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GROUND-WATER RESOURCES OF CACHE VALLEY, UTAH AND IDAHO

by

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GROUND-WATER RESOURCES OF CACHE VALLEY, UTAH AND IDAHO

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ABSTRACT

Cache Valley is a north-trending structural valley of about 660 square miles in northeastern Utah and southeastern Idaho. The Cache Valley drainage basin covers about 1,840 square miles and is a segment of the Bear River basin.

Cache Valley is a complex graben composed of downthrown fault blocks covered by rocks of Cenozoic age. Uplifted blocks surrounding the valley form mountain ranges. Maximum vertical displacement of the fault blocks probably exceeds 10,000 feet in parts of the valley. Interpretation of a gravity survey of Cache Valley indicates a maximum thickness of Cenozoic rocks of about 8,000 feet. Two oil and gas tests show depths to pre-Cenozoic rocks of 4,875 and 5,203 feet.

Most wells tap Quaternary sand and gravel, and a few wells tap sandstone, conglomerate, and fanglomerate of the Salt Lake Formation of Tertiary age. The principal springs issue from Paleozoic rocks (mostly limestone and dolomite) in the mountains and from Quaternary rocks in the valley.

Recharge to the ground-water reservoir in Cache Valley is mainly by infiltration of precipitation that falls directly on the valley, by seepage from streams and irrigation systems, and by subsurface inflow. Much of the reservoir is overflowing, and the annual change in storage therefore is assumed to be negligible; thus, the total recharge is regarded as about equal to the total discharge.

Artesian conditions exist in at least 200 square miles of the valley, and wells flow in an area of about 130 square miles. Heads of most flowing wells are less than 40 feet above land surface, but heads as high as 62 feet above land surface have been measured. Depths to water are as much as 300 feet below land surface along the margins of the valley. Water-table conditions exist near the edge of the valley beneath alluvial slopes, beneath benchlands near Preston, Idaho, and Lewiston and Trenton, Utah, and near the land surface in most of the area of flowing wells. Perched ground water exists locally in many places.

The most productive aquifer system in Cache Valley is in the Smithfield-Hyrum-Wellsville area in Utah. Fan and delta deposits of Summit Creek, Logan River, Blacksmith Fork, and Little Bear River coalesce to form a complex aquifer system that is at least 1,000 feet thick near Logan. Aquifer tests indicate that the transmissivity of the aquifer in this area ranges from about 10,000 to 330,000 cubic feet per day per foot. Yields to wells of as much as 3,500 gallons per minute have been measured, and yields of 500 gallons per minute or more are possible from most of the aquifer system. The concentration of dissolved solids in the water is generally less than 400 milligrams per liter.

The most productive aquifer systems in the Idaho part of Cache Valley are in the valley of Weston Creek and in fan deposits along the north and west sides of the valley. Well yields of as much as 2,500 gallons per minute have been reported, and the concentration of dissolved solids in the water ranges from about 200 to 1,500 milligrams per liter. Tests of the aquifer near Weston, Idaho, indicate an average transmissivity of about 30,000 cubic feet per day per foot in that area.

Water-level records in the Utah part of the valley indicate a long-term relation between precipitation and water levels. There is no apparent long-term upward nor downward trend of water levels. In the Smithfield-Hyrum-Wellsville aquifer system, water levels continue to rise during the irrigation season, despite discharge from wells for irrigation, because surface water used for irrigation is a major source of recharge. Along the west side of the valley in Idaho, water levels decline locally in areas of large withdrawals during the irrigation season.

Ground water in Cache Valley is discharged mainly from springs, seeps, and drains, by evapotranspiration, and by wells. Discharge by subsurface outflow is believed to be negligible. Many streams in Cache Valley originate at springs and seeps within the valley, and other streams gain in flow as they traverse the valley floor. About 140,000 acre-feet of ground water is discharged annually to streams from aquifers within the valley; additional spring discharge that does not reach streams is consumed by evapotranspiration. Total annual evapotranspiration from phreatophytes on 43,480 acres of wet lands in Cache Valley was estimated to be about 108,000 acre-feet. The average annual discharge from wells during 1967-69 was 29,000 acre-feet; thus the total annual ground-water discharge is approximately 280,000 acre-feet.

Underflow across the Utah-Idaho State line is estimated to be about 4,000 acre-feet annually—about 3,000 acre-feet on the west side of the valley and about 1,000 acre-feet on the east side. Between these areas, in the vicinity of Lewiston, Utah, and Fairview, Idaho, less than 50 acre-feet moves across the State line annually.

The specific conductance of most ground water in Cache Valley is less than 1,200 micromhos per centimeter at 25°C (equivalent to about 800 milligrams per liter of dissolved solids). Calcium, magnesium, and bicarbonate are the major chemical constituents present in the water. Conductances in excess of 2,400 micromhos per centimeter are rare and are related to saline water associated with fault zones or result from concentration of dissolved solids by evapotranspiration.

Most ground water in Cache Valley ranges in temperature from 9° to 15°C (48° - 59°F). The highest temperature recorded was 77°C (171°F) from Battle Hot Springs in Idaho. The hottest water from a well, 49°C (120°F), is from a well south of Trenton, Utah. Most of the hot water is associated with fault zones.

A water-budget analysis of Cache Valley indicates that about 1,700,000 acre-feet of water enters and leaves the valley each year. Inflow items include streamflow, imports for public supply, precipitation, and ground-water flow. Outflow items include streamflow, consumptive use by plants, evaporation from open water, and ground-water flow. Changes in storage are considered negligible.

INTRODUCTION

Purpose and scope of the study

This report is based on a study that was designed to provide information to enable the water managers and users in Cache Valley to develop, conserve, and administer their water resources. The report is primarily about the ground water in the valley, but it also includes a discussion of the relation of ground water to surface water and presents a general water-budget analysis for the valley. The report discusses the effects of climate, geology, and development on the source, occurrence, availability, quantity, movement, and chemical quality of the ground water. Most of the discussion pertains to ground water in the Quaternary valley fill, the principal water-bearing unit in the area, but it also includes some information about ground water in other rocks within the Cache Valley drainage basin.

The U.S. Geological Survey prepared this report in cooperation with the Utah Department of Natural Resources, Division of Water Rights. The U.S. Bureau of Reclamation and the U.S. Soil Conservation Service cooperated by providing services; and counties, cities, irrigation districts, and some local organizations and businesses in both Utah and Idaho cooperated financially through the Utah Department of Natural Resources. Fieldwork for the study began in July 1967 and continued through December 1969.

Well and spring data on which many of the interpretations and conclusions in this report are based are presented in a separate basic-data release (McGreevy and Bjorklund, 1970). The release includes a map and tables giving locations and detailed data regarding selected wells, springs, water levels, chemical quality of water, and drillers' logs. Detailed geologic and hydrologic data are shown on 16 cross sections of the valley which are presented separately by McGreevy and Bjorklund (1971).

Location and general features

Cache Valley, in northeastern Utah and southeastern Idaho (fig. 1), is a north trending structural valley. The valley floor is approximately 60 miles long and mostly 8 to 16 miles wide; it covers approximately 660 square miles, of which about 365 are in Utah and 295 are in Idaho. The Cache Valley drainage basin, a segment of the Bear River basin, includes approximately 1,840 square miles, mostly of mountainous terrain. Cache Valley is surrounded by mountains—the Bear River Range on the east, the Bannock, Malad, and Wasatch Ranges on the west, the Portneuf Range on the north, and South Hills on the south. (pl. 1)

Topography

The Cache Valley drainage basin is in two physiographic provinces. Cache Valley and mountains to the west are in the Great Basin section of the Basin and Range physiographic province; the mountains east of the valley are in the Middle Rocky Mountains physiographic province (Fenneman, 1931). The valley floor ranges in altitude from about 4,400 to 5,400 feet above mean sea level and includes almost all the cultivated land. The floor includes a low flat plain, gentle alluvial slopes, terraces and deltas left by ancient Lake Bonneville, and alluvial fans. The terraces, fans, and deltas skirt the valley and, in places, extend several miles into the valley. They are most prominent at the mouths of the principal canyons.

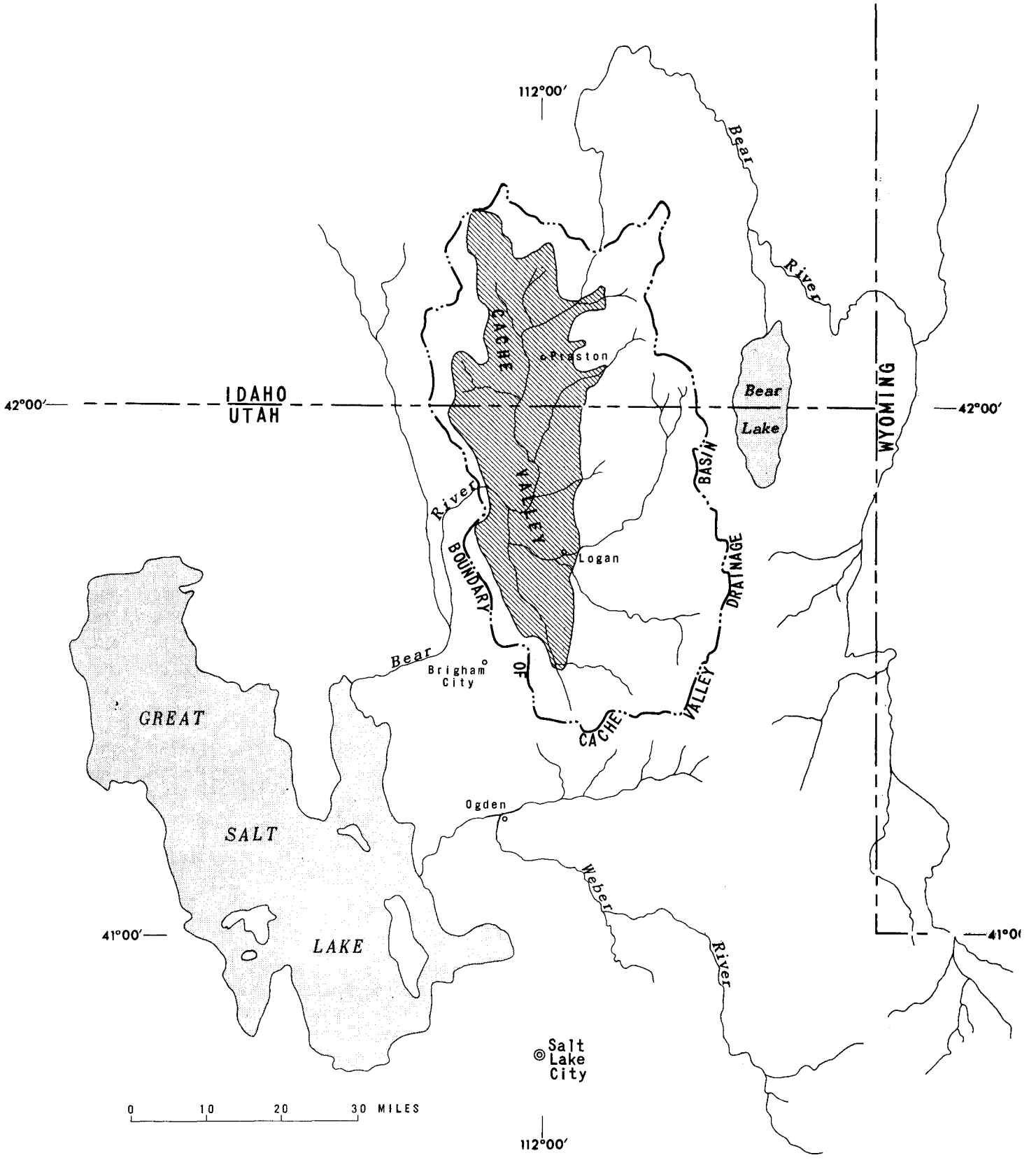


Figure 1.—Location of Cache Valley, Utah and Idaho, and the Cache Valley drainage basin.

The mountains surrounding the valley were caused mostly by faulting and subsequent erosion, and they rise abruptly at the valley edge. Most of the mountain crests are between 7,000 and 9,000 feet above sea level, but many scattered peaks rise above 9,000 feet. The mountains west of Cache Valley are relatively narrow ridges from 5 to 10 miles wide at their base; the mountains east of the valley consist of a dissected plateau about 25 miles wide. General features of topography are shown on plate 1.

Climate

Moderate precipitation, large daily temperature changes, cold damp winters, and warm dry summers are characteristic of Cache Valley. The air is usually calm, but a few days are moderately windy. The valley normally receives about 10 to 20 inches of precipitation annually, and the mountainous area surrounding the valley receives 20 to 50 inches. The maximum precipitation is in the higher parts of the Bear River Range east of the valley. Most of the precipitation results from humid air masses that move toward the valley from the North Pacific Ocean during fall, winter, and spring, and it accumulates as snow in the mountains until thawing takes place in the spring. The runoff, which results mostly from melting snow, usually reaches its maximum during May or June. Snow usually covers the valley floor during December, January, and February. The frost-free, or growing, season ordinarily lasts about 150 days from May through September.

Climatological data are collected by the National Weather Service (formerly U.S. Weather Bureau) at three weather stations near Logan, Utah, and at a station at Preston, Idaho. Normal monthly precipitation and temperature at the Utah State University station at Logan and at the Preston station are given in table 1, and graphs showing annual precipitation at Logan, cumulative departure from normal annual precipitation at Logan, water-level fluctuations in two observations wells, and annual discharge in the Logan River are shown in figure 2.

Table 1.—Normal monthly precipitation and temperature for 1931-60 at Utah State University, Logan, Utah, and at Preston, Idaho.

	Logan, Utah		Preston, Idaho	
Month	Precipitation (inches)	Temperature (°F)	Precipitation (inches)	Temperature (°F)
January	1.67	23.8	1.50	21.9
February	1.39	28.5	1.28	26.6
March	1.81	36.8	1.41	35.1
April	2.11	50.7	1.73	46.2
May	1.86	56.6	1.75	54.5
June	1.26	64.2	1.40	61.7
July	.39	73.5	.65	70.3
August	.74	71.9	.84	68.4
September	.89	63.0	.96	59.5
October	1.41	51.3	1.19	48.8
November	1.56	36.1	1.41	34.9
December	1.55	28.6	1.37	27.1
Annual	16.64	48.8	15.49	46.3

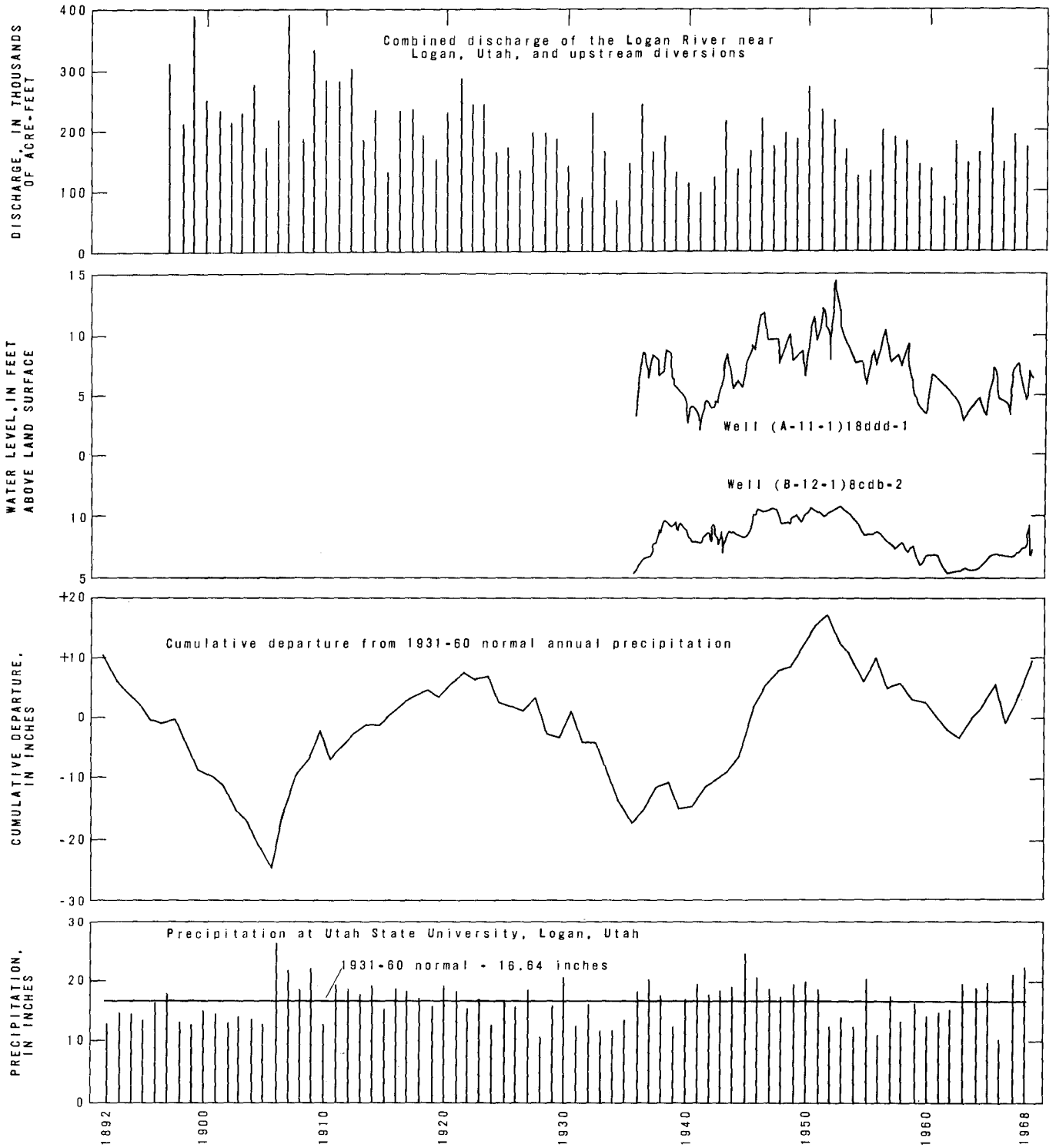


Figure 2.—Relation of annual precipitation, cumulative departure from normal annual precipitation, water levels in wells, and annual discharge of the Logan River.

Population and culture

Of the approximately 49,700 people who lived in Cache Valley in 1970, about 42,300 were in Cache County, Utah, and about 7,400 were in Franklin and Bannock Counties, Idaho. Agriculture, the principal industry, is devoted mostly to livestock, poultry, dairy products, alfalfa, small grains, corn, sugar beets, potatoes, fruit, and garden vegetables. Most of the people live in towns and rural communities, but many live on farms. Logan, Utah (Pop. 1970: 22,333), and Preston, Idaho (Pop. 1970: 3,310), are the principal cities and business centers.

Previous investigations

Several studies have been made of the geology and water resources of parts of Cache Valley. Peterson (1946) presented an inventory of wells and springs and described and evaluated the ground- and surface-water resources of the Utah part of the valley. Additional information regarding the occurrence, availability, and use of ground water was given by Beer (1967). The ground- and surface-water resources of the Idaho part of the valley were described by Dion (1969) as part of a hydrologic reconnaissance of the Bear River valley in Idaho. Streamflow data in the valley since 1889, and water-level data in wells since 1935 have been collected by the U.S. Geological Survey (1936-65, 1960, 1961a-69a, 1961b-69b, 1963). Data on the chemical quality of ground and surface water in Cache County, Utah, were compiled by Conner, Mitchell, and others (1958), and the quality of surface waters in the valley was evaluated by Waddell (1970) and Waddell and Price (1971) as part of a study of the Bear River and its tributaries.

Many studies of local ground-water conditions in the valley, mostly concerned with the feasibility of draining waterlogged lands for agriculture, have been made by the Utah State University at Logan. Israelsen and McLaughlin (1935) tested the effects of pumping a well that tapped an artesian aquifer on the flow from other wells in the vicinity. Israelsen (1953) pointed out the necessity of drainage in the Lewiston, Utah, area and Israelsen, Milligan, and Bishop (1955) discussed the drainage needs and possibilities of the Logan-Hyde Park-Benson area.

Many studies of various aspects of the geology of the area have been made. Keller (1952) mapped the Tertiary rocks in the Mink Creek, Idaho area, and Adamson, Hardy, and Williams (1955) discussed the Tertiary rocks of Cache Valley. A geologic map of Cache County, Utah, and a discussion of the geology was presented by Williams (1958); he included a list of springs in the mountains. Williams (1962) discussed the geology of the Utah part of Cache Valley in detail and presented a detailed geologic map of the valley. Most of the Idaho part of the area is included on a geologic map by Oriel and Platt (1968). Bright (1963) discussed Lake Bonneville and the initial entry of the Bear River into Cache Valley. Morrison (1966) discussed the initial entry of the Bear River into Cache Valley and the overflow of Lake Bonneville at Red Rock Pass.

Acknowledgments

The cooperation of the residents of Cache Valley and of officials of the States of Utah and Idaho, of the various counties, cities, and towns in the valley, of irrigation companies and other water users, of the Utah Water Research Laboratory, Utah State University, of the Utah Power and Light Co., and others who gave information and permitted measurements at wells and springs is gratefully acknowledged.

Most of the inventory of wells and the periodic water-level measurements in the Idaho part of Cache Valley were made by personnel of the Idaho District, Water Resources Division, U.S. Geological Survey, as part of a reconnaissance of the Bear River valley, Idaho (Dion, 1969).

SURFACE WATER

About 1 million acre-feet of water entered and left Cache Valley annually in streams during the 1960-68 water years.[1] About half the surface water originates in basins upstream from the Cache Valley drainage basin and enters the valley in the Bear River. The other half originates within the Cache Valley drainage basin and enters the valley in the Logan, Blacksmith Fork, Little Bear, and Cub Rivers, Mink Creek, and other tributaries to the Bear River. Virtually all the water leaving the valley is measured in the Bear River and two canals. Streamflow records and estimates for 16 streams entering the valley and outflow from the valley during 1960-68 are given in tables 2 and 3, and a flow diagram based on the average discharge in 1960-68 is shown in figure 3.

Tables 2 and 3 include average discharges for the years 1960-68. That period represents 4 years of below-normal precipitation (1960-62 and 1966) and 5 years of above-normal precipitation (1963-65, 1967, and 1968). The average precipitation at Utah State University at Logan for the 9-year period was 17.42 inches, compared to the 1931-60 normal annual precipitation of 16.64 inches.

The ratio of annual surface-water inflow to and outflow from the valley during 1960-68 ranged from 0.9 to 1.1 and averaged about 1.0 for the 9-year period. The inflow was greater than the outflow during years of lower streamflow and less than the outflow during years of higher streamflow. A double-mass diagram showing the general relation of inflow to outflow is shown in figure 4. The nearly consistent slope of the curve indicates that little change in water use took place in the valley during 1960-68.

The principal use of surface water in Cache Valley is for irrigation; surface water is also used for recreation, for fish culture, for livestock, and for generation of hydroelectric power. More than 300,000 acre-feet of water is diverted annually from streams to irrigate about 160,000 acres of farmland. Some water is diverted more than once because water seeping from irrigated lands and canals along the margins of the valley enters the ground-water reservoir and re-enters streams lower in the valley as ground-water discharge.

Water for irrigation is stored in Porcupine Reservoir on the East Fork of the Little Bear River, in Hyrum Reservoir on Little Bear River, in Newton Reservoir on Clarkston Creek, in Twin Lakes Reservoir (piped across the valley from Mink Creek), in Weston Creek Reservoir, and in several smaller reservoirs. Water is also stored, primarily for hydroelectric power generation, in Oneida and Cutler Reservoirs on the Bear River.

[1] The water year is the 12-month period October 1 through September 30, and it is designated by the calendar year in which it ends.

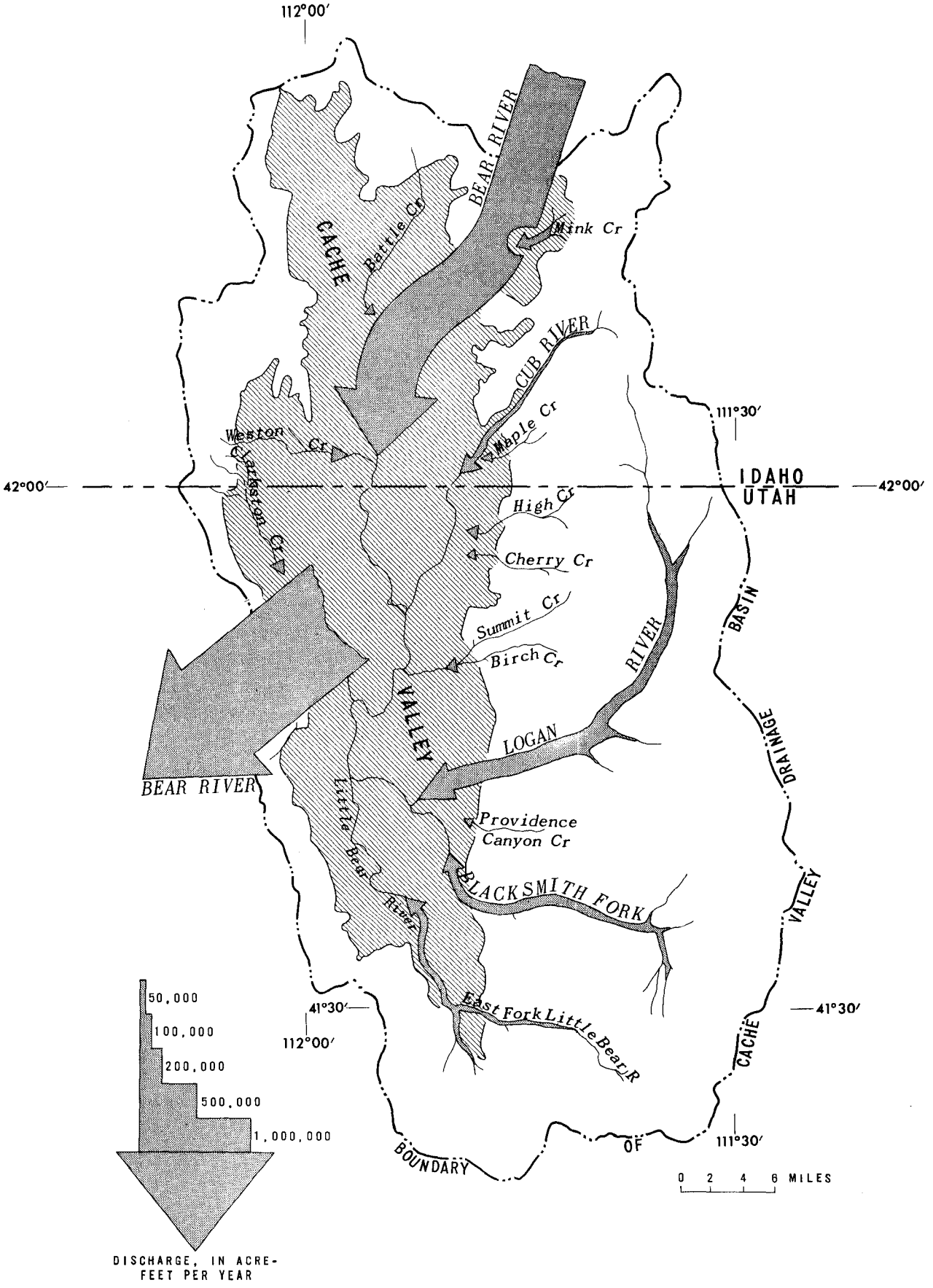


Figure 3.—Average discharge of principal streams entering and leaving Cache Valley, water years 1960-68.

Table 2.—Discharge of principal streams entering Cache Valley, 1960-68 water years.

(Thousands of acre-feet)

[All data from U.S. Geological Survey (1960, 1963, 1961a-68a, 1961b-68b) unless indicated otherwise. e, indicates the measurement was estimated.]

	1960	1961	1962	1963	1964	1965	1966	1967	1968	Average
Bear River	457	407	447	444	450	605	810	536	546	522
Logan River	139	95	171	146	159	230	154	190	172	162
Blacksmith Fork	60	44	85	64	74	114	82	101	85	79
Little Bear River below Davenport Creek	25e	17	42	24	33	41	34	46	36	33
East Fork Little Bear River	23e	13e	32e	18e	24	29	26	27	26	24
Mink Creek	51e	35e	76e	53e	75e	98e	47e	76e	59e	63
Cub River	46	35	62	47	62	77	43	62	51	54
High Creek	17e	12e	22	16e	21e	27e	15e	22e	18e	19
Summit Creek	10e	7e	13	9	15	17	10	15	13	12
Maple Creek	8e	4e	14e	9e	14e	19e	7e	14e	10e	11
Cherry Creek	3e	2e	4e	3e	5e	5e	3e	5e	4e	4
Birch Creek	2e	1e	2e	2e	3e	3e	2e	3e	2e	2
Battle Creek	1e	1e	1e	1e	1e	2e	1e	1e	1e	1
Weston Creek	2e	1	2e	2e	2	3e	1e	2e	2e	2
Providence Canyon Creek	6e	4	8	5e	9e	10e	6e	9e	8e	7
Clarkston Creek	3e	2e	9e	2e	4e	5e	4e	4e	4e	4
Totals	853	681	990	845	950	1,285	1,244	1,112	1,037	1,000 (rounded)

Explanation of stations and basis of estimates

Bear River - Bear River below Utah Power & Light Co.'s tailrace, Oneida, Idaho.

Logan River - Combined discharge of Logan River above State dam, Utah Power & Light Co.'s tailrace, and Logan, Hyde Park & Smithfield Canal at head, near Logan, Utah.

Blacksmith Fork - Blacksmith Fork above Utah Power & Light Co.'s dam, near Hyrum, Utah.

Little Bear River - Little Bear River below Davenport Creek, near Avon, Utah. Estimate for 1960 based on correlation with Blacksmith Fork.

East Fork Little Bear River - East Fork Little Bear River above reservoir, near Avon, Utah. Estimates for 1960-63 by Reid, Carroon, and Pyper (1969, p. 57) adjusted for changes in storage and evaporation in Porcupine Reservoir.

Mink Creek - Mink Creek near Mink Creek, Idaho. Estimates based on correlation with Cub River for 1944-52.

Cub River - Cub River near Preston, Idaho

High Creek - High Creek near Richmond, Utah. Estimates for 1966-68 based on correlation with Cub River for 1946-52. Estimates for 1960-65 by Reid, Carroon, and Pyper (1969, p. 54).

Summit Creek - Summit Creek above diversions, near Smithfield, Utah. Estimates for 1960-61 based on correlation with Logan River.

Maple Creek - Maple Creek near Franklin, Idaho. Estimates based on correlation with Cub River for 1946-52.

Cherry Creek - Cherry Creek near Richmond, Utah. Estimates based on correlation with Summit Creek for 1944-45.

Birch Creek - Birch Creek at mouth, near Smithfield, Utah. Estimates based on correlation with Summit Creek for 1944-45.

Battle Creek - Battle Creek near Treasureton, Idaho. Estimates based on correlation with Cub River for 1944.

Weston Creek - Estimated by irrigation company officials in 1962 and adjusted for other years on the basis of discharge in the Cub River.

Providence Canyon Creek - Estimates for 1961 and 1962 from Providence Irrigation Co. and adjusted for other years on the basis of discharge in Summit Creek.

Clarkston Creek - Estimated by U.S. Bureau of Reclamation from change in storage records for Newton Reservoir.

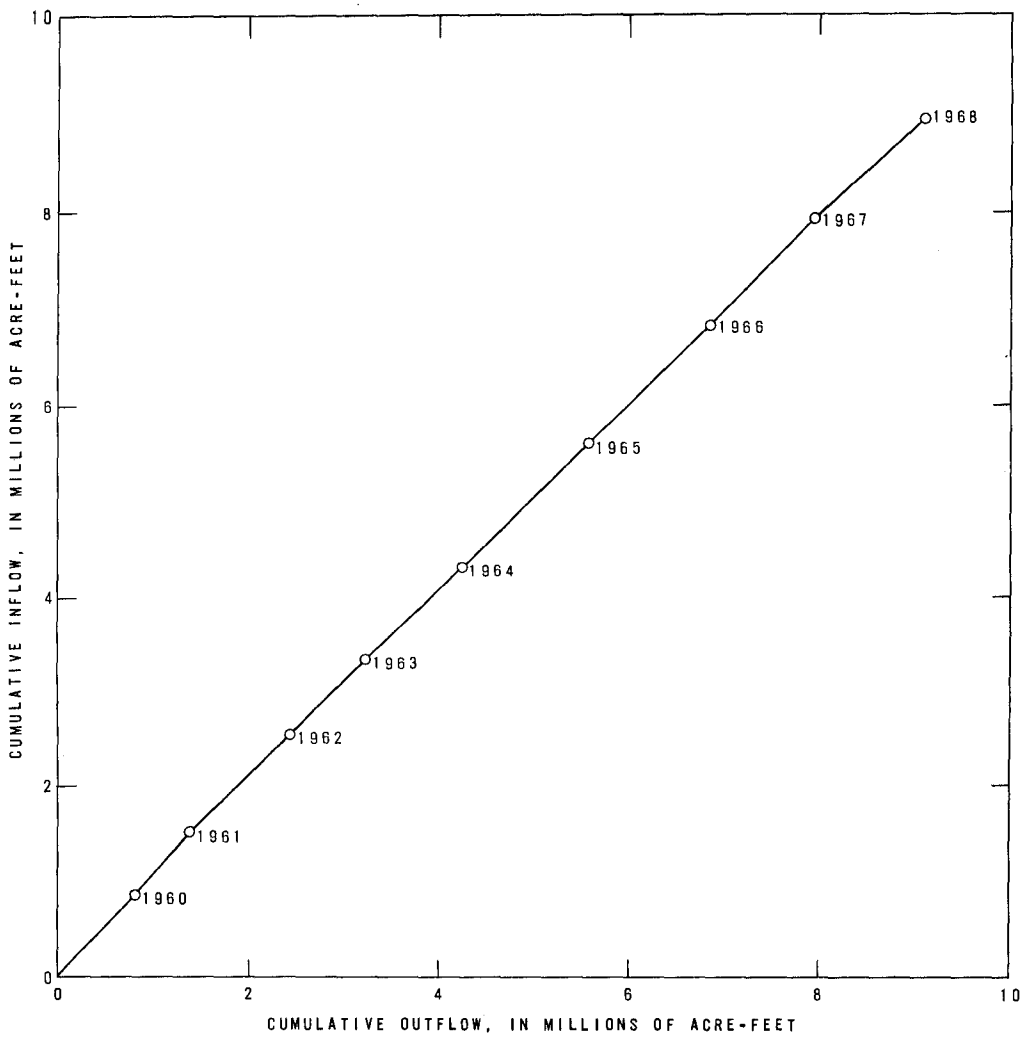


Figure 4.—Relation of cumulative inflow to Cache Valley in 16 principal streams to cumulative outflow, water years 1960-68.

Table 3.—Discharge of the Bear River and of canals leaving Cache Valley, 1960-68 water years
Data from U.S. Geological Survey (1960, 1963, 1961b-68b)
(Thousands of acre-feet)

	1960	1961	1962	1963	1964	1965	1966	1967	1968	Average
Bear River near Collinston, Utah	530	364	808	576	832	1,074	1,018	942	874	780
West Side Canal near Collinston, Utah	214	200	172	184	164	193	219	176	194	191
Hammond (east side) Canal near Collinston, Utah	46	43	37	37	35	41	46	35	38	39
Total	790	607	1,017	797	1,031	1,308	1,283	1,153	1,106	1,010

GROUND WATER

Geologic setting

The types, locations, and structures of the rock units of the area determine the occurrence and availability of ground water. Water occurs in the open spaces in rocks, such as fractures, solution openings, or spaces between grains. The ease with which water can enter and move through the rocks depends on the permeability (the ability of the rocks to transmit water), which depends on the size and interconnection of the open spaces in the rock. The principles of occurrence are discussed in detail by Meinzer (1923) and in E.E. Johnson, Inc. (1966). Rock units are listed in table 4, and areas of outcrop are shown on the geologic map (pl. 1).

Structure and stratigraphy

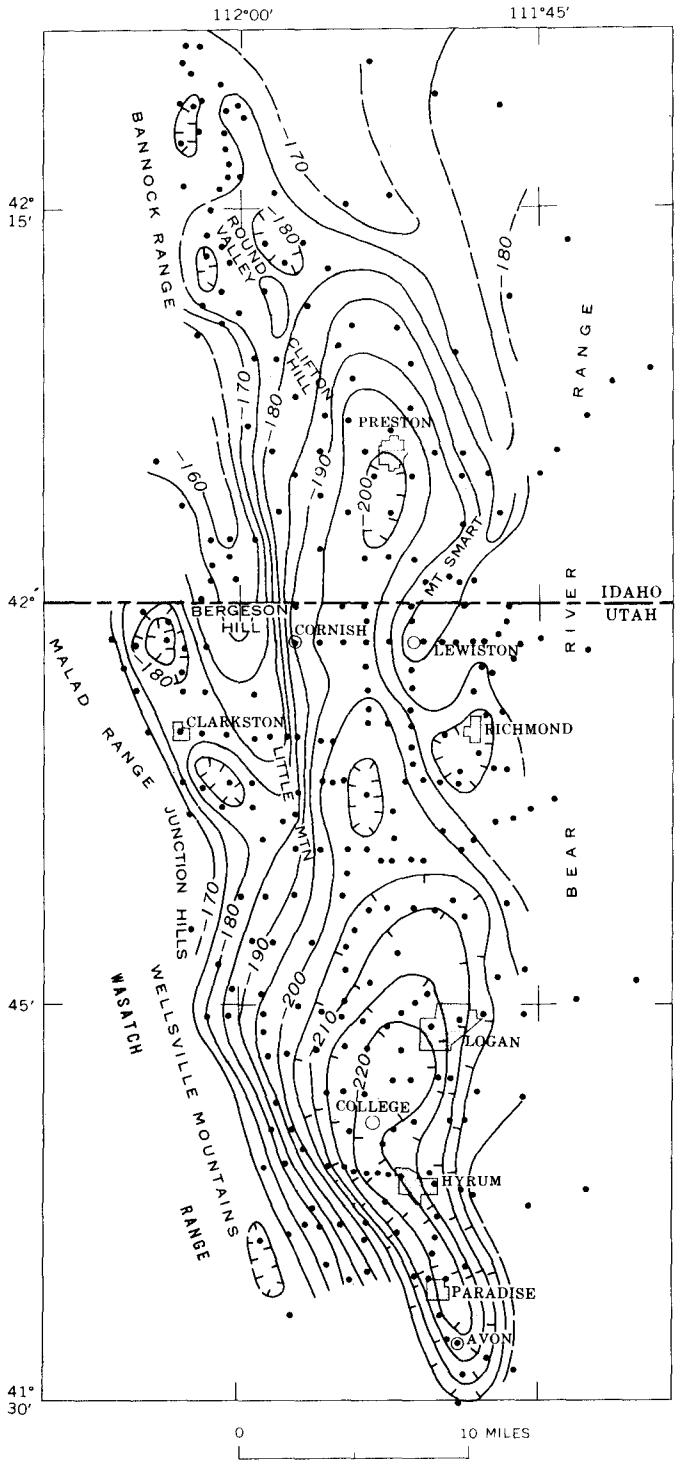
Cache Valley is a complex graben composed of downthrown fault blocks covered by deposits of Cenozoic age. Uplifted blocks surrounding the valley form mountain ranges. Maximum vertical displacement probably exceeds 10,000 feet in parts of the valley. The Bear River Range contains large folds that predate the block faulting. Thrust faults that also predate block faulting lie east and south of the area, and possibly underlie the area at great depth. Faults with minor displacement are common in the mountain ranges and probably exist in the blocks underlying the valley.

Precambrian, Paleozoic, and Cenozoic rocks are exposed in the area; Mesozoic rocks have not been mapped in the area but are present a few miles east near Bear Lake. Sedimentary and metamorphic rocks of Precambrian and Paleozoic age, predominantly limestone, dolomite, and quartzite, compose the mountain blocks surrounding Cache Valley and underlie younger rocks in the valley. Cenozoic rocks consist of two Tertiary units, the Wasatch(?) and the Salt Lake Formations, and of various Quaternary units. Remnants of the Wasatch(?) Formation, predominantly fluvial conglomerate, are present on the mountain blocks in the Utah part of the area. Scattered remnants of the Wasatch(?) Formation may underlie the Salt Lake Formation in Cache Valley, but probably most of the Wasatch was removed by erosion before Cache Valley began to form. Fluvial and lacustrine rocks of the Salt Lake Formation, predominantly tuffaceous, are present under younger rocks in Cache Valley and are exposed in hills around much of the valley. The Salt Lake Formation consists of diverse lithologic units but has not been studied in enough detail to be consistently subdivided. Quaternary rocks mostly consist of unconsolidated fluvial and lacustrine sediments in Cache Valley and fluvial and glacial deposits in the mountains.

Geophysical studies

A gravity survey of Cache Valley was made in 1968 to determine the approximate thickness of Cenozoic rocks in the valley and the gross structure of underlying pre-Cenozoic rock. Detailed results of the study are published in a separate paper (Peterson and Oriel, 1970). The gravity map from that report is shown as figure 5. Major faulting inferred from the gravity study is included on the geologic map (pl. 1) and general conclusions are integrated in this report.

The gravity map (fig. 5) shows differences in gravity that are largely due to differences in density of the rocks. Precambrian and Paleozoic rocks are more dense than the overlying Cenozoic rocks. A general interpretation of the gravity map is that the lower Bouguer gravity values indicate a greater thickness of less dense rocks and thus a greater depth to pre-Cenozoic bedrock. Because of regional gravity differences and other complexities discussed by Peterson and Oriel (1970), the correlation is not direct. However, figure 5 does show the gross structure of the valley in much the same way as do contours on the bedrock surface, and steep gravity gradients (closely spaced contours) indicate probable faults or fault zones.



EXPLANATION

—180— Gravity contour

Dashed where approximately located. Contour interval 5 milligals. Hachured contours enclose areas of low gravity

• Gravity station

Figure 5.—Bouguer gravity map of Cache Valley, Utah and Idaho. (From Peterson and Oriel, 1970.)

Interpretations of the depth to pre-Cenozoic bedrock were made from the gravity data by Peterson and Oriel (1970) along three profiles across the valley, one of which is integrated into the section of plate 1. Peterson and Oriel (1970) emphasize that gravity interpretations are inherently ambiguous and that the interpreted thickness of Cenozoic rocks may differ substantially from the actual thickness if the assumed density contrasts and regional gravity gradient are not approximately correct. Maximum interpreted thicknesses of Cenozoic rocks along the three profiles range from about 5,500 to 8,000 feet. Thicknesses of this magnitude agree with results of oil and gas tests near Trenton and Amalga, Utah, where wells (B-13-1)10acb-1 and (A-13-1)19cac-1 show depths to pre-Cenozoic rocks of 4,875 and 5,203 feet, respectively (see appendix for well- and spring-numbering systems used in this report).

Detailed geophysical studies near the Utah-Idaho State boundary were made by W.D. Stanley in 1969 as part of his graduate work at the University of Utah. Some interpretations from electrical resistivity and seismic surveys by Stanley and some of Stanley's general conclusions are utilized in this report.

Lake Bonneville

Cache Valley was a bay of ancient Lake Bonneville during a part of Pleistocene time, and the many related topographic features and deposits in the valley affect the occurrence and movement of ground water. A cyclic fluctuation of lake levels occurred in the Great Salt Lake basin during Pleistocene time. The name Lake "Bonneville" is given to the lake that occupied the basin during the last major glacial state, the Wisconsin, which began about 75,000 years ago (Morrison and Frye, 1965, fig. 2). Much of the Quaternary valley-fill deposits in Cache Valley are older than Wisconsin and were deposited by older lakes and streams. Gilbert (1890) recognized many of the features of Lake Bonneville, and many other workers have added to the knowledge of the lake; recent work has been done by Morrison and Frye (1965) and Morrison (1966).

The level of Lake Bonneville fluctuated with changes in climate—at its maximum stage it covered approximately 20,000 square miles in parts of three states; at its minimum stage it was probably smaller than the present Great Salt Lake and may have dried up completely. Shoreline features are prominent in Cache Valley at two general levels, which are called the Bonneville and Provo levels. The Bonneville level in Cache Valley is at an altitude of about 5,140 feet, and the Provo level is at about 4,800 feet. These levels are not consistent throughout the valley. Crittenden (1963, fig. 3) indicates that the altitude of the Bonneville level differs from place to place in Cache Valley by almost 100 feet, mainly because of isostatic rebound due to unloading as Lake Bonneville receded. The approximate trace of the highest shoreline of Lake Bonneville in Cache Valley (essentially the Bonneville level) is shown on plate 1 .

Lake Bonneville overflowed at Red Rock Pass at the northwestern end of Cache Valley at least once and perhaps twice (Morrison, 1966, p. 93; Malde, 1968, p. 10). Seismic exploration by Williams and Milligan (1968) indicates that the bedrock has been cut to an altitude of about 4,755 feet in the bottom of the channel at the pass. About 20 feet of alluvium has been added, and the land surface altitude at the pass is now about 4,775 feet. Scour and channel features cut by currents within the basin of the overflowing lake are visible for several miles between Oxford, Idaho, and the pass.

Deposits related to Lake Bonneville and earlier lakes play an important role in the occurrence of ground water in Cache Valley. The major aquifers are composed of sand and gravel in fans and deltas; interbedded layers of lake-bottom clays and silts confine the aquifers and cause widespread artesian conditions.

The Bear River delta is a lake feature that has significantly affected the hydrology of Cache Valley. Deltas and fans of other streams entering the valley contain a high percentage of gravel derived from nearby mountains and generally contain good aquifers. The Bear River delta, however, is composed mostly of fine sand and silt derived from upstream basins, and generally contains poor aquifers. The Bear River is a relative latecomer to Cache Valley; the river was diverted from the Snake River drainage about 27,000 years ago (Morrison, 1966, p. 95). Before the diversion, the Idaho part of Cache Valley upstream from Weston Creek was drained by Mink and Battle Creeks and their tributaries. The valleys probably contained fan, slope-wash, and lake deposits. Sometime after the Bear River entered the valley, Lake Bonneville rose again to a high level and, as the delta formed in the lake, fine-grained deposits filled the valleys. Potentially productive aquifers may lie beneath the delta deposits in the older deposits, but they have not been explored east of the present Bear River channel.

When Lake Bonneville receded below the delta, the Bear River cut a channel through the delta and redeposited the material in the receding lake. The river is presently incised nearly 300 feet into the delta north and west of Preston, Idaho. Reworked sand and silt from the delta were spread over lake-bottom clay and silt from near Fairview, Idaho, to Cutler Reservoir. These deposits, which are mapped as sand and silt on the geologic map (pl. 1), form a thin but extensive hydrologic unit.

Geologic units and their water-bearing properties

Most wells in the area derive water from units of Quaternary age; a few wells tap the Salt Lake Formation of Tertiary age. Springs issue from most rock units, but the Paleozoic rocks in the mountains and the Quaternary rocks in the valley are the sources of most of the principal springs. All geologic units that are exposed in the area are listed and described and their water-bearing properties summarized in table 4; in addition, the most important units are discussed below.

The Paleozoic rocks younger than the Brigham Quartzite transmit ground water mainly through fractures and openings enlarged by solution. The sandstones generally have low permeability, but fracturing has increased the permeability locally. Solution of carbonate rocks, particularly along fractures and bedding planes, however, has produced zones of high permeability. In the mountains, ground-water moves primarily through the systems of solution channels that may transmit water independently of surface topographic divides. Large caves have developed by solution, notably in the Garden City and Lodgepole Limestones; solution and subsequent collapse of overlying rock have produced many large sinks, notably in the Bloomington Formation, Garden City Limestone, Laketown Dolomite, Hyrum Dolomite, and Chesterfield Range Group; and large springs issue from solution channels in the carbonate rocks. A few oil and gas tests in the valley are the only wells known to penetrate Paleozoic rocks. One of the oil and gas tests (well (B-13-1)10 acb-1) discharges water that may be coming from Paleozoic rocks; the water is hot (49°C, 120°F) and saline (3,280 milligrams per liter of dissolved solids).

Most of the Salt Lake Formation is fine grained and well indurated and yields little water; however, some sandstone, conglomerate, and fanglomerate are water bearing. A few wells and springs tap the formation, mostly in or near outcrops along the margins of the valley.

Five oil and gas tests (wells (A-13-1)19cac-1, (B-13-1)10acb-1, (B-13-1)25bab-1, 15S-38E-36bab1, and 16S-38E-15aba1) penetrate the Salt Lake Formation, which is deeply buried beneath younger rocks in Cache Valley. The contact between the Salt Lake Formation and Quaternary rocks is difficult to distinguish in the subsurface because both contain similar

Table 4.—Generalized section of the geologic units and their water-bearing properties.

Era	System	Series	Geologic unit (approximate maximum thickness in feet)	Composition[1]	Water-bearing properties[2]
CENOZOIC	Quaternary	Pleistocene and Holocene	Flood-plain alluvium and terrace deposits (50)	Cobbles, gravel, sand, silt, and clay, well to poorly sorted, unconsolidated. Mapped units are generally less than 50 feet thick and are underlain by undivided valley fill in most of Cache Valley.	Permeability generally moderate to high. Yields generally adequate for domestic and stock supplies. Water contains less than about 1,000 mg/l (milligrams per liter) of dissolved solids.
			Sand and silt (30)	Sand and silt. Delta-levee deposits of the Bear River, which consist mostly of reworked material from the Bear River delta near Preston, Idaho.	Permeability generally low to moderate. Water perched on underlying lake-bottom clays that have very low permeability. Discharges to springs and seeps. Pumping from drains yields a few hundred gallons per minute (gpm). Quality of water varies widely with location and with season. Maximum concentration of dissolved solids is probably near 2,000 mg/l.
			Alluvial-fan deposits (Unknown)	Boulders, cobbles, gravel, sand, silt, and clay of fans deposited by minor streams. Mapped fans do not include the larger fan and delta-fan deposits of the major streams which are veneered by other mapped units.	Permeability moderate to high. A few wells tap these rocks in the northwest part of Cache Valley. Yields of as much as 2,500 gpm are reported. Maximum concentration of dissolved solids is probably 400 mg/l.
			Spring deposits (Unknown)	Calcareous tufa.	Not considered an aquifer.
			Lake Bonneville Group (Unknown)	Cobbles, gravel, sand, and silt along the margins of the valley grading to silt, clay, and sand in the central part of the valley. Mapped units are generally less than about 50 feet thick and in most of the valley overlie older rocks of the Lake Bonneville Group and pre-Lake Bonneville Group rocks, which are included in valley fill undivided.	Deposits along the margins of the valley are moderately to highly permeable but are generally drained; elsewhere they have generally low permeability.
			Colluvium, alluvium, and undifferentiated deposits (Unknown)	Unconsolidated rocks of all sizes and degrees of sorting. Includes glacial deposits in the Bear River Range.	Wide range of yields, depending on grain size, sorting, and thickness of material.
			Diamictite (Unknown)	Unconsolidated, strikingly unsorted, detrital deposits that range in size from clay and silt particles to blocks. Probably deposited in moraines, rock glaciers, landslides, and hill wash. (After Oriel and Platt, 1968.)	Water-bearing properties unknown.
			Valley fill undivided (1,340)	Cobbles, gravel, sand, silt, clay, and peat that underlie mapped Quaternary units in much of the valley.	Permeability is very low to very high. These rocks compose the major aquifers of the valley. Well yields range up to about 4,500 gpm. Water from most wells contains about 200-400 mg/l of dissolved solids, but higher concentrations are as much as about 3,600 mg/l.
	Tertiary	Pliocene	Salt Lake Formation (9,000)	Tuff, and mostly tuffaceous and calcareous siltstone, sandstone, conglomerate, limestone, and marl; white and light shades of gray, green, brown, yellow, and tan. A fanglomerate facies that crops out on the east side of the valley is composed of pebbles, cobbles, and boulders in sand and marl matrix with calcium carbonate cement; includes landslide blocks of pre-Tertiary rock (diamictite?). (Some rocks of the formation may be older than Pliocene.)	Permeability generally low to moderate depending on grain size, sorting, cementation, and solution. The fanglomerate facies has high permeability locally. Yields water to a few wells and springs. Yields are generally small to moderate (less than 100 gpm) except from the fanglomerate, which has small to large yields (as much as 3,600 gpm from springs). The largest springs issue from solution openings in the fanglomerate facies. A few chemical analyses and specific conductance measurements indicate that water from the formation generally contains about 300-800 mg/l of dissolved solids; water from the fanglomerate facies may contain 200 mg/l or less.
		Paleocene and Eocene	Wasatch(?) Formation (500)	Conglomerate, sandstone, mudstone, and some limestone, generally poorly sorted, partly cemented to well cemented with calcium carbonate; red, pink, brown, and gray. (Tentatively assigned to Wasatch Formation; correlation uncertain.)	Permeability generally low because of cementing and poor sorting but some moderately permeable beds probably present. Solution of carbonate has increased the permeability locally. Yields water to numerous small springs, and small-discharge wells would probably be possible at many places. Quality of water is not known in the area but dissolved solids probably slightly higher than in water from Paleozoic rocks[3].
PALEOZOIC	Permian		Oquirrh Formation (6,100)	Sandstone and limestone, gray; includes some black shale.	Permeability of the Paleozoic rocks is mostly due to fractures and to solution openings in carbonate rocks; very high permeability locally due to solution along fractures and bedding planes. Springs discharging more than 500 gpm are known to issue from the Langston, Blacksmith, Bloomington, Nounan, St. Charles, Garden City, Laketown, Hyrum, Beirdneau, and Lodgepole Formations, and Chesterfield Range Group. The maximum measured spring discharge is 32,000 gpm. Probably all formations yield water to at least a few small springs. Specific conductance and chemical analyses of water indicate a range in concentration of dissolved solids from about 150 to 310 mg/l.
	Pennsylvanian				
	Mississippian	Upper	Chesterfield Range Group (3,700)	Limestone, silty limestone, dolomite, sandstone and siltstone, thin- to thick-bedded, light- to dark-gray; contains layers and nodules of chert; most limestone is fetid. Dark-gray to black phosphatic limestone, shale, and chert form thin basal unit in Bear River Range.	
		Lower	Lodgepole Limestone (850)	Limestone and silty limestone, thin- to medium-bedded, gray; contains chert beds.	
			Leatham Formation (100)	Shale, siltstone, limestone, and some sandstone, thin-bedded, gray; absent or not recognized in most of the area.	

Table 4.—Generalized section of the geologic units and their water-bearing properties, continued.

Era	System	Series	Geologic unit (approximate maximum thickness in feet)	Composition1/	Water-bearing properties2/
PALEOZOIC	Devonian	Upper	Beirdneau Formation (850)	Sandstone, siltstone, dolomite, and limestone, thinly interbedded, gray and buff.	
		Middle and Upper	Hyrum Dolomite (1,200)	Dolomite, thin- to medium-bedded, fetid, dark-gray.	
		Lower	Water Canyon Formation (550)	Dolomite, sandy and silty sandstone, and sandy shale; light-gray, tan, and buff.	
	Silurian	Middle and Upper	Laketown Dolomite (1,500)	Dolomite, medium-bedded to massive, vuggy in part, light- to dark-gray; contains chert beds.	
	Ordovician	Upper	Fish Haven Dolomite (500)	Dolomite, massive, dark-gray; contains chert beds.	
		Middle	Swan Peak Quartzite (700)	Quartzite and quartzitic sandstone, thin-bedded to massive, and thin-bedded limestone and shale; includes fucoidal quartzite; buff, tan, pink, brown, green, gray, and black.	
		Lower	Garden City Limestone (1,800)	Limestone, shaly limestone, dolomite, and chert, gray.	
	Cambrian	Upper	St. Charles Limestone (1,100)	Dolomite and limestone thin- to medium-bedded, light- to dark-gray; contains chert layers. Worm Creek Quartzite Member at base is light-gray, pink, and tan quartzite and arkose.	
		Middle	Nounan Limestone (1,100)	Dolomite, thin-bedded to massive, and thin- to medium-bedded limestone, silty limestone, and sandstone; light- to dark-gray.	
			Bloomington Formation (1,500)	Mudstone, claystone, shale, limestone, and silty limestone; includes beds of locally quartzitic siltstone and very fine grained sandstone; mostly green, gray, and buff.	
			Blacksmith Limestone (900)	Limestone and dolomite, generally medium-bedded to massive; gray to buff.	
			Ute Limestone (750)	Limestone, mudstone, siltstone, and shale; gray, green, tan, and black.	
			Langston Dolomite (500)	Dolomite, limestone, shale, and mudstone; gray, green, and tan.	
	Cambrian and Precambrian		Brigham Quartzite (10,000)	Quartzite, partly conglomeratic; includes units of phyllite and argillite; white, tan, buff, brown, purple, pink, green, and gray.	Permeability low because of cementation, compaction, or crystallization; solution is not significant. Locally permeable where fractured or weathered. Yields water to a few small springs in the mountains, but prospects for wells are poor. Quality of the water is not known in this area4/.
	Pre-cambrian			Quartzite, metadiabase, metagraywacke, and slate; partly schistose; gray, green, and pink colors predominant; includes a few thin units of dark-gray limestone.	

1/ Based primarily on works by many writers (see selected references).
2/ Data for wells and springs given by McGreevy and Bjorklund (1970); data for additional springs in the mountains given by Williams (1958, p. 83-86).
3/ The concentration of dissolved solids in eight samples of water from the Wasatch(?) Formation in the Bear Lake area ranged from 232 to 320 mg/l (Kaliser, 1969, table 2).
4/ The concentration of dissolved solids in water from two springs discharging from similar rocks in the Bear Lake area was 230 and 240 mg/l (Kaliser, 1969, table 2).

materials; however, the top of a thick conglomerate at depths of about 1,100 to 1,300 feet in the tests is interpreted as the top of the Salt Lake Formation. Logs indicate that the conglomerate may be as much as 1,000 feet thick in places. Wells (A-13-1)19cac-1 and (B-13-1)25bab-1 derive water from the conglomerate. Well (A-13-1)19cac-1 reportedly flows 75 gpm (gallons per minute), and the water contains 789 mg/l (milligrams per liter) of dissolved solids. Well (B-13-1)25bab-1 reportedly flowed about 2,700 gpm when it was drilled in 1925 (Peterson, 1946, p. 14), but it now flows only about 300 gpm. The water contains about 700 mg/l of dissolved solids. Two of the tests (A-13-1)19cac-1 and (B-13-1)10acb-1, penetrated about 4,000 feet of Salt Lake Formation. Gravity data indicate that the formation may be more than 6,000 feet thick in some parts of the valley.

Quaternary units include the major aquifers discussed in this report and constitute the principal ground-water reservoir in Cache Valley. The surface units shown on plate 1 are generally thin, but in much of Cache Valley they overlie thick deposits of undivided Quaternary valley fill. Lithologic and hydrologic data for these rocks are shown in detailed geologic sections of the valley in a separate report (McGreevy and Bjorklund, 1971). Ground-water conditions differ greatly from one part of the valley to another and depend mostly on the composition and thickness of the Quaternary rocks. (See discussion of ground-water conditions by areas.)

Source and recharge

Most of the ground water in Cache Valley is derived from precipitation within the Cache Valley drainage basin. However, an unknown but relatively small percentage of the ground water is derived from two outside sources: (1) Some of the water that flows into the basin in the Bear River is diverted from the river for irrigation in the valley, and part of the diverted water subsequently moves downward to the ground-water reservoir; and (2) ground water that moves into the basin through solution channels and fractures in rocks of the Bear River Range.

Most of the recharge to the rocks in the mountains bordering Cache Valley takes place during the snowmelt-runoff season. Much recharge occurs in large areas in the Bear River Range where 30 to 50 inches of precipitation falls during most years (U.S. Weather Bureau, 1963, 1965). Some of this area consists of closed basins; all the water that is not used by vegetation, or does not evaporate, drains into sinkholes and other openings in the rocks. Closed basins and sinkholes also occur along the Wasatch Range, notably at Dry Lake, in T. 10 N., R. 1 W., where water accumulates during the runoff season but disappears into a sinkhole within a few weeks.

Recharge to the principal ground-water reservoir in Cache Valley occurs mainly by infiltration of water from precipitation, streams, canals, ditches, and irrigated fields and by subsurface inflow. The principal recharge area is along the margins of the valley and is underlain by permeable unconsolidated materials including beds of gravel and sand. In the lower parts of the valley, some water is recharged to shallow unconfined aquifers, but infiltrated water does not reach the confined aquifers because of the upward artesian gradient. (See fig. 6.)

The scope of this project did not allow for direct measurement of the total recharge to the ground-water reservoir in Cache Valley. Much of the reservoir is overflowing, and the annual change in storage therefore is assumed to be negligible; thus, the total recharge is regarded to be about equal to the total discharge. On this basis, the total annual recharge is about 280,000 acre-feet. (See section on ground-water discharge.)

Precipitation

Direct recharge from precipitation occurs in Cache Valley mainly during periods of snowmelt. At times, 2 or more feet of well-packed snow, containing several inches of water, will accumulate on the ground. If the snow melts slowly and the underlying soil is not frozen, most of the water will filter into the ground and some of it will reach the ground-water reservoir. On the other hand, a sudden thaw or a drenching rain on accumulated snow and frozen ground will cause quick runoff and allow little time for infiltration.

Recharge directly from rainfall in Cache Valley is small. Some of the water from heavy rains runs off before it can enter the soil, and most of the water that does infiltrate from rainfall is transpired by vegetation, is evaporated, or remains as soil moisture.

Streams

Infiltration of water from streams is an important source of recharge to the ground-water reservoir in Cache Valley. Recharge takes place where the streams flow from canyons onto coarse-grained deposits that permit water to infiltrate readily from the stream to the underlying ground-water reservoir. Most of the recharge is from perennial streams that provide a constant source, but some water is contributed by intermittent and ephemeral streams.

The Bear River is perhaps the only stream entering Cache Valley that does not directly contribute water to the ground-water reservoir. The Bear River flows through the lower part of the valley, which is predominantly an area of ground-water discharge; consequently, it is a gaining stream throughout its course through the valley. The river does contribute water indirectly, however, through infiltration of water diverted for irrigation.

Irrigation systems

Recharge to the ground-water reservoir in Cache Valley has been increased substantially by diverting water from streams for irrigation. More than 100,000 acre-feet of water enters the reservoir annually from about 600 miles of canals and ditches and 160,000 acres of irrigated land. Most of the recharge takes place along the edges of the valley where water infiltrates most readily, and where more irrigation water is applied than in other parts of the valley. According to R.D. Harrison (U.S. Soil Conservation Service, oral commun., 1969), as much as 5 acre-feet of water per acre is used annually for irrigation at some sites in the principal recharge area as compared to the average of about 2.5 acre-feet per acre used for irrigated lands in the entire valley.

Seepage studies were made by the U.S. Soil Conservation Service during 1966 on 13 canals and ditches on the east side of Cache Valley. Measured losses per mile ranged from 7 to 29 percent of the flow. The higher percentage losses were for flows of 3 cfs (cubic feet per second) or less. Three of the larger canals having flows of 4, 17, and 26 cfs showed losses of 12, 9, and 12 percent per mile, respectively (U.S. Soil Conservation Service, written commun., 1969).

A study of a 12.27-mile reach of the Porcupine High Line Canal, which diverts water from the East Fork of Little Bear River and flows northward to Blacksmith Fork Canyon, indicated losses ranging from 0.2 to 4.6 cfs per mile, or 3 to 32 percent per mile (G.V. Skogerbee, written commun., 1967). The flow entering the test reach was 18.8 cfs. The total loss was 10.0 cfs in 12.27 miles—an average of 0.8 cfs per mile.

The amount of recharge due to infiltration of applied irrigation water may decrease in the future, because many irrigators are turning to sprinkling in place of flooding. About 20,000 to 28,000 acres is presently irrigated by sprinkling in the Utah part of Cache Valley (R.D. Harrison, U.S. Soil Conservation Service, oral commun., 1969) and probably more than 5,000 acres is irrigated by sprinkling in the Idaho part. Sprinkling reduces recharge because less water is required for irrigation and infiltration to the ground-water reservoir is reduced.

Subsurface inflow

The valley fill in Cache Valley is recharged in part by water moving into it directly from rocks in the adjacent mountains. Numerous springs discharge in the mountains or along the base of the mountains bordering the valley, and it is reasonable to assume that water discharges into the valley fill at places where water-bearing openings in bedrock are deeply buried. The fill at the mountain edges generally consists largely of alluvial gravels that are permeable but unsaturated to a depth of 100 feet or more; thus large amounts of water could enter the fill in the subsurface without being apparent at the surface.

In other parts of Utah, subsurface inflow represents a major part of the total recharge to the valley fill. Data reported by Hely, Mower, and Harr (1971, p. 119) indicate that the subsurface inflow was 37 percent of the total recharge to the valley fill in the Jordan Valley, and data from Feth and others (1966, p. 39) indicate that the subsurface inflow in the East Shore area was 43 percent of the total recharge to the aquifers in the Weber Delta district.

Some water enters the valley fill through alluvium in the canyons, especially in those canyons that contain perennial streams. The total amount of water entering the valley fill by this means could be significant, although small compared to the amount of water flowing in the streams. The amount of water entering the valley through alluvium underlying the Bear River probably is small, because the alluvium underlying the river at Oneida Narrows apparently is thin and therefore incapable of transmitting substantial amounts of ground water.

Occurrence

Ground water in Cache Valley is both confined and unconfined. The most productive aquifers are beds of coarse, clean well-sorted gravel and sand that absorb water readily, store it in large quantities, and yield it readily to wells. Silt and clay, on the other hand, store much water but will not yield it readily to wells.

The general relation of confined, unconfined, and perched ground water in Cache Valley is illustrated in figure 6. Conditions shown in the diagram most nearly resemble those near Logan, Utah, but the principles and relations apply to the entire valley.

Confined ground water

Confined ground water occurs in Cache Valley in those localities where permeable water-bearing beds of gravel or sand are overlain by relatively impermeable beds of clay or silt. The confining beds, which extend from the center toward the sides of the valley, retard the upward movement of water and cause pressure as water moves from the areas of recharge toward the lower part of the valley. Confined ground water underlies at least 200 square miles in the valley. The water-bearing beds are not completely confined, however, and the ground water is regarded as being under leaky-artesian conditions.

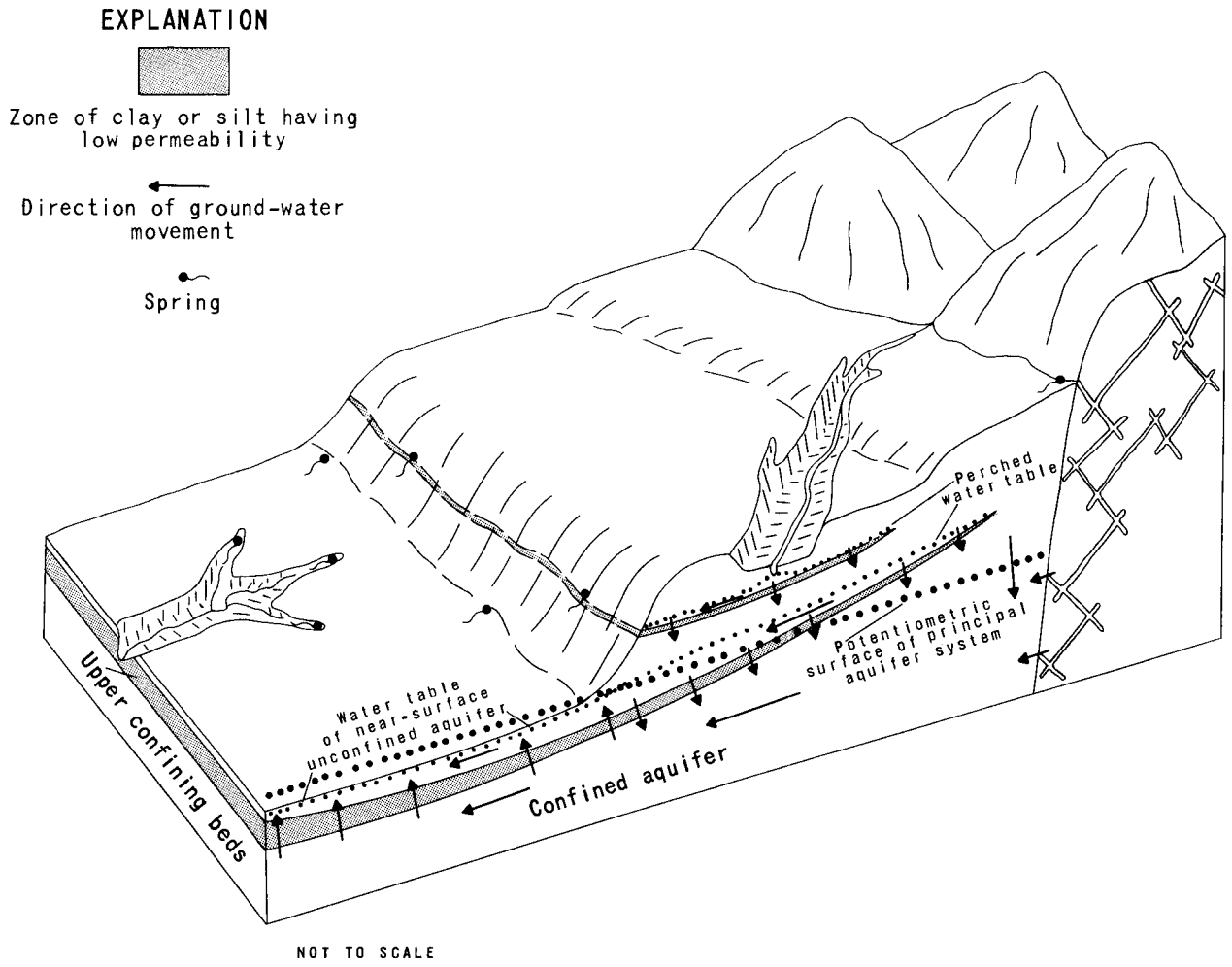


Figure 6.—Relation of confined, unconfined, and perched ground water in Cache Valley.

In about 130 square miles of the valley, the artesian pressure is great enough to force water above the land surface, causing wells to flow (pls. 2 and 3) and water to discharge through springs, seeps, and by evapotranspiration. Hydrostatic heads in some wells are as much as 62 feet above land surface, but heads of most wells are 40 feet or less.

Although the beds of gravel and sand are more or less hydraulically connected, the different beds usually have slightly different hydrostatic heads. The deeper beds usually have the higher heads. The highest heads in the valley were found in wells more than 500 feet deep in secs. 11 and 12, T. 12 N., R. 1 W., near the community of Benson.

Unconfined ground water

Near the margins of Cache Valley, the confining beds that overlie the principal aquifers are discontinuous or absent, and unconfined ground water underlies a narrow strip along the mountain fronts. The boundary between confined and unconfined ground water is indefinite; it generally is gradational rather than abrupt, and changes as the potentiometric surface rises or declines.

A water table near the land surface is common in most of the area of flowing wells (pl. 3). The configuration and fluctuations of this shallow water table are controlled by the permeability of the near-surface material, by evapotranspiration, by irrigation, by topography, and by natural and artificial drains. The shallow aquifer is recharged partly by water seeping upward from leaky artesian aquifers and partly by water seeping downward from canals, ditches, irrigated fields, or discharging wells. No attempt was made to map this water table, because very few wells tap the near-surface ground-water reservoir. However, the shape and slope of the water table is presumed to be generally about the same as that of the wet or damp land surface in artesian areas. In many places in Cache Valley, the water table underlying wet lands has been lowered several feet by drains and the lands utilized for farming.

Local perched ground-water bodies are common in many parts of Cache Valley. They develop above the main water table where beds of clay or other materials of low permeability intercept water percolating downward. Perched water is often encountered in wells on the alluvial slopes and fans and in excavations for construction. No attempt was made to map most of the perched ground-water bodies because some are poorly defined, some are seasonal, and they are not generally tapped by wells. However, both the main potentiometric surface and a local perched water table in the vicinity of Hyrum are shown on plate 4 . The shallow water table in thin deposits of gravel south of Hyrum becomes perched on layers of silt or clay interbedded with the gravel in a locality near Hyrum where the gravel deposits become thicker by several hundred feet. The main potentiometric surface in this locality is deeper than the shallow water. Water-level data for wells and springs near Hyrum show that the perched zone in places is more than 200 feet above the main potentiometric surface.

Aquifer characteristics

The transmissivity (T), the hydraulic conductivity (K), and the storage coefficient (S) of some gravel and sand aquifers in the Cache Valley fill were determined by pumping and recovery tests. In addition, the transmissivity of the water-bearing materials tapped by many wells was estimated from the specific capacities of the wells. The results of tests are given in table 5, and the terms T, K, and S are defined in the appendix. All the storage coefficients indicate that ground water is confined in the aquifers at the test sites.

Table 5.—Results of aquifer tests.

Pumped well	Observation well	Date and length of test	Discharge of well (gpm)	Transmissivity 1/ T (ft3 per day per ft)	Storage coefficient 1/ S	Hydraulic conductivity 1/ K (ft3 per day per ft2)	Test by	Rating of test	Water-bearing material 2/
				Pumping tests					
(A-11-1)20ada-1		July 3-11, 1968 190 hours	2,840				U.S. Geological Survey	Very good	282 ft gravel.
	(A-11-1)17bdd-1			140,000	0.00037	500			
	20acc-1			210,000	.00027	740			
(A-12-1)16dad-2		Sept. 1-2, 1932 11 hours	2,000				Israelsen and McLaughlin (1935, p. 15-19) and U.S. Geological Survey	Good	33 ft gravel.
	(A-12-1)15cba-1			19,000	.00019	580			
	16aac-1			10,000	.00010	300			
	16cac-1			20,000	.00014	610			
	16daa-2			11,000	.00025	330			
	16dba-1			10,000	.00013	300			
	16dcb-1			12,000	.00013	360			
16S-38E-24abc1		June 12, 1969 10 hours	1,300				U.S. Geological Survey	Poor	
	16S-38E-24acb1			15,000	-	-			
16S-38E-24bdd1		July 1, 1969 2 hours	1,300	60,000	-	400	do	Fair	About 150 ft sand and gravel.
	16S-38E-24abc1			60,000	.0014	400			
				Recovery tests					
(A-12-1)16dad-2		Sept. 2, 1932 8 hours	2,000				Israelsen and McLaughlin (1935, p. 19-21) and U.S. Geological Survey	Good	33 ft gravel.
	(A-12-1)15cba-1			21,000	0.00014	640			
	16aac-1			9,600	.00007	290			
	16cac-1			18,000	.00013	550			
	16daa-2			11,000	.00018	340			
	16dba-1			11,000	.00010	340			
	16dcb-1			12,000	.00017	360			
(A-12-1)34cca-1		Mar. 1, 1963 3 hours	4,400	150,000	-	370	Beer (1967, p. 63)	do	415 ft sand and gravel.
(A-13-1)28aaa-1		July 22, 1969 4 hours	3,600	330,000	-	1,400	U.S. Geological Survey	do	About 240 ft sand and gravel.
(A-14-1)34dca-1		Mar. 19, 1963 3 hours	250	2,200	-	40	Beer (1967, p. 74)	do	About 60 ft sand and gravel.
16S-38E-24bdd1		July 1, 1969 1 hour	1,300	50,000	-	330	U.S. Geological Survey	Fair	About 150 ft sand and gravel.
16S-40E-20dca2		July 10, 1967 1 hour	330	2,000	-	20	do	do	About 100 ft sand and gravel.

1/ The terms "transmissivity," "storage coefficient," and "hydraulic conductivity" and their units are discussed in the appendix.
2/ From drillers' logs.

Pumping tests

Aquifer tests performed by pumping a well and observing water levels in neighboring wells gave pertinent information regarding the principal water-bearing formations in Cache Valley. The values for transmissivity, hydraulic conductivity, and storage coefficient given in table 5 were determined by using methods described by Wenzel (1942, p. 87-91), Ferris and others (1962, p. 91-103), and Cooper (1963, p. C48-C55). As leaky-aquifer conditions prevail, the Cooper method was used wherever sufficient data were available.

The high transmissivity and low storage coefficient determined from the test at pumped well (A-11-1)20ada-1 (table 5) indicate high production from a confined aquifer. Values of T and K at observation wells (A-11-1)17bdd-1, 5,600 feet northwest of the pumped well, and (A-11-1)20acc-1, 2,600 feet west-southwest of the pumped well, and more than 1 mile apart, indicate that nearly uniform aquifer conditions exist over a large area in this part of the valley. Measurable drawdown at well (A-11-1)17bdd-1 appeared only 6 minutes after pumping began; but drawdown was only 0.85 foot after 8 days of pumping at 2,840 gpm, and the drawdown at well (A-11-1)20acc-1 was 1.00 foot after 8 days of pumping. Thus, pumping from a well in the general vicinity of well (A-11-1)20ada-1 causes prompt but small interference with other wells in the area.

The aquifer coefficients from the test at well (A-12-1)16dad-2 (table 5) were calculated by the writers of this report from data collected by Israelsen and McLaughlin (1935). The purpose of the test was to demonstrate the feasibility of alleviating the waterlogging of land by pumping from wells. According to Israelsen and McLaughlin, the test was considered successful for its purposes. The pumped well was drilled specifically for the test; it was perforated in 33 feet of water-bearing gravel that was overlain by 40 feet of clay. Water levels were measured during pumping and recovery in six observation wells 820 to 3,680 feet from the pumped well. The high transmissivity and low storage coefficient determined for the 33 feet of water-bearing gravel indicate high potential yields, a confined aquifer, and fairly uniform aquifer conditions over a large area. The transmissivity of the total thickness of the Quaternary valley fill at the site probably is much greater than the values determined by this test because the pumped and observed wells penetrated only the uppermost gravel in the fill.

Two pumping tests near Weston, Idaho, on the west side of Cache Valley indicated a high transmissivity and at least local confined conditions in the aquifer. The test at well 16S-38E-24abc1 was rated poor because of suspected poor hydraulic connection between the pumped well and the observed well due to caving in the observed well. The test at well 16S-38E-24bdd1, however, was more reliable because both the pumped and observed wells were new and in good condition. The aquifer characteristics listed for this test in table 5 are considered representative of the area.

Recovery tests

The Theis recovery method and the Cooper leaky-aquifer method were used to calculate aquifer characteristics from water-level recovery data. The methods of calculation are described by Ferris and others (1962, p. 100-103) and by Cooper (1963, p. C48-C55).

The recovery tests in six wells after pumping ceased at well (A-12-1)16dad-2 produced nearly the same values for aquifer characteristics as the pumping test at that well, thus confirming the pumping test and strengthening confidence in the validity of the results.

The largest transmissivity value determined for Cache Valley was indicated by the recovery test at well (A-13-1)28aaa-1 on the Summit Creek alluvial fan. This well, which has one of the largest yields of the wells in the valley, had been pumped continuously for 12 days at 3,600 gpm with a drawdown of 10 feet.

The recovery test at well 16S-38E-24bdd1 gave results in general agreement with the pumping test at the same site (table 5).

Aquifer coefficients at well 16S-40E-20dca2 at Franklin were calculated from recovery data. The alluvial deposits in the valley of the Cub River have only moderate transmissivity, and the largest wells in the area generally yield less than 450 gpm. The hydraulic conductivity of the alluvial gravel probably is very high locally, but the deposits probably are neither thick nor extensive.

Estimates of transmissivity from the specific capacities of wells

The transmissivities of the water-bearing materials at 105 selected wells in various parts of Cache Valley were estimated from the specific capacities of the wells using a method described by Theis, Brown, and Meyer (1963, p. 331-340). The specific capacity of a pumped well was determined by dividing its discharge by the drawdown, and the specific capacity of a flowing well was determined by dividing its discharge by the rise in head when the flow was stopped.

Estimates of transmissivity based on the specific capacity of wells were smaller than the transmissivities determined by aquifer tests at the same site, usually by 30-70 percent. At well (A-11-1)20ada-1, the estimate of transmissivity was 66,000 ft^3 per day per ft (cubic feet per day per foot) as compared to 140,000 and 210,000 ft^3 per day per ft determined at nearby observation wells during a pumping test. At well (A-12-1)16dad-2, the estimate was 9,000 ft^3 per day per ft as compared to a range of 10,000 to 21,000 ft^3 per day per ft derived from data collected at six observation wells during pumping and recovery tests. At well 16S-38E-24bdd1, near Weston, Idaho, the estimate was 38,000 ft^3 per day per ft as compared to 60,000 ft^3 per day per ft determined from a pumping test.

The transmissivities calculated from aquifer tests are believed to be more reliable than estimates from specific capacities. The estimates were useful in delineating the areas of nearly uniform aquifer conditions and in evaluating conditions in areas not covered by aquifer tests. (See section on ground-water conditions by areas.)

Movement

The general direction of ground-water movement in almost any part of Cache Valley can be inferred from plate 4 . The arrows on the map indicate the direction of ground-water movement and of the hydraulic gradient, which are perpendicular to the water-level contours.

Along the east side of Cache Valley, ground water moves from the major recharge areas along the mountain front of the Bear River Range westward toward points and areas of discharge in the lower parts of the valley. Ground water also moves from the fronts of the Bannock Range in Idaho eastward and southeastward toward discharge areas at Round Valley Marsh and along tributaries to the Bear River. In the southwestern part of the valley, ground water probably enters the valley fill from adjacent bedrock in the Wasatch Range, and much of it discharges from large springs in alluvium near Wellsville and Mendon. Much of the water moving through Cache Valley in the subsurface eventually reaches the Bear River and its tributaries.

The direction of ground-water movement in mountainous areas is usually unknown, because detailed water-level data are lacking. However, the general direction can usually be inferred on the basis of geologic structure, lithology, comparison of altitudes, recharge and discharge areas, and other considerations. For example, part of the discharge from DeWitt Spring, (A-12-2)22dc-S1, in Logan Canyon, probably comes from Green Canyon, several miles to the

north. Green Canyon does not have a perennial stream at its mouth; the flow of perennial streams in the upper reaches disappears into the subsurface about halfway down the canyon. The upper part of the canyon roughly parallels the axis of a syncline that plunges through an intervening mountain spur toward DeWitt Spring. The rocks comprising the syncline are mostly jointed limestone and dolomite. Although the actual movement of ground water cannot be observed, it is likely that solution channels in rocks between Green Canyon and DeWitt Spring carry part of the water discharged at the spring.

Configuration of the potentiometric surface

The potentiometric surface of the ground-water reservoir includes (1) the surface of the saturated zone in areas where the ground water is unconfined and (2) the imaginary surface defined by the hydrostatic head of the water in areas where it is confined. In Cache Valley the potentiometric surface is irregular and sloping. The contour lines on plate 4 show the configuration of the potentiometric surface.

The contours on plate 4 represent several major and several minor ground-water systems, some of which are hydraulically connected. Some of these systems are plotted separately, however, and have no contours shown in common with other systems. Potentiometric surfaces in different parts of Cache Valley are discussed in the section on ground-water conditions by areas.

Underflow at the State line

About 4,000 acre-feet of ground water moves annually from Idaho into Utah in Cache Valley. This includes about 3,000 acre-feet in the area west of the Bear River near Weston, Idaho, and Cornish, Utah, and about 1,000 acre-feet in the Cub River subvalley (area 5, fig. 3) mostly east of the Cub River. Between these areas, in the vicinity of Lewiston, Utah, and Fairview, Idaho, less than 50 acre-feet per year moves across the State line because the water-bearing materials have low transmissivity and the hydraulic gradient is almost level.

The 3,000 acre-feet per year moving across the State line in the Weston-Cornish area was estimated as follows: A transmissivity of 60,000 ft^3 per day per ft was determined from an aquifer test at well 16S-38E-24bdd1, 1.5 miles north of the State line (table 5). On the basis of a comparison of well logs in the area, however, a transmissivity of 30,000 ft^3 per day per ft was considered to be more representative of the total width of the aquifer. The hydraulic gradient at the test site was estimated to be 10 feet per mile southeastward and the aquifer to be about 2 miles wide. Thus a calculated 5,000 acre-feet of water per year was moving southeastward near the test site. The potentiometric contours on plate 4, however, indicate that about half of this water moves eastward and does not cross the State line as underflow. Furthermore, a lower transmissivity is indicated at the State line by the log for well (B-15-1)34ccc-1, which shows less permeable material than shown by the log of well 16S-38E-24bdd1 (McGreevy and Bjorklund, 1971).

Saturated sand and gravel near the land surface in the Weston-Cornish area transmits some additional water toward Bear River, but the amount crossing the State line is small because the local hydraulic gradient is almost parallel to the State line.

Underflow in the Cub River subvalley of about 1,000 acre-feet per year was estimated 1 mile north of the State line where an aquifer test was made at well 16S-40E-20dca2. It was assumed that the same amount of water crosses the State line as underflow in the subvalley.

Vertical movement

Ground water under hydrostatic pressure moves toward the land surface from confined aquifers through overlying beds of clay and silt in many parts of Cache Valley. The quantity of water moving at a given place is directly proportional to the hydrostatic head and the vertical permeability of the material through which it moves. The area in which upward movement takes place is discussed in greater detail in the section of this report on confined conditions.

The amount of ground water moving upward in some areas is sufficient to cause waterlogged conditions, such as occur in meadows in the midvalley area west of Logan and Smithfield. The upward movement in some places is not enough to keep the land surface wet, owing to evapotranspiration; but it impedes the downward movement of water applied at the surface, and thus contributes to waterlogging. Drains, both open and buried, are very effective in parts of the valley in removing excess water from upward leakage and from applied irrigation water. The drains not only alleviate waterlogging and make more land available for cultivation but also divert for beneficial use water otherwise consumed by phreatophytes.

A vertical hydraulic gradient through the confining bed of clay overlying a gravel artesian aquifer was demonstrated in 1926 by engineers at Utah State Agricultural College. They placed piezometer tubes at different depths in the confining clay in the SE¼ sec. 17, T. 12 N., R 1 E., and observed increasing hydrostatic heads with increasing depths below land surface (Israelsen and McLaughlin, 1935, p. 4-13). The purpose of the investigation was to show the feasibility of alleviating the waterlogging of land underlain by an artesian aquifer by reducing the hydrostatic head in the aquifer. Figure 7, an illustration adapted from their report, shows the progressive reduction in head as water moves from the aquifer through the confining clay toward the land surface.

Fluctuations of water levels

During the period of this investigation, water levels were measured monthly in 46 wells and annually (in March) in approximately 300 wells. At 14 of the wells, the monthly measurements were an extension of water-level data going back more than 30 years. Hydrographs of 24 selected wells and the locations of the wells are shown on plate 2 .

Long-term fluctuations and trends

Ground-water levels in Cache Valley usually fluctuate in response to variations in annual precipitation. Figure 2 shows that the hydrographs of wells (A-11-1)18ddd-1 and (B-12-1)8cdb-2 are roughly similar in shape to the graph showing cumulative departure from normal annual precipitation at Logan. This similarity indicates a long-term relationship between precipitation and water levels. The hydrographs of wells (A-11-1)8dda-3, (A-12-1)31dab-1, (A-13-1)29adc-1, (A-14-1)34adb-1, and (B-13-1)30acc-1 on plate 2 show similar relations in other parts of the valley.

No apparent upward or downward trend (other than the response to precipitation) for the ground-water levels in that part of Cache Valley in Utah is indicated by the long-term hydrographs in figure 2 and plate 2 . The valley is an overflowing basin, where water levels apparently are stabilized. The hydrographs indicate also that the natural recharge-discharge relationship has not been changed by the withdrawal of water from wells.

Only 3 years of water-level record is available for wells in the Idaho part of Cache Valley; six hydrographs showing these fluctuations are presented on plate 2. Three of the wells,

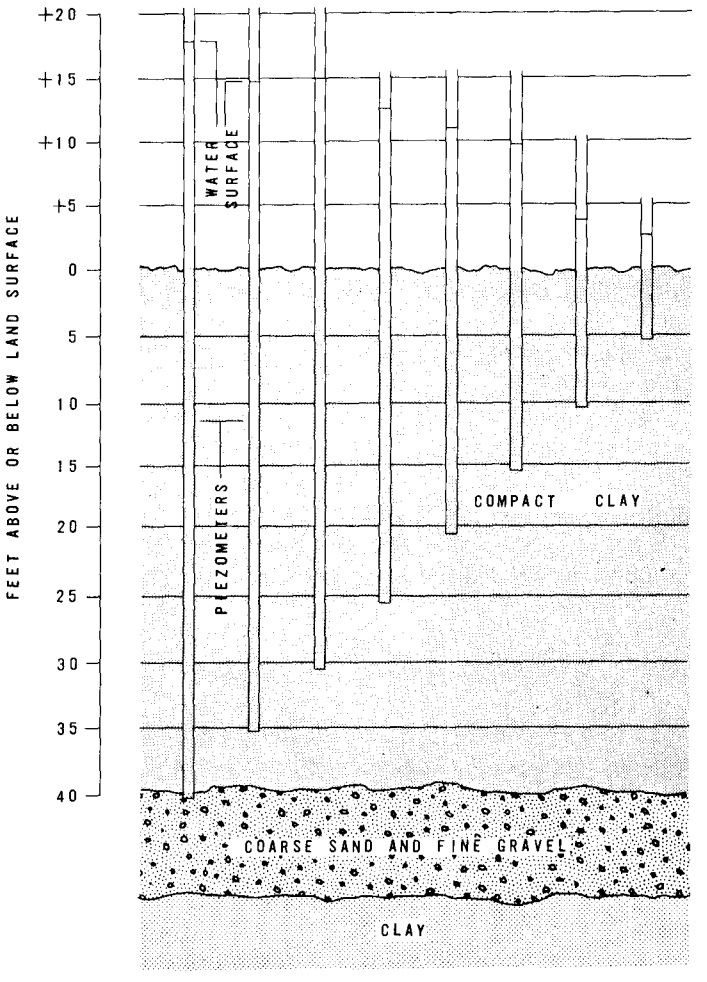


Figure 7.—Progressive reduction of hydrostatic head in confining clay overlying an artesian aquifer as shown by peizometers. (After Israelsen and McLaughlin, 1935, p. 6.)

14S-38E-15cdc1, 14S-39E-8ada1, and 16S-39E-18cda1, indicate a slight rise in water levels during 1967-69, and the other wells show little or no change. The rises are due partly or indirectly to greater than average precipitation during 1967-69, but mostly to recovery from heavy pumping from wells for irrigation during 1966, which was a very dry year. Areas of rising water levels due to recovery from pumping are indicated in figures 8 and 9 by circular patterns.

Seasonal fluctuations

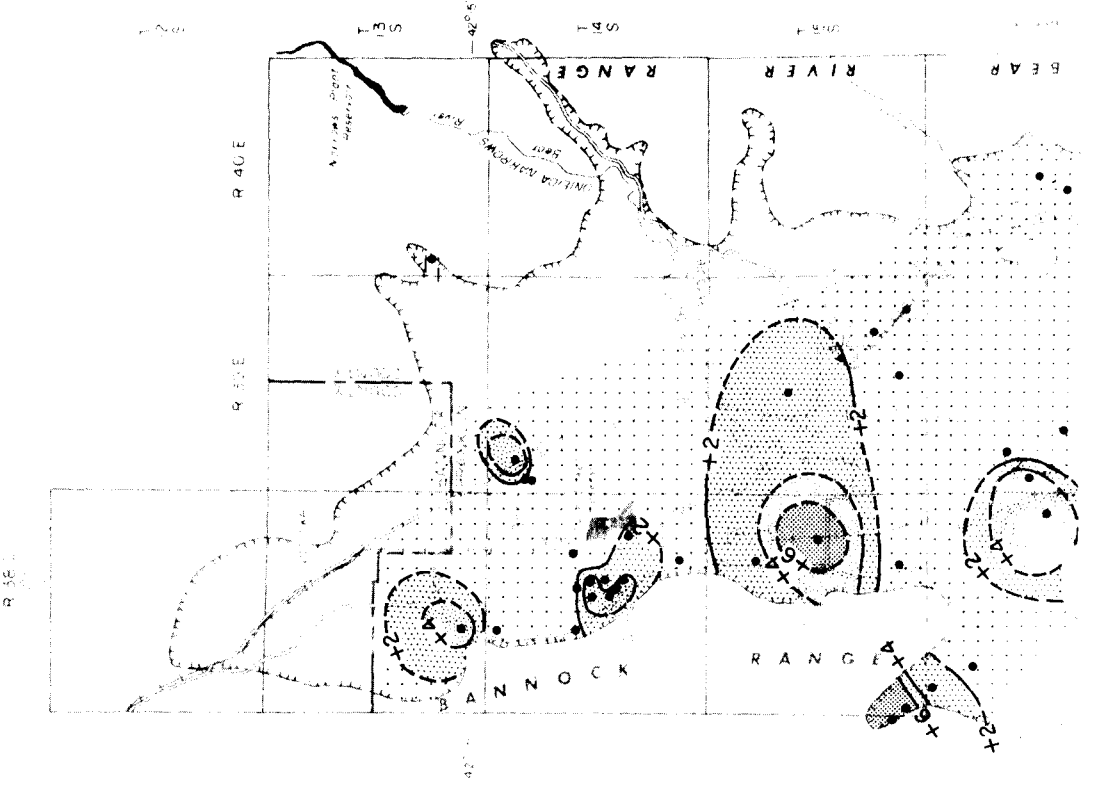
Seasonal fluctuations of water levels are caused by seasonal changes in recharge and discharge, and they differ from one part of Cache Valley to another, as indicated by hydrographs on plate 2. In most of the valley, water levels begin to rise in the spring when the snow melts. The rises usually continue during the irrigation season and reach their peak late in the summer or in the fall.

Hydrographs indicate that water levels rise during the irrigation season in most of the eastern part of Cache Valley in Utah. (See hydrographs of wells (A-10-1)16dad-1, (A-11-1)20ada-1, (A-11-1)8dda-3, (A-12-1)3bbb-1, (A-12-1)31dab-1, (A-13-1)29adc-1, and (A-14-1)1ccc-1 on pl. 2 .) Water levels rise even though some wells in the area, including observation wells (A-11-1)20ada-1 and (A-11-1)27cdc-1, are pumped heavily during parts of the irrigation season. The hydrograph of well (A-11-1)4daa-2 shows drawdown from local pumping superimposed on a general rising trend during the irrigation season.

Hydrographs of wells in the western part of Cache Valley in Utah show a diversity of seasonal fluctuations. Water-level rises during the irrigation season are indicated by the hydrographs of wells (B-11-1)14aaa-3, (B-11-1)35caa-2, and (B-15-1)34ccc-1 (pl. 2). Rises due to snowmelt and spring precipitation followed by rises during the irrigation season are indicated by the hydrographs of wells (B-11-1)9cdb-1, (B-13-1)28acb-1, and (B-14-2)27ddd-1.

Declines of water level are caused by pumping for irrigation in some of the western and northern parts of Cache Valley in Idaho, as indicated by the hydrographs of wells 13S-40E-30acb1, 14S-38E-15cdc1, 14S-39E-8ada1, and 16S-39E-18cda1 (pl. 2). Discharge by pumping exceeds recharge during the irrigation season. Water levels begin to recover promptly after the irrigation season, which usually ends late in the summer, and continue to rise until pumping begins again in May or June of the following year. The water level in well 15S-38E-22ddc1 rises during the irrigation season because recharge from irrigation and from a nearby canal locally exceeds discharge by pumping.

The hydrographs of wells (A-11-1)18ddd-1, (A-11-1)20ada-1, and (A-11-1)27cdc-1, south of Logan (pl. 2), are almost identical, even though the wells are several miles apart, one is a flowing well, and the depths to water in the other two wells are approximately 25 and 118 feet. The two pumped wells, (A-11-1)20ada-1 and (A-11-1)27cdc-1, are highly productive irrigation wells, each yielding more than 2,700 gpm when pumped. Two important inferences can be made from the remarkable similarity of the hydrographs and the other facts given above: (1) The aquifer is extremely permeable, allowing identical fluctuations at points more than 2 miles apart. Solution channels may be developed in the limestone gravels that underlie the area and constitute the aquifer. (2) The highly permeable aquifer is quite uniform over a large area and extends into the flowing-well area.


R 40 E
R 39 E
R 38 E
T 3 S
T 4 S
RANGE
RIVER
BEAR
BANNOCK
RANGE

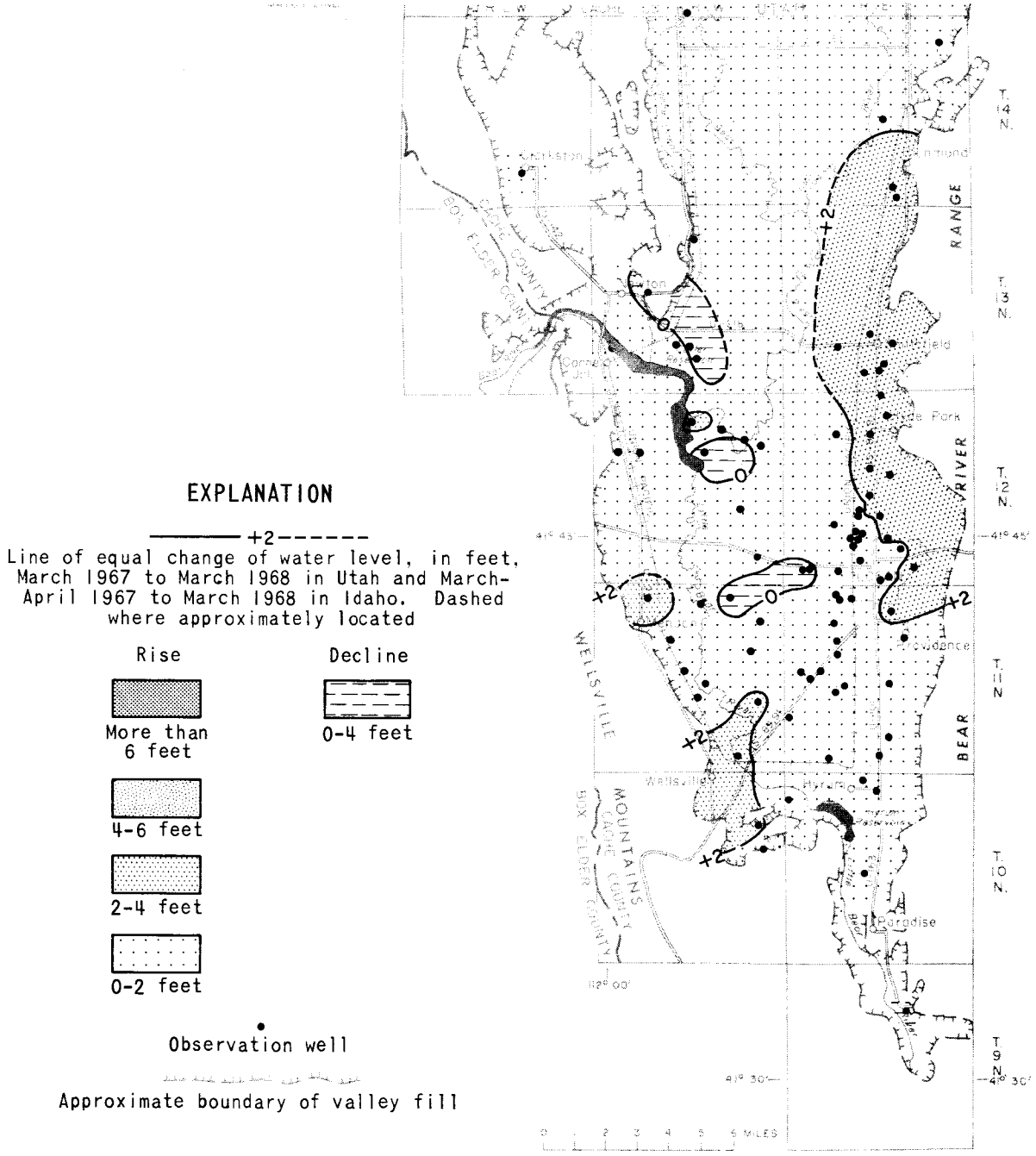
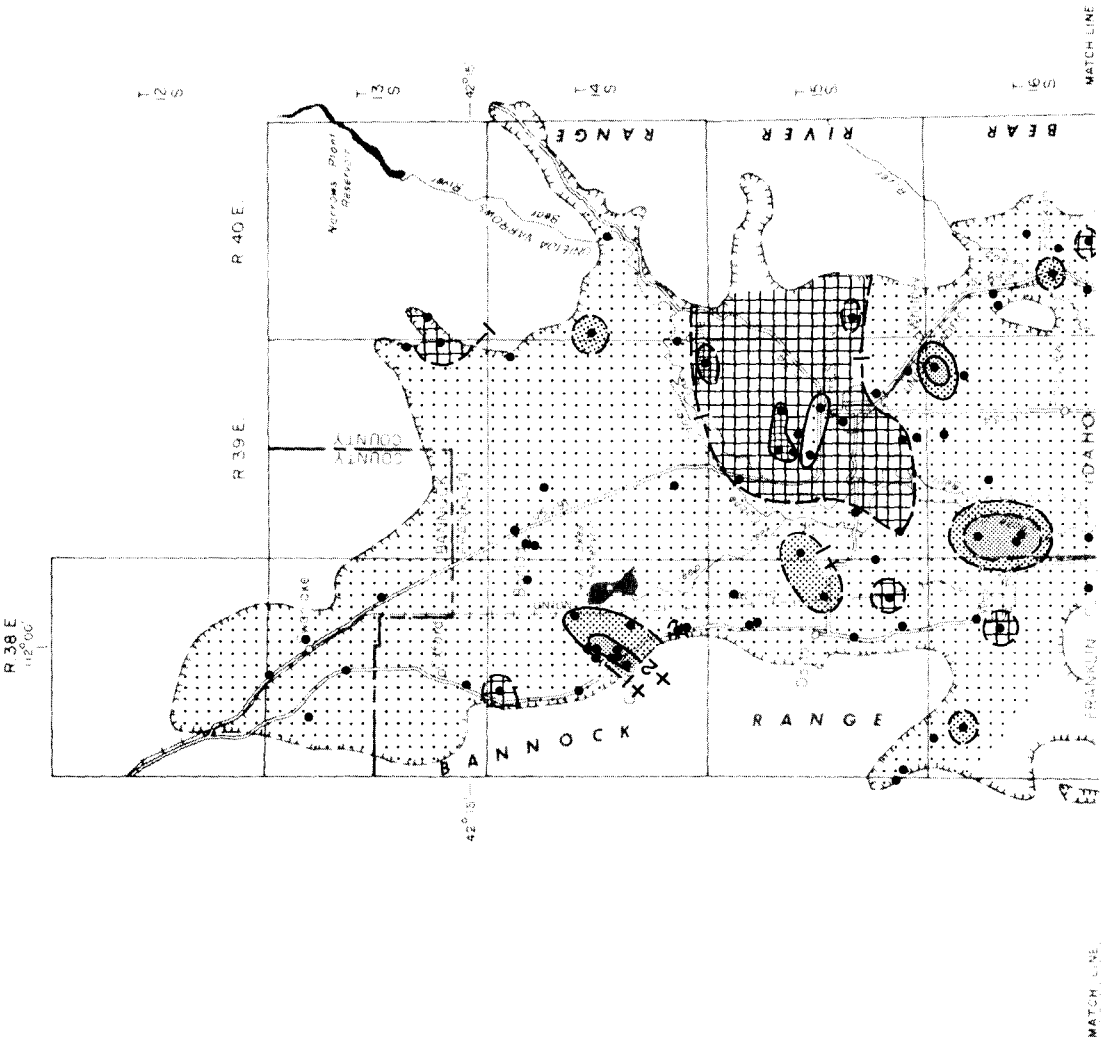


Figure 8.—Map of Cache Valley showing change of ground-water levels from March 1967 to March 1968 in Utah and from March-April 1967 to March 1968 in Idaho. (From Cordova and others, 1968, p. 20.)


MATCH LINE
T 6 S
T 5 S
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T 3 S
T 2 S
42°15'
42°00'
R 40 E
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R 38 E
112°00'
BEAR
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BANNOCK
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COUNTY
COUNTY
IDAHO
MATCH LINE

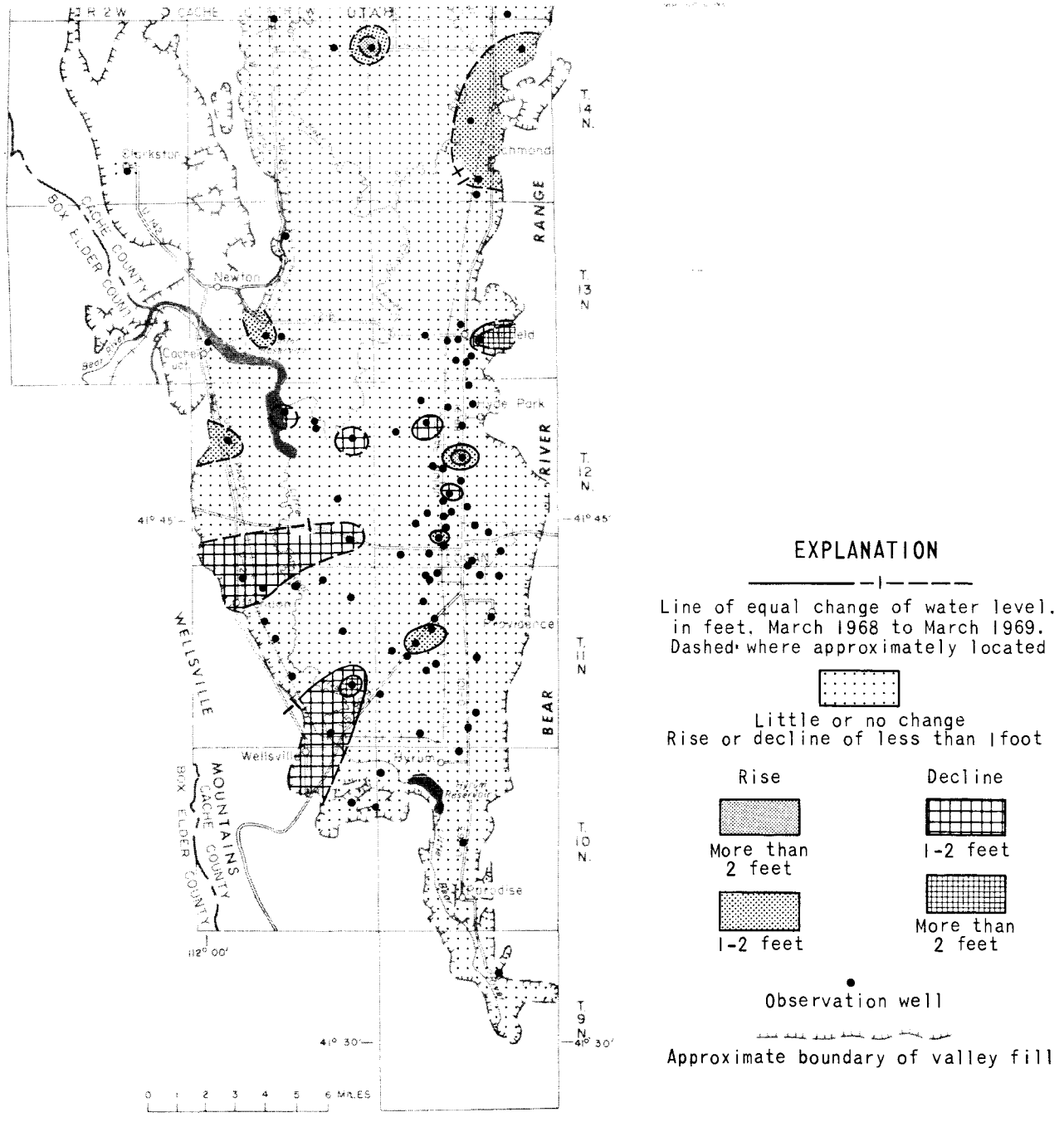


Figure 9.—Map of Cache Valley showing change of ground-water levels from March 1968 to March 1969. (From Baker and others, 1969, p. 14.)

Fluctuations caused by well interference

Water-level fluctuations due to changing rates of discharge from wells is common in the artesian areas in Cache Valley. When water is withdrawn from a confined aquifer the hydrostatic pressure in the aquifer is reduced. The potentiometric surface assumes the form of an inverted cone, the apex of which is at the discharging well. A change of hydrostatic pressure spreads rapidly to other wells that tap the same aquifer. Such interference effects from pumping are shown in the hydrograph of well (A-11-1)4daa-2 (pl. 2), which was prepared from the record of a continuous water-level recording gage. Interference from flowing wells is indicated in the hydrograph of well (B-11-1)14aaa-3. An example of prompt water-level changes was noted in the aquifer test at well (A-11-1)20ada-1, which is described in the section of this report on pumping tests. This test indicated that effects of well interference, although they are small, may extend rapidly for long distances from a pumped well.

Storage

An estimated minimum of 40 million acre-feet of water is stored in the rocks of Quaternary age in Cache Valley, and additional water is stored in the older rocks; however, only a small percentage of the total water in storage is available for development. The water in gravel or sand will move readily to wells, but water in silt or clay is not readily available to wells in significant quantities.

An estimate of the total volume of ground water that can be recovered from storage in Cache Valley would require more detailed knowledge of the volume and specific yield of the aquifer materials, neither of which is precisely known. However, estimates of these factors indicate that with the potentiometric surface at the position shown on plate 4 , the upper foot of saturated materials in Cache Valley contains about 25,000 acre-feet of recoverable water in storage. As water levels are lowered, the amount of water removed per foot of decline would change, but the change would not become significant until water levels are lowered at least 20 feet.

Discharge

Ground water is discharged in the Cache Valley drainage basin mainly from springs, seeps, and drains, by evapotranspiration, and by wells. Discharge by subsurface outflow is believed to be negligible. The average ground-water discharge from the valley for the period 1967-68 was about 280,000 acre-feet per year.

Over a long period of years and under natural conditions, change in ground-water storage is small and discharge is approximately equal to recharge. Hydrographs on plate 2 indicate that little net change in ground-water storage has occurred in the Utah part of Cache Valley in more than 30 years, and that little net change has occurred in the Idaho part during 1967-69.

Springs, seeps, and drains

Many springs and seeps discharge water from the fill in Cache Valley, from bedrock in the surrounding mountains, and from alluvium in the canyons. The base flow of all the perennial streams flowing into the valley, or originating within the valley, is derived from springs and seeps and ground-water seepage from adjacent formations directly into the stream channel. The location of representative springs for which data were collected is shown on plate 2 , and the data are tabulated in a basic-data release by McGreevy and Bjorklund (1970).

Springs in the mountains.—The many springs in the mountainous areas of the Cache Valley drainage basin probably discharge more than 250,000 acre-feet annually. Most of the springs, and the largest, are in the Bear River Range east of the valley. Williams (1958, p. 83-86) listed 74 of the many springs in the Bear River Range in Utah; a large number of springs also exists in the range in Idaho.

Most of the springs in the mountainous areas discharge, directly or indirectly, from solution channels in carbonate rocks, and the discharge ranges from seeps to as much as 70 cfs. The discharge of some springs is seasonal and varies greatly during the year, whereas discharge in other springs is quite uniform throughout the year. Ricks Spring, (A-13-3)27ad-S1, ranges from little or no discharge late in the summer or in the fall to as much as 70 cfs during May or June. Some of the large springs with relatively uniform discharge are DeWitt Spring, (A-12-2)22dc-S1, reported at 20 cfs; Mink Creek Spring, 13S-41E-27bad1, estimated 50 cfs; and spring 15S-41E-12db1, estimated 30 cfs. Many of the springs in the mountains are diverted for irrigation and public supply. Figure 12 shows the location of springs used for public supply.

Springs, seeps, and drains in the valley.—Many springs and seeps discharge from aquifers in Cache Valley, and drains locally remove water from the shallow unconfined aquifers. Water discharged from springs, seeps, and drains in the areas of flowing wells (pl. 2) is derived partly from water moving upward from the confined aquifers and partly from the shallow unconfined aquifer. Individual springs in the areas of flowing wells discharge as much as 7 cfs, but groups of springs and spring areas may discharge from 10 to 20 cfs. Some small springs on the alluvial slopes skirting the valley discharge from perched ground-water bodies. Water from small springs, seeps, and drains that do not discharge directly into streams is consumed by evapotranspiration.

Accretion of ground water to streams in Cache Valley.—The total accretion to streams from ground water within Cache Valley is estimated to be about 140,000 acre-feet annually. Many streams originate at springs within the valley and flow to the Bear River or to one of its tributaries, collecting additional water from springs, seeps, and drains along the way. Streams that originate outside the valley, such as the principal rivers and creeks, gain flow within the valley from springs and seeps along their courses or from tributaries that originate within the valley.

The largest stream that originates on the valley floor is Spring Creek, southwest of Logan. This creek begins at spring (A-11-1)17bdb-S1, 2 miles southwest of Logan, and flows to the Little Bear River. The accretion of ground water to this stream, as determined by a seepage run during November 16-17, 1967, was 54.5 cfs in 4.9 miles. Details of the seepage runs on Spring Creek and its tributary, Hyrum Slough, are presented in tables 6 and 7.

Evapotranspiration

The total annual evapotranspiration from about 43,480 acres of wet lands in Cache Valley is estimated to be about 108,000 acre-feet. Of this, 63,000 acre-feet is discharged from 22,440 acres in Utah, and 45,000 acre-feet is discharged from 21,040 acres in Idaho. Discharge of ground water by evapotranspiration, which includes evaporation from the land surface and transpiration by vegetation, occurs mostly in the wet meadowlands in the lower parts of the valley, where the potentiometric surface of the ground-water reservoir is above the land surface (pl. 3).

Table 6.—Approximate gain in flow of Spring Creek due to ground-water discharge, November 16-17, 1967.

Location and description of measuring station	Approximate distance from head of stream along streambed (miles)	Water temperature °C (°F)	Specific conductance of water (micromhos per cm at 25°C)	Flow at measuring station (cfs)	Flow at station due to ground-water discharge (cfs)	Net gain or loss (-) in flow due to ground-water discharge in reach (cfs)	Cumulative gain to creek due to ground-water discharge (cfs)
Spring Creek near head, NW¼SE¼NW¼ sec. 17, T. 11 N., R. 1 E.	0.15	11 (52)	470	5.2	5.2	5.2	5.2
Spring Creek at road culvert, SW¼NW¼NE¼ sec. 18, T. 11 N., R. 1 E.	1.05	11 (52)	500	15.0	15.0	9.8	15.0
Tributary spring, SE¼SE¼NW¼ sec. 18, T. 11 N., R. 1 E. Flows into Spring Creek at SW¼NE¼NW¼ sec. 18.	1.35 (at confluence)	10 (50)	445	6 e	6 e	6 e	21
Tributary spring, SE¼SW¼NW¼ sec. 18, T. 11 N., R. 1 E. Flows into Spring Creek at SE¼NW¼NW¼ sec. 18.	1.40 (at confluence)	11 (52)	500	6 e	6 e	6 e	27
Spring Creek at road crossing, SE¼NE¼NE¼ sec. 13, T. 11 N., R. 1 W.	1.65	12 (53)	475	30.6	30.6	3.6	30.6
Tributary, Hyrum Slough, at road crossing, SE¼SW¼NE¼ sec. 13, T. 11 N. R. 1 W. Enters Spring Creek at NE¼NW¼NE¼ sec. 13.	1.95 (at confluence)	6 (43)	500	1/20.7	15.7e	15.7	46.3
Tributary spring, NW¼NE¼NE¼ sec. 13, T. 11 N., R. 1 W. near Spring Creek	2.0	12 (53)	475	1.0	1.0	1.0	47.3
Spring Creek north of E-W bridge, SE¼SE¼SW¼ T. 11 N., R. 1 W.	2.35	8 (46)	480	1/[illegible].0	46.0	-1.3	46.0
Spring Creek at N-S road crossing, SE¼NE¼SE¼ sec. 11.	2.85	8 (47)	480	1/61.0	56.0	10.0	56.0
Tributary, Pelican Pond Creek at road crossing, SE¼SE¼NE¼ sec. 14, T. 11 N., R. 1 W. Enters Spring Creek at SW¼NW¼SE¼ sec. 11.	3.3	7 (44)	600	.5	.5	.5	56.5
Spring Creek at Mendon road, NE¼NW¼SW¼ sec. 2, T. 11 N., R. 1 W.	4.9	8 (46)	490	1/54.5	54.5	-2.0	54.5

1/ Includes an estimated 5 cfs of surface water that was spilling into Hyrum Slough from canals and ditches.

Table 7.—Approximate gain in flow of Hyrum Slough due to ground-water discharge between Blacksmith Fork - Hyrum Canal and Spring Creek, November 17-21, 1967

Location and description of measuring station	Approximate distance from Blacksmith Fork-Hyrum Canal (miles)	Water temperature C (°F)	Specific conductance of water (micromhos per cm at 25°C)	Flow at measuring station (cfs)	Flow at station due to ground-water discharge (cfs)	Net gain due to ground-water discharge in reach (cfs)	Cumulative gain to creek due to ground-water discharge (cfs)
Hyrum Slough at E-W Nibley road crossing, SW¼NE¼SE¼ sec. 19, T. 11 N., R. 1 E.	2.5	7 (45)	480	8.1 [1]	3.1	3.1	3.1
Hyrum Slough at N-S road crossing near College Ward, NW¼SW¼NE¼ sec. 19, T. 11 N., R. 1 E.	3.1	7 (44)	520	8.5	3.5	.4	3.5
Hyrum Slough at road crossing, SE¼SW¼NE¼ sec. 13, T. 11 N., R. 1 W.	4.3	6 (43)	500	20.7	15.7	12.2	15.7
Hyrum Slough at confluence with Spring Creek NE¼NW¼NE¼ sec. 13, T. 11 N., R. 1 W.	4.7	-----	-----	-----	-----	-----	15.7

[1] An estimated 5 cfs is spilling into slough in this reach from stock water in canals and ditches.

The phreatophytes in Cache Valley were mapped, wetness conditions observed, and appropriate consumptive-use coefficients applied to each mapped area by the U.S. Soil Conservation Service in 1969. The mapped units are saltgrass (*Distichlis stricta*), greasewood (*Sacobatus vermiculatus*), cottonwood (*Populus* sp.), willow (*Salix* sp.), bulrush (*Scirpus* sp.), annual weeds and grasses, and seeded perennial range grasses. The phreatophyte areas are shown on plate 4 .

Evapotranspiration on lands occupied by plants other than phreatophytes is discussed in the section on water-budget analysis.

Wells

The approximate amount of water discharged from wells in Cache Valley was 28,600 acre-feet during 1967, 26,700 acre-feet during 1968, and 32,000 acre-feet during 1969. The low figure for 1968 was due largely to heavy rains late in the summer, which allowed stopping most of the pumping for irrigation for the year. The high figure for 1969 was due largely to less rainfall and a longer pumping season. The discharge from pumped and flowing wells for the principal uses of water is given in table 8.

Table 8.—Water discharged from wells in Cache Valley, in acre-feet, 1967-69

	1967			1968			1969		
	Pumped	Flowing	Total	Pumped	Flowing	Total	Pumped	Flowing	Total
Utah									
Irrigation	3,400	10,000	13,400	2,200	9,000	11,200	3,500	9,100	12,600
Industry	400	6,400	6,800	250	6,650	6,900	550	6,650	7,200
Public supply	1,000	350	1,350	1,400	400	1,800	3,000	400	3,400
Domestic and stock	50	2,000	2,050	50	2,100	2,150	50	2,300	2,400
Subtotal (rounded)	4,800	18,800	23,600	3,900	18,200	22,000	7,100	18,500	25,600
Idaho									
Irrigation	3,300	1,200	4,500	2,900	1,300	4,200	4,500	1,400	5,900
Industry	350	0	350	300	0	300	250	0	250
Public supply	40	0	40	40	0	40	Negligible	0	Negligible
Domestic and stock	100	50	150	100	50	150	125	50	175
Subtotal (rounded)	3,800	1,200	5,000	3,300	1,400	4,700	4,900	1,400	6,300
Total (rounded)	8,600	20,000	28,600	7,200	19,600	26,700	12,000	20,000	32,000

Subsurface outflow

Subsurface outflow from Cache Valley is believed to be negligible. Complex mountain ranges along the west side of the valley form a barrier to ground-water movement. Ground-water gradients near the east side of these mountains are toward Cache Valley (pl. 4). Some ground water could move toward the lower Bear River valley in the rocks beneath Cutler Reservoir, but the amount would be small.

Chemical quality

Chemical analyses of ground water from the principal aquifers in Cache Valley indicate that the water is of generally good quality and that the quality has not changed since 1941. Data on the quality of ground water that were collected for this project are presented in the basic-data release by McGreevy and Bjorklund (1970). Much of that information is shown in the generalized form on illustrations presented in this section. A few representative chemical analyses are presented in table 9, and the units used to express the quality of water are defined and discussed in the appendix.

Table 9.—Representative chemical analyses of water from selected wells and springs in Cache Valley.

Agency making analysis: GS, U.S. Geological Survey; IH, Idaho State Department of Health; UH, Utah State Department of Health.

Location	Depth of well (feet)	Date of collection	Temperature (°C)	Milligrams per liter: Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Hardness as $CaCO_3$	Noncarbonate hardness as $CaCO_3$	Dissolved solids: Determined	Dissolved solids: Calculated	Specific conductance (micromhos per cm at 25°C)	Sodium-adsorption ratio	pH	Agency making analysis
(A-10-1)4daa-1	472	6-17-68	12	9.7	-	68	28	12	1.4	294	0	56	12	0.4	0.9	0.04	287	46	334	333	564	0.3	7.4	GS
(A-12-1)28abd-1	90	7-13-60	-	28	0.09	52	14	37	9.7	255	1	23	28	.4	.3	.21	189	0	309	-	564	1.2	7.6	UH
35bcc-1	978	3-14-63	-	7.3	.05	46	21	6.5	.2	218	4	14	10	.3	.9	.08	201	22	234	-	372	.2	8.5	UH
(A-12-2)22dc-S1	Spring	5- 8-68	7	3.8	-	50	14	1.0	.2	216	0	5.5	2.2	.2	.8	.02	182	5	180	184	326	0	8.0	GS
(A-13-1)19cac-1	1/3,500	7- 9-57	21	13	.67	42	36	204	4.9	286	0	1.2	342	.1	.3	.40	254	19	789	786	1,480	5.6	6.8	GS
(A-13-1)28aaa-1	477	7- 9-68	11	8.6	-	48	26	5.2	.5	266	0	7.5	5.1	.1	7.8	.01	228	10	233	240	427	.1	7.7	GS
(A-14-1)6ccc-1	20	4-17-68	7	13	-	112	112	239		722	0	239	268	-	50	-	740	148	1,410	1,390	2,220	3.8	7.7	GS
26dad-1	631	5- 9-68	-	34	.00	19	18	17	10	165	0	11	20	.4	7.5	.04	120	0	200	-	334	.7	7.5	UH
(B-10-1)10aac-S1	Spring	5- 9-68	12	14	-	77	29	39	3.7	268	8	17	95	.3	8.5	.01	312	79	470	424	765	1.0	8.3	GS
(B-11-1)9cdb-1	136	4-17-68	10	50	-	92	29		72	480	0	1.8	79	-	.7	-	350	0	525	560	945	1.7	7.5	GS
(B-12-1)2bcd-1	764	4-18-68	21	24	-	128	53		107	250	0	.5	400	-	.0	-	536	331	1,010	835	1,600	2.0	7.9	GS
(B-14-2)27ddd-2	40	6-24-68	-	47	-	127	37	28	24	420	0	54	55	.5	127	.00	468	124	721	706	1,040	.6	7.7	GS
13S-40E-30acb1	290	7-19-68	10	21	-	69	30	21	1.9	326	0	22	30	.4	13	.00	296	29	368	368	625	.5	7.6	GS
13S-41E-27bad1	Spring	7-28-66	9	-	.00	35	14	4.0	-	224	0	5.0	5.0	.0	.0	-	192	8	175	-	-	.1	7.7	IH
14S-38E-22aba1	200	3-11-68	11	28	-	69	14		21	279	0	16	19	-	5.1	-	231	2	303	309	504	.6	7.4	GS
14S-39E-8ada1	206	7-18-68	13	34	-	72	33	69	3.2	324	0	61	85	.7	9.8	.08	314	48	531	527	880	1.7	7.7	GS
15S-39E-8bdc1	Spring	3-13-68	77	72	-	154	18	3,340		704	0	26	5,050	-	2.6	-	460	0	9,180	9,010	14,900	68	7.1	GS
15S-39E-23bbb1	11	7-18-68	13	38	-	68	59	29	4.0	492	0	24	36	.5	.5	.08	414	11	486	501	831	.6	7.8	GS
16S-38E-6aad1	109	7-16-68	12	35	-	95	40	62	10	372	0	91	95	.5	12	.02	400	95	632	623	1,020	1.4	7.8	GS
16S-38E-24acb1	548	7-16-68	24	68	-	60	29	80	19	414	0	5.0	84	.4	.6	.47	268	0	533	550	872	2.1	7.8	GS
16S-40E-17bbb1	180	8-13-68	13	53	-	34	18	111	8.3	352	0	11	81	1.3	.6	.10	160	0	486	491	793	3.8	7.8	GS

1/ Producing interval 1,150 to 2,050 feet.

The quality of surface water in the project area and in the Bear River drainage as a whole has been reported in some detail by Waddell (1970) and by Waddell and Price (1971) and is not discussed in this report.

Salinity

The concentration of dissolved solids in water is an indication of the salinity of the water. The specific conductance of water is closely related to the concentration of dissolved solids; therefore, the specific conductance may also be used as an indicator of salinity.

The relation of concentration of dissolved solids to specific conductance depends on the particular constituents in solution, but it is generally consistent in a particular area or aquifer. The ratio of dissolved solids, in milligrams per liter, to specific conductance, in micromhos per centimeter at 25°C, may range from about 0.5:1 to 1:1; but it is generally about 0.6:1. Figure 10 shows graphically the relation in Cache Valley as determined by chemical analyses; the ratio is about 0.6:1. Specific conductance is easily measured in the field and provides a quick estimate of the concentration of dissolved solids.

The salinity of the ground water in Cache Valley is indicated by the specific conductances shown on plate 5 . Specific conductance of most of the water sampled was less than 1,200 micromhos per centimeter (about 800 mg/l of dissolved solids). Conductances in excess of 2,400 micromhos per centimeter (about 1,600 mg/l of dissolved solids) are rare and are related to saline water associated with fault zones or to concentration of dissolved solids by evapotranspiration.

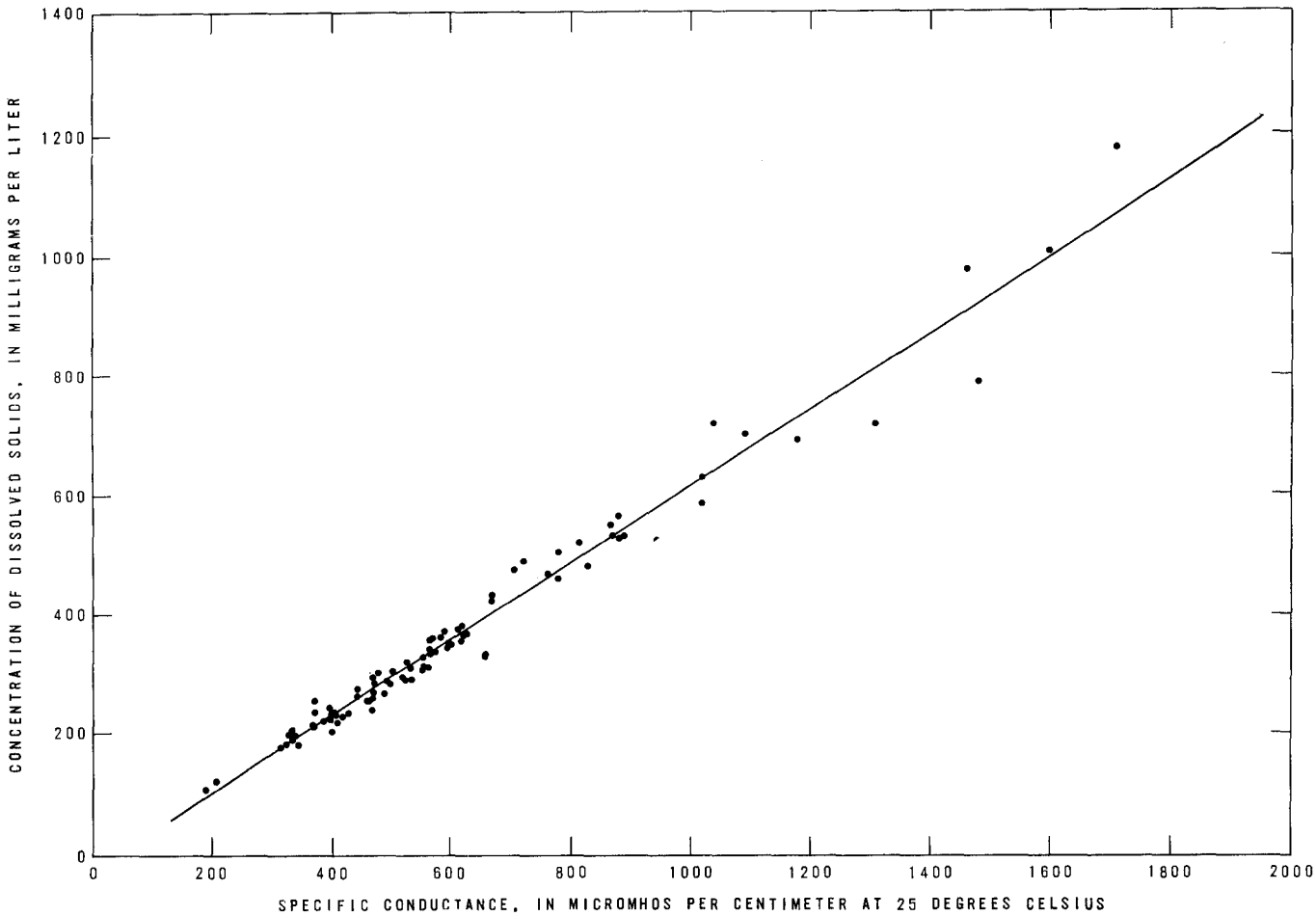


Figure 10.—Relation of specific conductance to concentration of dissolved solids in selected ground-water samples collected in Cache Valley, Utah and Idaho.

Major constituents

The major chemical constituents in the ground water are indicated on plate 5 by pattern diagrams (Stiff, 1951). The diagrams indicate the similarity of the water in the mountains, in the area along the east side of Cache Valley in Utah, and in the northwest part of the valley in Idaho. Calcium, magnesium, and bicarbonate are the major constituents of the water in these areas. Near North Logan, three diagrams indicate a slightly higher sodium concentration in an area of generally warm ground water (pl. 6). The diagrams on plate 5 also indicate that the concentration of sodium and chloride is generally higher on the west than on the east side of the valley in Utah.

Hot saline water, which is associated with fault zones, discharges in springs south of Clifton Hill in Idaho and in springs and from well (B-13-1)10acb-1 near the east side of Newton Hill in Utah. The water contains concentrations of sodium and of chloride that exceed 1,000 mg/l, and it is distinct from other water in Cache Valley. (See diagrams for well (B-13-1)10acb-1 and springs (B-14-1)33abd-S1 and 15S-39E-8bdc1 on pl. 5 .)

Water quality is judged according to the use for which the water is needed. Generally, the lower the concentration of dissolved solids, the better the water; however, for some uses, the concentration of particular substances in water may be more significant than the total concentration of dissolved solids. Some general criteria for evaluating water for common uses are discussed below, and more detailed information may be obtained from the publications cited in the discussion.

Hardness of water is an important quality consideration for domestic use and for many industrial uses. Hardness is that property of a water that causes soap to form an insoluble curd and is the major contributor to the scale that forms in boilers and pipes. Hem (1970, p. 224-226) presents a discussion of hardness and a classification of water with respect to hardness as follows:

Classification	Hardness as $CaCO_3$ (mg/l)
Soft	0-60
Moderately hard	61-120
Hard	121-180
Very hard	More than 180

Almost all ground water in the Cache Valley area is classified as hard or very hard.

Quality standards for potable water used by public carriers and by others subject to Federal quarantine regulations have been established by the U.S. Public Health Service (1962). These standards concern bacteria, radioactivity, and chemical constituents that may be objectionable in a water supply. The following is a list of the standards that pertain to those constituents for which analyses are given in this report:

> "The following chemical substances should not be present in a water supply in excess of the listed concentrations where * * * other more suitable supplies are or can be made available." U.S. Public Helath Service, 1962, p. 7)

Substance	Recommended limit (mg/l)
Chloride (Cl)	250
Fluoride (F)	1.3[1]
Iron (Fe)	.3
Nitrate (NO_3)	45
Sulfate (SO_4)	250
Dissolved solids	500

[1] Based on the annual average of maximum daily air temperature of 59.2°F at Logan, Utah, for 1896-1960.

Most ground water in Cache Valley is suitable for domestic use. Locally, water from a few wells and springs exceeds the recommended limits of chloride, fluoride, iron, or nitrate. The recommended limit of dissolved solids is exceeded in water from some wells, most of which have been used for years for domestic purposes without problems related to the concentration of dissolved solids. The recommended limit of dissolved solids is influenced primarily by considerations of taste (U.S. Public Health Service, 1962, p. 34). If the dissolved-solids limit is greatly exceeded, however, the concentration of individual constituents may become objectionable.

Water-quality requirements for industrial use differ widely according to the particular use. Criteria for evaluating water for many industrial uses are given in McKee and Wolf (1963, p. 92-106).

The tolerance of animals to dissolved solids in water depends on the species, age, and physiological condition of the animal; on the amount of water consumption; and on the quantity and type of salts in the water. However, standards for most of these factors have not been determined, and general standards based on the total concentration of dissolved solids are sometimes used. McKee and Wolf (1963, p. 112) discuss some of the criteria that have been used. Beath and others (1953) suggest the following classification as a guide for evaluating water for livestock use:

Classification	Dissolved solids (mg/l)
Good	Under 1,000
Fair (usable)	1,000 to 3,000
Poor (usable)	3,000 to 5,000
Very poor (questionable)	5,000 to 7,000
Not advisable	Over 7,000

Using this classification, almost all ground water in the area is good to fair for use by livestock.

Among the principal factors determining the suitability of water for irrigation are the concentration of boron in the water, the salinity of the water (salinity hazard), and the proportion of sodium to calcium and magnesium in the water (sodium hazard). Boron in more than trace concentrations is toxic to plants. Salinity affects plant growth by limiting the ability of the plant to take in water. The proportion of sodium to calcium and magnesium affects the extent to which soil minerals will adsorb sodium from the water. The adsorption of sodium breaks down the flocculation of the soil and makes it gummy, less permeable, and less fertile. An index to the sodium hazard is called the sodium-adsorption ratio (SAR); it is expressed as:

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$$

where the concentrations of the ions are expressed in milliequivalents per liter.

Excess boron in ground water is not a problem for irrigation in Cache Valley. Only one analysis, that of hot saline water from well (B-13-1)10acb-1, showed a boron concentration exceeding permissible limits given by Hem (1970, p. 329).

The salinity and sodium hazards of ground-water samples collected from selected wells and springs in the area are classified in figure 11, according to the method of the U.S. Salinity Laboratory Staff (1954, p. 80). 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. As the diagram indicates, most ground water in the area has a low-sodium hazard and medium- or high-salinity hazard.

Well numbers are given in figure 11 for sampled wells that yield water with a sodium hazard greater than that for water from most wells. Wells (B-12-1)32abc-1 and (B-14-1)17add-1 tap aquifers that probably would not yield sufficient water for irrigation. Wells (A-13-1)19cac-1 and (B-13-1)25bab-1, which tap buried Tertiary conglomerate, yield moderate quantities of irrigation water. Well (A-14-1)6ccc-1 taps sand and silt in the Lewiston area; ground water from this aquifer is variable in quality but is being used for irrigation to supplement surface-water supplies.

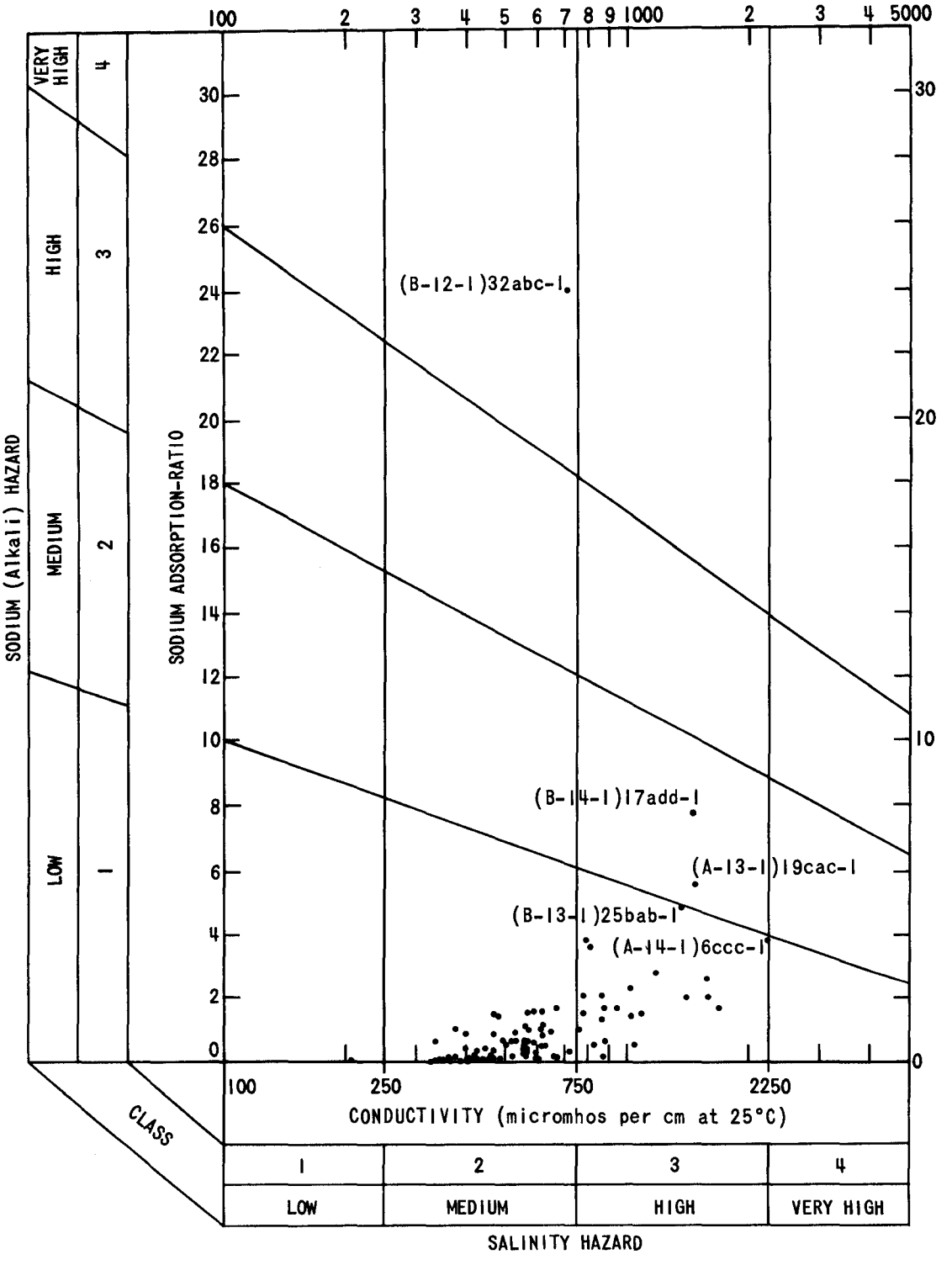


Figure 11.—Classification of ground water for irrigation. (Adapted from U.S. Salinity Laboratory Staff, 1954.)

Temperature

Ground-water temperatures in the Cache Valley area are shown on plate 6 . The temperature of water from springs in the mountains is generally less than 9°C (48°F). Most ground water in the valley ranges in temperature from 9° to 15°C (48° to 59°F), but several small areas of warm and hot water are scattered throughout the valley.

The hottest ground water in the valley, from Battle Hot Springs, 15S-39E-8bdc1, in Idaho, has a temperature of 77°C (171°F). The hottest water from a well is from oil and gas test (B-13-1)10acb-1, which was drilled to a depth of 5,208 feet and yielded water with a temperature of 49°C (120°F). Most of the hot ground water in the valley is associated with fault zones (compare pls. 1 and 6).

Development and utilization

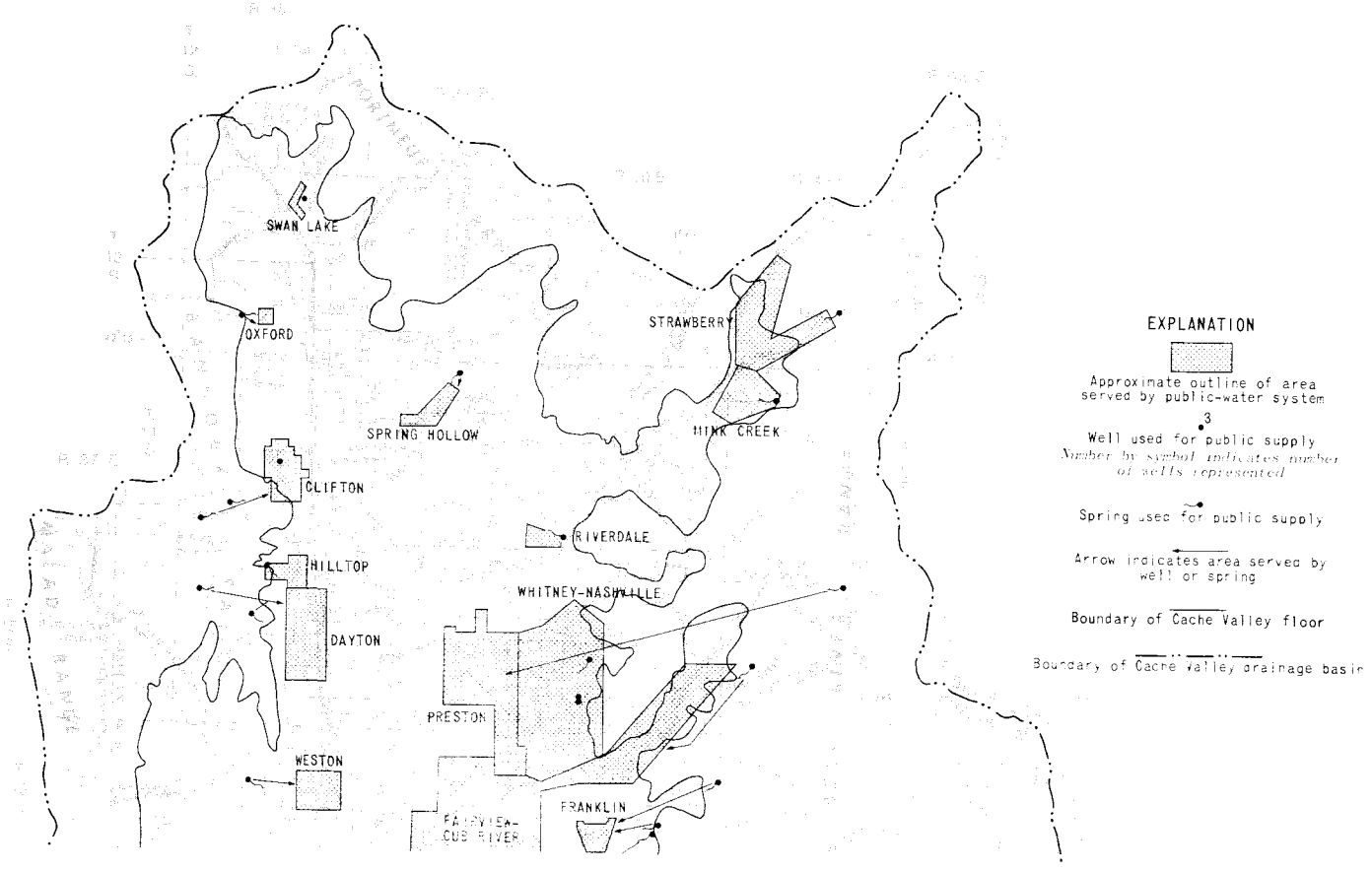
Ground water from more than 2,400 wells and many springs is used in Cache Valley for irrigation, public supply, industry, livestock, and domestic purposes. The locations of selected wells in the valley are shown on plate 2 , and table 8 shows the amount of withdrawal from wells for different uses during 1967-69.

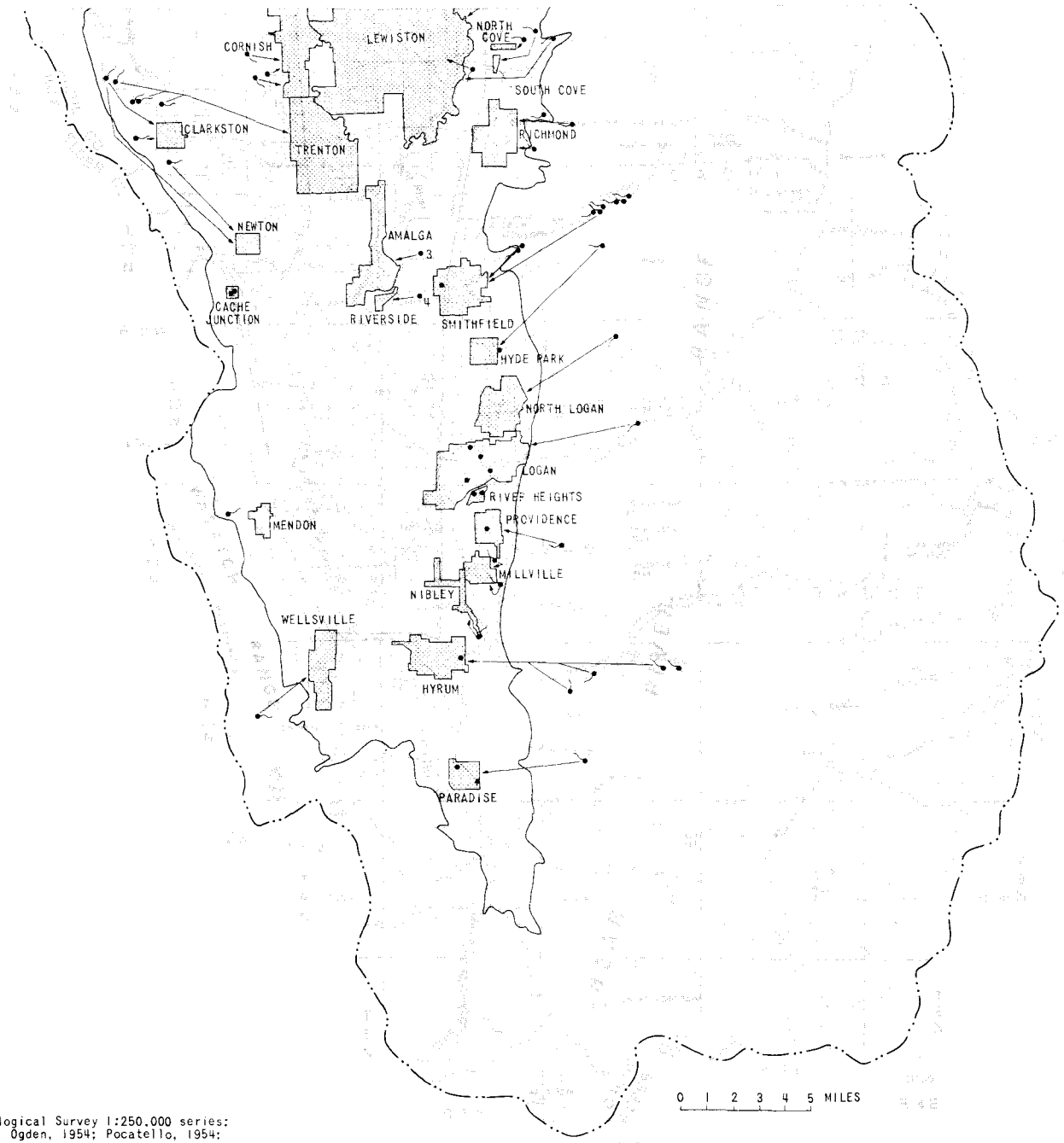
Ground water from wells is used for irrigation mainly along the east side of Cache Valley in Utah and along the west and north sides of the valley in Idaho. Generally, the water pumped is supplementary to surface water. Many of the wells in Utah are owned by irrigation companies and discharge directly into canals. The wells in Idaho are commonly owned by individuals, but much of the land irrigated is also irrigated at times with surface water. Approximately 215 wells in Cache Valley are used primarily for irrigation. Of these, about 90 are pumped wells and 125 are flowing wells. Most of the flowing wells and about half the pumped wells are in Utah. Water from about 30 industrial wells is reused for irrigation because the industrial use of water is mostly nonconsumptive.

Thirty-seven communities in Cache Valley—23 in Utah and 14 in Idaho—have public-supply water systems. All the systems derive water from ground-water sources, mostly from springs flowing from rocks in the Bear River, Wasatch, Malad, and Bannock Ranges and from alluvial deposits flanking these ranges. Some of these systems are urban and some are rural, and they distribute water over a total area of approximately 138 square miles. More than 26,000 acre-feet of water was distributed through public-supply systems in 1968. The approximate area covered by each system and its principal sources of water are shown in figure 12, and detailed information on the systems is given in table 10.

Most of the ground water used in Cache Valley for industrial purposes is for fish culture. Water from springs, including (A-10-1)28cac-S1 and (A-10-1)33bac-S1 near Paradise, from 17 large-yield flowing wells in sec. 32, T. 12 N., R. 1 E., near Logan, and from eight large-yield flowing wells and several springs in sec. 29, T. 13 N., R. 1 E., near Smithfield is used for that purpose. No significant amount of water is consumed in the process, and the water is reused downstream for irrigation. Lesser amounts of ground water are used in canning factories, a meat packing plant, a sugar factory, dairy-products plants, and for washing gravel and potatoes.

In the areas not served by public-water supplies, water for domestic and stock use is obtained from springs and privately owned wells. Most of the domestic wells on farms are also used for livestock. Many homes in the area of flowing wells (pl. 3) rely on the hydrostatic pressure in the artesian aquifer to force water through their piping systems.


SWAN LAKE
OXFORD
STRAWBERRY
SPRING HOLLOW
MINK CREEK
CLIFTON
RIVERDALE
HILLTOP
WHITNEY-NASHVILLE
DAYTON
PRESTON
WESTON
FRANKLIN
FAIRVIEW-CUB RIVER
EXPLANATION
Approximate outline of area served by public-water system
3
Well used for public supply
Number by symbol indicates number of wells represented
Spring used for public supply
Arrow indicates area served by well or spring
Boundary of Cache Valley floor
Boundary of Cache Valley drainage basin



Base from U.S. Geological Survey 1:250,000 series: Brigham City, 1962; Ogden, 1954; Pocatello, 1954; Preston, 1962

Figure 12.—Map showing areas in Cache Valley served by public-supply systems and sources of the water.

Table 10.—Public-supply systems in Cache Valley and sources of the water.

Name of city, town, or public-water system	Population (reported for 1968)	Area included in water-distribution system (sq mi)	Source of water	Location number of principal springs or wells	Storage facilities	Source of pressure in mains	Number of service outlets	Treatment	Approximate amount of water used in 1968 (reported or estimated) (acre-ft)	Chemical analysis in McGreevy and Bjorklund (1970)	
										Well or spring	Composite
					UTAH						
Amalga	225	3.8	3 wells	(A-13-1)20ach-1 20ach-2 20ach-3	2 reservoirs 27,000 gal.	Pumps	45	None	346	X	X
Clarkston	435	1.1	3 springs	(B-14-2)16cbc-S1 17dba-S1 28ddb-S1	2 reservoirs 190,000 gal.	Gravity	147	Chlorine	565		X
Cache Junction	86	.2	2 wells	(B-13-1)30caa-1 30cac-1	Elevated tank	Gravity and pump	18	do	-	X	
Cornish	300	5.0	2 springs 1 well	(B-14-1)8cbc-S1 17caa-S1 17add-1	100,000 gal.	Gravity	57	do	120	X	X
Hyde Park	1,000	1.2	Spring Well	(A-13-2)21ba-S1 (A-12-1)11baa-1	2 reservoirs 225,000 gal.	do	225	do	365	X	
Hyrum	2,250	3.0	4 springs 1 well	(A-10-2)1cc-S1 2dc-S1 8cc-S1 9bb-S1 (A-10-1)4daa-1	Reservoir 263,000 gal.	Gravity and pump	669	do	1,480	X X	X
Lewiston	1,300	24.6	3 springs	(A-14-1)15acb-S1 (A-14-2)7abc-S1 16S-40E-22dbb1	2 reservoirs 473,000 gal.	do	382	do	1,385	X X	X
Logan	24,000	6.5	Spring 4 wells	(A-12-2)22dc-S1 (A-12-1)27cab-1 27dcd-1 34cca-1 35bcc-1	Reservoirs 4,000,000 gal.	Gravity and pumps	5,213	do	10,350	X X X X X	X
Mendon	450	.7	Spring	(B-11-1)7bbb-S1	Reservoir 50,000 gal.	Gravity	105	None		X	
Millville	420	1.1	2 springs	(A-11-1)14ccd-S1 23cda-S1	2 reservoirs 72,000 gal.	do	117	do	650	X	
Newton	400	.8	3 springs	(B-14-2)16cbc-S1 17dba-S1 34dad-S1	2 reservoirs 230,000 gal.	do	135	Chlorine	203		X
Nibley	350	1.1	Spring	(A-11-1)34dcb-S1	Reservoir 100,000 gal.	do	112	do	370	X	
North Cove	60	.3	do	(A-14-1)12bad-S1	Reservoir 20,000 gal.	do	14	None	57	X	
North Logan	1,200	3.2	Spring1/	(A-12-2)4da-S1	Concrete reservoir	do	308	Chlorine	195		X
Paradise	500	1.3	Spring 2 wells	(A-10-2)29acd-S1 (A-10-1)28dba-1 34bac-1	Concrete reservoir 174,000 gal.	Gravity and pump	125	None		X X	
Providence	2,000	1.3	Spring Well	(A-11-2)18acd-S1 (A-11-1)10dad-1	2 reservoirs 630,000 gal.	do	402	Chlorine	210	X X	
Richmond	1,100	3.2	4 springs	(A-14-1)36adb-S1 (A-14-2)29bcd-S1 30bba-S1	2 reservoirs 306,000 gal.	Gravity	449	do	477	X	
River Heights	900	.4	2 wells2/	(A-11-1)3aca-1 3bda-1	Reservoir 500,000 gal.	Gravity and pump	245	None	190	X X	X
Riverside	135	.4	4 wells	(A-13-1)29cdd-1 29cdd-2 29cdd-3 29cdd-4	None	Artesian	19	do		X	
Smithfield	3,000	3.3	10 springs 1 well	(A-13-1)24bba-S1 24bcb-S1 (A-13-2)9ca-S1 9cc-S1 9cd-S1 9da-S1 10bd-S1 10cb-S1 (A-13-1)28cab-1	2 reservoirs 2,500,000 gal.	Gravity	900	Chlorine	1,360		X
South Cove	68	.2	Spring	(A-14-1)1ddd-S1	Reservoir 20,000 gal.	do	18	None	40	X	

Table 10.—Public-supply systems in Cache Valley and sources of the water, continued

Name of city, town, or public-water system	Population (reported for 1968)	Area included in water-distribution system (sq mi)	Source of water	Location number of principal springs or wells	Storage facilities	Source of pressure in mains	Number of service outlets	Treatment	Approximate amount of water used in 1968 (reported or estimated) (acre-ft)	Chemical analysis in McGreevy and Bjorklund (1970)	
										Well or spring	Composite
UTAH--Continued											
Trenton	450	7.8	4 springs	(B-14-3)17dba-S1 21acd-S1 21add-S1 22dba-S1	Reservoir 300,000 gal.	Gravity	105	None	83		X
Wellsville	1,200	2.7	Spring	(B-10-1)1/cac-S1	Reservoir 160,000 gal.	do	385	do	185	X	
IDAHO											
Clifton	160	2.3	2 springs Well	14S-38E-29dca1 3/ 14S-38E-31adb1 3/ 14S-38E-22bdc1	Reservoir 67,329 gal.	Gravity	40	None	70		X
Dayton	260	4.5	2 springs	15S-38E-7dba1 15S-38E-16bda1	2 reservoirs 200,000 gal.	do	50	do	1,450		X
Fairview-Cub River	575	20.8	Spring	15S-41E-19ddd1	Reservoir 150,720 gal.	do	105	Chlorine	1,000	X	
Franklin	475	1.0	2 springs	16S-40E-12dac1 16S-40E-22adb1	Reservoir	do	163	None			X
Hilltop	15	1.3	Spring	15S-38E-4dda1	Tank	do	5	do	20	X	
Mink Creek	90	2.3	do	14S-41E-8bad1	Tank 18,000 gal.	do	24	do	100		
Oxford	110	.3	Springs and private wells	13S-38E-29dad1 3/	None	do	7	do	30		
Preston	3,640	8.2	2 springs	15S-41E-10a1	3 reservoirs 1,008,560 gal.	Gravity and pump	1,200	Chlorine	3,300	X	
Riverdale	15	.7	Spring	14S-40E-31dbc1	None	Gravity	8	None	20		
Spring Hollow 4/	30	1.2	do	14S-39E-3bc1	do	do	8	do			
Strawberry	100	5.3	do	13S-41E-27bad1	do	do	21	do	100	X	
Swan Lake	45	.4	Well	13S-38E-3dda1	Reservoir 32,257 gal.	Gravity and pump	13	do	30	X	
Weston	350	2.1	Spring	16S-38E-16baa1	Reservoir 90,000 gal.	Gravity	90	do	720	X	
Whitney-Nashville	310	14.2	Spring 2 wells	15S-40E-20dbc1 3/ 15S-40E-29ccd1 32bba1	Tank 4,300 gal.	do	73	do	720		

1/ Also uses water from Logan.
2/ Also uses water from Providence.
3/ Spring.
4/ Temporarily not operative.

Ground-water conditions by areas

The principal aquifer systems, or areas where ground-water conditions are generally similar, are shown in figure 13. None of the areas in Cache Valley are independent of other areas; they generally grade into each other. Boundaries shown between the areas are not lines of separation but show approximately where general conditions change.

Outside of those areas discussed individually, ground water occurs locally in slope wash and alluvium, in sandstone and conglomerate of the Salt Lake and Wasatch(?) Formations, and in fracture and solution openings in older rocks.

Smithfield-Hyrum-Wellsville

Coarse fan and delta deposits of Summit Creek, Logan River, Blacksmith Fork, and Little Bear River coalesce to form a single, but complex, aquifer system in the Smithfield-Hyrum-Wellsville area in Utah (area 1, fig. 13). Near Logan, the water-bearing materials are at least 1,000 feet thick. They are very coarse along the mountain front but become finer grained westward. Clay and silt confine the ground water throughout most of the principal aquifer system, but unconfined ground water probably underlies an area along the mountain front.

This aquifer system is the largest and most productive in Cache Valley. The water-level contours on plate 4 indicate that the hydraulic gradient in most of the area ranges from 2 to 20 feet per mile; locally it probably is about 1 foot per mile. The system is very permeable, and the transmissivity probably ranges from about 10,000 to 330,000 ft^3 per day per ft. Measured yeilds of wells are as large as 3,500 gpm, and yields of 500 gpm or more are probably possible in most of the area. The quality of water is generally good; the concentration of dissolved solids in the water is generally less than 400 mg/l.

Although the aquifer system in the Smithfield-Hyrum-Wellsville area is the most intensely developed in Cache Valley, little or no long-term changes in water level are indicated in 34 years of record. The area is an overflowing ground-water basin; the water level rises and discharge increases during the irrigation season because of recharge from surface water used for irrigation. The area has great potential for additional ground-water development; the present withdrawal could be doubled without causing large general declines in water level. However, reduction of head in the confined aquifer as a result of increased withdrawals would decrease or stop the flow in some wells.

Little Bear River area south of Hyrum

An aquifer system extends southward from Hyrum along the flood plain and terraces of the Little Bear River (area 2, fig. 13). Thin deposits of gravel, generally less than 30 feet thick, overlie mostly fine-grained material. Ground water is unconfined, and recharge is mostly by seepage from streams and canals and from irrigation. Springs discharge along the edges of the terraces and thus prevent or reduce waterlogging on the terraces. The water table slopes northwestward, and the hydraulic gradient is about 40 feet per mile (pl. 4). The gravel generally is very permeable, but estimated transmissivities are less than about 15,000 ft^3 per day per ft because the aquifer is thin. Wells in the area yield as much as 200 gpm. The chemical quality of the water is generally good; the concentration of dissolved solids in the water is less than 400 mg/l.

Wellsville to Newton

Ground-water conditions along the west side of Cache Valley from southeast of Wellsville to near Newton (area, 3, fig. 13) are poorly known. The Quaternary valley fill is mostly underlain by Tertiary rocks and ranges in thickness from several feet in most of the area to probably several hundred feet near Cutler Reservoir. The fill is predominantly fine grained and of low permeability, but it includes some permeable sand and gravel. Ground water is both confined and unconfined. Yields to wells are low, generally less than 30 gpm but yields of about 300 gpm may be possible locally. The concentration of dissolved solids in the water generally ranges from 400 to 800 mg/l.

Lower Little Bear River-Benson-The Barrens

The Quaternary deposits in the central part of Cache Valley along the lower part of the Little Bear River and near Benson and The Barrens (area 4, fig. 13) are predominantly clay and silt, but include thin beds of sand and fine gravel that contain confined ground water. The hydraulic connection between the water-producing beds is poor and estimates of transmissivity of the aquifer system as a whole would probably be meaningless. The deposits are more than 1,000 feet thick and overlie Tertiary conglomerate in part of the area. Most wells near Benson produce water from a depth of about 300 to 700 feet, but wells are shallower in the southern part of the area near the Little Bear River.

An apparent anomaly in the form of a mound on the potentiometric surface in the middle of Cache Valley about 5 miles northwest of Logan (pl. 4) probably results from differences in artesian pressure in wells of different depths. Wells in the vicinity of the mound tap sand and gravel artesian aquifers at depths ranging from 480 to 760 feet below land surface, whereas wells in the surrounding area tap aquifers at shallower depths.

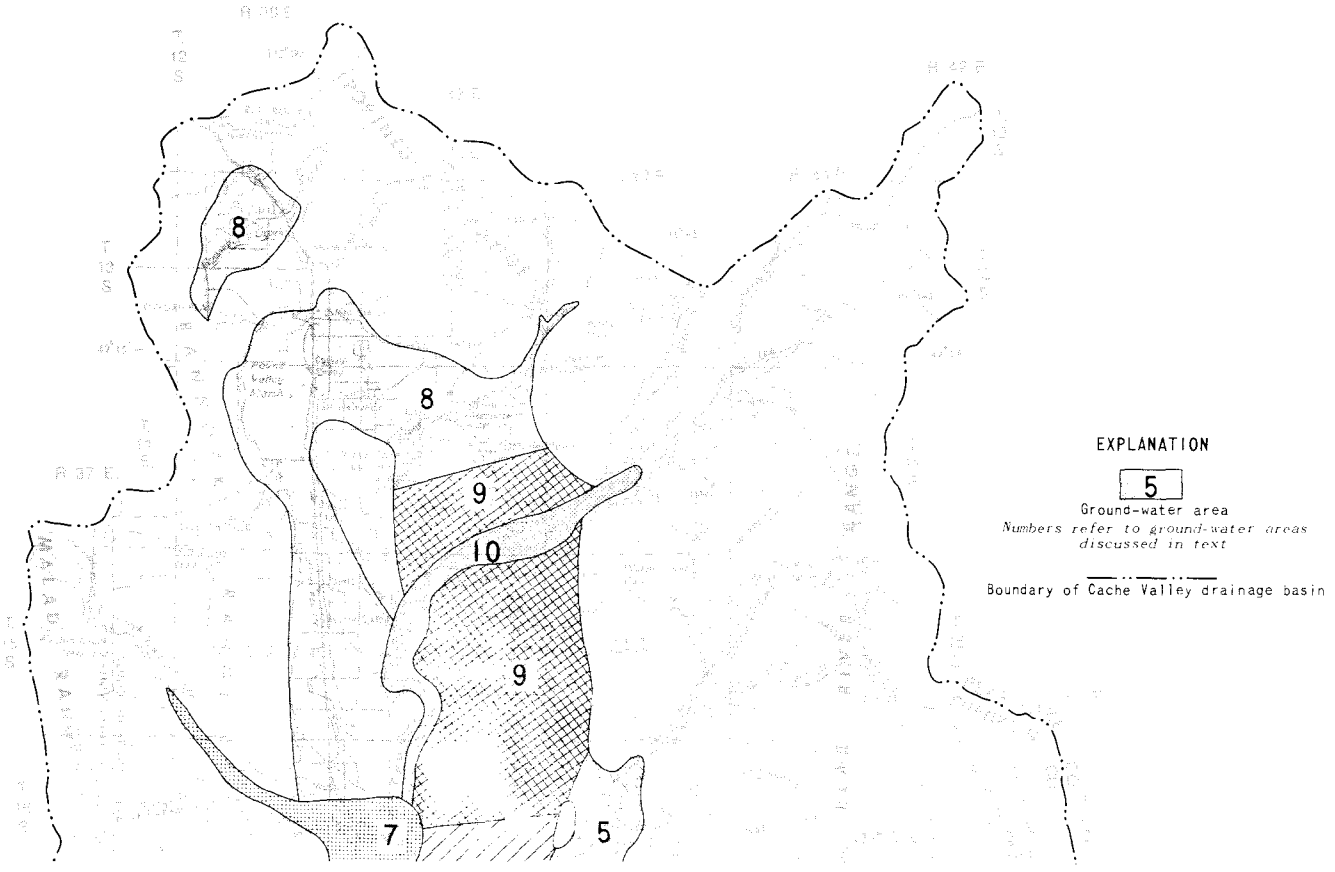
Artesian pressures are high in most of area 4, and heads of as much as 62 feet above land surface have been measured. Deep wells near Benson flow as much as 120 gpm, but most of the shallower wells near the Little Bear River flow less than 5 gpm. The concentration of dissolved solids in the water ranges from about 400 to 800 mg/l in the area along the Little Bear River but is as high as 1,200 mg/l near Benson and The Barrens.

Specially constructed wells in the area probably could yield sufficient water for irrigation but the wells would be deep (500 to 1,000 feet) and costly. Furthermore, much of the land is waterlogged, and all the tillable land is supplied with surface water. The aquifers, however, could be further developed to obtain water for domestic and livestock use.

Cub River subvalley

An aquifer system extends along the Cub River from near Franklin to a few miles south of Richmond (area 5, fig. 13). The Quaternary deposits consist of a few hundred feet of interbedded clay, silt, sand, and gravel that overlie Tertiary conglomerate in most of the area. The gravel and sand beds are moderately permeable, but they generally are thin. Transmissivities in most of the area probably range from about 1,000 to 4,000 ft^3 per day per ft. The gravel deposits of the Cherry Creek and High Creek alluvial fans, however, are thicker and transmissivities are higher.

The ground water is mostly confined and some wells flow. The hydraulic gradient ranges from about 20 to 40 feet per mile (pl. 4). Most wells are less than 400 feet deep and yield from 50 to 300 gpm. Yields of as much as 1,800 gpm are possible in the Cherry Creek and High Creek fans. Water levels in the areas are fairly stable, and further development is possible. The concentration of dissolved solids in the water ranges from about 300 to 800 mg/l.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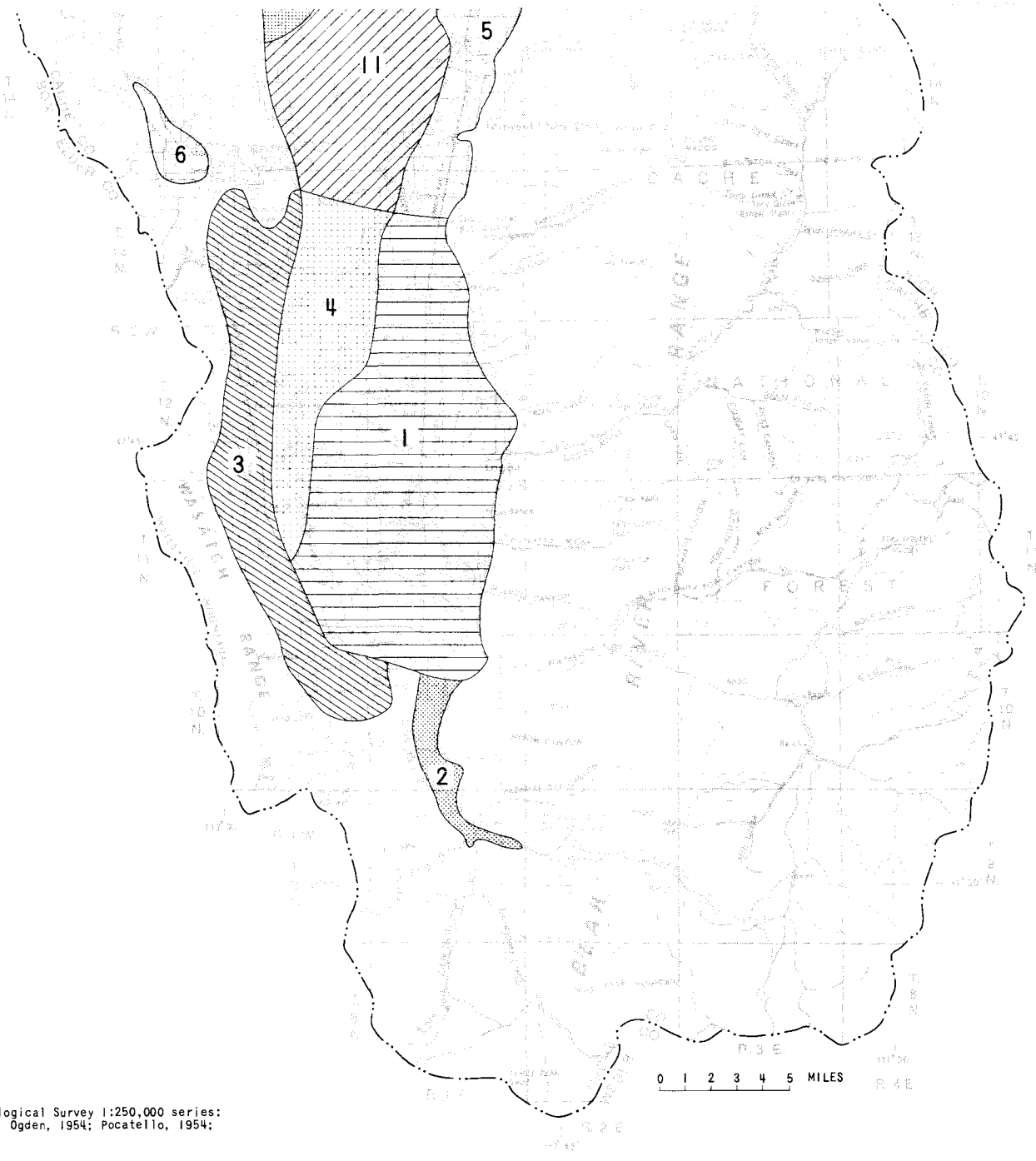
EXPLANATION
5
Ground-water area
Numbers refer to ground-water areas discussed in text
Boundary of Cache Valley drainage basin



Base from U.S. Geological Survey 1:250,000 series: Brigham City, 1962; Ogden, 1954; Pocatello, 1954; Preston, 1962

Figure 13.—Map showing ground-water areas in Cache Valley, Utah and Idaho.

Clarkston

In the area near Clarkston (area 6, fig. 13) sand and gravel deposits yield water to a few wells. Little is known of the thickness or extent of the water-bearing materials, but they probably occur mostly along Clarkston Creek and on the slopes west of the creek. The existing small-diameter wells in the area yield less than 30 gpm but irrigation wells might produce as much as 300 gpm. Some development for irrigation is possible. The concentration of dissovled solids in the water ranges from about 300 to 900 mg/l.

Weston Creek subvalley

One of the major aquifer systems in the Idaho part of Cache Valley is in the Weston Creek subvalley (area 7, fig. 13). Upstream from Weston, alluvial deposits that are about 200 feet thick and contain permeable gravel overlie Tertiary rock. Southeast of Weston, Quaternary valley fill, which includes sand and gravel of the Weston Creek alluvial fan and is probably more than 1,000 feet thick, overlies Tertiary rock. Gravel beds in these deposits are very permeable. The average transmissivity in the area southeast of Weston is estimated to be about 30,000 ft^3 per day per ft. The proportion of permeable water-bearing materials decreases southward and eastward from near Weston. Northward from Weston, the fan coalesces with deposits of area 8 (fig. 13). Ground water in area 7 is both confined and unconfined. Water-level contours on plate 4 indicate that the hydraulic gradient ranges from about 10 to 70 feet per mile.

Available short-term records suggest that water levels in part of this area may be declining. Although additional development is possible, local effects of well interference should be expected and water-level declines may increase pumping lifts appreciably. Most irrigation wells in the area yield from 450 to 1,350 gpm and yields as large as 2,500 gpm are reported. The concentration of dissolved solids in the water ranges from about 300 to 800 mg/l.

Water-level contours south of Weston, in the vicinity of the State line, are plotted on plate 4 independently from those north and west of Weston because they are about 200 feet lower, although the aquifer represented by the lower water levels presumably receives water from the aquifer represented by the higher water levels.

Dayton-Banida-Swan Lake

The west side of Cache Valley east of the Bannock Range and the north end of the valley (area 8, fig. 13) is a complex area of fan deposits interfingered with deposits of Lake Bonneville. These combined deposits are 200-600 feet thick under most of the area, but may be more than 1,000 feet thick locally. Fine sand and silt from the Bear River delta covers most of the lower areas and the rolling hills east of Banida.

Permeable deposits of sand and gravel are as much as 150 feet thick and contain both confined and unconfined ground water. The average transmissivity is estimated to be about 25,000 ft^3 per day per ft, but transmissivity may be as high as 50,000 ft^3 per day per ft locally. The hydraulic gradient ranges from about 5 to 60 feet per mile (pl. 4). The concentration of dissolved solids ranges from about 200 to 1,500 mg/l.

Most irrigation wells yield from 450 to 1,800 gpm, but yields as great as 2,500 gpm have been reported. Farmland in this area is irrigated mainly with surface water, but ground water is used as a supplementary supply when surface supplies are insufficient. Large withdrawals during

relatively dry years result in local areas of depressed ground-water levels. The water levels recover during relatively wet years, however, mainly because of recharge from the surface water applied for irrigation and because of the decreased pumpage. Increased development of the area is possible, but the consequent lowering of water levels would cause some well interference and increased pumping lifts.

Preston

The high bench area north and south of the Bear River near Preston (area 9, fig. 13) is composed of thick deposits of fine sand and silt of the Bear River delta that probably overlie fan and slope-wash deposits. The delta deposits are more than 300 feet thick in places. Ground water in the sand and silt is unconfined; the water table is near the land surface in most of the area and fluctuates only a few feet during the year, as is indicated by the hydrograph of well 15S-39E-34cbd1 (pl. 2). The permeability is generally low, and the materials are poorly drained, although streams are cut deeply into the deposits. The water-level gradient ranges from a few feet per mile to 80 feet per mile (pl. 4). Shallow domestic and stock wells yield a few gallons per minute, but development of irrigation supplies from the delta deposits is probably not feasible. The concentration of dissolved solids in water from the delta deposits generally ranges from about 400 to 1,600 mg/l.

A few wells near Whitney obtain water from fan and slope-wash deposits along the margin of the delta, where yields of as much as 1,000 gpm are reported, and the concentration of dissolved solids is as low as about 300 mg/l. Deposits underlying the delta have not been explored, but they probably contain confined ground water in places. Test drilling would be required to determine the quantity and quality of water available from these deeper deposits.

Bear River inner valley

The Bear River has cut through its delta and formed an inner valley nearly 300 feet below the benchlands near Preston. The inner valley from about 4 miles above Riverdale to east of Weston is shown as area 10 in figure 13. Alluvial deposits of the flood plain and terraces contain water-bearing sand and gravel that yield water to domestic wells. Large-capacity wells have not been drilled but moderate yields have been reported from both drilled wells and shallow dug wells. The concentration of dissolved solids in the water generally rnages from about 400 to 800 mg/l. The ground water is generally unconfined and the downvalley hydraulic gradient ranges from about 3 feet per mile near the State line to about 30 feet per mile for a 5-mile reach below Oneida Narrows (pl. 4). Water levels have little or no relation to water levels in the adjacent benchlands, and the ground-water gradient is controlled largely by the gradient of the river.

Fairview-Lewiston-Trenton

As the Bear River eroded into its delta near Preston, it deposited reworked sand and silt from near Fairview to Cutler Reservoir. These deposits are the principal water-bearing materials in the area from near Fairview and Lewiston to near Trenton (area 11, fig. 13). In most of the area, the sand and silt is approximately 20 feet thick and covers lake-bottom clays that have very low permeability. Ground water is unconfined and is near the land surface. The permeability of the sand and silt in this area is probably higher than that in the Preston area, but these deposits are very thin and, thus, the transmissivity is low—probably less than 1,000 ft^3 per day per ft. The water-level gradient is generally less than 10 feet per mile (pl. 4) and is controlled mostly by the land-surface gradient.

Many shallow wells were once used for domestic supply, but most have been destroyed and public-water systems now supply the area.

Irrigation and drainage practices generally affect the depth to water and the chemical quality of the water. Some of the land is subirrigated, and ground-water levels are regulated in part by valves at drainage-pipe outlets, which control the discharge from drains. As the land-surface gradient is almost flat, the natural drainage is inhibited and extensive drains have been installed in agricultural lands. Several drainage wells yield as much as 450 gpm from the systems of underground drains.

The quality of the water varies from place to place and from season to season, but generally the concentration of dissolved solids ranges from about 800 to 1,600 mg/l. The magnitude of seasonal variation is demonstrated at well (A-14-1)6ccc-1, where the water had a specific conductance of 1,300 micromhos per centimeter in September 1967 and 2,200 micromhos per centimeter in April 1968.

WATER-BUDGET ANALYSIS OF CACHE VALLEY

The quantity of water entering Cache Valley is equal to the quantity leaving the valley plus or minus the change in storage within the valley. Water enters the valley by surface flow, ground-water flow, precipitation, and through pipelines; it leaves the valley by surface flow and evapotranspiration. Items of inflow and outflow are given in table 11.

Table 11.—Water-budget analysis, Cache Valley, Utah and Idaho

	Thousands of acre-feet
Inflow	
Principal streams, average 1960-68 water years (table 2)	1,000
Runoff not included in principal streams[1]	30
Imports through pipelines for public supply[2]	25
Springs near valley edge (near edge of analysis area)[3]	40
Precipitation on Cache Valley[4]	582
Ground-water inflow not accounted for in springs near the valley edge	32
Total (rounded)	1,700
Outflow	
Streams, average 1960-68 water years (table 3)	1,010
Consumptive use by phreatophytes[5]	108
Consumptive use on irrigated land[6]	335
Consumptive use in urban areas[7]	42
Consumptive use on dry farm and noncleared land[8]	194
Evaporation from open water[9]	20
Ground-water outflow[10]	Negligible
Total (rounded)	1,700
Change in surface-water storage[11]	Negligible
Change in ground-water storage[12]	Negligible

[1] About 160 square miles of mountain area bordering Cache Valley is drained by relatively small intermittent and ephemeral streams. Runoff factors taken from an annual-runoff map (Utah Water and Power Board and Utah State University, 1963, fig. 4) were used to estimate inflow to the valley from this source.

[2] Most of the public-water supplies in Cache Valley are piped into the valley from springs in the surrounding mountains. (See fig. 12 and table 10.)

[3]The discharge of many springs near the valley edge was measured, estimated, or reported, and the total annual discharge was estimated.

[4]The average annual precipitation on Cache Valley was estimated from normal annual precipitation maps of Utah and Idaho (U.S. Weather Bureau, 1963, 1965).

[5]The areas covered by phreatophytes in Cache Valley are shown on plate 4. .

[6]The total irrigated acreage in Cache Valley, Utah, was taken from data furnished by the Utah Water Research Laboratory (Haws, 1969) and F.W. Haws (oral commun., 1969). Data for irrigated acreage in the Idaho part of the valley were furnished by the U.S. Soil Conservation Service (Glade Moser, written commun., 1969). The average consumptive use of water by crops in Idaho was assumed to be the same as in Utah. The approximate outer boundary of the general irrigated area, determined by field inspection and from aerial photographs, is shown on plate 4. .

[7]Urban areas in Cache Valley are estimated to include about 16,600 acres. This includes only the larger cities and towns in the valley; the smaller towns and scattered communities are regarded as part of the surrounding cropland and are not included as urban areas.

[8]A consumptive use of 11.71 inches annually was determined for idle cropland in Cache Valley by the Utah Water Research Laboratory (F.W. Haws, oral commun., 1969), and the same figure was applied to dry farm and noncleared land within the area.

[9]The estimate is based on an open-water area of approximately 6,700 acres (measured on U.S. Geological Survey topographic maps) and an annual evaporation of 36 inches.

[10]See section on subsurface outflow.

[11]The quantity of water stored in surface-water reservoirs in Cache Valley remains about the same from year to year, although it may change greatly during a particular year. Most of the reservoirs are filled at least once during most years; therefore, the average annual change in surface-water storage during 1960-68 is regarded as negligible.

[12]The total quantity of ground water stored in Cache Valley changed very little during 1960-68, and the annual change in ground-water storage is considered to be negligible.

The boundary of the area used for this analysis is the general outer boundary of the cultivated area, and is shown on plate 4. . It was determined from aerial photographs and field inspection. Although the area includes cultivated parts of the surrounding hillsides as well as the valley bottom, the analysis area is called Cache Valley.

An analysis based on average annual inflow and outflow during the 1960-68 water years was considered meaningful and representative because:

1. Good discharge records are available or reliable estimates based on correlation with measured streams were made for all the principal streams in the valley for the 1960-68 water years. The period includes both relatively dry and relatively wet years (tables 2 and 3).

2. All data for consumptive use, evaporation, precipitation, and runoff not included in principal streams are based on long-term averages.

3. Estimates of imports for public supply and of spring discharge near the valley edge, although based on data collected during 1967 and 1968, should apply to most years.

The one item of inflow that could not be estimated directly from available data was subsurface inflow from the adjacent mountains. Water moves through fractures and solution openings in the rocks, and some water certainly enters the valley fill from this source. However, detailed studies to estimate the subsurface inflow not accounted for in springs have not been made. The estimates of total discharge and recharge show a difference of about 32,000 acre-feet per year. The recharge from subsurface inflow is probably of this magnitude.

CONCLUSIONS

The valley-fill deposits in Cache Valley include more than 5,000 feet of gravel, sand, silt, clay, and conglomerate of Tertiary and Quaternary age and contain at least 40 million acre-feet of ground water. Only a small percentage of this water is available for development, however, because much of it is in fine-grained deposits that do not yield water to wells readily. Available ground water in the fill is both confined and unconfined in beds of permeable gravel and sand in many parts of the valley. Confined ground water underlies at least 200 square miles in the valley.

The largest and most productive aquifer system in Cache Valley is in the Smithfield-Hyrum-Wellsville area, where locally the yields to wells are as much as 3,500 gpm and the transmissivity is as much as 330,000 ft^3 per day per ft. The aquifer is regarded as an overflowing ground-water reservoir. The second most productive aquifer is along the west and north sides of the valley in Idaho.

The total recharge to and discharge from the ground-water reservoir in Cache Valley is estimated to be about 280,000 acre-feet annually. Recharge occurs directly from precipitation, from streams near the edge of the valley, from subsurface inflow, and from irrigation. Seepage from canals, ditches, and irrigated fields is a principal form of recharge.

Ground water in Cache Valley moves from areas of recharge at the edges of the valley to areas of discharge in the lower parts of the valley. Underflow across the Utah-Idaho State line is estimated to be about 4,000 acre-feet annually.

Water levels in the main aquifer in Utah have not changed significantly since 1935, although fluctuations due to annual changes in precipitation do occur. Along the west side of the valley in Idaho, water levels fluctuate seasonally in response to pumping for irrigation. Water levels in this area were lowered in 1966, which was a dry year when irrigation wells were heavily pumped and ground-water levels declined locally, and have shown a general rising trend since that time.

Ground water from more than 2,400 wells and many springs is used in Cache Valley for irrigation, public supply, industry, livestock, and domestic purposes. Additional ground-water development is physically feasible in the Smithfield-Hyrum-Wellsville area where the present withdrawal could be doubled without causing large general declines in water level, provided recharge remains about the same as in the past. However, reduction of head in the confined aquifer as a result of increased withdrawals would cause diminished flow in flowing wells and stoppage of flow in some wells in artesian fringe areas. Some additional ground-water development also is feasible in Idaho in the Dayton-Banida-Swan Lake area and in the Weston Creek subvalley. Local effects of well interference and increased pumping lifts could be expected, however.

Chemical analyses of ground water collected during 1941-68 from the principal aquifers in Cache Valley indicate that the water is of generally good quality and that the chemical quality has not changed.

About 1 million acre-feet of surface water entered and left Cache Valley annually during 1960-68. The relation of surface-water inflow to outflow has not changed significantly during 1960-68. Within the valley, ground-water accretion to streams amounts to about 140,000 acre-feet annually.

A water-budget analysis for Cache Valley indicates that an average amount of about 1,700,000 acre-feet of water enters and leaves the valley annually. Annual changes in both surface- and ground-water storage are considered to be negligible.

Some of the estimated 108,000 acre-feet of water consumed annually by phreatophytes in Cache Valley can be salvaged by lowering water levels in wetland areas. Water levels can be lowered by constructing drainage systems and by withdrawing additional water from wells.

Future ground-water investigations in Cache Valley should include continued measurements of water levels in selected wells on an annual or semiannual basis. Future test drilling should include test holes in the vicinity of Preston to determine whether gravel or sand aquifers underlie the thick deposits of silt and clay exposed there.

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APPENDIX

Well- and spring-numbering systems

The system of numbering wells and springs in Utah is based on the cadastral land-survey system of the U.S. Government. The number identifies the well or spring and 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 letters following the section number 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 numbers that follow the letters indicate the serial number of the well or spring within the 10-acre tract. Thus well (A-11-1)8cbb-1 in Cache Valley is in the NW¼NW¼SW¼ sec. 8, T. 11 N., R. 1 E., and it is the first well constructed or visited in that tract. (See fig. 14.)

Springs are numbered similarly except that they are designated by the letter S preceding the serial number. Thus (B-10-1)10aac-S1 is a spring in the SW¼NE¼NE¼ sec. 10, T. 10 N., R. 1 W.

In Idaho, the well- and spring-numbering system is based on the cadastral land-survey system with reference to the Boise base line and meridian. It is similar to the Utah system except that springs are not designated by the letter S and the quadrant letter is omitted; the townships are labeled N or S to designate north or south, and the ranges are labeled E or W to designate east or west. Thus well 15S-38E-22ddc1 is the first well visited in the SW¼SE¼SE¼ sec. 22, T. 15 S., R. 38 E. (See fig. 14.)

Terms describing aquifer characteristics

The capacity of an aquifer to transmit and store water is described by the transmissivity and the storage coefficient of the aquifer. The transmissivity is equal to the product of the aquifer thickness and the hydraulic conductivity.

Transmissivity (T) is the rate at which water of the prevailing viscosity is transmitted through a unit width of the aquifer under a unit hydraulic gradient. The units for *T* are cubic feet per day per foot (ft^3 per day per ft) which reduces to ft^2 per day. The term transmissivity replaces the term coefficient of transmissibility, which was formerly used by the U.S. Geological Survey and which was reported in units of gallons per day per foot. To convert a value for coefficient of transmissibility to the equivalent value of transmissivity, miltiply by 0.134; to convert from transmissivity to coefficient of transmissibility, miltiply by 7.48.

The *hydraulic conductivity (K)* of a water-bearing material is the volume of water of the prevailing viscosity that will move through a unit cross section of the material in unit time under a unit hydraulic gradient. The units for *K* are cubic feet per day per square foot (ft^3 per day per ft^2), which reduces to ft per day. The term hydraulic conductivity replaces the term field coefficient of permeability, which was formerly used by the U.S. Geological Survey and which was reported in units of gallons per day per square foot. To convert a value for field coefficient of permeability to the equivalent value of hydraulic conductivity, miltiply by 0.134; to convert from hydraulic conductivity to coefficient of permeability, multiply by 7.48.

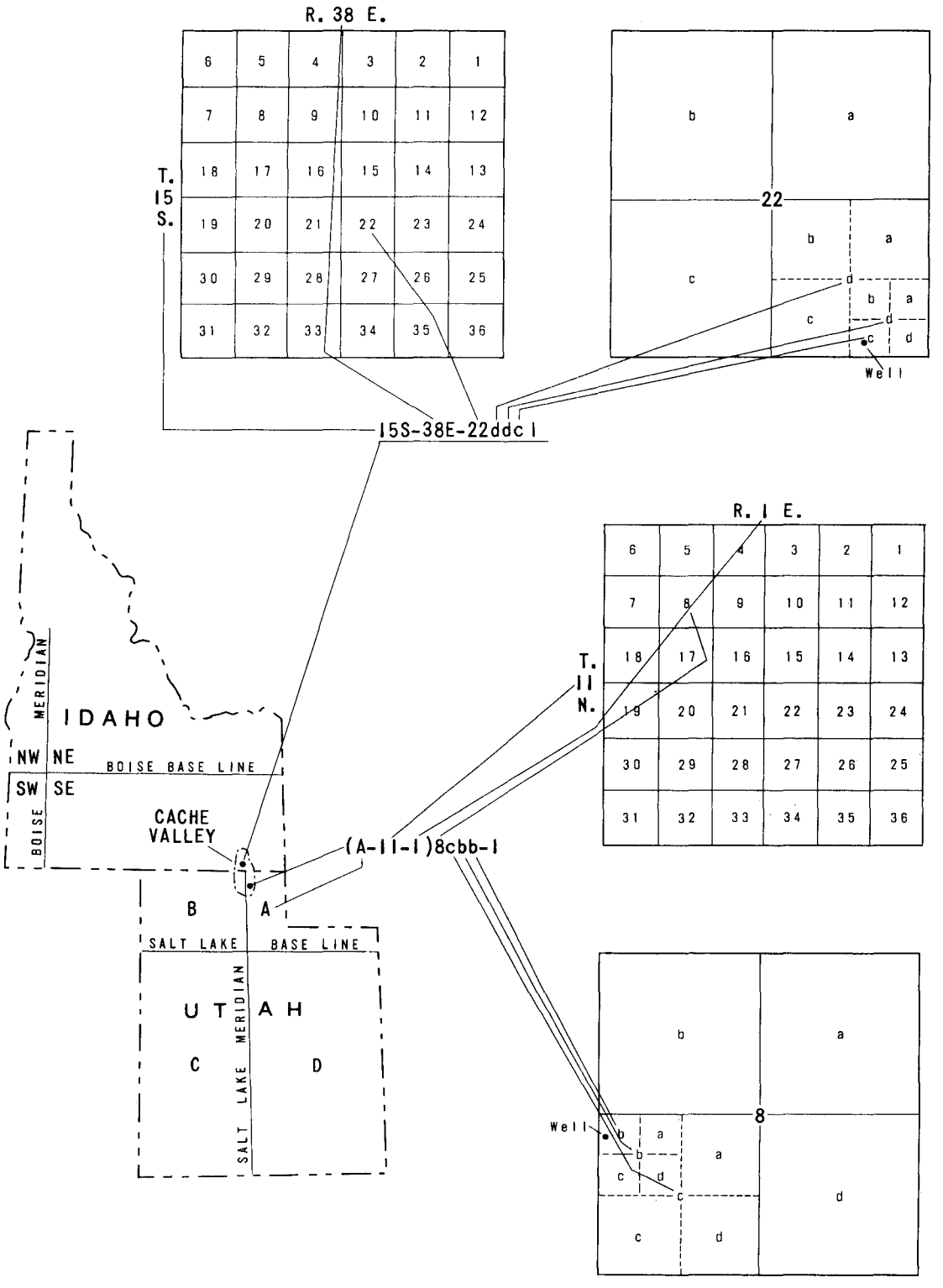

Figure 14.—Well- and spring-numbering systems used in Utah and Idaho.

The *storage coefficient (S)* of an aquifer is the volume of water it releases from or takes into storage per unit surface area of the aquifer per unit change in head. *S* is a dimensionless number. Under confined conditions, *S* is typically small, generally between 0.00001 and 0.001. Under unconfined conditions, *S* is much larger, typically from 0.05 to 0.30.

Use of metric units

The results of chemical analyses and temperature measurements are given in this report in metric units, rather than the more familiar English units. Temperatures are given in degrees Celsius, and analytical data are reported in milligrams per liter or milliequivalents per liter.

Degrees Celsius (°C) are the units used for reporting temperature in the metric system. One degree Celsius is equal to 9/5 degrees Fahrenheit, and the freezing point of water is 0° on the Celsius scale. Therefore, a temperature in °C = 5/9 (°F – 32). The following table may be used to convert the temperature data given in this report to the more familiar Fahrenheit scale:

TEMPERATURE-CONVERSION TABLE

Temperatures in °C are rounded to nearest 0.5 degree. Underscored temperatures are exact equivalents. To convert from °F to °C where two lines have the same value for °F, use the line marked with an asterisk (*) to obtain equivalent °C.

°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F
-20.0	-4	-10.0	14	0.0	32	10.0	50	20.0	68	30.0	86	40.0	104
-19.5	-3	-9.5	15	+0.5	33	10.5	51	20.5	69	30.5	87	40.5	105
-19.0	-2	-9.0	16	1.0	34	11.0	52	21.0	70	31.0	88	41.0	106
-18.5	-1	-8.5	17	1.5	35	11.5	53	21.5	71	31.5	89	41.5	107
-18.0 *	0	-8.0 *	18	2.0 *	36	12.0 *	54	22.0 *	72	32.0 *	90	42.0 *	108
-17.5	0	-7.5	18	2.5	36	12.5	54	22.5	72	32.5	90	42.5	108
-17.0	1	-7.0	19	3.0	37	13.0	55	23.0	73	33.0	91	43.0	109
-16.5	2	-6.5	20	3.5	38	13.5	56	23.5	74	33.5	92	43.5	110
-16.0	3	-6.0	21	4.0	39	14.0	57	24.0	75	34.0	93	44.0	111
-15.5	4	-5.5	22	4.5	40	14.5	58	24.5	76	34.5	94	44.5	112
-15.0	5	-5.0	23	5.0	41	15.0	59	25.0	77	35.0	95	45.0	113
-14.5	6	-4.5	24	5.5	42	15.5	60	25.5	78	35.5	96	45.5	114
-14.0	7	-4.0	25	6.0	43	16.0	61	26.0	79	36.0	97	46.0	115
-13.5	8	-3.5	26	6.5	44	16.5	62	26.5	80	36.5	98	46.5	116
-13.0	9	-3.0	27	7.0	45	17.0	63	27.0	81	37.0	99	47.0	117
-12.5	10	-2.5	28	7.5	46	17.5	64	27.5	82	37.5	100	47.5	118
-12.0 *	10	-2.0 *	28	8.0 *	46	18.0 *	64	28.0 *	82	38.0 *	100	48.0 *	118
-11.5	11	-1.5	29	8.5	47	18.5	65	28.5	83	38.5	101	48.5	119
-11.0	12	-1.0	30	9.0	48	19.0	66	29.0	84	39.0	102	49.0	120
-10.5	13	-0.5	31	9.5	49	19.5	67	29.5	85	39.5	103	49.5	121

For temperature conversions beyond the limits of the table, use the equations C = 0.5556 (F – 32) and F = 1.8(°C) + 32. The formulae say, in effect, that from the freezing point of water (0°C, 32°F) the temperature in °C rises (or falls) 5° for every rise (or fall) of 9°F.

Milligrams per liter (mg/l) is a unit for expressing the concentration of chemical constituents in solution, and it represents the weight of solute per unit volume of water. For concentrations of less than about 7,000 mg/l, this unit is numerically equal to the unit parts per million (ppm), which was formerly used by the U.S. Geological Survey.

Milliequivalents per liter (meq/l) is a unit for expressing the concentration of chemical constituents in terms of the interacting values of the electrically charged particles, or ions, in solution. One meq/l of a positively charged ion can react with 1 meq/l of a negatively charged ion. Milligrams per liter can be converted to milliequivalents per liter by multiplying by the reciprocal of the combining weight of the ion. Milliequivalents per liter is numerically equal to the unit equivalents per million, which was formerly used by the U.S. Geological Survey. For comparison of water types and for graphical presentation, meq/l is a more convenient unit than mg/l.

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No. 35. Ground-water conditions in the East Shore area, Box Elder, Davis, and Weber Counties, Utah, 1960-69, by E.L. Bolke and K.M. Waddell, U.S. Geological Survey, 1972.

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*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.

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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.

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*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.

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*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.

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*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.

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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.

No. 21. Hydrogeology of the eastern portion of the south slopes of the Uinta Mountains, Utah, by L. G. Moore and D. A. Barker, U. S. Bureau of Reclamation, and James D. Maxwell and Bob L. Bridges, Soil Conservation Service, 1971.

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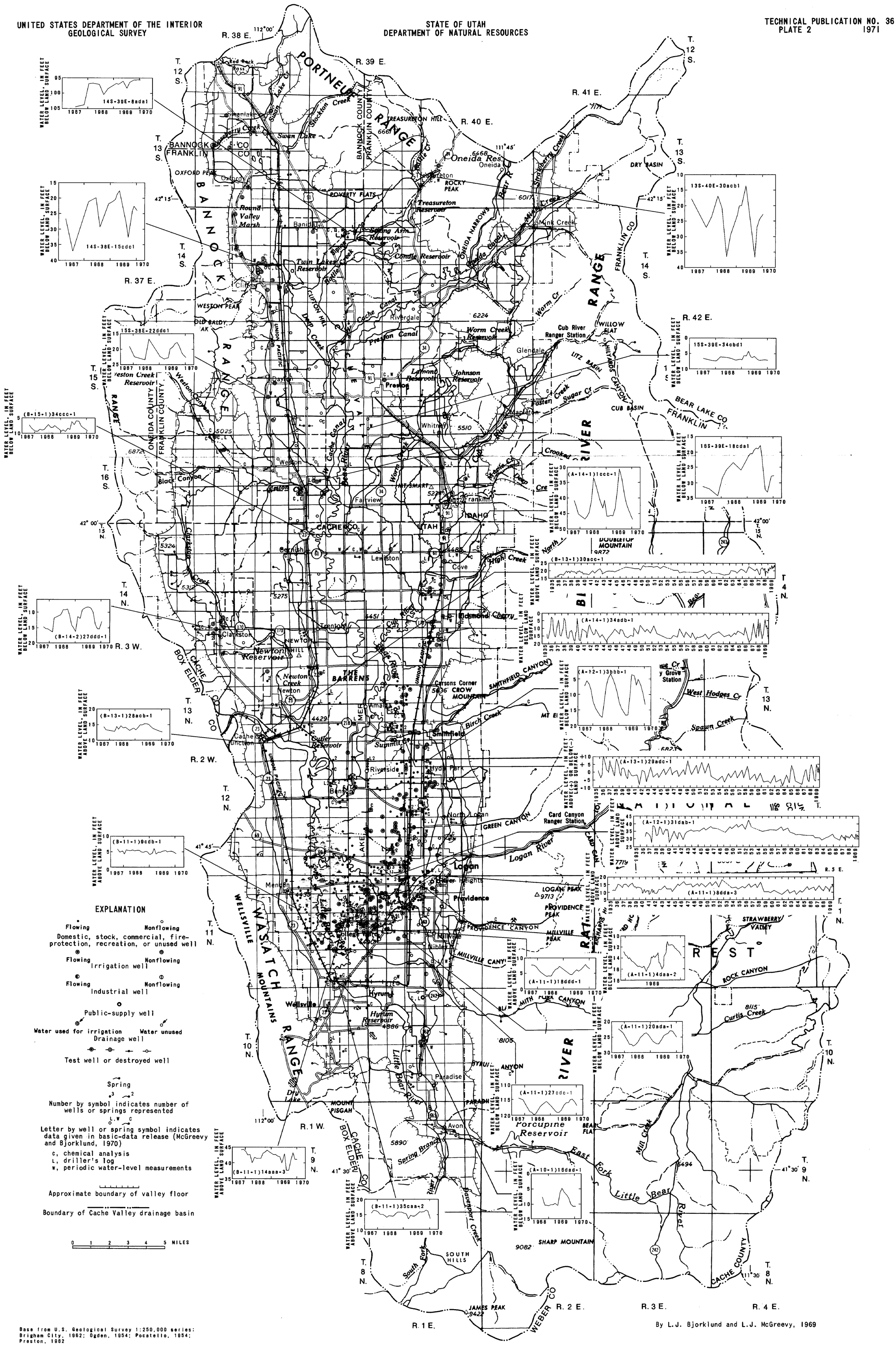
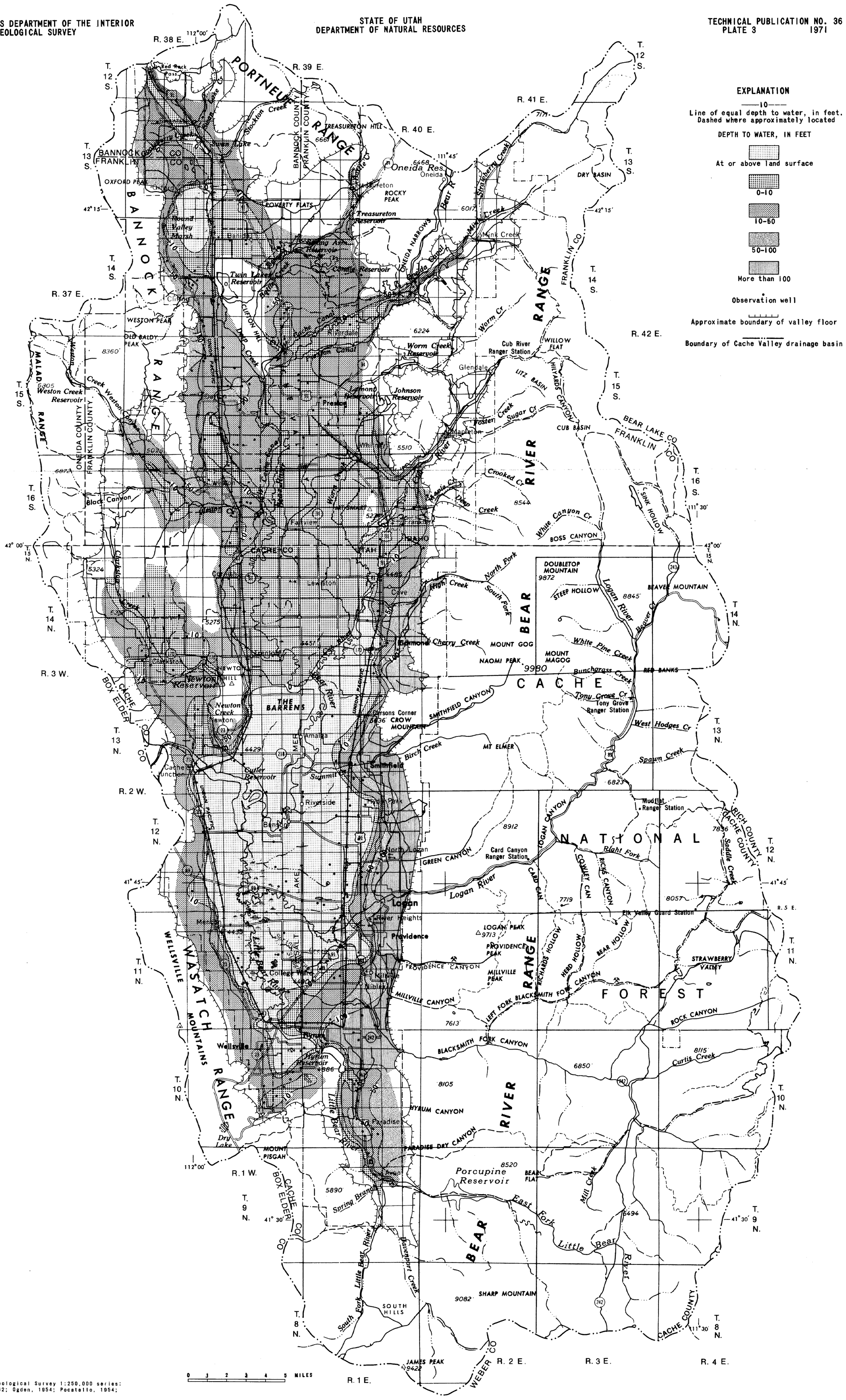


Base from U.S. Geological Survey 1:250,000 series: Brigham City, 1962; Ogden, 1954; Pocatello, 1954; Preston, 1962

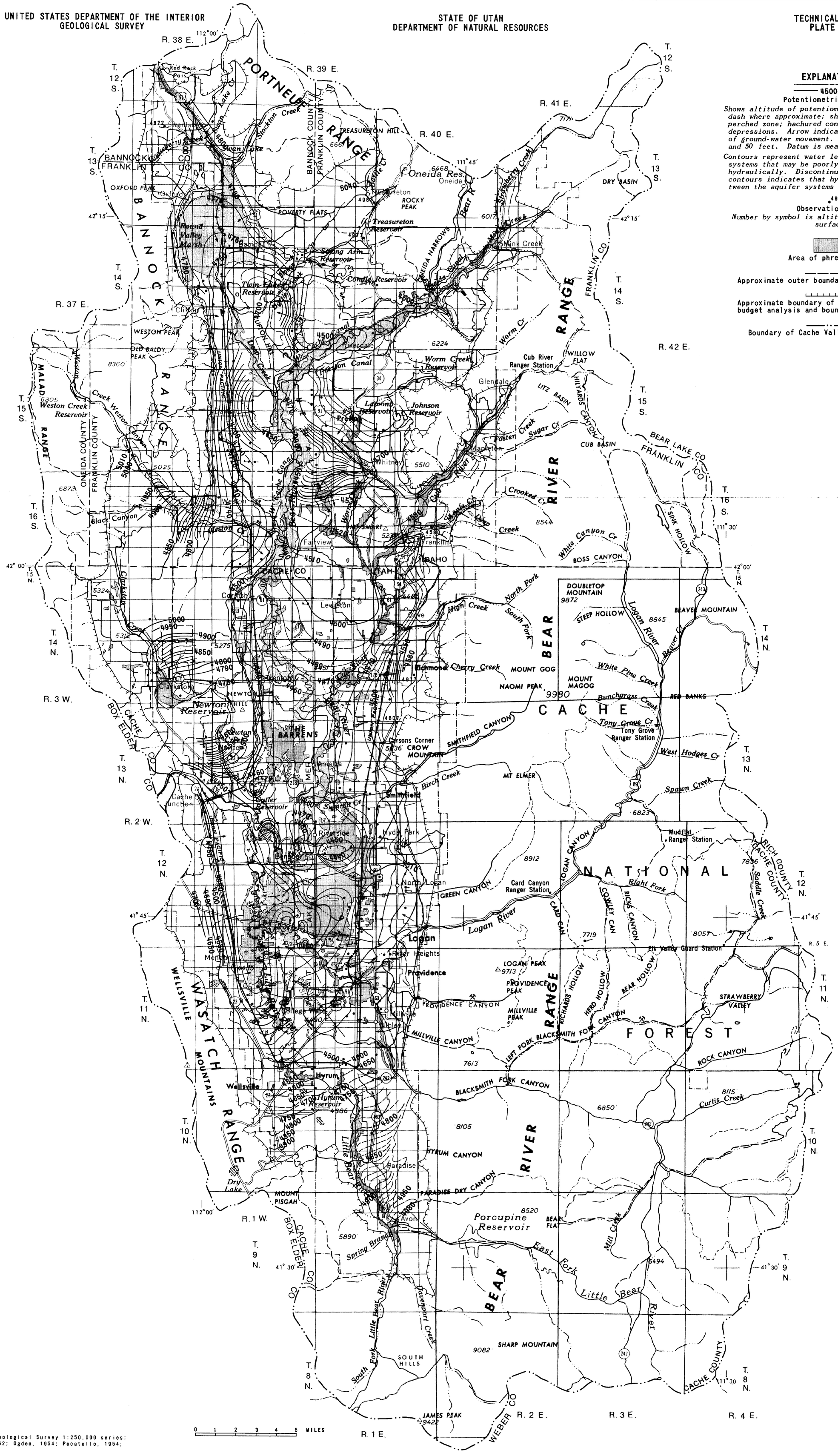
By L.J. Bjorklund and L.J. McGreevy, 1969

MAP SHOWING LOCATIONS OF SELECTED WELLS AND SPRINGS AND HYDROGRAPHS OF SELECTED WELLS IN CACHE VALLEY, UTAH AND IDAHO



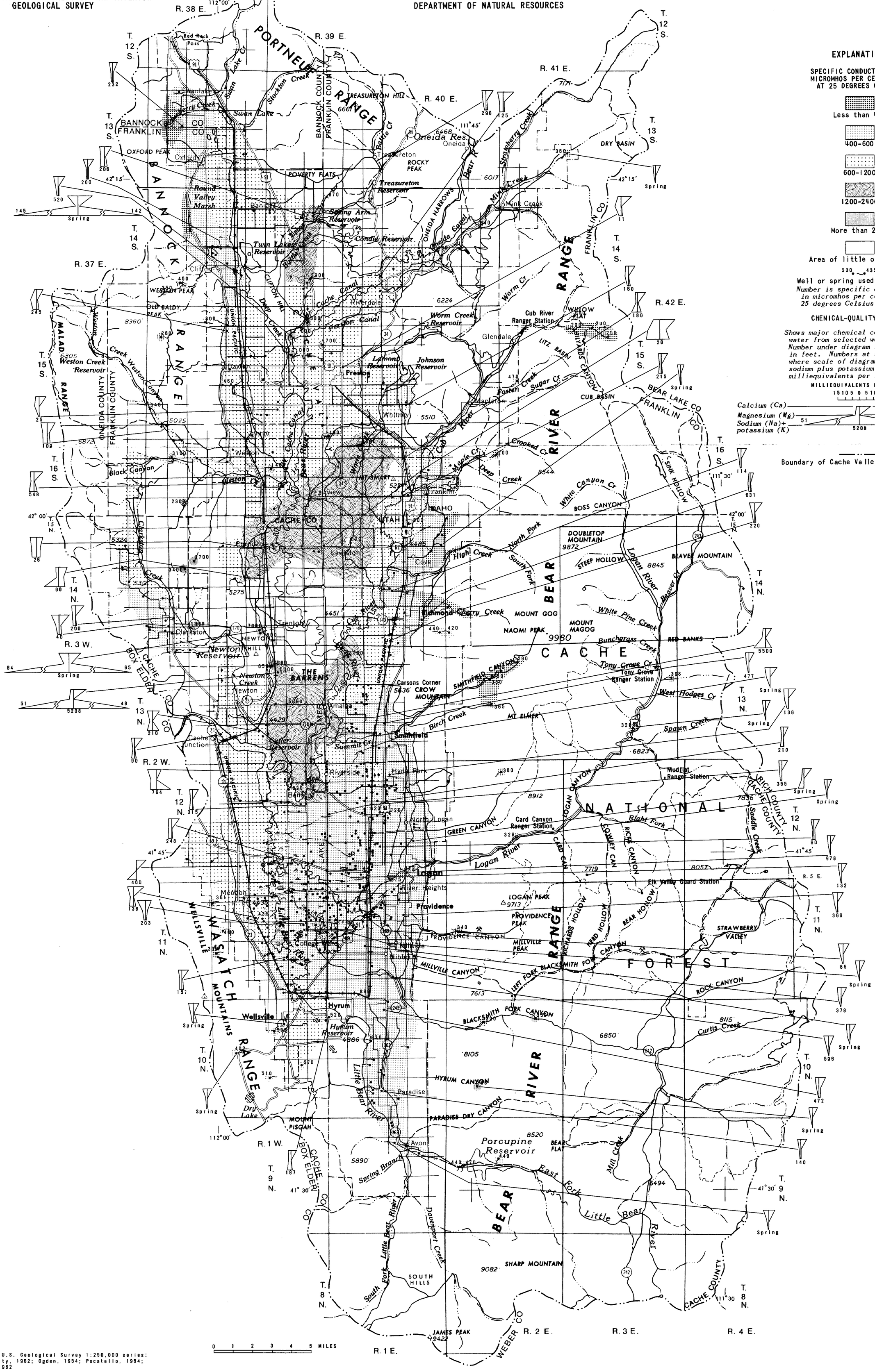
Base from U.S. Geological Survey 1:250,000 series: Brigham City, 1962; Ogden, 1954; Pocatello, 1954; Preston, 1962

MAP SHOWING RELATION OF WATER LEVELS TO LAND SURFACE IN CACHE VALLEY, UTAH AND IDAHO



Base from U.S. Geological Survey 1:250,000 series: Brigham City, 1962; Ogden, 1954; Pocatello, 1954; Preston, 1962

MAP SHOWING CONFIGURATION OF THE POTENTIOMETRIC SURFACE AND DIRECTION OF GROUND-WATER MOVEMENT, MARCH 1969, AND AREAS OF PHREATOPHYTES AND OF CULTIVATED LAND IN CACHE VALLEY, UTAH AND IDAHO



EXPLANATION

SPECIFIC CONDUCTANCE, IN MICROMHOS PER CENTIMETER AT 25 DEGREES CELSIUS

- Less than 400
- 400-600
- 600-1200
- 1200-2400
- More than 2400
- Area of little or no data

330 435 Well or spring used for control
Number is specific conductance, in micromhos per centimeter at 25 degrees Celsius

CHEMICAL-QUALITY DIAGRAM

Shows major chemical constituents in water from selected wells and springs. Number under diagram is depth of well, in feet. Numbers at sides of diagrams, where scale of diagram is broken, are sodium plus potassium and chloride, in milliequivalents per liter

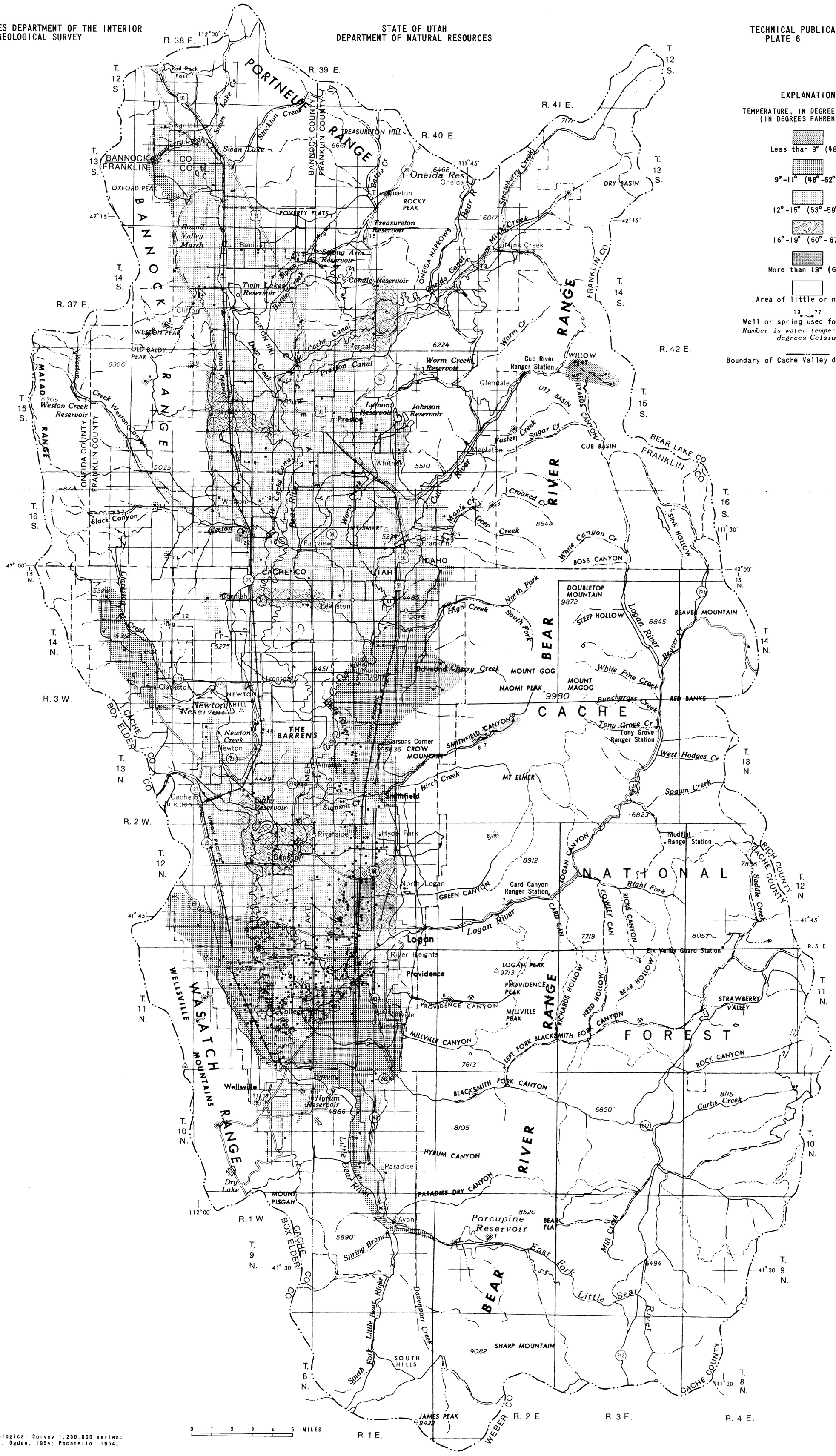
MILLIEQUIVALENTS PER LITER
15 10 5 0 5 10 15

Calcium (Ca) — *Bicarbonate (HCO_3)*
Magnesium (Mg) — *Sulfate (SO_4)*
Sodium (Na)+ potassium (K) — *Chloride (Cl)*
51 5208 48

Boundary of Cache Valley drainage basin

Base from U.S. Geological Survey 1:250,000 series: Brigham City, 1962; Ogden, 1954; Pocatello, 1954; Preston, 1962

MAP SHOWING CHEMICAL QUALITY OF GROUND WATER IN CACHE VALLEY, UTAH AND IDAHO



Base from U.S. Geological Survey 1:250,000 series: Brigham City, 1962; Ogden, 1954; Pocatello, 1954; Preston, 1962

MAP SHOWING TEMPERATURE OF GROUND WATER IN CACHE VALLEY, UTAH AND IDAHO