3,000	1,000	12	100	30	2	20	1	0	0	0	56	600	30	22	200	6	8	80	.8	60
10S - 1E 2E	6,000	2,000	9	200	50	60	1,000	50	0	0	0	0	0	0	31	600	20	0	0	0	100
Totals	100,000	40,000	-	4,000	1,000	-	10,000	600	-	3,000	800	-	4,000	200	-	20,000	500	-	600	6	3,000
GOSHEN VALLEY																					
7S - 1W 8S - 1W 2W	18,000	1/1,800	0	0	0	100	1,800	90	0	0	0	0	0	0	0	0	0	0	0	0	90
9S - 1W 2W	27,000	11,000	8	900	200	11	1,200	60	3	300	80	24	2,600	100	54	5,900	200	0	0	0	600
10S - 1W 2W	24,000	9,600	33	3,200	800	52	5,000	200	0	0	0	2	200	10	13	1,200	40	0	0	0	1,000
11S - 1W 2W	9,000	4,000	57	2,000	500	29	1,000	50	1	40	10	0	0	0	13	500	20	0	0	0	600
9S - 1E	9,000	4,000	2/25	1,000	200	0	0	0	0	0	0	0	0	0	2/75	3,000	90	0	0	0	300
10S - 1E	4,000	2,000	2/25	500	100	0	0	0	0	0	0	0	0	0	2/75	1,500	40	0	0	0	100
Totals	90,000	30,000	-	8,000	2,000	-	9,000	400	-	300	90	-	3,000	100	-	10,000	400	-	0	0	3,000
Grand totals	200,000	70,000	-	10,000	3,000	-	20,000	1,000	-	3,000	900	-	7,000	300	-	30,000	900	-	600	6	6,000

1/ Calculated for upper 100 feet of saturated materials because bedrock is probably within 400 feet of land surface.

2/ Estimated on basis of distribution by percent of gravel (see fig. 3).

Table 13.—Classification of wells as of December 31,1966

(Based on applications, claims, and well drillers' reports filed with the Department of Natural Resources, Division of Water Rights)

Classification	Southern Utah Valley High-lands	Southern Utah Valley Lake plain	Goshen Valley High-lands	Goshen Valley Lake plain	Total
Use:					
Domestic (D)	29	27	2	6	64
Irrigation (I)	111	44	21	4	180
Stock (S)	143	305	-	9	457
Combined D, I, and S	293	625	2	18	938
Industrial	9	27	2	-	38
Public supply	10	2	-	1	13
Unused	0	2	7	10	19
Total	595	1,032	34	48	1,709
Depth (feet):					
Not reported	145	294	-	2	441
Less than 100	141	73	1	19	234
100-200	188	276	5	9	478
201-300	63	110	2	9	184
301-400	36	135	5	7	183
401-500	12	108	5	-	125
More than 500	10	36	16	2	64
Total	595	1,032	34	48	1,709
Diameter (inches):					
Jetted or drilled					
Not reported	10	37	-	-	47
2 or less	282	764	-	19	1,065
2¼-3	83	124	2	1	210
3¼-4	116	63	4	10	193
4¼-5	3	5	-	-	8
5¼-6	26	10	6	12	54
6¼-8	15	9	-	1	25
More than 8	37	14	22	3	76
Dug	23	6	-	2	31
Total	595	1,032	34	48	1,709
Flowing wells	365	929	-	28	1,322

to transmit water to wells. For this report well-drillers' reports of yields were used to determine the range of yield and average yield of wells in the project area, because these yields were generally measured soon after completion of the well. The yield obtained by a driller does not represent the maximum possible water production from an aquifer, but is the maximum for the type of finishing methods most used in the project area. Most of the small-diameter wells used for stock, domestic purposes, and small-scale irrigation are finished in the upper part of an aquifer, and generally the casing is either not perforated or it has a few perforations in the lower few feet. Wells thus finished do not receive water from the full thickness of the aquifer and this condition is reflected in smaller yields than would be expected from a fully penetrating well.

Yields of wells in southern Utah Valley and Goshen Valley range from less than 1 gpm to as much as 4,100 gpm. Most of the wells are 8 inches or less in diameter and flowed when drilled. The overall average yield of these wells was at the time of their completion about 40 gpm in southern Utah Valley and 16 gpm in Goshen Valley. Excluding the uncommonly high yields in determining the overall average yield, the average was 20 and 10 gpm, respectively. The yields of all flowing and pumped wells with diameters of more than 8 inches average about 1,200 gpm in southern Utah Valley and 1,500 gpm in Goshen Valley.

Most of the large-diameter wells are in the highlands, are equipped with pumps, and in the highlands have an average yield of 1,300 gpm in southern Utah Valley and 1,750 gpm in Goshen Valley. A few large-diameter wells have been constructed in the lake plain in southern Utah Valley; but only about half have been equipped with pumps, and the average yield of both pumped and nonpumped wells in the lake plain is 1,100 gpm. However, the high average yield is not representative of the entire lake plain because half of the wells are near the highlands, where the water-bearing properties of the aquifers are similar to the properties of aquifers under the highlands. Excluding the high yields of these wells, the average yield of the large-diameter wells in the lake plain is about 200 gpm.

Legal status of water rights

Decrees in the late 1800's and early 1900's adjudicated the rights to the flows of Spanish Fork, Hobble Creek, and some of the minor perennial streams flowing into southern Utah Valley. However, these decrees did not adjudicate ground-water rights in the drainage basins of these streams or the rights of the water users of Utah Lake, which is partly supplied by streamflow. In 1936 the adjudication of surface- and ground-water rights in the Jordan River drainage basin was called for in the legal suit of Salt Lake City, et al., versus Tamar Anderson, et al. The court subsequently ordered the Utah State Engineer to determine the rights within the basin. The determination was still in progress on January 1, 1968.

CHEMICAL QUALITY

Selected data from 78 wells, 20 springs, mines, and tunnels, and 5 streams are summarized in table 14; the selected data are representative of about 400 chemical analyses of water from sources in southern Utah Valley and Goshen Valley. Plate 4 shows the dissolved-solids and chloride content and the dominant anions in ground and surface waters in and near southern Utah Valley and Goshen Valley.

Relation to source

Southern Utah Valley

The summary of chemical-quality data in table 14 shows that (1) water from the Tertiary artesian aquifer has the lowest concentration of dissolved constituents of the ground water represented and has only slightly more dissolved constituents than does water from most streams flowing from the Wasatch Range, and (2) water from springs in the Quaternary deposits and from wells in the water-table aquifer generally have the highest concentrations of dissolved constituents.

Plate 4 shows that ground water in southern Utah Valley is bicarbonate in type, except near Lincoln Point where the ground water is chloride in type and locally along the eastern side of the valley where the ground water is of the sulfate type. The waters from most springs in the Wasatch Range and from streams draining the Wasatch Range are bicarbonate in type.

The average concentration of dissolved solids in waters from the Tertiary artesian aquifer and from the streams draining the Wasatch Range are similar, both contain water of the bicarbonate type. This similarity of chemical composition suggests that seepage from streams, probably close to the mountain front, is the main source of recharge to the Tertiary artesian aquifer. The Tertiary artesian aquifer probably also is recharged directly from the Paleozoic rocks in the Wasatch Range. The Paleozoic rocks of the Wasatch Range, as shown in table 14, locally may contain water with a higher content of dissolved solids than does the Tertiary artesian aquifer. However, the average concentration of dissolved solids for water from the Paleozoic rocks, as shown in table 14, was determined by including water from Cold Springs, (D-9-3)12bda-S1, which contains 690 mg/l (milligrams per liter) of dissolved solids. By excluding Cold Springs, the average concentration of dissolved solids would be 281 mg/l, which is almost the same as the concentration in water from the Tertiary artesian aquifer.

The concentration of dissolved solids in the aquifers in southern Utah Valley generally increases progressively from the Tertiary artesian aquifer, upward toward the water-table aquifer. This increase of dissolved solids with decreasing depth partly results from the solution of minerals as the water moves upward through the fine-grained confining beds between the aquifers and partly from the solution of minerals in the aquifers themselves.

Goshen Valley

The summary of chemical-quality data in table 14 shows that (1) water from the valley fill in Goshen Valley has considerably higher average concentrations of dissolved solids than does water in the valley fill in southern Utah Valley; (2) water from rocks of Tertiary age in the East Tintic Mountains and Long Ridge has an average concentration of dissolved solids that is similar to that of water from the Paleozoic rocks of the Wasatch Range; (3) water from springs, mines, and tunnels contains the highest concentration of dissolved solids of any of the surface and ground waters in southern Utah Valley and Goshen Valley; and (4) Currant Creek contains considerably more dissolved solids than does any other stream entering either valley.

The eastern and northwestern parts of Goshen Valley contain ground water that is chloride in chemical type, whereas in the southwestern part of the valley the ground water is bicarbonate in type (pl. 4). Locally, chloride type water may lie above bicarbonate type water.

Table 14.—Summary of selected chemical-quality data and temperature of ground water in and near southern Utah Valley and Goshen Valley.

Source			Number of samples	Milligrams per liter: Dissolved solids		Hardness as $CaCO_3$		Sulfate (SO_4)		Chloride (Cl)		Bicarbonate (HCO_3)		Temperature (°C)	
				Range	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average
Wells	Water-table aquifer	Southern Utah Valley	7	246-569	408	211-416	293	32-156	75	3.7-122	41	128-402	268	9-16	12
		Highlands unit	5	246-569	401	218-416	301	32-156	82	3.7-54	25	184-402	288	9-15	11
		Lake plain unit	2	421-435	428	211-334	273	48-70	59	40-122	82	128-310	219	12-16	14
		Goshen Valley	26	340-5,188	1,043	144-3,030	494	27-1,026	195	58-2,078	312	22-332	182	11-21	17
		Highlands unit	21	340-2,940	825	156-1,707	391	27-950	166	58-686	210	82-311	175	14-21	18
		Lake plain unit	5	821-5,188	1,960	270-3,030	926	95-1,026	315	275-2,078	743	22-332	209	11-14	13
	Shallow Pleistocene artesian aquifer and its unconfined extensions	Southern Utah Valley	21	243-559	335	154-382	240	3.9-97	40	5.8-78	27	218-374	277	8-16	13
		Highlands unit	6	243-559	340	216-382	262	7.7-92	44	5.8-78	24	223-321	262	8-16	12
		Lake plain unit	15	260-415	333	154-319	231	3.9-97	38	12-54	28	218-374	283	12-15	13
	Deep Pleistocene artesian aquifer	Southern Utah Valley	15	239-443	318	189-296	226	5.3-102	38	9.6-43	21	160-376	261	13-19	15
		Highlands unit	1	-	401	-	286	-	48	-	25	-	340	-	-
		Lake plain unit	14	239-443	312	189-296	207	5.3-102	37	9.6-43	21	160-376	256	13-19	15
	Tertiary artesian aquifer	Southern Utah Valley	8	189-428	280	102-268	152	2.5-84	31	9.2-48	19	154-268	209	16-20	17
		Highlands unit	1	-	428	-	268	-	84	-	48	-	268	-	16
		Lake plain unit	7	189-345	259	102-200	136	2.5-48	24	9.2-36	15	154-266	201	16-20	17
Springs, mines, and tunnels	Quaternary deposits	Southern Utah Valley	7	243-651	436	227-470	326	21-96	82	3.3-38	22	214-508	319	9-13	11
		Goshen Valley	3	1,390-6,664	4,863	405-1,664	1,075	139-1,094	644	563-2,912	2,015	318-755	561	-	-
	Tertiary rocks	East Tintic Mountains and Long Ridge	4	336-504	395	202-357	260	14-95	42	38-56	42	229-354	267	9-11	10
	Paleozoic rocks	Wasatch Range	5	201-690	363	189-480	297	10-258	81	2.5-55	18	204-324	268	8-13	11
		Burgin Mine, East Tintic Mountains	1	-	6,770	-	1,058	-	319	-	3,362	-	608	-	54
Streams	Currant Creek	Juab Valley	2	494-1,060	777	304-443	374	94-210	152	100-342	221	231-281	256	-	-
	Hobble Creek	Wasatch Range	2	209-246	228	169-180	174	40-46	43	6.7-8.5	7.6	160-170	165	-	-
	Peteetneet Creek	Wasatch Range	2	197-230	214	126-197	162	5.8-20	13	6.7-8.2	7.4	154-201	178	-	-
	Summit Creek	Wasatch Range	2	177-188	182	157-187	172	15-22	18	3.2-5.3	4.2	162-190	176	-	-
	Spanish Fork	Wasatch Range	4	251-537	395	180-299	244	36-118	78	14-91	52	172-277	222	-	-

Relation to use

Public supply

The U. S. Public Health Service (1962) has recommended quality standards for drinking water and water-supply systems. A partial list of these standards is as follows:

Constituent	Recommended maximum limit (milligrams per liter)
Dissolved solids	500
Sulfate	250
Chloride	250
Nitrate	45

In southern Utah Valley, the concentrations of chemical constituents in most ground water fall within the recommended limits. Of 52 representative wells in southern Utah Valley, only 3 wells yield water that contains more than the recommended maximum limit of dissolved solids. One of these wells is in the Springville area, one is in the Payson area, and one is in the Santaquin area (see pl. 4). Some wells in the Salem area are reported to yield water that contains an inflammable gas, but the gas can be removed by aeration.

In Goshen Valley, most wells yield water that contains more than the recommended maximum limit of dissolved solids. About 40 percent of the wells yield water with chloride concentrations that exceed the recommended maximum limit. The poorest quality water is from shallow wells in the lake plain.

Irrigation

The ground water in southern Utah Valley and Goshen Valley was classified in figures 27 and 28 according to salinity hazard and sodium hazard, using the method of the U. S. Salinity Laboratory Staff (1954, p. 69). In classifying water for irrigation, it is assumed that an average quantity of water will be used under average conditions of soil texture, salt tolerance of crops, climate, drainage, and infiltration. The classification in figures 27 and 28 is based on the relation between sodium-adsorption ratio (SAR) and conductivity (specific conductance). The SAR is a measure of the sodium hazard and the conductivity, is a measure of the salinity hazard. According to the values of SAR and conductivity, a water may fit into one of 16 classes on the diagram.

For southern Utah Valley, the water from 37 representative wells fits mostly in the low-sodium hazard class and the medium-salinity hazard class (fig. 27). Low-sodium hazard water is usable on nearly all soils without the development of harmful amounts of exchangeable sodium, although some sodium sensitive plants such as stone-fruit trees may be harmed. Medium-salinity hazard water is usable if a moderate amount of leaching occurs and plants with moderate salt tolerance can be grown.

For Goshen Valley, the water from 25 representative wells fits mostly in the low-sodium hazard class and the high-salinity hazard class (fig. 28). High-salinity hazard water is not recommended for use on poorly drained soil and special salinity management practices may be required even with well-drained soil.

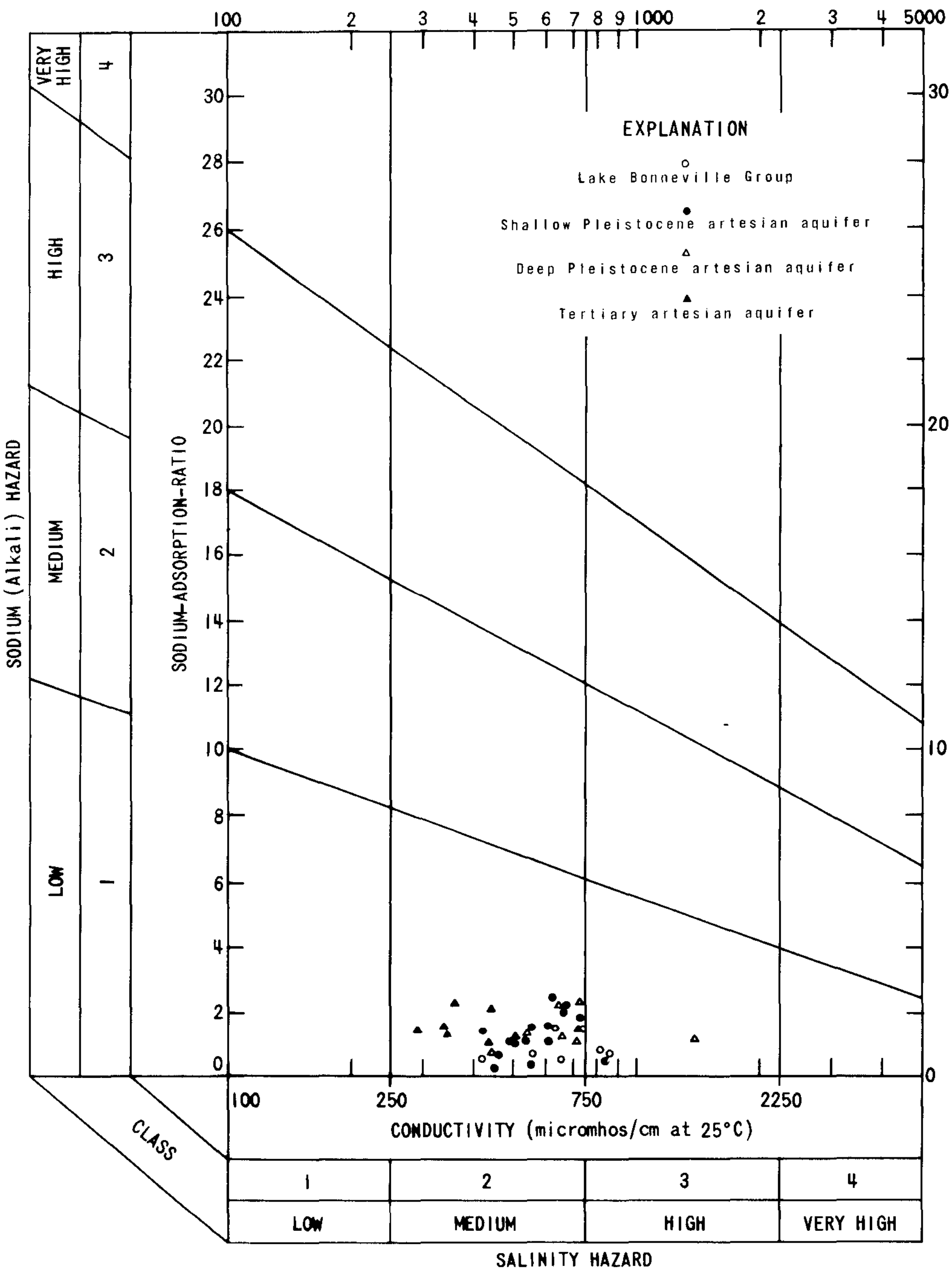


Figure 27.—Relation between sodium-adsorption ratio and conductivity of water from selected wells in southern Utah Valley.

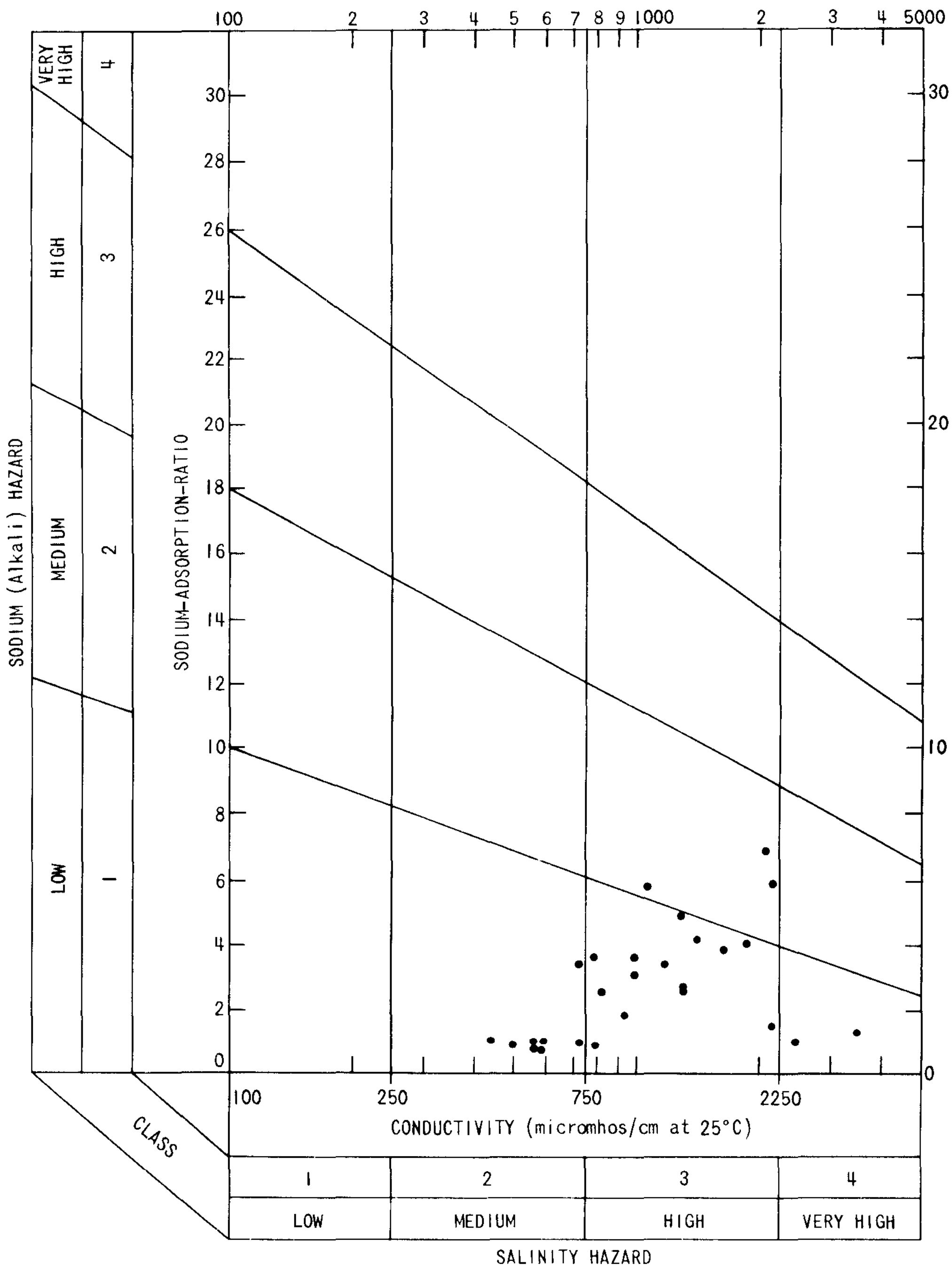


Figure 28.—Relation between sodium-adsorption ratio and conductivity of water from selected wells in Goshen Valley.

TEMPERATURE OF GROUND WATER

Wells

The range of temperature of water from each aquifer in southern Utah Valley is shown in table 14. The temperature of the water from wells in a particular aquifer varies from place to place depending on the depths of the wells and on local variations in the steepness of the thermal gradient. The average thermal gradient in the valley fill in southern Utah Valley is about 1°C (1.8°F) for each 100 feet of depth.

Some wells in the Benjamin area discharge water that has abnormally high temperatures. For example, well (D-8-2)28ccc-1 is 276 feet deep and yields water having a temperature of 33°C (91°F), whereas many nearby wells up to 500 feet deep yield water having temperatures less than 21°C (70°F). Such local steeper thermal gradients probably result from the deep circulation of meteoric water along permeable fault zones in the unconsolidated rocks.

Temperatures of water from deep wells in Goshen Valley are higher than those of water from shallow wells, but the available temperature data are not sufficient to determine a thermal gradient.

Springs, mines, and tunnels

The temperature of water reported in table 14 from springs, mines, and tunnels in southern Utah and Goshen Valleys and the bordering mountains ranges from about 10°C (49°F) to 54°C (129°F). The highest temperatures are for relatively highly mineralized water from a mine and a few springs, as shown in the following table:

Name or location of source	Location of measurement site	Date	Temperature (°C)	Dissolved solids (mg/l)
Burgin Mine in East Tintic Mountains	(C-10-2)15ddd	6-16-66	54	6,770
Bird Island	(D-7-1)26c	1-27-60	21	6,644
Lincoln Point	(D-8-1)3dda	6-16-66	31	6,554
Warm Springs	(D-10-1)8cab	6-15-66	21	1,390

MANAGEMENT OF THE GROUND-WATER RESERVOIR

The investigation in southern Utah Valley and Goshen Valley indicates several factors that should be considered in future plans for management of the ground-water reservoir. These factors are (1) increased withdrawal of water from wells, (2) wastage of water from uncontrolled flowing wells, (3) saltcedar infestation, (4) sewage reclamation or disposal, and (5) the importation and salvage water resulting from the Central Utah Project.

Increased withdrawal of water from wells

Prior to the construction of wells, the water levels in a ground-water reservoir represent an equilibrium between recharge and discharge, and they fluctuate only in response to variations in precipitation and other sources of recharge. The withdrawal of ground water by wells causes a lowering of water levels, the amount of lowering being proportional to the amount of withdrawal. If withdrawal by wells does not cause total discharge to exceed recharge, water levels continue to fluctuate in response to precipitation. Any withdrawal by wells, however, diminishes the amount of ground water moving toward areas of natural discharge such as springs or Utah Lake, and after sufficient time natural discharge is reduced by an equivalent quantity. If the amount of withdrawal causes total discharge to exceed recharge, water levels will decline and ground-water storage will be depleted as long as this imbalance exists, regardless of variations in precipitation. The latter effect is referred to as mining of ground water.

Water levels in southern Utah Valley do not show any long-term downward trend, and they fluctuate in response to variations in precipitation. Additional water, therefore, possibly can be withdrawn by wells from the ground-water reservoir in the valley without mining.

Water levels in Goshen Valley have trended downward since about 1962 regardless of fluctuations in precipitation. This indicates that ground water is being mined. Increasing the rate of withdrawal of ground water in Goshen Valley will increase the rate of water-level decline, and consequently of ground-water mining.

The theoretical maximum amount of water that wells can withdraw annually from the ground-water reservoir in southern Utah Valley without causing mining is approximately equal to the total discharge during 1966 (160,000 acre-feet). The practicable maximum withdrawal probably is 80,000 acre-feet per year, or less, and storage depletion probably would occur around local centers of heavy pumpage.

In southern Utah Valley, increasing the withdrawal from wells would result in a decrease of the amount of ground water moving toward areas of natural discharge, and it would also result in a lowering of water levels and artesian pressures. Water withdrawn from artesian aquifers causes a reduction of artesian pressures that are noticed soon in wide areas; whereas water withdrawn from water-table aquifers causes effects that travel very slowly and are noticed in areas limited largely to the vicinity of pumped wells. Eventually, however, the effects of pumping artesian wells will extend to the water-table areas and the effects of pumping water-table wells will extend to the artesian areas. The proper location and spacing of new wells in both the confined and unconfined aquifers will allow for a minimum lowering of water levels or artesian pressures at existing wells and springs.

The withdrawal of water from wells in either the confined or unconfined aquifers anywhere in southern Utah Valley eventually causes some lowering of water levels in all aquifers elsewhere in the valley. The amount of lowering is related to the hydraulic properties of the aquifer materials, distances, both horizontally and vertically from the pumped well, the pumping rate, and the length of the pumping period.

Drawdown in a well at any selected point in southern Utah Valley caused by pumping another well at any other selected point in the valley may be computed from aquifer coefficients determined from aquifer tests. Drawdowns at distances of 0.1 mile and greater from a pumped well may be determined using the family of time-distance-drawdown curves in figure 29. The curves are based on aquifer tests made in the valley with the assumptions that describe an ideal aquifer. The aquifer in southern Utah Valley does not fully satisfy all these assumptions, but the curves are useful in determining probably maximum drawdowns.

The time-distance-drawdown curves were prepared for a well pumping continuously at a constant rate of 1,000 gpm from an ideal aquifer having a transmissiblility of 100,000 gpd per

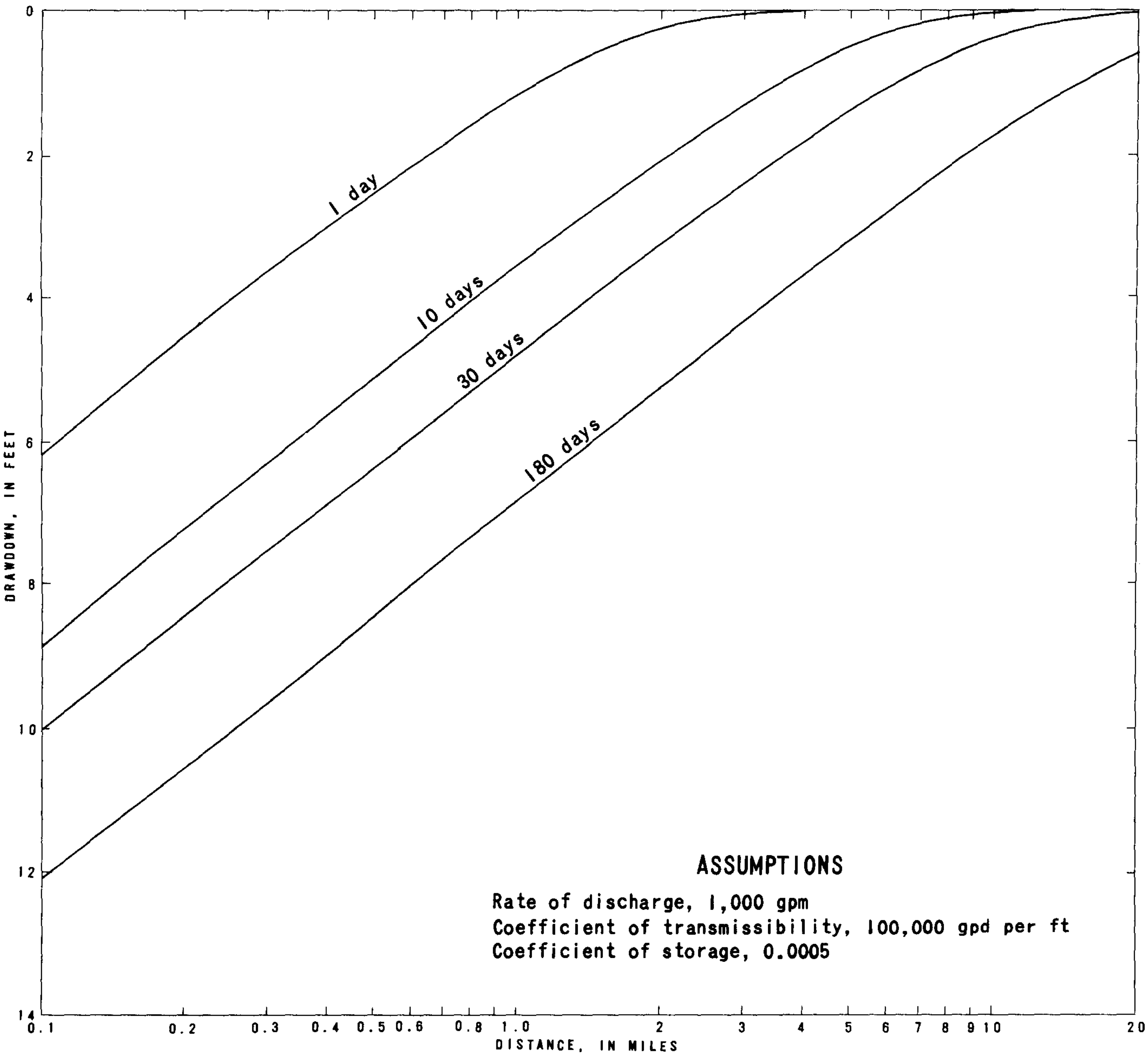


Figure 29.—Drawdown in an ideal aquifer caused by continuous discharge of a well.

foot and a storage coefficient of 0.0005. The aquifer coefficients are assumed to be applicable for most of the area of small-discharge flowing wells, but they are not applicable outside the area of flowing wells.

The curves can be used to determine the probably maximum drawdown at distances as great as 20 miles from the pumped well after various periods of pumping. For example, to find the drawdown in a well 1 mile from the pumped well after 180 days of continuous pumping, follow the 180-day time curve to the vertical line representing 1 mile and read the drawdown of 6.8 feet on the drawdown axis along the left edge of the graph. If an estimate of drawdown is desired for some pumping rate other than 1,000 gpm, it can be computed by determining the drawdown for a well pumping 1,000 gpm and increasing or decreasing the drawdown according to the proportionate difference in pumping rate between the actual rate and 1,000 gpm. To illustrate, in the example above, if the pumping rate were 500 gpm, the drawdown would be half of 6.8 feet or 3.4 feet.

The curves in figure 29 may also be used to determine the effect that flowing wells have on each other. As an example of this effect, consider the wells in sec. 29, T. 8 S., R. 2 E.

The discharge of the wells tested in sec. 29 ranged from 2 to 50 gpm, but most were less than 25 gpm and the average was about 10 gpm. If a well in sec. 29 is assumed to flow continuously for 30 days at the average rate of 10 gpm, then the computed drawdown in a well 1 mile away completed at the same level is 0.05 foot. If the well is allowed to flow for 180 days, the computed drawdown in the second well is 0.07 foot. If all wells in sec. 29 had a total discharge of 100 gpm, the aggregate drawdown 1 mile away would be 0.48 foot after 30 days and 0.68 foot after 180 days. The aggregate drawdown would be greater at shorter distances; for example, at a distance of 0.1 mile, the drawdowns after 30 and 180 days would be 1.0 and 1.21 feet, respectively.

The previous discussion concerns the interference between flowing wells finished at the same level. A flowing well tapping a deep aquifer also can draw down the water level in flowing wells in a shallower aquifer. The effects of pumping water from a deep aquifer on water levels in shallower aquifers were shown by pumping well (D-8-2)25dac-3. Conversely, withdrawals from a shallow aquifer also would affect water levels in wells tapping deeper aquifers.

Wastage of water from wells

A sizeable but unknown amount of water is wasted by wells that flow or leak continuously in southern Utah Valley and Goshen Valley. Such wells are scattered throughout the lake plain, although there are concentrations near Payson, Palmyra, and Lake Shore. Most of these wells are allowed to flow continuously because well owners fear that the flow would be shut off by fine-grained suspended materials that would settle in the bottoms of the wells if they were closed.

Waste from the flowing wells can be reduced by installing replacement wells that are properly finished and developed. Most, if not all, the wells that waste water by continuous flow contain blank casing with only an open end exposed to the water-bearing formation; thus, nothing prevents entry of sediment into the wells. Wells finished with a short length of screen, or "strainer," and adequately developed to remove the fine fraction of the formation near the screen usually can be shut in without danger of plugging or reducing flow.

Saltcedar infestation

A comparison of aerial photographs taken in August 1947 with aerial photographs taken in July 1965 indicates that saltcedar was present around Utah Lake in 1947 but since has thickened in density and spread landward from the lakeshore. Field surveys in 1965 showed that single plants and thinly populated tracts of saltcedar are growing in the stream channels of the major natural drainageways in parts of southern Utah Valley and Goshen Valley upstream as far as the highlands. This invasion along stream channels is probably fairly recent. After saltcedar settles in a locality that is suitable for its growth, density increases and larger and larger quantities of ground water are used. Saltcedar, because of its low economic value, high water-use rate, and rapid infestation and growth, warrants special attention by users of ground water to protect their resource from large-scale waste.

Sewage disposal

Polluted water is a hazard to health wherever it can percolate to springs or wells supplying water for human consumption. Many homes throughout the rural areas in southern Utah Valley and Goshen Valley use septic tanks to dispose of sewage. Only Springville, Spanish Fork, Salem, and Payson have municipal sewer systems and sewage-treatment plants. The treated sewage water is either conducted in open, unlined drains from the treatment plants to Utah Lake or is used for irrigation. Some of the treated sewage water and some of the untreated sewage water from the septic tanks infiltrates to the water table. If the water table is several hundred feet beneath the land surface, the sewage water is probably adequately filtered before it reaches the water table. If the water table is close to the land surface, however, polluted water may reach the water table and contaminate nearby wells. In artesian areas, where ground-water movement is upward at all times, it is extremely unlikely that polluted water seeping from septic tanks, drains, or irrigated fields would be able to reach the artesian aquifers.

The Central Utah Project

The major effect of the Central Utah Project on the ground-water reservoir in southern Utah Valley and Goshen Valley will be to increase the amount of recharge. Approximately 45,500 acre-feet of water is to be imported into the valleys annually for irrigation, and an additional 39,200 acre-feet of water salvaged annually is to be used for irrigation (U. S. Bur. of Reclamation, oral commun., 1968). It is reasonable to assume that seepage from these sources will result in recharge rates similar to those shown in table 1 for irrigated land and waterways. An average figure for such seepage losses would be 25 percent, and applying this to the total estimated amount of 84,700 acre-feet to be used for irrigation on land from which seepage will recharge the ground-water reservoir gives an increased annual recharge rate of about 20,000 acre-feet per year.

The increase of recharge to the ground-water reservoir will result in an increase of water in storage and an increase of discharge. Unless accounted for by additional withdrawal from wells, the discharge will be through springs, drains, evapotranspiration, or discharge into Utah Lake.

Some of the discharge into Utah Lake is in Provo and Goshen Bays. The rate of seepage discharge varies inversely with the stage of the lake and directly with the artesian pressure in the ground-water reservoir. Separating Provo and Goshen Bays from Utah Lake by diking and draining will remove the effects of a changing lake stage and increase the artesian head in those areas, and increasing recharge to the ground-water reservoir will further increase the artesian pressure. These processes, therefore, will result in an increase of ground-water discharge in Provo and Goshen Bays. The amount of the increase is unknown but probably will be small.

SUMMARY OF CONCLUSIONS

The valley fill in southern Utah Valley and Goshen Valley includes four main aquifers—a water-table aquifer and three artesian aquifers—which are traceable from northern Utah Valley.

Recharge to the aquifers in 1966 was an estimated minimum of 150,000 acre-feet of water; discharge was an estimated minimum of 220,000 acre-feet. The decrease in storage in 1966 was about 29,000 acre-feet, so that the difference of 41,000 acre-feet between recharge and discharge is mainly the result of equating their minimum totals. The amount of undetermined recharge from subsurface inflow and from ephemeral and intermittent streams probably accounts for the 41,000 acre-feet.

The long-term trend in water-level fluctuations in southern Utah Valley indicates that discharge has not exceeded recharge. Water levels in Goshen Valley have declined since 1962 regardless of variations in precipitation and show that discharge is exceeding recharge. An increase of withdrawals from wells in Goshen Valley would increase the rate of decline of water levels. Water-level contours indicate that ground water in southern Utah and Goshen Valleys moves from the bordering mountains toward Utah Lake.

Aquifer tests indicated that well interference is common, especially in southern Utah Valley. They also showed that the confining beds between the aquifers leak, so that withdrawing water from a well in one artesian aquifer may cause drawdown effects in another artesian aquifer. If the amount of water withdrawn from wells in southern Utah Valley is increased, interference effects will increase. The proper location and spacing of new wells, however, would keep such effects to a minimum.

The withdrawal of water from wells in southern Utah Valley theoretically could be increased to the average annual amount of ground-water discharge (160,000 acre-feet). The practicable maximum withdrawal probably is 80,000 acre-feet, or less, and any increase over the present average annual rate of pumpage of about 20,000 acre-feet would be at the expense of present water levels and rates of natural discharge. Lowering of water levels in the artesian aquifers would be noticeable fairly soon after increasing the rate of withdrawal, but an attendent decrease of natural discharge would not be noticeable as soon.

The amount of ground water recoverable by wells from storage in the upper 400 feet of saturated valley fill is estimated to be 3 million acre-feet in southern Utah Valley and 3 million acre-feet in Goshen Valley.

The dissolved-solids content of ground water in southern Utah Valley generally decreases with depth, and the water is mainly of the becarbonate type. Ground water in Goshen Valley generally contains greater concentrations of dissolved solids than does ground water in southern Utah Valley. In the northwestern and eastern parts of Goshen Valley the water is chloride in type, but in the southwestern part of the valley it is bicarbonate in type.

The planned operation of the Central Utah Project will increase recharge to the ground-water reservoir by about 20,000 acre-feet per year. As a result water in storage will increase and ground-water discharge also will increase. A quantitative evaluation of the actual effects of operating the Central Utah Project can be made only by a comprehensive water-resources study of the entire Utah Lake Valley.

REFERENCES CITED

Bentall, Ray, compiler, 1963, Methods of determining permeability, transmissibility, and drawdown: U. S. Geol. Survey Water-Supply Paper 1536-I.

Bissell, H. J., 1963, Lake Bonneville: Geology of southern Utah Valley, Utah: U. S. Geol. Survey Prof. Paper 257-B

Blaney, H. F., and Criddle, W. D., 1962, Determining consumptive use and irrigation water requirements: U. S. Dept. Agriculture Tech. Bull. 1275.

Cook, K. L., and Berg, J. W., Jr., 1961, Regional gravity survey along the central and southern Wasatch Front, Utah: U. S. Geol. Survey Prof. Paper 316-E.

Cordova, R. M., 1969, Selected hydrologic data, southern Utah and Goshen Valleys, Utah: U. S. Geol. Survey open-file rept. (duplicated as Utah Basic-Data Release No. 16).

Cordova, R. M., and Mower, R. W., 1967, The effect of pumping large-discharge wells on the ground-water reservoir in southern Utah Valley, Utah County, Utah: Utah State Engineer Inf. Bull. 18.

Ferris, J. G., Knowles, D. B., Brown, R. H., and Stallman, R. W., 1962, Theory of aquifer tests: U. S. Geol. Survey Water-Supply Paper 1536-E.

Gardner, D. I., 1967, Utah Lake and Jordan River distribution for the year 1966: Ann. Rept. to the Utah State Engineer for the year 1966.

Hantush, M. S., 1960, Modification of the theory of leaky aquifers: Jour. Geophys. Research, v. 65, no. 11, p. 3713-3725.

Hintze, L. F., ed., 1962, Geology of the southern Wasatch Mountains and vicinity, Utah: Geology Studies, Brigham Young Univ., v. 9, pt. 1, May 1962.

Hunt, C. B., Varnes, H. D., and Thomas, H. E., 1953, Lake Bonneville: Geology of northern Utah Valley, Utah: U. S. Geol. Survey Prof. Paper 257-A.

Johnson, A. I., 1967, Specific yield - Compilation of specific yields for various materials: U. S. Geol. Survey Water-Supply Paper 1662-D.

Lindgren, Waldemar, and Loughlin, G. F., 1919, Geology and ore deposits of the Tintic Mining District, Utah: U. S. Geol. Survey Prof. Paper 107.

Mabey, D. R., Crittenden, M. D., Jr., Morris, H. T., Roberts, R. J., and Tooker, E. W., 1964, Aeromagnetic and generalized geologic map of part of north-central Utah: U. S. Geol. Survey Geophys. Inv. Map GP-422.

Richardson, G. B., 1906, Underground water in the valleys of Utah Lake and Jordan River, Utah: U. S. Geol. Survey Water-Supply Paper 157.

U. S. Environmental Science Services Administration, Environmental Data Service, 1967, Climatologic data, Utah, 1966: v. 68, no. 13.

U. S. Public Health Service, 1962, Drinking water standards: U. S. Public Health Service Pub. 956.

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

Utah State Engineer, 1940, Underground water: 22d bienn. rept. for the biennium July 1, 1938 to June 30, 1940, p. 30-45.

Utah Water Research Laboratory, 1968, Water related land use in the Utah Lake drainage area: Rept. PR-WG40-1.

PUBLICATIONS OF THE UTAH DEPARTMENT OF NATURAL RESOURCES, DIVISION OF WATER RIGHTS

(*)—Out of Print

TECHNICAL PUBLICATIONS

No. 1. Underground leakage from artesian wells in the Flowell area, near Fillmore, Utah, by Penn Livingston and G. B. Maxey, U. S. Geological Survey, 1944.

No. 2. The Ogden Valley artesian reservoir, Weber County, Utah, by H. E. Thomas, U. S. Geological Survey, 1945.

*No. 3. Ground water in Pavant Valley, Millard County, Utah, by P. E. Dennis, G. B. Maxey, and H. E. Thomas, U. S. Geological Survey, 1946.

*No. 4. Ground water in Tooele Valley, Tooele County, Utah, by H. E. Thomas, U. S. Geological Survey, in Utah State Eng. 25th Bienn. Rept., p. 91-238, pls. 1-6, 1946.

*No. 5. Ground water in the East Shore area, Utah: Part I, Bountiful District, Davis County, Utah, by H. E. Thomas and W. B. Nelson, U. S. Geological Survey, in Utah State Eng. 26th Bienn. Rept., p. 53-206, pls. 1-2, 1948.

*No. 6. Ground water in the Escalante Valley, Beaver, Iron, and Washington Counties, Utah, by P. F. Fix, W. B. Nelson, B. E. Lofgren, and R. G. Butler, U. S. Geological Survey, in Utah State Eng. 27th Bienn. Rept., p. 107-210, pls. 1-10, 1950.

No. 7. Status of development of selected ground-water basins in Utah, by H. E. Thomas, W. B. Nelson, B. E. Lofgren, and R. G. Butler, U. S. Geological Survey, 1952.

*No. 8. Consumptive use of water and irrigation requirements of crops in Utah, by C. O. Roskelly and Wayne D. Criddle, 1952.

No. 8. (Revised) Consumptive use and water requirements for Utah, by W. D. Criddle, K. Harris, and L. S. Willardson, 1962.

No. 9. Progress report on selected ground water basins in Utah, by H. A. Waite, W. B. Nelson, and others, U. S. Geological Survey, 1954.

No. 10. A compilation of chemical quality data for ground and surface waters in Utah, by J. G. Connor, C. G. Mitchell, and others, U. S. Geological Survey, 1958.

No. 11. Ground water in northern Utah Valley, Utah: A progress report for the period 1948-63, by R. M. Cordova and Seymour Subitzky, U. S. Geological Survey, 1965.

No. 12. Reevaluation of the ground-water resources of Tooele Valley, Utah, by Joseph S. Gates, U. S. Geological Survey, 1965.

*No. 13. Ground-water resources of selected basins in southwestern Utah, by G. W. Sandberg, U. S. Geological Survey, 1966.

No. 14. Water-resources appraisal of the Snake Valley area, Utah and Nevada, by J. W. Hood and F. E. Rush, U. S. Geological Survey, 1966.

No. 15. Water from bedrock in the Colorado Plateau of Utah, by R. D. Feltis, U. S. Geological Survey, 1966.

No. 16. Ground-water conditions in Cedar Valley, Utah County, Utah, by R. D. Feltis, U. S. Geological Survey, 1967.

No. 17. Ground-water resources of northern Juab Valley, Utah, by L. J. Bjorklund, U. S. Geological Survey, 1968.

No. 18. Hydrologic reconnaissance of Skull Valley, Tooele County, Utah, by J. W. Hood and K. M. Waddell, U. S. Geological Survey, 1968.

No. 19. An appraisal of the quality of surface water in the Sevier Lake basin, Utah, by D. C. Hahl and J. C. Mundorff, U. S. Geological Survey, 1968.

No. 20. Extensions of streamflow records in Utah, by J. K. Reid, L. E. Carroon, and G. E. Pyper, U. S. Geological Survey, 1969.

No. 21. Summary of maximum discharges in Utah streams, by G. L. Whitaker, U. S. Geological Survey, 1969.

No. 22. Reconnaissance of the ground-water resources of the upper Fremont River valley, Wayne County, Utah, by L. J. Bjorklund, U. S. Geological Survey, 1969.

No. 23. Hydrologic reconnaissance of Rush Valley, Tooele County, Utah, by J. W. Hood, Don Price, and K. M. Waddell, U. S. Geological Survey, 1969.

No. 24. Hydrologic reconnaissance of Deep Creek valley, Tooele and Juab Counties, Utah, and Elko and White Pine Counties, Nevada, by J. W. Hood and K. M. Waddell, U. S. Geological Survey, 1969.

No. 25. Hydrologic reconnaissance of Curlew Valley, Utah and Idaho, by E. L. Bolke and Don Price, U. S. Geological Survey, 1969.

No. 26. Hydrologic reconnaissance of the Sink Valley area, Tooele and Box Elder Counties, Utah, by Don Price and E. L. Bolke, U. S. Geological Survey, 1969.

No. 27. Water resources of the Heber-Kamas-Park City area, north-central Utah, by C. H. Baker, Jr., U. S. Geological Survey, 1970.

WATER CIRCULAR

No. 1. Ground water in the Jordan Valley, Salt Lake County, Utah, by Ted Arnow, U. S. Geological Survey, 1965.

No. 2. Ground water in Tooele Valley, Utah, by J. S. Gates and O. A. Keller, U. S. Geological Survey, 1970.

BASIC-DATA REPORTS

No. 1. Records and water-level measurements of selected wells and chemical analyses of ground water, East Shore area, Davis, Weber, and Box Elder Counties, Utah, by R. E. Smith, U. S. Geological Survey, 1961.

No. 2. Records of selected wells and springs, selected drillers' logs of wells, and chemical analyses of ground and surface waters, northern Utah Valley, Utah County, Utah, by Seymour Subitzky, U. S. Geological Survey, 1962.

No. 3. Ground-water data, central Sevier Valley, parts of Sanpete, Sevier, and Piute Counties, Utah, by C. H. Carpenter and R. A. Young, U. S. Geological Survey, 1963.

No. 4. Selected hydrologic data, Jordan Valley, Salt Lake County, Utah, by I. W. Marine and Don Price, U. S. Geological Survey, 1963.

No. 5. Selected hydrologic data, Pavant Valley, Millard County, Utah, by R. W. Mower U. S. Geological Survey, 1963.

*No. 6. Ground-water data, parts of Washington, Iron, Beaver, and Millard Counties, Utah, by G. W. Sandberg, U. S. Geological Survey, 1963.

No. 7. Selected hydrologic data, Tooele Valley, Tooele County, Utah, by J. S. Gates, U. S. Geological Survey, 1963.

No. 8. Selected hydrologic data, upper Sevier River basin, Utah, by C. H. Carpenter, G. B. Robinson, Jr., and L. J. Bjorklund, U. S. Geological Survey, 1964.

No. 9. Ground-water data, Sevier Desert, Utah, by R. W. Mower and R. D. Feltis. U. S. Geological Survey, 1964.

No. 10. Quality of surface water in the Sevier Lake basin, Utah, by D. C. Hahl and R. E. Cabell, U. S. Geological Survey, 1965.

No. 11. Hydrologic and climatologic data, collected through 1964, Salt Lake County, Utah by W. V. Iorns, R. W. Mower, and C. A. Horr, U. S. Geological Survey, 1966.

No. 12. Hydrologic and climatologic data, 1965, Salt Lake County, Utah, by W. V. Iorns, R. W. Mower, and C. A. Horr, U. S. Geological Survey, 1966.

No. 13. Hydrologic and climatologic data, 1966, Salt Lake County, Utah, by A. G. Hely, R. W. Mower, and C. A. Horr, U. S. Geological Survey, 1967.

No. 14. Selected hydrologic data, San Pitch River drainage basin, Utah, by G. B. Robinson, Jr., U. S. Geological Survey, 1968.

No. 15. Hydrologic and climatologic data, 1967, Salt Lake County, Utah, by A. G. Hely, R. W. Mower, and C. A. Horr, U. S. Geological Survey, 1968.

No. 16. Selected hydrologic data, southern Utah and Goshen Valleys, Utah, by R. M. Cordova, U. S. Geological Survey, 1969.

No. 17. Hydrologic and climatologic data, 1968, Salt Lake County, Utah, by A. G. Hely, R. W. Mower, and C. A. Horr, U. S. Geological Survey, 1969.

No. 18. Quality of surface water in the Bear River basin, Utah, Wyoming, and Idaho, by K. M. Waddell, U. S. Geological Survey, 1970.

No. 19. Daily water-temperature records for Utah streams, 1944-68, by G. L. Whitaker, U. S. Geological Survey, 1970.

INFORMATION BULLETINS

*No. 1. Plan of work for the Sevier River Basin (Sec. 6, P. L. 566), U. S. Department of Agriculture, 1960.

No. 2. Water production from oil wells in Utah, by Jerry Tuttle, Utah State Engineer's Office, 1960.

No. 3. Ground-water areas and well logs, central Sevier Valley, Utah, by R. A. Young, U. S. Geological Survey, 1960.

*No. 4. Ground-water investigations in Utah in 1960 and reports published by the U. S. Geological Survey or the Utah State Engineer prior to 1960, by H. D. Goode, U. S. Geological Survey, 1960.

No. 5. Developing ground water in the central Sevier Valley, Utah, by R. A. Young and C. H. Carpenter, U. S. Geological Survey, 1961.

*No. 6. Work outline and report outline for Sevier River basin survey, (Sec. 6, P.L. 566), U. S. Department of Agriculture, 1961.

No. 7. Relation of the deep and shallow artesian aquifers near Lynndyl, Utah, by R. W. Mower, U. S. Geological Survey, 1961.

No. 8. Projected 1975 municipal water-use requirements, Davis County, Utah, by Utah State Engineer's Office, 1962.

No. 9. Projected 1975 municipal water-use requirements, Weber County, Utah, by Utah State Engineer's Office, 1962.

No. 10. Effects on the shallow artesian aquifer of withdrawing water from the deep artesian aquifer near Sugarville, Millard County, Utah, by R. W. Mower, U. S. Geological Survey, 1963.

No. 11. Amendments to plan of work and work outline for the Sevier River basin (Sec. 6, P.L. 566), U. S. Department of Agriculture, 1964.

No. 12. Test drilling in the upper Sevier River drainage basin, Garfield and Piute Counties, Utah, by R. D. Feltis and G. B. Robinson, Jr., U. S. Geological Survey, 1963.

No. 13. Water requirements of lower Jordan River, Utah, by Karl Harris, Irrigation Engineer, Agricultural Research Service, Phoenix, Arizona, prepared under informal cooperation approved by Mr. William W. Donnan, Chief, Southwest Branch (Riverside, California) Soil and Water Conservation Research Division, Agricultural Research Service, U.S.D.A. and by Wayne D. Criddle, State Engineer, State of Utah, Salt Lake City, Utah, 1964.

*No. 14. Consumptive use of water by native vegetation and irrigated crops in the Virgin River area of Utah, by Wayne D. Criddle, Jay M. Bagley, R. Keith Higginson, and David W. Hendricks, through cooperation of Utah Agricultural Experiment Station, Agricultural Research Service, Soil and Water Conservation Branch, Western Soil and Water Management Section, Utah Water and Power Board, and Utah State Engineer, Salt Lake City, Utah, 1964.

No. 15. Ground-water conditions and related water-administration problems in Cedar City Valley, Iron County, Utah, February, 1966, by Jack A. Barnett and Francis T. Mayo, Utah State Engineer's Office.

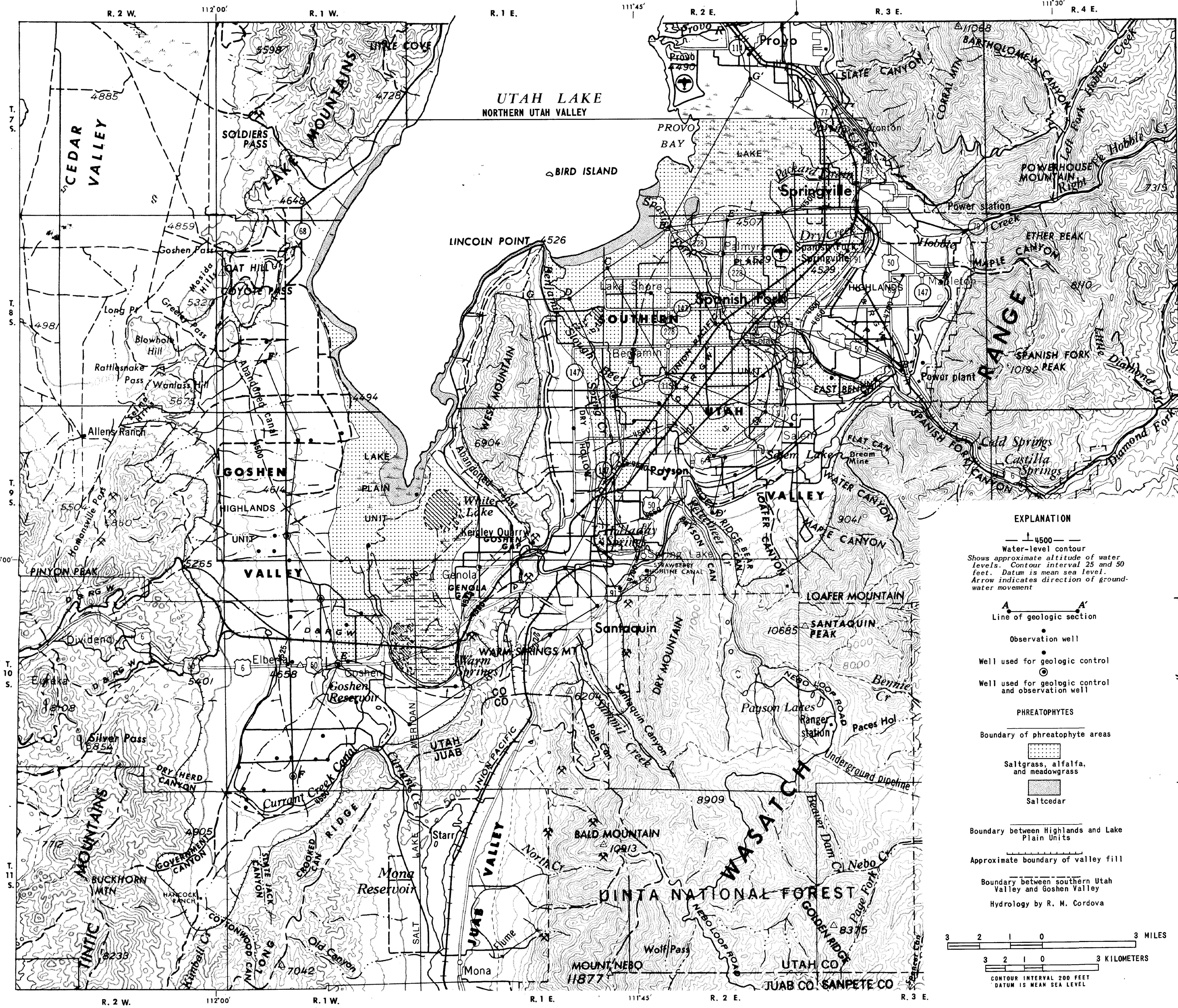
No. 16. Summary of water well drilling activities in Utah, 1960 through 1965, compiled by Utah State Engineer's Office, 1966.

No. 17. Bibliography of U. S. Geological Survey Water Resources Reports for Utah, compiled by Olive A. Keller, U. S. Geological Survey, 1966.

No. 18. The effect of pumping large-discharge wells on the ground-water reservoir in southern Utah Valley, Utah County, Utah, by R. M. Cordova and R. W. Mower, U. S. Geological Survey 1967.

No. 19. Ground-water hydrology of southern Cache Valley, Utah, by L. P. Beer, 1967.

No. 20. Fluvial sediment in Utah, 1905-65, A data compilation by J. C. Mundorff, U. S. Geological Survey, 1968.



Base from U.S. Geological Survey 1:250,000 Series: Delta, 1962; Price, 1962; Salt Lake City, Utah-Wyo., 1964; and Tooele, 1962

MAP OF SOUTHERN UTAH VALLEY, GOSHEN VALLEY, AND PART OF NORTHERN UTAH VALLEY, UTAH, SHOWING PHYSIOGRAPHIC UNITS, LINES OF GEOLOGIC SECTIONS, CONTOURS OF THE WATER TABLE IN MARCH 1965, AND GENERAL AREAS OF PHREATOPHYTES IN 1966

— Areas and kinds of phreatophytes compiled from field observations (1966), aerial photographs (July 1965), and data from U S Conservation Service (oral commun., 1968), U.S. Bureau of Reclamation (oral commun., 1968), and Utah Water Research Laboratory (1968)

UNITED STATES DEPARTMENT OF THE INTERIOR
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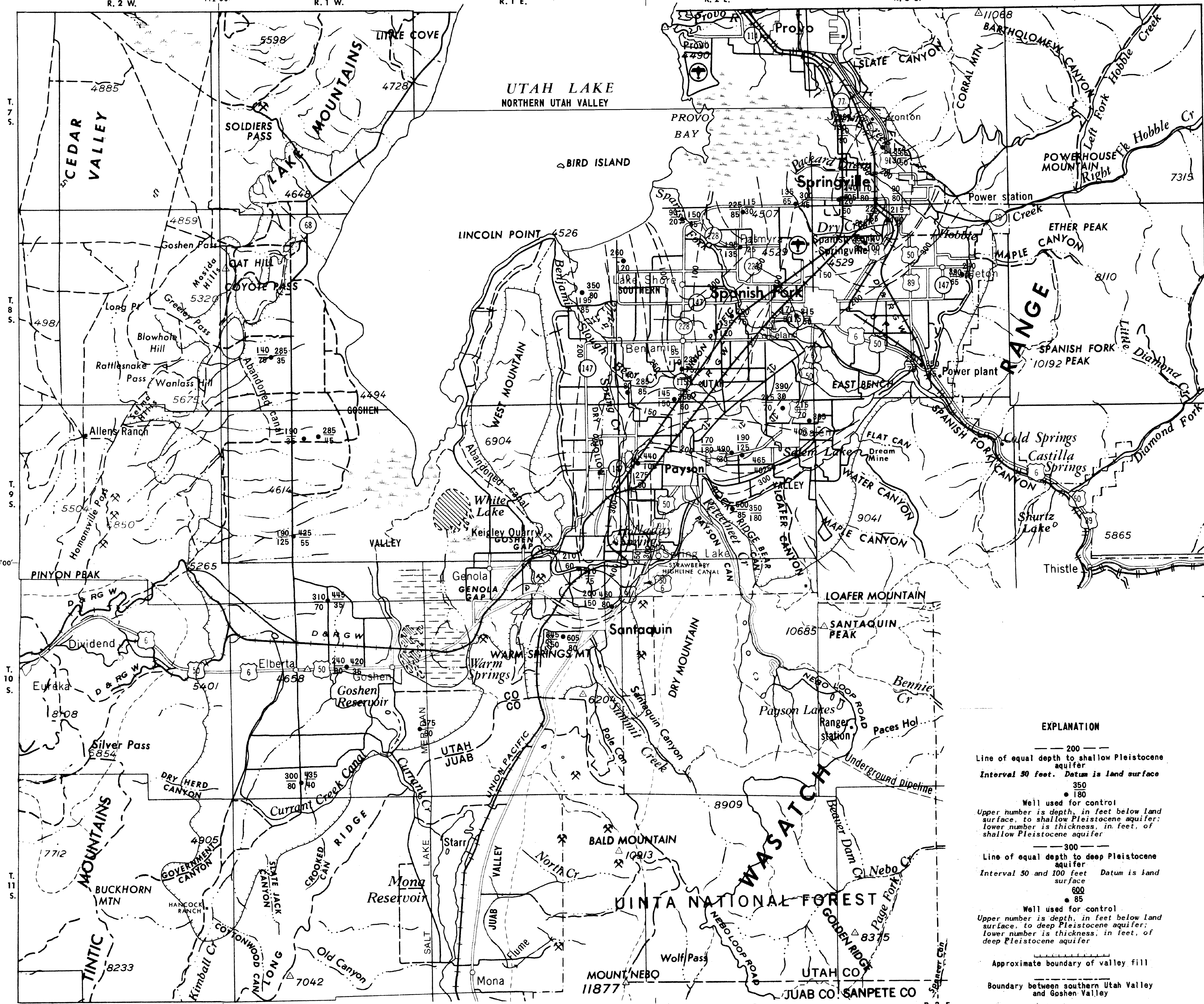

Base from U.S. Geological Survey 1:250,000 Series: Delta, 1962; Price, 1962; Salt Lake City, Utah-Wyo., 1964; and Tooele, 1962

3 2 1 0 3 MILES

3 2 1 0 3 KILOMETERS

EXPLANATION

— — 200 — —
Line of equal depth to shallow Pleistocene aquifer
Interval 50 feet. Datum is land surface

350
● 180
Well used for control
Upper number is depth, in feet below land surface, to shallow Pleistocene aquifer; lower number is thickness, in feet, of shallow Pleistocene aquifer

— — 300 — —
Line of equal depth to deep Pleistocene aquifer
Interval 50 and 100 feet Datum is land surface

600
● 85
Well used for control
Upper number is depth, in feet below land surface, to deep Pleistocene aquifer; lower number is thickness, in feet, of deep Pleistocene aquifer

Approximate boundary of valley fill

Boundary between southern Utah Valley and Goshen Valley

Hydrology by R. M. Cordova

MAP OF SOUTHERN UTAH VALLEY AND GOSHEN VALLEY, UTAH, SHOWING DEPTHS TO TOPS OF AND THICKNESSES OF THE SHALLOW AND DEEP PLEISTOCENE ARTESIAN AQUIFERS AND THEIR UNCONFINED EXTENSIONS

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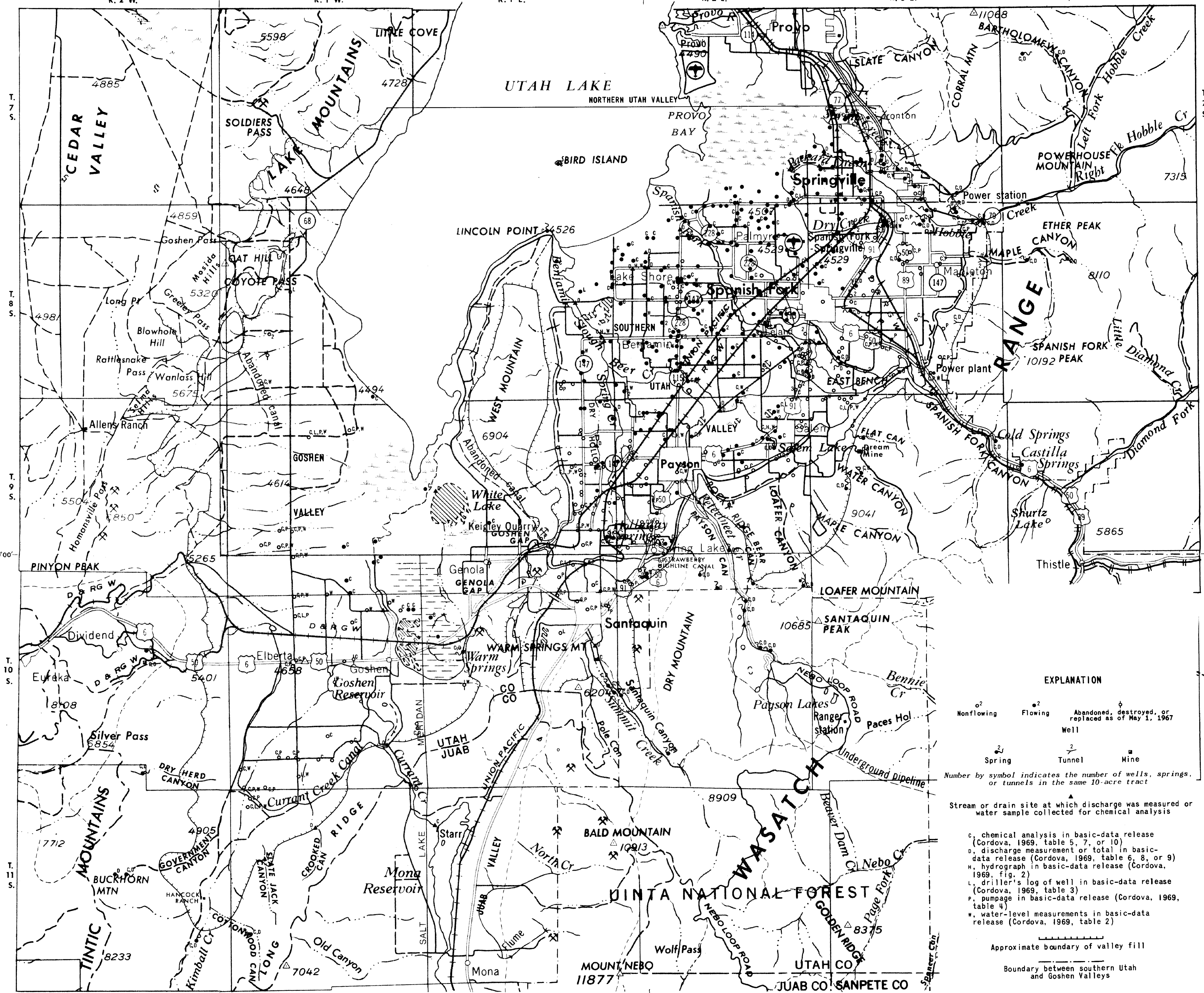

Base from U.S. Geological Survey 1:250,000 Series: Delta, 1962; Price, 1962; Salt Lake City, Utah-Wyo., 1964; and Tooele, 1962

3 2 1 0 3 MILES

3 2 1 0 3 KILOMETERS

By R. M. Cordova

MAP OF SOUTHERN UTAH VALLEY AND GOSHEN VALLEY, UTAH, SHOWING DISTRIBUTION OF SELECTED WELLS AND SPRINGS

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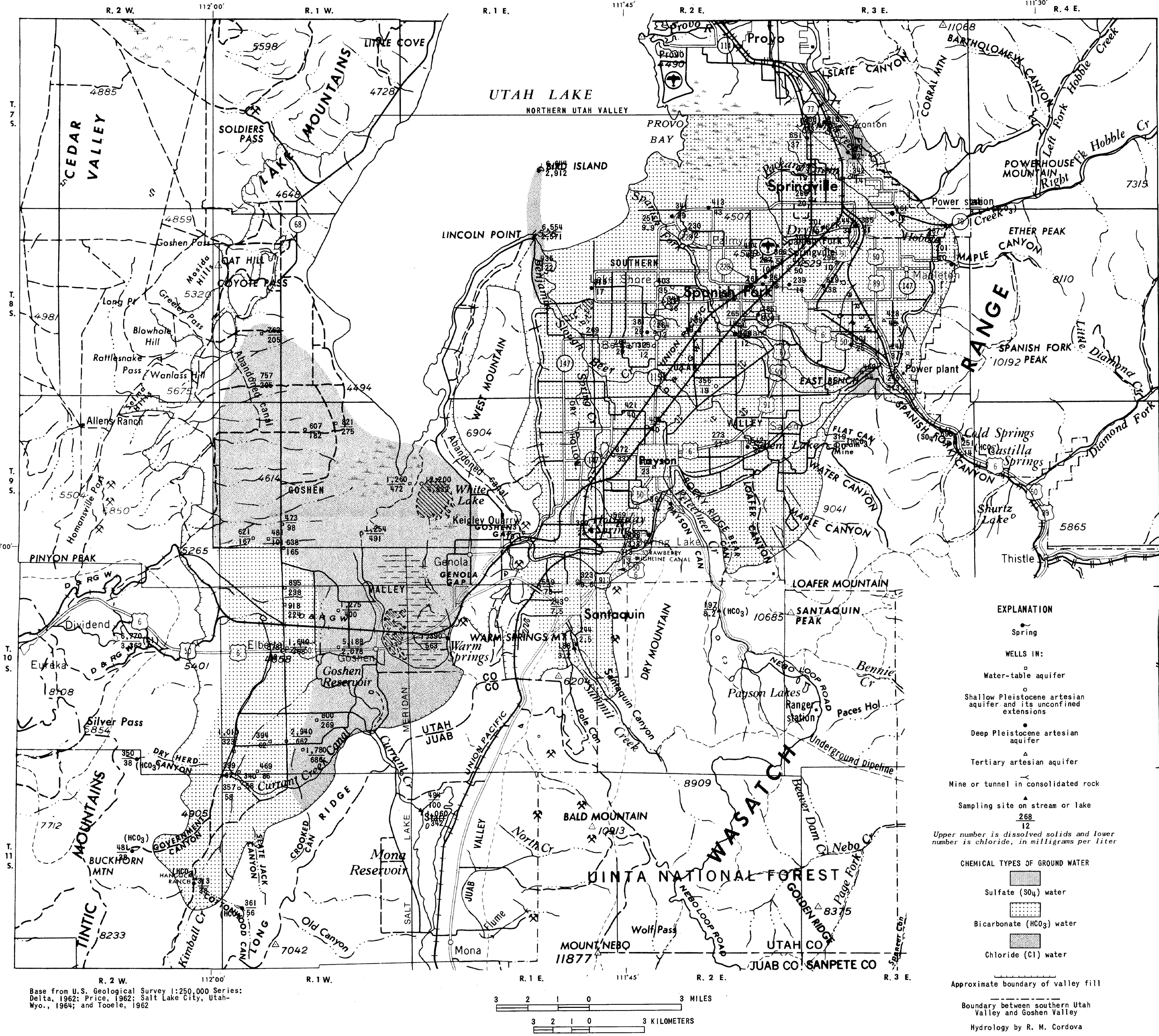

Base from U.S. Geological Survey 1:250,000 Series: Delta, 1962; Price, 1962; Salt Lake City, Utah-Wyo., 1964; and Tooele, 1962

MAP SHOWING DISSOLVED-SOLIDS AND CHLORIDE CONTENTS AND DOMINANT ANIONS IN GROUND AND SURFACE WATERS IN AND NEAR SOUTHERN UTAH VALLEY AND GOSHEN VALLEY, UTAH