Ground-Water Resources of Camas Prairie Camas and Elmore Counties Idaho

By WILLIAM C. WALTON

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1609

Prepared on behalf of the
U.S. Bureau of Reclamation

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1962

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington 25, D.C.

CONTENTS

	Page
Abstract	1
Introduction	2
Purpose and scope of the investigation	2
Acknowledgments	2
Location and extent of the area	2
Previous investigations	2
Well-numbering system	4
Geography	5
Climate	5
Precipitation	5
Temperature	8
Physiography and drainage	8
Economic development	9
Geology	10
Consolidated rocks and their water-bearing properties	10
Valley-fill deposits and their water-bearing properties	11
Ground water	15
Occurrence	15
Movement	16
Hydraulic properties	17
Aquifer test	18
Underflow	20
Leakage through the clay bed	21
Recharge	21
Evapotranspiration	22
Development of wells	22
Present status	22
Yields of wells	23
Constructional features of wells in the valley-fill deposits	25
Well interference and spacing	26
Drawdown in an infinite aquifer	26
Effects of hydrogeologic boundaries	29
Theoretical drawdown in a heavily pumped well	30
Effects of ground-water development	32
Surface water	33
Ground-water discharge to streams	33
Quality of water	34
Chemical analyses	34
Chemical character of ground water	36
Suitability of ground waters for domestic and irrigation use	37
Temperature of ground water	39
Chemical character of surface waters	40
Suitability of surface waters for irrigation use	41

	Page
Summary	42
Records of wells	45
References	55
Index	56

ILLUSTRATIONS

			Page
PLATE	1.	Geologic and hydrologic map of Camas Creek basin	In pocket
FIGURE	1.	Index map of southern Idaho showing area included in this report	3
	2.	Well-numbering system	4
	3.	Annual precipitation and cumulative departure from average at Hill City, 1923–57	6
	4.	Annual precipitation and cumulative departures from average at Soldier Creek Ranger Station, 1910–47	7
	5.	Geologic cross section *A–A′* and profile of piezometric surface of valley-fill deposits and basalts	12
	6.	Geologic cross section *B–B′* and profile of piezometric surface of valley-fill deposits	14
	7.	Water level in well 1S–14E–9db1 and atmospheric-pressure fluctuations during the aquifer test	19
	8.	Time-recovery graph for well 1S–14E–9db1	20
	9.	Theoretical semilog distance-drawdown graphs for aquifers underlying Camas Prairie	27
	10.	Theoretical distance-drawdown curves for aquifers underlying Camas Prairie	28
	11.	Graphical representation of chemical analyses of ground and surface waters in Camas Prairie	34
	12.	Classification of ground and surface waters in Camas Prairie for irrigation	38
	13.	Variations of ground-water temperatures with depth	40

TABLES

			Page
TABLE	1.	Specific-capacity data	24
	2.	Chemical analyses of ground and surface waters in Camas Prairie	35
	3.	Temperature of ground water in Camas Prairie	36
	4.	Logs of representative wells	45
	5.	Records of representative wells	51

GROUND-WATER RESOURCES OF CAMAS PRAIRIE, CAMAS AND ELMORE COUNTIES, IDAHO

By William C. Walton

ABSTRACT

Camas Prairie is an eastward-trending intermontane basin along the north flank of the Snake River Plain in southern Idaho. The basin is about 40 miles long and averages about 8 miles wide. It was formed as a structural depression in which a considerable thickness of alluvial and lake deposits accumulated behind basalt flows, which at times blocked the outlet to the east. Intrusive and extrusive rocks of Cretaceous to Quarternary age enclose the basin on the north, west, and east. The enclosing rocks yield small amounts of water to springs and wells from the weathered mantle and fractures.

The principal aquifers are sand and gravel in the alluvial fill, and basalt. Water in the shallow deposits is not confined, and the water table generally is less than 10 feet below the surface at most places. Ground water in the deeper deposits occurs chiefly in two horizons that comprise the upper and lower artesian aquifers. Throughout much of the prairie, the pressure is sufficient that water will flow from wells in these aquifers.

Recharge to the basin is from direct precipitation and percolation of stream runoff from the bordering mountains. Ground water moves from the higher areas at the base of the encircling mountains toward the center of the basin and the eastern outlet. The artesian aquifers leak by upward percolation through the imperfectly confining beds and help maintain the shallow water table. Basalt, which interfingers with the alluvial deposits, is an important aquifer near the southeast margin of the prairie and at the east end. Annual recharge to the artesian aquifers is estimated to be about 40,000 acre-feet. Discharge from the artesian aquifers is about equally divided between upward leakage to the shallow aquifers and underflow out of the prairie. Most of the underflow discharges into Camas Creek or Magic Reservoir east of the prairie; little of the underflow reaches the Snake River Plain.

Wells drilled for irrigation generally yield 500 to 1,200 gallons per minute from the artesian aquifers. Better construction and development methods would result in considerably better yields. Wells drilled in the basalt will yield 2,000 to 3,000 gallons per minute with moderate drawdowns.

Computations made using aquifer coefficients, estimated on the basis of data collected during the investigation, suggest that 12,000 acre-feet of ground water might be withdrawn annually. However, the aquifers are limited in areal extent, and productivity of the alluvial aquifers is not great. Consequently heavy development would result in large drawdowns in wells, and there would be much interference between wells. The postulated large withdrawals from wells on the prairie would be supplied in part by a reduction in underflow from the prairie and in part by a decrease in leakage from the artesian aquifers, which in turn would cause a decline in the shallow water table.

INTRODUCTION

PURPOSE AND SCOPE OF THE INVESTIGATION

This report is one in a series of investigations of the ground-water resources of several areas in and adjacent to the Snake River Plain in southern Idaho made by the U.S. Geological Survey on behalf of the U.S. Bureau of Reclamation. The studies were an integral part of the Bureau of Reclamation's comprehensive investigation and evaluation of undeveloped land and water resources of the upper and middle Snake River basin. The objectives of the investigations were to locate and delineate areas where undeveloped ground water is available and to appraise the magnitude of these resources.

This report describes the geology, the ground-water resources, and the quality and temperature of ground water in the Camas Prairie, Camas and Elmore Counties, Idaho. The occurrence, movement, and utilization of ground water; and the recharge to, underflow in, and evapotranspiration and leakage from the aquifers underlying Camas Prairie were evaluated. Surface-water resources and ground-water discharge to streams also were appraised.

Field work on the hydrologic phases of the investigation was started in July 1957 and completed in November 1957. The author was assisted in the field by his colleagues, E. G. Grosthwaite and K. H. Fowler. The geologic sections of this report was based largely on the geologic data collected in 1924 by Arthur M. Piper (1925).

ACKNOWLEDGMENTS

The cooperation of residents of Camas Prairie in supplying data and allowing measurements and tests to be made on their wells is greatly appreciated. Thanks are given to well drillers, especially Mr. Clarence H. Cole, who willingly supplied copies of drilling logs. The writer also wishes to thank Mr. T. T. Wokersien, treasurer of the village of Fairfield, who provided invaluable assistance and information.

LOCATION AND EXTENT OF THE AREA

Camas Prairie is in the southern part of Idaho, the central part of the prairie being about 55 miles north-northwest of Twin Falls and about 75 miles east-southeast of Boise (fig. 1). Most of the prairie lies in Camas County, but the west end is in Elmore County. The area studied during the present investigation includes that part of the drainage basin of Camas Creek in Tps. 1 and 2 S., Rs. 11–17 E., and covers an area of about 300 square miles.

PREVIOUS INVESTIGATIONS

A study of the ground-water conditions of Camas Prairie was made by Piper (1925). Most of the conclusions reached as a result

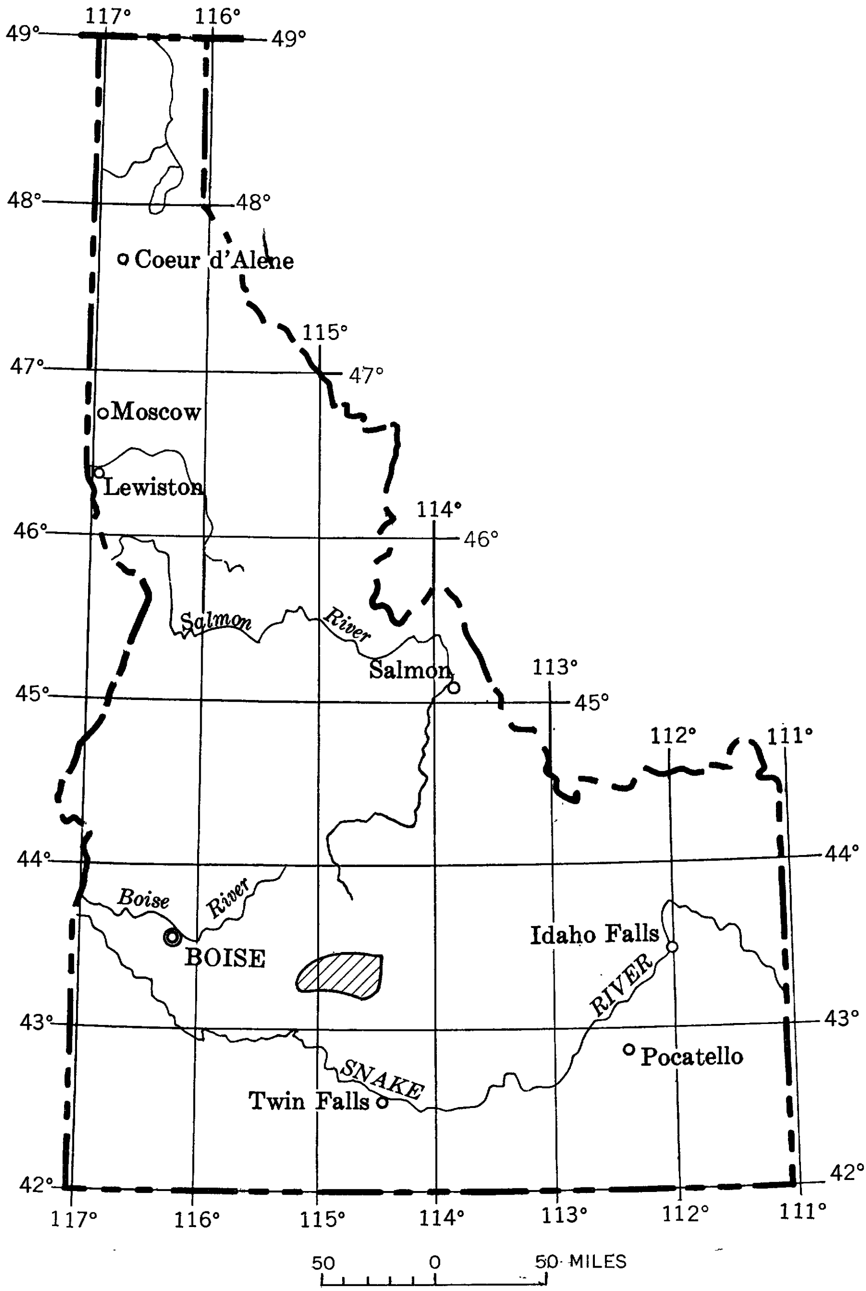

FIGURE 1.—Index map of southern Idaho showing area included in this report.

of Piper's investigation are applicable at present. This report contains a résumé of the geologic data presented in the above-mentioned report and many of the logs given in table 4 were taken from Piper's report.

WELL-NUMBERING SYSTEM

The well-numbering system used in Idaho indicates the locations of wells within the official rectangular subdivisions of the public lands, with reference to the Boise base line and meridian. The first two segments of a number designate the township and range. The third segment gives the section and is followed by two letters and a numeral, which indicate the quarter section, the 40-acre tract, and the serial number of the well within the tract. Quarter sections are

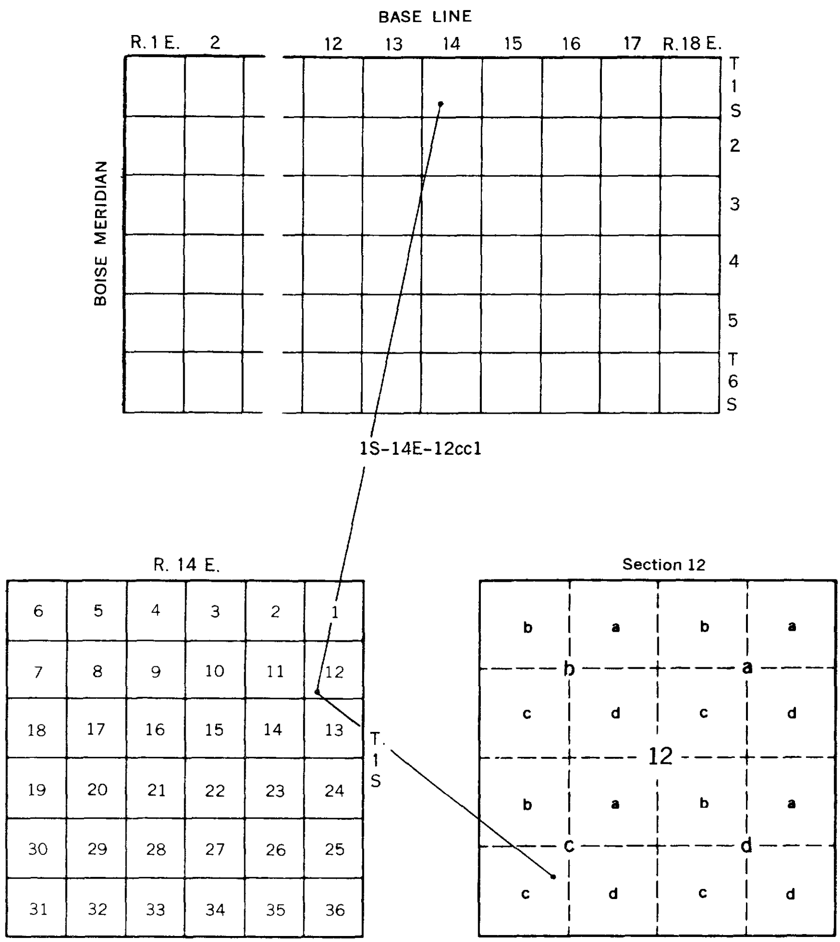

FIGURE 2.—Well-numbering system.

lettered a, b, c, and d in counterclockwise order, from the northeast quarter of each section. (See fig. 2.) Within the quarter sections 40-acre tracts are lettered in the same manner. Well 3S–32E–12cc1 is in the SW¼SW¼ sec. 12, T. 3 S., R. 32 E., and is the well first visited in that tract.

GEOGRAPHY

CLIMATE

The climate of Camas Prairie is semiarid, characterized by low precipitation, high evaporation, and large daily fluctuations in temperature. Precipitation is greater in the mountainous areas bordering the prairie. The average growing season is short, about 80 days in the greater part of the prairie. The prevailing wind is from the west.

PRECIPITATION

The U.S. Weather Bureau has recorded precipitation at Hill City, near the west end of the prairie, at Fairfield near the central part of the prairie, at Soldier north of Fairfield, and at Soldier Creek Ranger Station in the mountainous area north of Soldier. The following table, showing average monthly and annual precipitation data for these weather stations, was compiled from records of the U.S. Weather Bureau. The precipitation at the Solider Creek Ranger Station is nearly 50 percent greater than that measured at the stations on the prairie.

The months of greatest precipitation are January, February, March, May, November, and December, each having more than 1 inch. July, August, and September are the months of least precipitation, each generally having less than half an inch. Taking into considera-

Average monthly and annual precipitation at weather stations in and near Camas Prairie

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

	Fairfield	Soldier	Hill City	Soldier Creek Ranger Station
Altitude	5,065	5,140	5,092	5,821
Years of record:				
Number of years	9	15	35	38
Dates	1949–58	1895–1910	1923–58	1910–48
January	3.06	2.67	2.32	3.53
February	2.12	2.34	1.92	3.21
March	1.24	2.08	1.30	1.94
April	.90	.61	.99	1.58
May	1.72	1.23	1.23	1.43
June	.83	.72	.80	1.18
July	.29	.40	.25	.59
August	.09	.48	.37	.54
September	.30	.50	.39	.75
October	.76	.99	1.07	1.69
November	1.48	1.89	1.69	2.78
December	2.59	1.91	2.33	3.59
Total annual	15.38	15.82	14.66	22.81

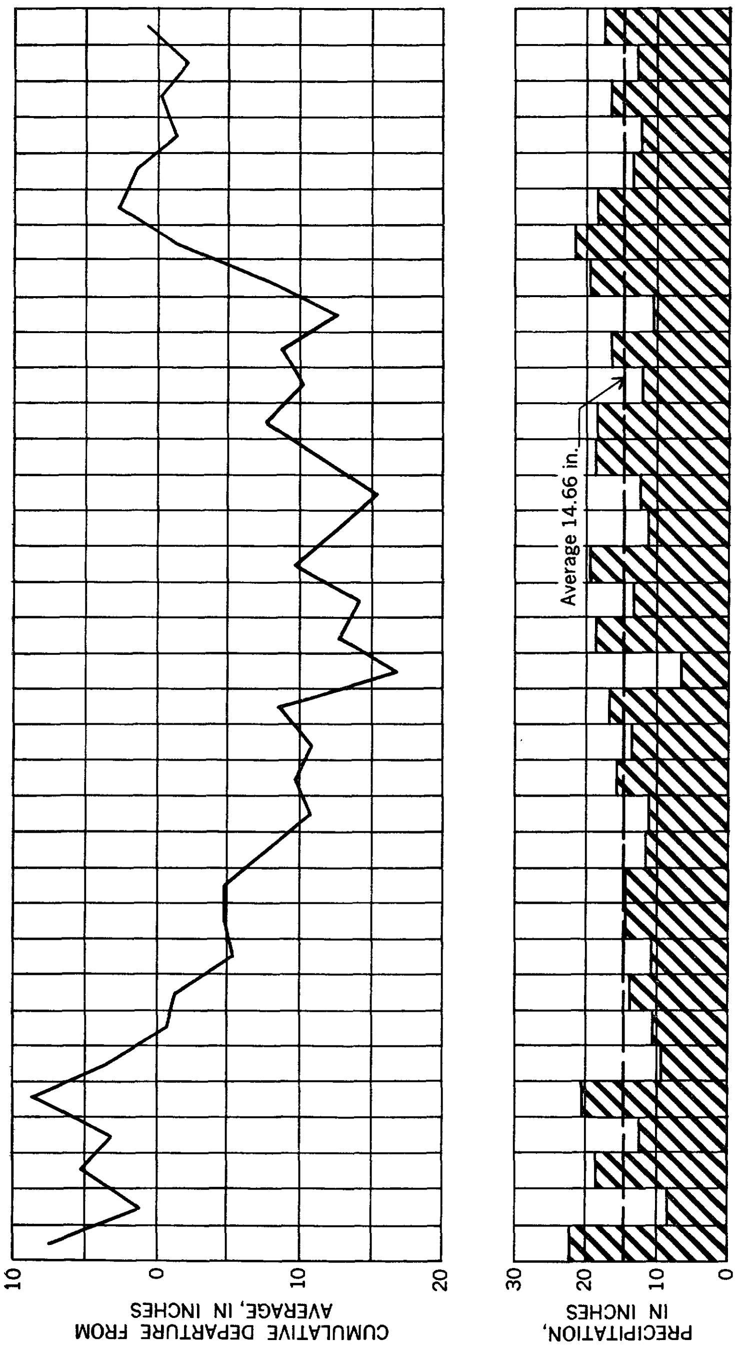

FIGURE 3.—Annual precipitation and cumulative departure from average at Hill City, 1923–57.

tion the data given in the table and topographic influences, the average annual precipitation on the area under study is estimated to be about 17 inches.

The annual precipitation at Hill City for the period 1923–57 and the cumulative departures from the normal annual precipitation for the same period are shown in figure 3. Climatic conditions at Hill City are considered representative for much of the prairie. The lowest annual precipitation at Hill City was 6.67 inches, recorded for the year 1939, and the highest was 22.17 inches measured in 1923. The downward slope of the graph of cumulative departure, during the 16-year period 1928–44, shows that in general the precipitation was below average and that the accumulated deficiency of precipitation was 15.53 inches. The slope of the graph is generally upward from 1944 through 1957, indicating a period of above-average precipitation.

The annual precipitation at the Soldier Creek Ranger Station for the period 1910–47 is shown in figure 4. The lowest precipitation was 13.45 inches in 1928, and the highest was 34.02 inches in 1927. The graph of the cumulative departure from the mean annual precipitation shows that in general the precipitation during the 12-year period 1928–39 was below average; the accumulated deficiency was about 10 inches. Precipitation during the period 1940–46 was above normal.

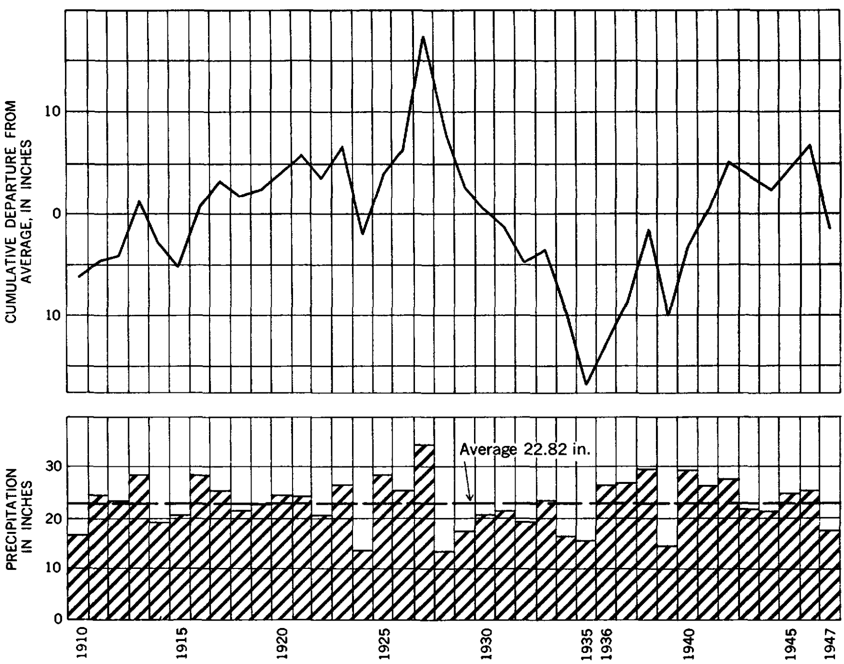

FIGURE 4.—Annual precipitation and cumulative departure from average at Soldier Creek Ranger Station, 1910–47.

The amount of water needed for irrigation increases during the years when the precipitation is below average. Therefore, precipitation data given above are significant because they indicate periods of below-average precipitation and reduction in the water available for crop use and for ground-water recharge.

TEMPERATURE

Average monthly and annual temperatures at Fairfield, Hill City, and Soldier Creek Ranger Station are given in the following table. Temperatures recorded by the U.S. Weather Bureau at stations on the prairie are generally lower than those at the Soldier Creek Ranger Station in the mountainous area north of the prairie. Minimum temperatures are usually recorded during January; July is the hottest month. The average annual temperature for the prairie is about 41° F.

Average monthly and annual temperatures for weather stations in and near Camas Prairie

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

	Fairfield	Hill City	Soldier Creek Ranger Station
Altitude	5,065	5,092	5,821
Years of record	6	25	15
January	17.1	15.3	20.1
February	18.7	19.6	24.3
March	26.6	27.1	31.7
April	41.2	40.2	42.2
May	50.6	49.9	49.8
June	56.7	55.8	56.0
July	65.2	65.8	66.1
August	63.1	61.3	65.3
September	56.5	53.9	56.3
October	45.6	44.2	46.5
November	30.4	30.2	32.7
December	22.2	20.2	25.2
Annual average	41.2	40.3	43.0

The highest temperatures recorded at the Fairfield and Hill City stations are 96° F and 102° F, respectively, and the lowest temperatures are −35° F and −44° F, respectively. Corresponding extremes at the Soldier Creek Ranger Station are 100° F and −34° F.

PHYSIOGRAPHY AND DRAINAGE

Camas Prairie is in the Northern Rocky Mountain physiographic province (Fenneman, 1931) and is an eastward-trending intermontane valley about 40 miles in length, averaging about 8 miles in width. It is filled in large part with detrital material washed in from the adjacent mountains. The sediments were deposited when lava flows dammed the eastern outlet of the valley, possibly beginning in Pliocene time and continuing into the Pleistocene and Recent.

The prairie consists of a very gently undulating valley floor that slopes southeastward about 7 feet per mile from an altitude of 5,200 feet at its west end. Prominent broad alluvial fans slope southward about 40 feet per mile from the foot of the mountains north of the prairie.

Soldier Mountains on the north side of the prairie is the most prominent mountain bordering the valley. Rugged ridges rise to an altitude of 10,095 feet above mean sea level at Smoky Dome, about 7 miles north of the prairie. The Mount Bennett Hills on the south rise to an altitude of about 6,800 feet. Flat-topped ridges, slightly dissected by erosion, separate the prairie from the Snake River Plain to the south. On the west, summits, having altitudes of about 6,200 feet, separate the prairie from the basin of the South Fork of the Boise River.

The prairie terminates 8 miles east of Fairfield against an undulating basalt plain, having an average altitude of 5,000 feet above mean sea level. The plain trends southeastward 15 miles east of Fairfield and joins the main Snake River Plain 24 miles southeast of Fairfield at an altitude of about 4,900 feet above mean sea level.

Camas Creek has a drainage area of about 648 square miles (above a gaging station near the east border of the prairie) and discharges into the Big Wood River, which in turn is tributary to the Snake River. Camas Creek is sluggish and meanders eastward along the south border of the prairie (pl. 1) at a gradient of about 5 feet per mile between Hill City and Blaine. Below Blaine the creek has cut a deep, rugged canyon into basalt. However, the gradient from Blaine to the Big Wood River is only slightly greater than that above Blaine.

Streams from the north tributary to Camas Creek include Elk, Deer, Soldier, Threemile, Corral, Chimney, and Sheep Creeks. They are ephemeral and flow during only part of the year. During the summer their entire flow is lost by infiltration along the channel reach across the alluvial fans at the foot of the mountains. During the late autumn, as precipitation increases over the mountains and evapotranspiration decreases, the streams begin to discharge water into Camas Creek and generally flow until the following summer. Willow Creek, a tributary east of Blaine, is deeply incised into sediments and has a small perennial flow. A few ephemeral streams drain the northern slope of the Mount Bennett Hills.

ECONOMIC DEVELOPMENT

According to the U.S. Census of Population, the population of Camas County was 1,079 in 1950, 281 less than in 1940. The populations of Blaine, Corral, Fairfield, Hill City, and Manard precincts were 54, 127, 736, 80, and 82, respectively. The village of Fairfield, the county seat of Camas County and business center of the prairie, had a population of 502 in 1950. Camas Prairie is served by the Hill City Branch of the Union Pacific Railroad, from the south by the asphalt-surfaced State Route 46, and from the east and west by graded State Route 68. The agricultural economy of the area is based chiefly on the production of wheat without the aid of irrigation (dry farming). Livestock is grazed in the mountainous areas bordering the prairie during the summer and on the prairie during the autumn and winter.

GEOLOGY

The rocks of Camas Prairie and of the surrounding mountains can be divided into two general groups on the basis of their control of the occurrence and movement of ground water: bedrock, consisting of consolidated sedimentary and igneous rocks in the mountains and extending beneath the prairie, and valley fill, consisting of alluvial and lake deposits. The consolidated rocks exposed in the mountainous areas adjacent to the prairie are for the most part intrusive and extrusive igneous rocks, ranging in age from Cretaceous to Quaternary. Sedimentary rocks of Carboniferous age are exposed in one small area in the northeastern part of the drainage basin (pl. 1). Camas Prairie is regarded as a structural depression that has been filled by alluvial fill mainly of Pleistocene age. The alluvium accumulated behind lavas of Pliocene and Pleistocene age that barred the eastern outlet of the basin. Well logs show that the alluvial fill is more than 500 feet thick. The areal distribution of the valley-fill deposits and the consolidated rocks is shown in plate 1. The broad structural aspects of the valley area have been described by Piper (1925):

> Camas Prairie occupied part of a zone within which recurrent adjustments have taken place in response to those regional earth stresses which have produced broad warpings in the Snake River Plain to the south and extensive uplift of the central Idaho mountain mass to the north. Adjustment has been by high-angle faulting.

CONSOLIDATED ROCKS AND THEIR WATER-BEARING PROPERTIES

The Idaho batholith and broadly related rocks bordering the prairie northwest and southwest of Fairfield are medium- and coarse-grained crystalline rocks and include quartz monzonite, granodiorite, quartz diorite, and granite. The Challis volcanics and associated rocks, consisting for the most part of andesite, dacite, and rhyolite, are exposed in the ridges of the mountains north and northeast of Fairfield. The silicic volcanic rocks, which occur in the Mount Bennett Hills south of the prairie, are predominantly dacite and latite and include beds of welded tuff. At some places the silicic volcanic rocks are capped by basalt.

The formations mentioned above yield small to moderate amounts of ground water to wells and springs from weathered zones and contain a complex system of fractures that permeate the otherwise dense and relatively impervious rocks. Yields are sufficient for stock and domestic purposes but are rarely more than 50 gpm. The rocks occur beneath the valley fill of the prairie and are saturated to great depth. However, because of their low permeability, movement of water through them is very slow.

The Snake River basalt of Pliocene to Recent age is exposed in places along the ridges and rolling hills that bound Camas Prairie to the east, west, and south (pl. 1). The formation consists of many lava flows spread out in successive sheets. The rocks are fine grained to dense, dark gray to black, and basaltic. The youngest basalt of the formation is exposed along the southeast margin of the prairie and in the deep trench occupied by Camas Creek east of the prairie. The logs of wells 1S–14E–36ab1, 1S–15E–15bc1, 1S–15E–16db1, 1S–15E–19cc1, 1S–15E–21ad1, 1S–15E–27ba1, and 1S–16E–3dc1 show that the Snake River basalt extends 1 to 3 miles beneath the valley fill northwest of its exposed margin (pl. 1, fig. 5). Data collected for wells near the buried margin suggest that the basalt terminates along precipitous frontal slopes. (However, the frontal slope shown in figure 5 is much more steeply inclined than it actually is because of exaggeration of the vertical scale.) The Snake River basalt is 188 feet thick in well 1S–15E–21ad1, is overlain by 92 feet of alluvial deposits, and rests on clay at a depth of 280 feet.

An unbroken unit of basalt is relatively impermeable, but porous, permeable zones along contacts between separate flows, joints, and other crevices yield large amounts of ground water to wells. The Snake River basalt yields large amounts of water near the east margin of the prairie. Well 1S–15E–16db1 extends only 4 feet into the basalt and yielded 1,280 gpm with 35 feet of drawdown. Well 1S–15E–21ad1 was drilled into 188 feet of basalt and yielded 1,350 gpm with 12 feet of drawdown.

VALLEY-FILL DEPOSITS AND THEIR WATER-BEARING PROPERTIES

During the Pliocene and Pleistocene epochs, lava flows blocked the eastern outlet of the structural basin that forms the Camas Creek drainage area. Large quantities of sedimentary material or valley fill, derived by erosion from rocks in the adjacent mountain areas, were deposited in the basin while Camas Creek was cutting a new channel in the lava barrier. The sediments of the valley fill are poorly sorted and range in grain size from clay to boulders. The

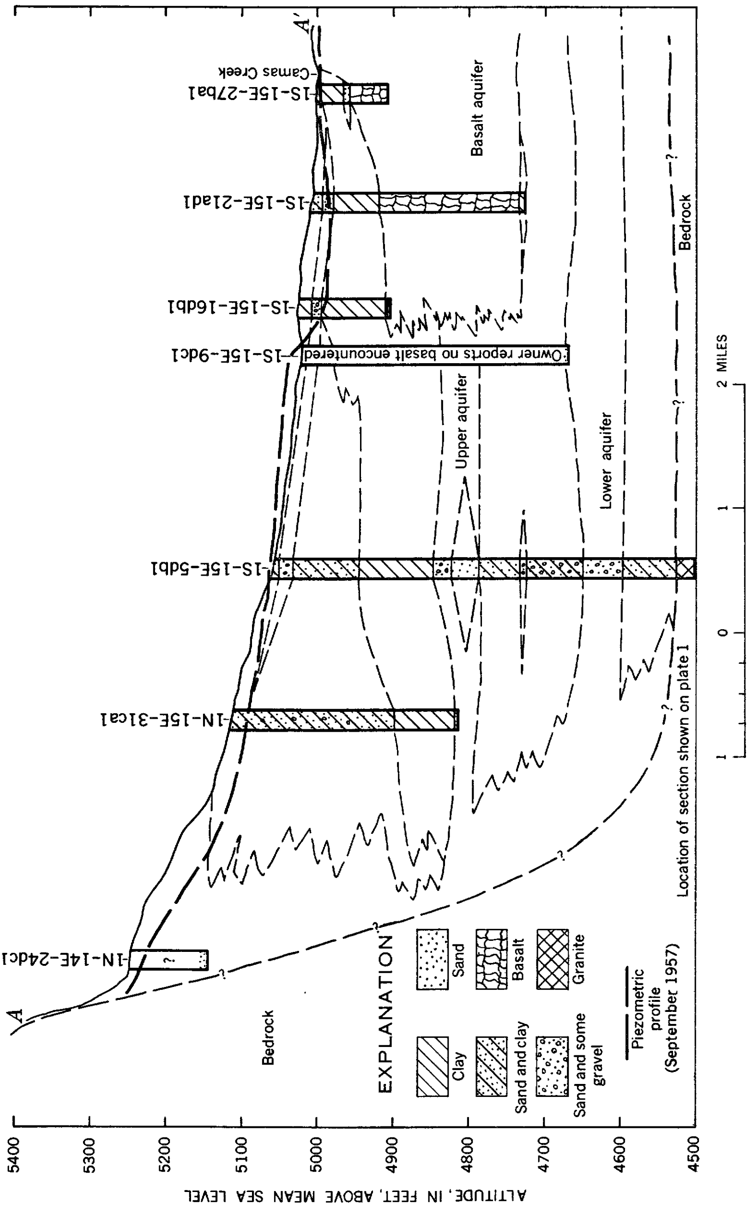

FIGURE 5.—Geologic cross section *A–A'* and profile of piezometric surface of valley-fill deposits and basalts.

materials were carried into the basin by streams and sheet runoff, the coarse debris was deposited at the base of the mountains to the north, and the fine-grained material was deposited farther south as the transporting power of the water diminished. Thus, in general, the grain size of the valley fill decreases from coarse at the foot of the northern mountains to fine south of the center of the prairie (figs. 5 and 6). Conditions of deposition were complex, and as a result the texture and character of the valley fill change markedly from place to place both horizontally and vertically. Lens-shaped and fingerlike deposits of clay, silt, sand, and gravel are common. However, the valley fill is preponderantly fine grained, as shown by the logs of wells in table 4.

A clay unit averaging 90 feet in thickness is reported in drillers' logs of most wells in the prairie, indicating that a lake of considerable size existed in the Camas Creek basin, probably during the Pleistocene epoch. The extensive clay deposit is between the average depths of 120 and 210 feet below the land surface. According to the logs of 21 wells scattered over the prairie, the upper surface of the clay has an average elevation of 4,930 feet above mean sea level; the base has an average elevation of 4,840 feet above mean sea level. The relief on the upper and lower surfaces is not great (less than 50 feet). The thickness of the clay decreases near the south margin of the prairie beneath Camas Creek.

In well 1S–16E–3dc1 at the eastern outlet of the prairie basalt was penetrated between the depths of 105 and 145 feet. The top of the basalt at the well is 4,939 feet above mean sea level, about the same altitude (4,930) as the average upper surface of the clay bed. Southeast of well 1S–16E–3dc1 the exposed basalt has an altitude of more than 5,000 feet above mean sea level. These data suggest that the basalt in the vicinity of well 1S–16E–3dc1 represents a spillway eroded into one of the basalt dams, behind which the lake was formed.

The entire thickness of the valley fill has been penetrated in two wells, 1S–14E–9db1 and 1S–15E–5db1, in which bedrock was found at depths of 497 and 550 feet below the land surface, respectively. The maximum thickness of the valley fill in other areas is not known; however, according to the logs or reports of owners of wells 2S–12E–5bb1, 1S–12E–34dc1, 1S–12E–14ba1, 1S–12E–13ba1, 1S–13E–8cc2, 1S–13E–14da1, 1S–13E–27cc1, and 1S–14E–22db1, the maximum thickness is estimated to be not less than 300, 450, and 500 feet in the areas south of Hill City, Corral, and Fairfield, respectively.

Sand and gravel in the valley fill are important aquifers in the Camas Prairie and yield ground water in quantities sufficient for irrigation or other large-scale use. Logs of wells show that permeable

633992—62——2

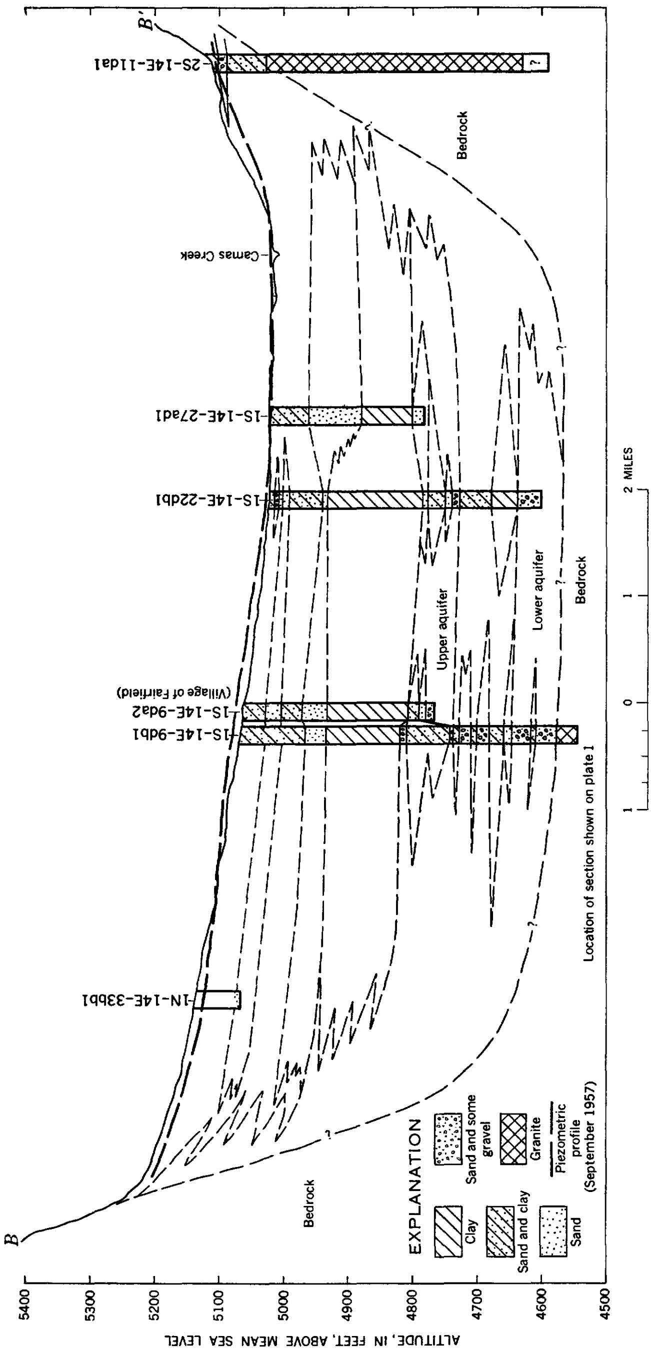

FIGURE 6.—Geologic cross section B-B' and profile of piezometric surface of valley-fill deposits.

sand and gravel are found in two zones below the clay unit; above the clay are alternating beds of sand, sandy silt, silt, and clay, which are only moderately permeable. Fine- to medium-grained sand and some gravel interbedded with relatively thin lenses of clay lie immediately below the main clay unit (fig. 6). The thickness of this zone, herein termed the "upper artesian aquifer," is variable but averages about 50 feet. Permeable sand and gravel, interbedded with lenses and layers of clay and averaging about 85 feet thick, occur at the base of the valley fill and are called the "lower artesian aquifer." The upper and lower aquifers are separated by beds of sandy and silty clay that are relatively impermeable. The bulk of the sediments of the two aquifers are rather fine grained, and therefore their permeability is low.

GROUND WATER

OCCURRENCE

The surface below which all the openings of an aquifer are saturated with water under hydrostatic pressure is the water table. The relief of the water table is less than but generally similar to that of the land surface. The water in aquifers that have a water table is unconfined, and when the water table is lowered some of the aquifer is dewatered. Conversely, unsaturated materials become saturated when the water table rises. Ground water that is thus unconfined is said to occur under water-table conditions.

A confining bed or layer of relatively impermeable material may overlie an aquifer. If recharge is derived at an altitude higher than the base of the overlying impermeable beds and the aquifer is completely saturated with the water exerting an upward pressure on the base of the confining bed, then water is said to occur under artesian conditions. If a well is drilled through the confining bed and into the aquifer, the water in the well will rise above the top of the aquifer. Water may or may not flow over the top of the well. The imaginary surface to which water will rise under artesian conditions, as defined by water levels in a number of wells, is the piezometric surface. When artesian pressure, and hence the piezometric surface, are lowered by the pumping or free flow of wells, the aquifer is not dewatered but is still completely full. The water discharged is derived by the compaction of the aquifer and associated beds, by the expansion of the confined water itself, and by water movement from the recharge area.

Water-table conditions occur only in the shallow deposits of the valley fill. Wells drilled to depths greater than about 40 feet in the valley-fill deposits reach lenses and layers of clay and silt that tend to confine the water. The water table generally is very near the surface of the prairie. The depth to water in 26 shallow wells inventoried in

1957 ranged from 1 to 19 feet below the land surface and averaged about 7 feet.

Ground water in the deeply buried deposits (upper and lower artesian aquifers) below the extensive clay unit and in the Snake River basalt occurs under artesian conditions. Water in the sand and gravel deposits above the clay but below a depth of about 40 feet also is under artesian pressure. Artesian pressure over most of the prairie is sufficient to cause wells to flow. The head above land surface in the flowing wells seldom exceeds 10 feet. The discharge of most flowing wells is small; flows of about 1 gpm are common.

The boundary of the area within which wells will flow is very irregular, owing largely to topographic features.

MOVEMENT

Ground water moves downgradient at right angles to the water-table contours or to isopiestic lines (lines of equal elevation on the piezometric surface). Piper (1925) prepared a map showing the shape of the water table under the prairie. In general, Piper's water-table map and studies made by the author during the recent investigation show that the ground water in the shallow deposits of the valley fill is moving southeastward from the upland areas bordering the mountains toward Camas Creek and other effluent (gaining) streams. The slope of the water table is controlled in part by the topography and in part by the permeability of the valley-fill deposits.

The approximate piezometric surface of the artesian aquifers of Camas Prairie is shown on plate 1. The map was prepared from water-level measurements largely made in September 1957. The altitudes of the land surface at the wells were determined by means of altimeters. The upper and lower artesian aquifers have slightly different heads at the same location; the lower aquifer was observed to have the higher head at most places. Only a few wells extend into the lower aquifer, and it was not practical to map the piezometric surfaces of both artesian aquifers separately. On the basis of measured water levels and data reported by well drillers on water levels at different depths, it is probable that the piezometric surfaces of the upper and lower aquifers are in general very similar. Accordingly, the contours on plate 1 show the approximate directions of movement of ground water and the average hydraulic gradients of the piezometric surfaces in both aquifers underlying the clay bed.

Ground water in the deeply buried aquifers moves from the upland areas at the foot of the mountains and hills enclosing the prairie toward a pronounced eastward-trending trough in the piezometric surface, whose axis roughly coincides with the course of Camas Creek.

Ground water moves eastward as underflow in the trough down the hydraulic gradient.

The clay unit overlying the upper artesian aquifer in the area of the trough impedes but does not completely prevent vertical movement of ground water from the lower part of the valley fill to the shallow deposits. There is a large amount of vertical seepage of water from the deeply buried aquifers, and only a part of the water moving toward and in the trough is transmitted as underflow out of the prairie.

The average slope of the piezometric surface is about 20 feet per mile, but gradients are steeper near the foot of the mountains where the thickness of the valley fill decreases rapidly. The gradient of the piezometric surface is controlled also by the permeability of the deposits. For example, the gradient decreases abruptly in the vicinity of the contact between the valley-fill deposits and the basalt at the eastern outlet of the prairie (fig. 5), because the permeability of the basalt is much greater than that of the valley fill.

A significant feature shown by the contours of the piezometric surface is the bending of contours around areas of heavy withdrawal. Pumping from wells at and near Fairfield has distorted the isopiestic lines, so that the 5,080-foot contour has moved about three-quarters of a mile northwest from its estimated original position in response to withdrawals from wells of the Church of Jesus Christ of Latter Day Saints and the village of Fairfield. Contours in the vicinity of heavily pumped irrigation wells 1S–15E–5db1, 1S–15E–16db1, and 1S–15E–21ad1 also are distorted. Several domestic and stock wells, flowing at rates of 20 to 40 gpm, also have distorted the isopiestic lines. Cones of depression exist around flowing stock and domestic wells on the prairie, but the cones could not be contoured because there were not enough wells in which water levels could be measured.

The piezometric surface is above the water table except near the foot of the mountains where water-table conditions prevail and the piezometric surface merges with the water table. The isopiestic lines in plate 1 are dashed in areas where insufficient observation-well data are available for an accurate interpretation of the position of the contours.

HYDRAULIC PROPERTIES

The hydraulic properties of an aquifer are expressed in terms of the coefficients of transmissibility, permeability, and storage. The coefficient of transmissibility, T, is defined as the rate of flow of water, in gallons per day, through a vertical strip of the aquifer 1 foot wide and extending the full saturated thickness under a hydraulic gradient of 1 foot per foot and at the prevailing temperature of the water. The field coefficient of permeability, P_f, is defined as the rate of flow of water, in gallons per day, through a cross-sectional area of 1 square foot of the aquifer under a hydraulic gradient of 1 foot per foot and at the prevailing temperature of the water. The coefficient of transmissibility indicates the capacity of the aquifer as a whole to transmit water. The coefficient of permeability indicates the capacity of a unit cross section of the aquifer to transmit water, and the average field permeability is equal to the coefficient of transmissibility divided by the saturated thickness of the aquifer, in feet. The coefficient of permeability is useful in comparing relative transmissive capacities of aquifers of different thicknesses. The storage properties of an aquifer are expressed by its coefficient of storage. The coefficient of storage, *S*, is defined as the volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface and is expressed as a decimal fraction.

AQUIFER TEST

An aquifer test was made on well 1S–14E–9db1 to determine the hydraulic properties of the lower aquifer. The well was allowed to flow for a period of 4 hours from 1:00 p.m. until 5:00 p.m. on November 7, 1957. The flow decreased continually during the test from about 61 gpm to 50 gpm. However, the rate of decrease in flow after about 30 minutes was very small, and for practical purposes the discharge of the well was constant during most of the flowing period. The well was plugged at 5:00 p.m. and measurements of water-level recovery were made until 8:40 p.m. Water-level and atmospheric-pressure data for the test are given in figure 7.

Water-level fluctuations caused by changes in atmospheric pressure during the recovery period were insignificant. After flow stopped, the recovery of the water level was plotted against time on semilog paper. The slope of the straight line through the plotted points and the modified nonequilibrium formula (Ferris, 1951) were used to determine the coefficient of transmissibility as shown in figure 8. The computed T is about 30,000 gpd per foot. The coefficient of storage of the aquifer cannot be determined from the results of the tests because well loss (loss of head through friction as the water enters and travels up the well) is appreciable and the effective radius of the well is unknown. However, ground water in the vicinity of the well occurs under artesian conditions, and the coefficient of storage of the aquifer undoubtedly is in the artesian range, which generally is on the order of 0.001 to 0.00001.

According to the driller, the casing in well 1S–14E–9db1 is perforated in the lower aquifer between the depths of 372 and 495 feet; the

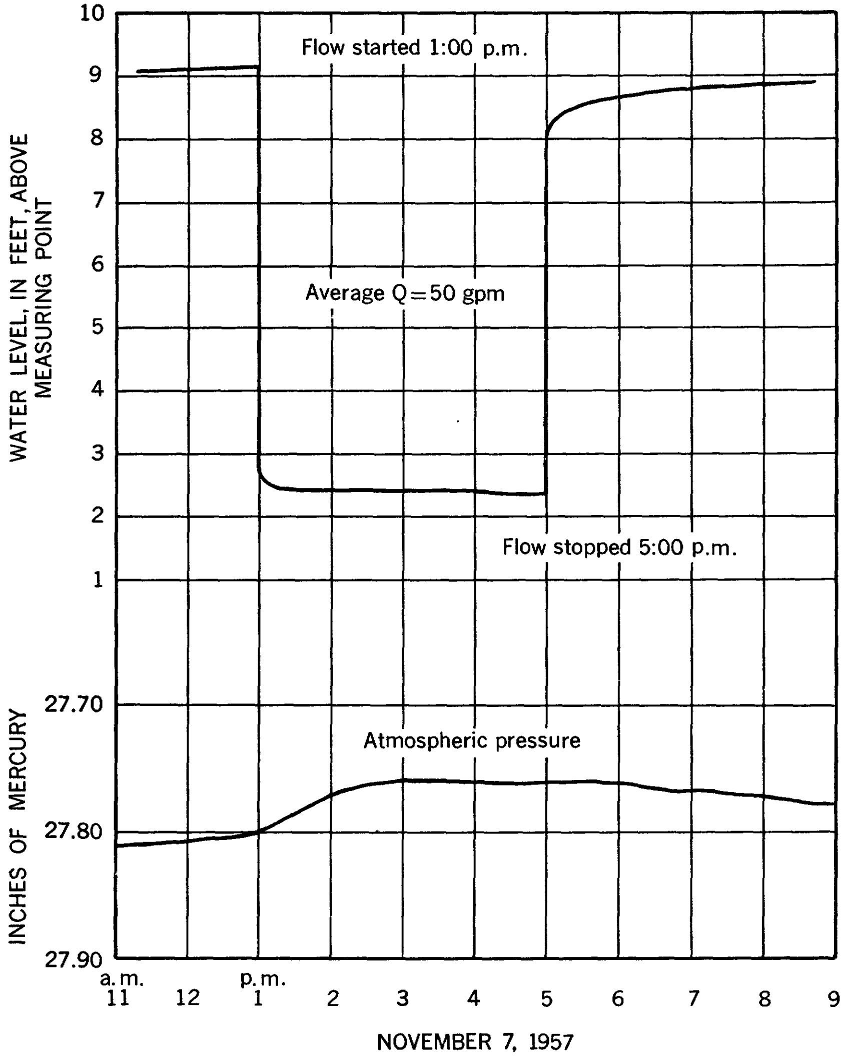

FIGURE 7.—Water level in well 1S–14E–9db1 and atmospheric-pressure fluctuations during the aquifer test.

top of the aquifer is at 371 and the base is at 497 feet. Thus the thickness of the strata tested is 126 feet. The total thickness of strata below the main clay unit is estimated to be about 270 feet. Assuming that the transmissibility of the 126-foot interval sampled in the aquifer test on well 1S–14E–9db1 is representative of the entire thickness of strata below the clay unit (including both the upper and lower artesian aquifers), the total transmissibility of these strata would be roughly 70,000 gpd per foot.

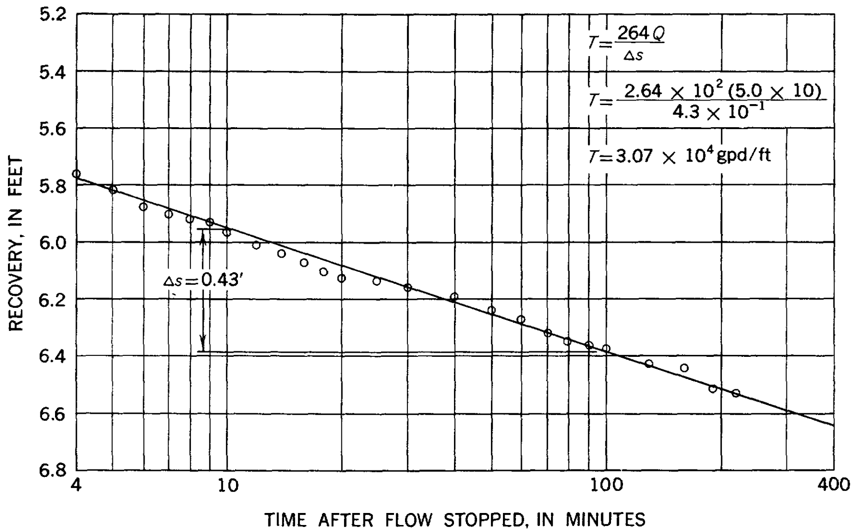

FIGURE 8.—Time-recovery graph for well 1S-14E-9db1.

UNDERFLOW

The quantity of water percolating through a given cross section of an aquifer is proportional to the hydraulic gradient and the coefficient of transmissibility and can be computed by using the following formula (Ferris, 1951):

$$Q=TIL \qquad (1)$$

in which Q is the discharge, in gallons per day; T is the coefficient of transmissibility, in gallons per day per foot; I is the hydraulic gradient, in feet per mile; and L is the width of the cross section, in miles, through which discharge occurs.

The underflow from Camas Prairie was estimated from a study of the flow through the upper and lower artesian aquifers between the 5,040 and 5,020 isopiestic contours (pl. 1) near the eastern outlet of the prairie. The coefficient of transmissibility of the section of valley-fill deposits under study is estimated to be roughly 70,000 gpd per foot. The average hydraulic gradient between the 5,040 and 5,020 isopiestic contours is 23 feet per mile. The average length of the contours between flow lines limiting the cross section through which most of the underflow occurs is about 12 miles. Using the data given above and equation 1, the underflow was computed to be about 1.9×10^7 gpd, or about 20,000 acre-feet per year.

Water-level data for wells at Magic show that most of the underflow from the prairie discharges into Camas Creek or Magic Reservoir in Tps. 1–2 S., R. 17 E. Little, if any, of the underflow reaches the Snake River Plain.

LEAKAGE THROUGH THE CLAY BED

As explained earlier, the clay bed overlying the upper artesian aquifer impedes but does not prevent vertical movement of ground water from the deposits below the clay bed to the shallow valley-fill deposits. The order of magnitude of the vertical leakage was determined by comparing the underflow through two sections of the aquifer. The underflow through the upper and lower aquifers between the 5,080 and 5,060 isopiestic contours was computed to be 3.6×10^7 gpd by the same method (equation 1) used to determine the underflow between the 5,040 and 5,020 isopiestic contours in the preceding section of this report. The difference, 1.7×10^7 gpd or roughly 20,000 acre-feet per year, between the underflow through sections 1 and 2 is the approximate amount of vertical leakage through the clay bed between the 5,060 and 5,040 isopiestic contours.

The average thickness of the clay bed in the area between the 5,060 and 5,040 isopiestic contours is 90 feet. There is an average head differential of 13 feet between the top and bottom surfaces of the clay bed in the area under study. The surface area of clay between the 5,060 and 5,040 isopiestic contours, through which leakage occurs, is about 30 square miles. The rate of leakage related to head differential is given by the variant of Darcy's law (Ferris, 1951).

$$Q_d = P'IA \qquad (2)$$

where Q_d is the discharge, in gallons per day, through a specified area of confining beds, P' is the vertical field permeability of the confining bed, in gallons per day per square foot; I is the hydraulic gradient imposed on the confining bed (head differential divided by thickness of clay bed), and A is the area of confining bed through which leakage occurs.

Using the data mentioned above in equation 2 and solving for P', the leakage of water in the amount of 1.7×10^7 gpd requires a vertical field permeability of about 0.2 gpd per square foot. Material that has a vertical permeability of 0.2 gpd per square foot is listed by Wenzel (1942, p. 13, lab. No. 2,278), and consists of about 49 percent clay and about 45 percent silt (by weight). This suggests that the material forming the confining bed in this area may be similar in composition to that described by Wenzel.

RECHARGE

The sources of recharge to the upper and lower artesian aquifers are direct precipitation on the intake area and downward percolation of stream runoff. Much of the water that the tributary streams bring to the basin is readily absorbed by the valley-fill deposits as the streams cross the intake area. Recharge occurs on the alluvial fans lying between the base of the mountain and the valley floor in areas where the piezometric surface is at or below the water table in the shallow valley-fill deposits and where the clay beds pinch out. Most of the recharge occurs north of the Boise base line. The intake area is estimated to be about 75 square miles.

The annual recharge to the upper and lower artesian aquifers balances the underflow from the valley and the leakage through the clay bed. Underflow and leakage were estimated in preceding sections of this report and total about 40,000 acre-feet per year, or about 10 inches of water over the intake area. The average annual precipitation on the intake area is about 17 inches.

If all the recharge were derived directly from precipitation, this would mean that 59 percent of the average annual precipitation would have to percolate to the upper and lower artesian aquifers. It is probable, however, that more than half the recharge (about 25,000 acre-feet per year, or 6 inches of water over the intake area) occurs by the downward percolation of stream runoff. Recharge from direct precipitation on 75 square miles of recharge area is estimated, therefore, to be about 4 inches, or 15,000 acre-feet per year.

EVAPOTRANSPIRATION

The term "evapotranspiration" is considered to include all water losses from an area by transpiration and by evaporation from water surfaces, soil, snow, ice, and vegetation, Evapotranspiration from the intake area is equal to the precipitation minus the water that escapes the area by ground-water underflow and surface runoff. The average annual surface runoff from the intake area is estimated to be about 8,000 acre-feet, or about 2 inches of water over the intake area. Recharge from precipitation to the upper and lower artesian aquifers was estimated in the preceding section to be 4 inches. The average annual rate of evapotranspiration is, therefore, 17 minus 6, or about 11 inches of water over the intake area, or about two-thirds of the average annual precipitation. Although the amount of evapotranspiration is based on estimated values of surface runoff and recharge to the upper and lower artesian aquifers from precipitation, it is believed to be of the proper order of magnitude.

DEVELOPMENT OF WELLS

PRESENT STATUS

Prior to 1923 ground water in the prairie was developed by means of only a few stock and domestic wells. About 50 deep wells were drilled in the upper aquifer during the autumn of 1923 and the spring and summer of 1924. Most of the wells were flowing at that time; their yields ranged from 2 to 100 gpm and the average discharge rate of

39 flowing wells was 20 gpm. The wells drilled on Camas Prairie in 1923 and 1924 were cased only into the top of the clay bed overlying the upper artesian aquifer. As a result, most of the wells clogged, as fine sand caved into them. Flows decreased greatly within a few weeks of the time they were drilled. Total withdrawal of ground water from the prairie in 1924 is estimated to have been about 600 acre-feet.

Development of ground water for irrigation on a significant scale began in 1953 with the drilling of well 1S–14E–22db1. Later in 1953, large-capacity irrigation wells 1S–15E–5db1, 1S–15E–16db1, and 1S–15E–21ad1 were drilled. Wells 1S–14E–9db1, 1S–16E–3dc1, and 1S–16E–4cb1 were completed in 1954 and 1955. The estimated pumpage from irrigation wells on the prairie in 1957 was about 1,300 acre-feet. The water was withdrawn largely from 7 wells during an average 60-day pumping season. About 960 acres of wheat, alfalfa, hay, clover, and barley were irrigated.

The public water supply of Fairfield is obtained from wells 1S–14E–9da2 and 1S–14E–10cc1, which are about 300 feet deep. Flow from the wells is sufficient to meet the municipal demand during most of the year. However, in the summer the wells are pumped occasionally when the demand increases because of irrigation of lawns and gardens. The water supply of Fairfield is not metered. On the basis of a per capita consumption of 100 gpd, the municipal use in 1957 is estimated at about 50 acre-feet. Water is obtained from individual privately owned wells in Corral and Hill City.

An inventory of the flow from wells on the prairie was made during the summer and autumn of 1957. The discharge from 30 wells was measured. Flows ranged from a trickle to 50 gpm. Wells 1S–14E–22db1, 1S–15E–7dd1, 1S–13E–14da1, and 1S–12E–34dc1 had the largest discharges, of about 50, 40, 20, and 40 gpm, respectively. Springs and seeps are found along the flanks of the mountains bordering the prairie, at the head of the prairie, and along the east margin of the prairie (pl. 1). The total discharge from flowing wells and springs on the prairie in 1957 is estimated to have been about 200 acre-feet.

Total discharge of ground water for irrigation, municipal, domestic, and stock use in Camas Prairie in 1957 was roughly 2,000 acre-feet.

YIELDS OF WELLS

The yield of a well may be expressed in terms of its specific capacity, which is commonly expressed as the yield in gallons per minute per foot of drawdown. The specific capacity of a well varies with the duration of pumping, and also to some extent with the pumping rate. Specific-capacity data for wells in Camas Prairie are summarized in table 1.

TABLE 1.—*Specific-capacity data*

Well	Pumping rate (gpm)	Drawdown (feet)	Duration of test (hours)	Specific capacity (gpm per ft)	Date of test	Aquifer
1S-14E-9db1	1,100	60	18	18	1954	Sand.
9db1	50	6.5	4	8	11-7-57	Sand.
1S-15E-16db1	1,280	35	4	37	1953	Basalt.
21ad1	1,350	12	3	112	1953	Basalt.
1S-16E-3dc1	700	125	10	6	1955	Basalt and sand.
4cb1	900	40	4	22	1955	Sand.

The casing in well 1S–14E–9db1 is perforated in the lower aquifer and well 1S–16E–4cb1 is developed in the upper aquifer. Water in both aquifers occurs under artesian conditions. The specific capacities of these two wells, 18 and 22 gpm per foot, respectively, are nearly the same, indicating that the hydraulic properties of the upper and lower aquifers are about the same. The value of T (computed from the results of the aquifer test) of 30,000 gpd per foot and an assumed value of S of 0.001 were substituted in the nonequilibrium formula developed by Theis (1935), and the theoretical specific capacity of a well 12 inches in diameter for a pumping period of 24 hours was computed to be about 15 gpm per foot. Using the same value for T, and assuming 0.00001 for S, the theoretical specific capacity is 12 gpm per foot. The specific capacities of wells 1S–16E–4cb1 and 1S–14E–9db1 are a little greater than the theoretical specific capacity, suggesting that the yield of these wells, measured upon completion of the wells, is about as high as aquifer conditions permit.

The specific capacity of well 1S–14E–9db1 decreased from 18 gpm per foot in 1954 to 8 gpm per foot in 1957. Fine sand apparently moved into the formation surrounding the well and into the well and partly plugged it because of the high velocities associated with pumping the well at high rates.

Wells 1S–15E–16db1 and 1S–15E–21ad1 are open in the Snake River basalt near the eastern outlet of the prairie. Well 1S–15E–16db1 extends 4 feet into the basalt and has a specific capacity of 37 gpm per foot; well 1S–15E–21ad1 is drilled in 188 feet of basalt and has a specific capacity of 112 gpm per foot. These data indicate that the yield of a well in the basalt increases with the depth of penetration below the top of the aquifer, as would be expected.

The specific capacities of the wells in basalt are much greater than the specific capacities of wells in the valley-fill deposits, suggesting that the coefficient of transmissibility of the basalt is much greater than that of the valley-fill deposits. Computations based on the specific capacity and on the assumption that the effective well radius is the same as the actual radius suggest that the transmissibility of the upper part of the basalt aquifer is about 200,000 gpd per foot, or about 3 times the transmissibility of the upper and lower artesian aquifers combined.

CONSTRUCTIONAL FEATURES OF WELLS IN THE VALLEY-FILL DEPOSIT

The large-capacity irrigation wells drilled in the valley-fill deposits in Camas Prairie have perforated pipe screens and are gravel packed. A Mills knife is used to produce vertical openings approximately three-eighths of an inch wide by 4½ inches long. There are generally 6 slots per row and rows are spaced on 1-foot centers. There are 600 slots in the 15-inch casing in well 1S–14E–9db1, which provide about 7 square feet of open area. The sand and gravel particles around the perforated pipe partially close the openings. It is estimated that the effective open area is about 50 percent of the actual open area, or about 3.5 square feet. For comparison, a continuous-slot screen having a slot opening of 0.1 inch has an effective open area of 3.5 square feet for each 4 or 5 feet of length.

Babbitt and Doland (1955) recommend that entrance velocities into well screens be less than about 0.125 to 0.2 foot per second to prevent movement of fine sand into the formation immediately around the screen and into the well. The permissible maximum pumping rate is, by the general formula for the quantity of flow in conduits, equal to the product of the effective open screen area and the critical entrance velocity. Computations based on a critical entrance velocity of 0.125 feet per second (7.5 feet per minute) for well 1S–14E–9db1 show a permissible maximum pumping rate of 200 gpm. The well has been pumped at rates exceeding 500 gpm and, presumably as a result, the specific capacity of the well has been reduced materially (table 1). Similar conditions affect other large-capacity irrigation wells in the valley-fill deposits.

The purpose of a screen is to hold back the sand and gravel and to allow water to flow into the casing without excessive head loss or the passage of fine materials during pumping. The materials of the valley-fill deposits are predominantly fine grained. To control the entrance of fine silt and sand from the valley fill into a well requires that the openings in the screen be relatively small, whether or not the well is packed with gravel. The size of slot openings is contingent upon the effective grain size and uniformity coefficient of the formation to be screened (Bennison, 1947). These factors are determined from mechanical (particle-size) analyses of samples of the materials obtained from the well. Packing the well with gravel allows the use of larger slot openings. However, the grading of the gravel pack, like the proper slot opening, depends upon the grain-size distribution of the formation to be screened, and it must be such that the infiltration of fine sand into the well is controlled. Fine particles will move through a gravel pack into a well if the effective grain size of the gravel pack is too much greater than that of the formation to be screened. Because the valley-fill deposits are predominantly fine grained, it is probable that the proper gravel pack for a well in Camas Prairie would be a coarse sand or fine gravel.

Commonly, the size of the gravel used in packing a well is about 4 times the average size of the coarsest 25 percent of the material in the formation. The slot opening is three-fourths the size of the gravel. In the Camas Prairie the proper slot opening may be on the order of 0.1 inch. If a gravel pack is not used the proper slot opening may be in the magnitude of 0.025-inch. However, a sieve analysis of formation material is necessary to determine the proper slot opening for any given well.

The ⅜-inch slots produced by the Mills knife are much too wide to control the passage of fine materials during pumping. That this is true has been demonstrated by the failure of well 1S–14E–9bb1 and the decrease in the specific capacity of well 1S–14E–9db1. Large-capacity irrigation wells were developed with considerable difficulty in the valley-fill deposits because of the frequent clogging of the wells with sand.

Computations, made on the basis of a 16-inch-diameter well having a continuous-slot screen with a slot opening of 0.04 inch and a critical entrance velocity of 7.5 feet per minute, show that 70 feet of screen would be required if the well were to be pumped at a rate of 2,250 gpm. The average total thickness of the upper and lower aquifers is about 140 feet. If the more permeable zones within the two aquifers were screened, it is probable that a yield of 2,250 gpm could be obtained from a 16-inch gravel-packed well that was properly developed (Bennison, 1947).

From the preceding discussion it is apparent that considerable study, based in large part on mechanical analyses of the samples of materials obtained during drilling of the well, must be made before a screen is designed. Most commercial screen-manufacturing companies will assist the driller and the well owner in selecting the proper screen for a well.

WELL INTERFERENCE AND SPACING

DRAWDOWN IN AN INFINITE AQUIFER

When a well is pumped, water levels in its vicinity are lowered and a cone of depression is formed around the well. The shape of the cone and its rate of growth and lateral extent are determined principally by the hydraulic properties of the aquifer. As pumping continues, the cone deepens and broadens as water is taken from storage within the aquifer and the cone affects more and more distant parts of the aquifer. Water occurs under artesian conditions in the principal aquifers of Camas Prairie. Under artesian conditions, the extent of the cone is great, largely because the coefficient of storage is small.

The estimated coefficient of transmissibility of 70,000 gpd per foot, and an assumed coefficient of storage of 0.001, were substituted in the nonequilibrium formula to compute the effects of pumping a well in the valley-fill deposits. The distance-drawdown, graph A, given in figure 9 shows a part of a cross-sectional view of the cone of influence created by pumping a well for 60 days at a rate of 2,250 gpm in an aquifer having the properties indicated. The aquifer is assumed to be infinite in areal extent. The average length of the pumping season on the prairie is 60 days, and the potential yield of a well that is properly constructed and developed is 2,250 gpm. The data for drawdown given in figure 9 occur at equal distances from the well in all directions. Using an assumed coefficient of storage of 0.00001 would increase the computed drawdown by about 25 percent.

According to the above assumptions, the drawdown is appreciable several miles from the pumped well, indicating that widely spaced wells in the valley-fill deposits will interfere with one another. For example, the drawdown at a distance of 5 miles after 60 days of continuous pumping is about 3.5 feet for a storage coefficient of 0.001.

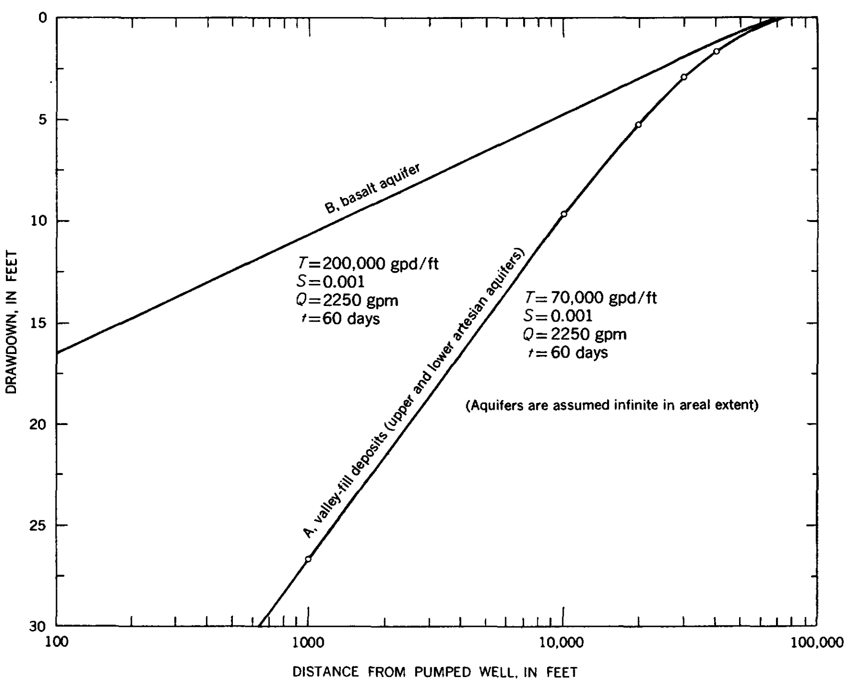

FIGURE 9.—Theoretical semilog distance-drawdown graphs for aquifers underlying Camas Prairie.

Drawdown is directly proportional to the pumping rate. If the pumping rate were 1,125 gpm, the drawdown at a point 5 miles from the pumped well would be about 2 feet.

The cone of influence was plotted on rectangular coordinate paper as shown in figure 10. Again using the same assumption, the cone is

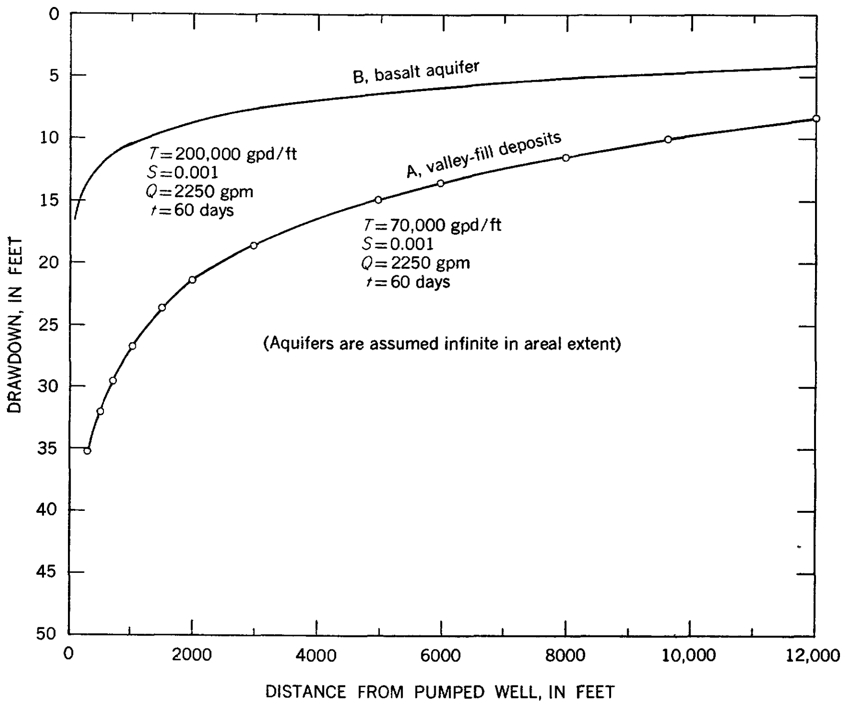

FIGURE 10.—Theoretical distance-drawdown curves for aquifers underlying Camas Prairie.

relatively steep as far as 1,000 feet between wells in the valley-fill deposits, as suggested by curve *A* in figure 10, considering only well interference. The coefficients of storage assumed above apply only to the artesian aquifers. If, under large-scale and long-continued pumping, the artesian pressure declined sufficiently that water leaked down from the shallow aquifers instead of upwards into them, then some water would be derived from storage in these shallow aquifers; and the coefficient of storage of the entire hydraulic system, consisting of the artesian aquifers and the water-table aquifer, might be considerably larger than assumed above.

Curves B in figures 9 and 10 were computed for the basalt aquifer by substituting in the nonequilibrium formula the estimated value of T of 200,000 gpd per foot and the assumed value of S of 0.001. These show that the cone of influence in basalt is not as deep as that in the valley-fill deposits. Interference between wells in basalt is much less than the interference between wells in the valley-fill deposits. According to the above assumptions, a spacing of at least 500 feet between wells tapping the upper 200 feet of basalt is suggested by curve B in figure 10, considering only well interference.

EFFECTS OF HYDROGEOLOGIC BOUNDARIES

The graphs and curves in figures 9 and 10 assume an aquifer of infinite extent. However, geologic conditions limit the extent of the valley-fill deposits and the basalt aquifer (pl. 1). The valley-fill deposits are bounded on the north, south, and west by relatively impervious bedrocks that delimit the aquifer and act as barrier boundaries. The barrier boundaries increase the rate of water-level decline and distort the cone of depression produced by pumping. Such distortion must be taken into account in long-range predictions of drawdown. By treating the boundaries as straight lines, the image-well theory described by Ferris (1951) can be used with the non-equilibrium formula to estimate the effects on drawdown caused by the barrier boundaries.

The image-well theory as applied to barrier boundaries may be stated as follows: The effect of an impervious geologic boundary (barrier) on the water table or piezometric surface as a result of pumping from a well is the same as though the aquifer were infinite and a like discharging well were located across the real boundary, on a line at right angles thereto, and at the same distance from the boundary as the real pumping well. Thus, an imaginary hydraulic system of a well and its image counterpart in an infinite aquifer satisfies the actual barrier boundary conditions.

The valley-fill deposits are bounded by two nearly parallel barrier boundaries (on the north and south) intersected at approximate right angles by a third barrier boundary on the west. The arrangement of the boundaries is such that analysis by the image-well theory requires the use of a multiple image-well system extending to infinity (Knowles, 1955).

Water occurs under water-table conditions in the valley-fill deposits and the permeability of the valley-fill deposits increases near the foot of the mountains to the north. The transmissibility of the upper part of the basalt bounding the valley-fill deposits along the east margin of the prairie is probably about 3 times as great as that of the valley-fill deposits. There is leakage through the clay bed from the upper and lower aquifers into the shallow deposits. These hydrogeologic features also distort the cone of influence, but unlike the barrier boundaries they tend to reduce the drawdown in wells. The effects of the hydrogeologic features can be imitated by assuming that

633992—62——3

some of the drawdown due to the barrier boundaries is balanced by the hydrogeologic features, and by using only a limited number of discharging image wells associated with the barrier boundaries, and by increasing the effective distances from pumped wells to the barrier boundaries.

Withdrawals from heavily pumped wells will be balanced in part by a decrease in underflow from the prairie. Most of the underflow from the prairie discharges into Camas Creek in the vicinity of Magic Reservoir; thus, withdrawals will decrease the discharge of ground water to the creek. The reach of the creek where ground-water discharge occurs is a recharge boundary, which will limit the spread of the cone of influence. The effect of a recharge boundary on the drawdown in a well is the same as though the aquifer were infinite and a like recharging well were located across the real boundary, on a line at right angles thereto, and at the same distance from the boundary as the real pumping well.

The results of geologic and hydrologic studies made in Camas Prairie indicate that the effects of barrier and recharge boundaries and hydrogeologic features on the response of the valley-fill deposits to development by wells can be determined roughly by mathematical analysis of a rectangular hydraulic system. The rectangular hydraulic system is 7 miles wide and 30 miles long and consists of two parallel barrier boundaries (on the north and south) intersected at right angles by a third barrier boundary on the west and a recharge boundary on the east. Most of the assumptions are highly tentative, based on crudely determined or arbitrarily assumed hydraulic coefficients, and thus give results of only the right order of magnitude.

THEORETICAL DRAWDOWN IN A HEAVILY PUMPED WELL

Suppose that two 16-inch wells, 500 feet deep and having 70 feet of screen, are developed in the upper and lower aquifers on a line along State Route 68 and are spaced 5 miles apart, one well at Fairfield and the other well east of Fairfield. Also suppose that each well is pumped continuously at rates of 2,250 gpm for 60 days during the pumping season. The total drawdown, s_t, at the end of the 60-day pumping period in the well at Fairfield (for purposes of identification named well 1) is equal to the drawdown, s_1, due to pumping the well itself, plus the interference, s_2, due to pumping the well east of Fairfield (for purposes of identification named well 2), plus the drawdown, s_3, due to the discharging image wells associated with barrier boundaries, minus the buildup, s_4, due to the recharging image wells associated with the recharge boundary or

$$s_t = s_1 + s_2 + s_3 - s_4 \tag{3}$$

The drawdown, s_1, is composed of two components, the drawdown or head loss due to the laminar flow of water in the aquifer towards the well, s_a, and the drawdown or head loss (well loss), s_w, resulting from the turbulent flow of water in the aquifer in the immediate vicinity of the well, through the well screen, and in the well casing. Well loss, s_w, in feet, may be represented approximately by the following relationship (Jacob, 1947):

$$\text{Well loss} = CQ^2 \qquad (4)$$

where C is the "well-loss" constant, its dimension being in sec²/ft⁵, and Q is the rate of pumping, in cubic feet per second.

The nonequilibrium formula was used to compute s_a. An effective radius equal to the nominal radius (8 inches) was assumed in the computations, as was a storage coefficient of 0.001. A reasonable estimate of the value of C for a properly constructed and developed well is 0.10. s_w was determined by using a C value of 0.10 and the equation for well loss. s_2 and s_3 were obtained by using the rectangular hydraulic system described earlier and the hypothetical curves in figure 9.

The values of s_1, s_2, and s_3 are given below.

Component of drawdown	*Drawdown (feet)*
s_a	80
s_w	3
$s_1 = s_a + s_w$	83
s_2	4
s_3	7

The total drawdown, s_t, in well 1 as the result of pumping wells 1 and 2 at rates of 2,250 gpm for 60 days is about 94 feet. The static water level at Fairfield is about 10 feet above the land surface. The pumping level in well 1 at the end of the pumping period thus would be about 80 feet below the land surface, 160 feet above the top of the upper aquifer. Computations show that the piezometric surface midway between wells 1 and 2 would decline about 23 feet as the result of the development.

The effects of the recharge boundary east of Fairfield, s_4, are not appreciable at the end of a 60-day pumping period because of the great distance to the recharging image wells. However, the recharge boundary would appreciably affect drawdown caused by long-term pumping (more than 1 irrigation season).

Theoretical values for drawdown were computed and presented in this section of the report to give the reader an understanding of the factors governing the response of an aquifer to heavy pumping. Moreover, the results are based on several assumptions that can be made realistic only by making additional carefully controlled aquifer tests in the area.

EFFECTS OF GROUND-WATER DEVELOPMENT

Underflow from Camas Prairie is about 20,000 acre-feet per year and leakage through the clay bed is about the same. The amount of the underflow and leakage that could be intercepted by wells and used within the prairie is governed largely by the hydraulic properties and hydrogeologic boundaries of the aquifers. The aquifers beneath Camas Prairie are limited greatly in areal extent and the valley-fill deposits are not highly productive. Consequently, heavy development by wells will result in large drawdown in wells and interference between production wells will be great.

A study was made of the theoretical values for drawdown associated with the development of 9,000 acre-feet per year from wells in the artesian aquifers and 3,000 acre-feet per year from wells in the basalt aquifer west of Camas Creek. Computations made, using the estimated and assumed hydraulic properties and hydrogeologic boundaries of the aquifers in Camas Prairie, suggest that water levels in production wells in the artesian aquifers would decline to a position a few feet above the top of the upper artesian aquifer and 50 feet below the top of the basalt aquifer at the end of a 60-day pumping season as the result of such development. Similarly, the piezometric surface at Fairfield would decline about 150 feet as the result of the large-scale development. Additional recharge that might result from drawing down water levels in the shallow water-table aquifer and the decrease in ground water in storage in the alluvial deposits around the margin of the area where water-table conditions occur were not considered in this study.

Assuming an average duty of water of 1¾ acre-feet per acre, withdrawals of 12,000 acre-feet a year by the development of the aquifers is sufficient to irrigate about 7,000 acres. It is emphasized that this discussion contemplates withdrawing the entire 12,000 acre-feet during a 60-day pumping season; this amount is not a measure of the perennial yield of the ground-water basin.

The postulated large withdrawals from wells on the prairie would be supplied in part by a reduction in underflow from the prairie and in part by a decrease in or cessation of leakage from the upper and lower artesian aquifers. Large-scale development would reduce the artesian pressure considerably, and wells on the prairie would cease to flow. Under present conditions the leakage from the deeply buried deposits upward into the shallow valley-fill deposits supports the shallow unconfined water body. The postulated large drawdown of water levels accompanying heavy development would reduce or stop leakage to the water table and cause the water table to decline.

SURFACE WATER

The discharge of Camas Creek has been measured intermittently since 1911 by the U.S. Geological Survey at gage A (pl. 1) in sec. 15, T. 1 S., R. 16 E., a quarter of a mile north of the Macon siding of the Hill City Branch of the Union Pacific Railroad and 4 miles southeast of Blaine. The drainage area above the gage is 648 square miles. The average discharge for the 11 years of record (1944–55) was 175 cfs, or 127,000 acre-feet per year. The average annual runoff amounts to a depth of about 3.7 inches on the drainage area. The maximum discharge recorded through the 1955 water year was 9,780 cfs on April 8, 1943; the minimum was 1.5 cfs on August 29, 1940. Water is diverted from the creek to irrigate about 9,300 acres above the gaging station. Flow of the creek is regulated by Twin Lakes Reservoir on Lake Creek, which has a reported capacity of 31,240 acre-feet, and by three minor reservoirs having a combined capacity of 580 acre-feet.

GROUND-WATER DISCHARGE TO STREAMS

Along Camas Creek east of Rands, ground water moving southeastward from the foot of the mountains north of Rands and Blaine (pl. 1) discharges into the creek. The hydraulic interconnection of the creek and the valley-fill deposits is poor southwest of Rands, and the amount of ground water discharged into the creek is small. Because of confinement by clayey materials beneath the bed of Camas Creek, underflow occurs out of the prairie beneath the creek in T. 1 S., R. 15 E. Willow Creek has cut deeply into the valley-fill deposits and drains the aquifer in the lower reaches of the stream. The other tributaries of Camas Creek lose water to the shallow valley-fill deposits and thus are influent. During the summer months, water that the tributaries discharge onto the prairie is absorbed by the deposits near the foot of the mountains. Dry-weather flow seldom occurs in the small streams south of the base line, 2 miles north of Fairfield.

An investigation of low flows in Camas Creek and in the tributaries near the eastern outlet of the prairie was made on November 7, 1957. Streamflow was measured at the 13 stations shown in plate 1. The results of the measurements are summarized in the following table.

Approximately 89 percent of the low-flow discharge (12.6 cfs) at station A came from Willow Creek (station D). The discharge of Camas Creek immediately upstream from Willow Creek (station E) was only 1.4 cfs. The flow in Willow Creek increased from 8.2 cfs to 11.2 cfs between stations B and D along the 3-mile reach of the creek south of the base line.

The observations of streamflow show that ground-water discharge to Camas Creek, during low-flow periods in autumn, at the eastern outlet of the prairie is very small. The gain in flow in Camas Creek between station M and E, about 10 miles apart, was 1.3 cfs.

Streamflow measurements

Gaging station	Discharge (cfs)	Gaging station	Discharge (cfs)
A	12.6	H	0
B	8.2	I	0
C	0	J	0
D	11.2	K	0
E	1.4	L	0
F	.09	M	.08
G	.08		

QUALITY OF WATER

CHEMICAL ANALYSES

The chemical character of the ground water in Camas Prairie is known from the analyses of water from 6 wells. The results of the analyses are given in table 2 and also, in diagrammatic form, in figure 11. The constituents listed in table 2 are given in ionic form in parts per million. The same constituents, expressed in equivalents

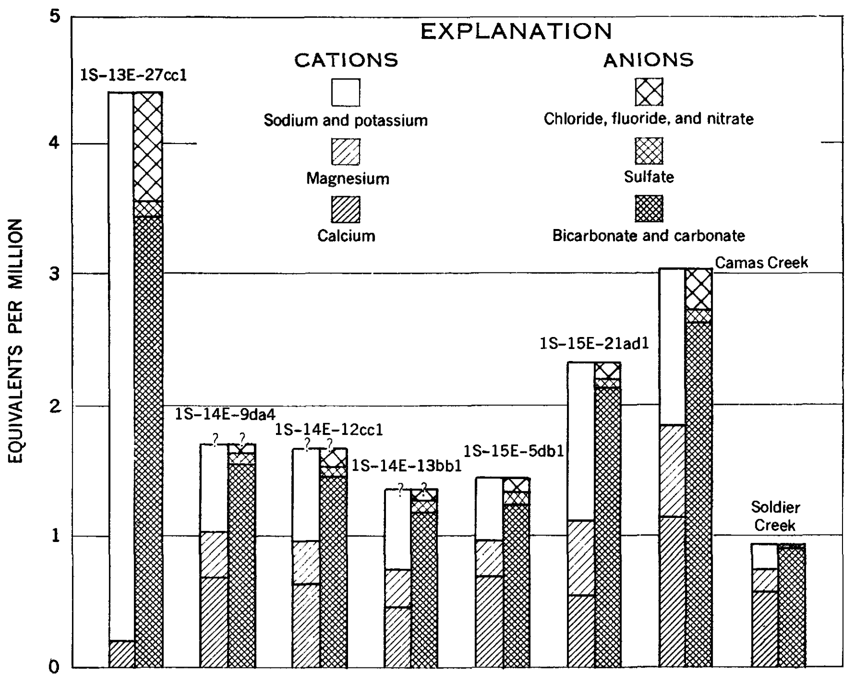

FIGURE 11.—Graphic representation of chemical analyses of ground and surface waters in Camas Prairie.

TABLE 2.—*Chemical analyses of ground and surface waters in Camas Prairie*

[Chemical constituents in parts per million]

Well or stream	Date of collection	Temperature (°F)	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)	Phosphate (PO_4)	Dissolved solids: Parts per million	Dissolved solids: Tons per acre-foot	Hardness as $CaCO_3$	Percent sodium	pH	Specific conductance (micromhos at 25°C)
1S-13E-27cc1	9-4-57	95	78	0.03	4.0	0.0	96	1.4	211	0	4.7	11	9.0	0.6	0.2	309	0.420	10	95	8.0	415
1S-14E-9da4	Aug. 1924	------	41	.40	14	4.1	14		93	0	5.8	1.0	------	------	------	124	.169	52	------	------	------
12cc1	Aug. 1924	------	54	.50	13	3.9	13		90	0	2.0	1.0	------	------	------	128	.174	48	------	------	------
13bb1	Aug. 1924	------	39	.05	9.6	3.0	13		73	0	4.1	3.0	------	------	------	103	.140	36	------	------	------
1S-15E-5db1	7-30-57	63	26	.60	14	3.4	10	2.0	76	0	3.3	1.5	.3	4.6	.4	125	.170	49	30	7.2	142
21ad1	7-30-57	58	45	.23	11	6.8	25	5.0	133	0	.7	3.5	.4	.3	.4	157	.214	55	47	7.3	235
Camas Creek	7-30-57	72	24	.01	23	8.8	23	5.4	160	0	4.8	6.0	.5	1.4	.6	176	.239	94	33	7.3	280
Soldier Creek	9-18-57	52	16	.18	12	1.9	3.8	.6	55	0	1.0	.2	.1	.8	0	63	.086	38	18	7.8	91.7

per million, are shown graphically in figure 11. The analyses of water from wells 1S–13E–27cc1, 1S–15E–5db1, and 1S–15E–21ad1 were made by the laboratory of the U.S. Geological Survey, Denver, Colo.; the analyses of water from the other wells were reported by Piper (1925).

Information collected on the temperature of ground water is presented in table 3. The temperature of water in 37 flowing wells was measured for the most part by the author during the autumn of 1957. A few of the temperatures were reported by Piper (1925).

The streamflow in Camas and Soldier Creeks was sampled in sec. 18, T. 1 S., R. 16 E., and in sec. 5, T. 1 N., R. 14 E., respectively. Table 2 lists the analyses of water from these two streams. At the time of sampling the flow was mostly ground-water discharge.

TABLE 3. *Temperature of ground water in Camas Prairie*

Well	Depth (feet)	Temperature (°F)	Well	Depth (feet)	Temperature (°F)
1N–13E–14ca1	110	49	1S–14E–9db1	535	65
1S–12E–24aa1	170	62	10aa1	256	54
31cb1	400	85	10ad1	273	57
34dc1	180	60	10cc1	300	62
35bb1	254	58	12cc1	247	58
1S–13E–8cc2	150	52	13ad1	212	61
12dd1	230	59	13bb1	126	59
14da1	300	71	14cb1	240	61
15dd1	228	64	15ba1	226	59
19ad1	240	59	15ba2	245	59
20ad1	220	66	22db1	434	71
20ad2	194	65	27ad1	240	62
21da1	170	62	1S–15E–5db1	578	64
25dc1	218	59	9dc1	360	66
27cc1	190	95	21ad1	280	58
1S–14E–8dd1	320	62	22ad1	15	49
9aa1	256	52	27ba1	97	58
9da2	300	60	2S–12E–11bd1	40	56
9da3	164	56			

CHEMICAL CHARACTER OF GROUND WATER

Water from 5 of the 6 wells sampled contained less than 160 ppm of dissolved solids. The dissolved solids consist mostly of silica, sodium, calcium, and bicarbonate. Water from well 1S–13E–27cc1 had a dissolved-solids content of 309 ppm; the concentrations of sodium, silica, and bicarbonate were much greater than those of the water from the other 5 wells.

The analyses show that the water from 5 wells contains relatively small amounts of iron, chloride, and fluoride. The water from well 1S–13E–27cc1 has an excessive concentration of fluoride (9.0 ppm) and a high percent sodium (95).

The chemical composition of the water from well 1S–13E–27cc1 is very different from that of the water generally found in the valley-fill deposits but similar to water at a spring (spring No. 47 in Piper's report) along Camas Creek about 1 mile south of the well. The temperatures of the water from the well and the spring are much higher than the average temperature of ground water in Camas Prairie. It is probable that the water sampled in well 1S–13E–27cc1, and in the spring, has migrated upward from a fractured zone in the deeply buried rocks beneath the valley fill and is derived from a source different than that of the main body of ground water.

SUITABILITY OF GROUND WATER FOR DOMESTIC AND IRRIGATION USE

Analyses made by the U.S. Geological Survey do not indicate the sanitary condition of the water analyzed. The waters sampled contain much less than 1,000 ppm of the dissolved solids, which is the maximum amount considered acceptable for use for human consumption by the U.S. Public Health Service (1946). Water in which the concentration of fluoride exceeds 2 ppm can cause mottling of the tooth enamel of children who drink the water during calcification and formation of the teeth (Dean, 1936). The water from well 1S–13E-27cc1 is unsuitable in this respect, owing to the excessive amount of fluoride (9 ppm). The fluoride content of water from wells 1S–15E–5db1 and 1S–15E–21ad1 is less than 1 ppm, and it is probable that the ground water in Camas Prairie is generally suitable as drinking water for children.

The suitability of a water for irrigation, assuming soil character to be favorable, can usually be determined if the following chemical factors are known: the concentration of dissolved solids, the percent sodium, the residual sodium carbonate, and the concentration of boron. The total concentration of mineral constituents is indicated by the specific conductance, the reciprocal of the electrical resistivity of water expressed in micromhos per centimeter ($K \times 10^6$ at 25° C). Waters were classed by the U.S. Department of Agriculture (U.S. Salinity Laboratory Staff, 1954) on the basis of electrical conductivity as those having low, medium, high, and very high salinity. The dividing points between classes are 250, 750, and 2,250 micromhos. Except for the water from well 1S–13E–27cc1, which has medium salinity, all the waters sampled have low salinity.

Wilcox (1948) devised a method for classifying water for irrigation in which the total concentration and percentage of sodium is an important factor. Water is classified by use of a diagram on which are plotted values for percent sodium and specific conductance. The percent sodium is determined mathematically by the formula

$$\text{Percent Na} = \frac{Na^{+} \times 100}{Ca^{++} + Mg^{++} + Na^{+} + K^{+}}$$

in which the concentrations of sodium, calcium, magnesium, and potassium are expressed in equivalents per million (epm). The suitability for irrigation of the water from wells 1S–13E–27cc1, 1S–15E–5db1, and 1S–15E–21ad1 is indicated by the plotted points shown on the diagram in figure 12. According to the Wilcox method, the water from wells 1S–15E–5db1 and 1S–15E–21ad1 is excellent to good in quality and that from well 1S–13E–27cc1 is doubtful to unsuitable. Well 1S–15E–5db1 is in the valley-fill deposits and well 1S–15E–21ad1 is in basalt.

The U.S. Salinity Laboratory Staff (1954) has proposed the use of the sodium-adsorption-ratio (SAR) for evaluating the potential sodium hazard of an irrigation water. The sodium-adsorption-ratio,

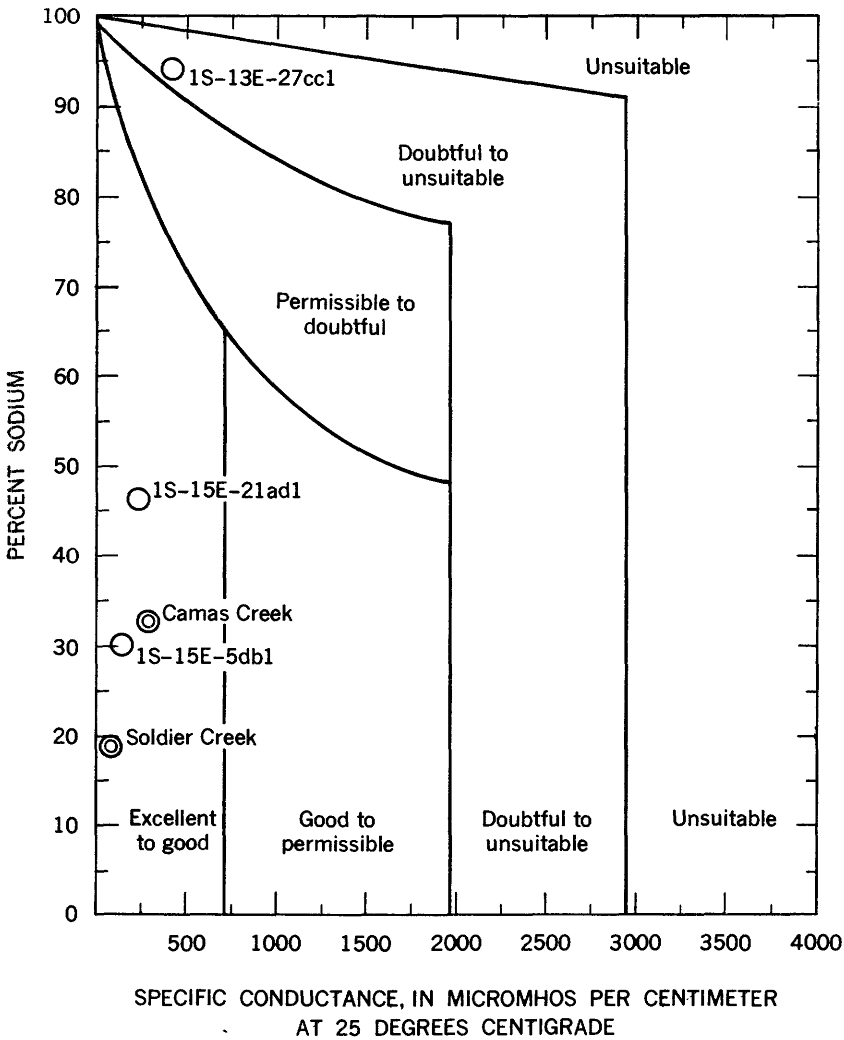

FIGURE 12.—Classification of ground and surface waters in Camas Prairie for irrigation (Wilcox method).

which is related to the extent the soil will adsorb sodium, is defined by the equation

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

The concentrations of sodium, calcium, and magnesium are expressed in equivalents per million (epm). Water is divided into four sodium-hazard classes by the SAR values: low (S_1), medium (S_2), high (S_3), and very high (S_4). Water in wells 1S–15E–5db1 and 1S–15E–21ad1 has a low sodium hazard and water in well 1S–13E–27cc1 has a medium sodium hazard based on the SAR values.

The suitability of water for irrigation depends also upon the amount of residual sodium carbonate (RSC), which can be determined by the equation

$$RSC=(HCO^- + CO_3^{--}) - (Ca^{++} + Mg^{++})$$

The U.S. Salinity Laboratory Staff (1954) states:

> waters with more than 2.5 meq/l (milli-equivalents per liter) residual sodium carbonate are not suitable for irrigation purposes. Water containing 1.25 to 2.5 meq/l are marginal, and those containing less than 1.25 meq/l are probably safe.

Except for the water from well 1S–13E–27cc1, which is not suitable for irrigation purposes, all the waters sampled are safe.

According to the Wilcox and Salinity Laboratory Staff methods of classification, water from the valley-fill deposits and basalt in Camas Prairie is excellent to good in quality for irrigation. Water from the valley-fill deposits mingled with hot spring waters, as that in well 1S–13E–27cc1, is unsuitable for irrigation. The classifications given above were made without considering the soil character. Factors such as soil texture, type of soil, and drainage also must be considered before large scale application of water for irrigation is started.

TEMPERATURE OF GROUND WATER

Temperatures of the water in 37 flowing wells on the prairie were plotted on graph paper against the depths of the wells, as shown in figure 13, to determine the geothermal gradient of the ground water. A line was drawn through the center of the plotted data. The slope of the line, the temperature gradient, is 6° F per 100 feet of depth. Except for the data for wells 1S–14E–9db1, 1S–15E–5db1, and 1S–13E–27cc1, the data plot reasonably close to the line. The data for wells 1S–14E–9db1 and 1S–15E–5db1 fall far below the line because the casings in these wells are perforated in both the upper and the lower artesian aquifers, and water at different temperatures from various depths mingle in these wells. Well 1S–13E–27cc1 is in an area where more than the normal amount of ground water moves up from the deeply buried rocks beneath the valley fill.

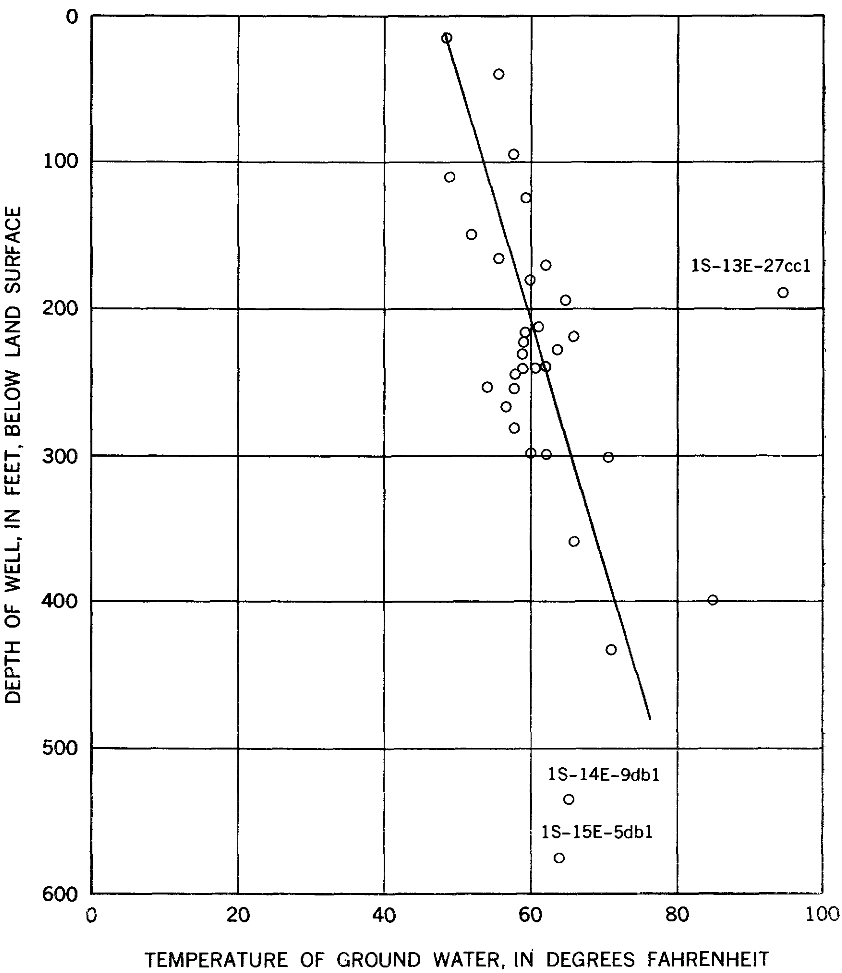

FIGURE 13.—Variations of ground-water temperature with depth.

There is a natural increase of temperature downward in the earth's crust. For sedimentary materials, the average temperature gradient is about 1°–2° F for each 100 feet of depth. In the valley-fill deposits in Camas Prairie, the temperature gradient (6° F per 100 feet) is much greater than average. The reason for the abnormal gradient is not known, but it may be caused by hot water or steam that mixes with water in the valley-fill deposits.

CHEMICAL CHARACTER OF SURFACE WATERS

The chemical character of the water in Camas and Soldier Creeks is somewhat similar to that of the ground water generally found in the prairie, which is shown in figure 11. The dissolved-solids content of the water in Camas Creek (176 ppm) is slightly greater than that of the water in most wells. The dissolved-solids content of the water in Soldier Creek (63 ppm) is only about half that of the water in most wells. The dissolved solids consist mostly of silica, sodium, calcium, and bicarbonate. The water from the creeks contains small amounts of iron, chloride, and fluoride.

SUITABILITY OF SURFACE WATERS FOR IRRIGATION USE

Water in Camas and Soldier Creeks is "excellent to good" in quality for irrigation use, as evaluated according to the standards suggested by Wilcox (1948) and the U.S. Salinity Laboratory Staff (1954). The waters are classified on the basis of percent sodium in figure 12.

SUMMARY

Camas Prairie is in the southern part of Idaho north of the Snake River Plain, and is part of the Camas Creek valley, a large eastward-trending intermontane trough about 40 miles in length and averaging about 8 miles in width. Camas Prairie is regarded as a structural depression that has been filled by alluvial and lake deposits mainly of Pleistocene age. The valley fill accumulated behind Pliocene and Pleistocene lavas which dammed the eastern outlet of the basin. The consolidated rocks of the mountains and hills enclosing the prairie on the north, south, and west are composed largely of intrusive and extrusive igneous rocks, ranging in age from Cretaceous to Quaternary but including some sedimentary rocks of Carboniferous age. The consolidated formations yield small amounts of ground water to wells and springs from the complex systems of fractures and weathered zones that permeate the otherwise dense and relatively impervious rocks.

The principal aquifers in Camas Prairie are the sand and gravel deposits (valley fill), and the basalt at the eastern outlet of the prairie. The valley-fill deposits are about 550 feet thick at Fairfield; 188 feet of basalt was penetrated above clay in an irrigation well near the east margin of the prairie. An extensive clay bed, averaging 90 feet in thickness and penetrated between the average depths of 120 and 210 feet below the land surface, separates the shallow and deep valley-fill deposits. Permeable sand and gravel deposits are found in two zones below the clay bed; above the clay are alternating beds of sand, sandy silt, silt, and clay, which are not very permeable. Fine- to medium-grained sand and some gravel lie immediately below the clay bed. The average thickness of this zone (upper artesian aquifer) is about 50 feet. Permeable sand and gravel deposits (lower artesian aquifer) averaging 85 feet in thickness occur at the base of the valley fill. The upper and lower aquifers are separated by beds of sandy and clayey materials that are relatively impermeable. The bulk of the sediments of the two aquifers are rather fine grained and their permeability is low.

Confined water is reached by wells extending to depths greater than 40 feet in the valley fill and by wells in the basalt aquifer. The confined water is under sufficient pressure to cause it to rise above the land surface over much of the prairie, and flowing artesian wells are common. The head above land surface in the flowing wells seldom exceeds 10 feet. Water occurs under water-table conditions in the shallow deposits above the clay bed. The water table lies at shallow depth, less than 10 feet in most places.

Ground water in the shallow deposits of the valley fill moves in a general southeastward direction from the upland areas bordering the mountains toward the valley floor and Camas Creek and other effluent streams. Ground water in the deeply buried deposits (upper and lower artesian aquifers) moves from the upland areas at the foot of the mountains and hills enclosing the prairie toward a pronounced eastward-trending trough in the piezometric surface whose axis roughly coincides with the course of Camas Creek. Ground water moves in the trough down the hydraulic gradient as underflow. The clay bed impedes but does not prevent upward movement of ground water from the deep part of the valley fill to the shallow deposits. There is a large amount of vertical seepage of water from the deeply buried aquifers, and only a part of the water moving toward and in the trough is transmitted as underflow out of the prairie.

The transmissibility of a 126-foot interval in the lower alluvial aquifer was determined to be about 30,000 gpd (gallons per day) per foot from the results of an aquifer test. The coefficient of transmissibility of the upper and lower alluvial aquifers together is estimated to be about 70,000 gpd per foot. The coefficient of storage for purposes of computation is assumed to be 0.001. Specific-capacity data suggest that the coefficient of transmissibility of the upper 200 feet of the basalt aquifer is about 200,000 gpd per foot, or roughly 3 times that of the upper and lower alluvial aquifers together.

The underflow from Camas Prairie and the vertical leakage through the clay bed were estimated from a study of the quantity of ground water percolating through sections of the upper and lower artesian aquifers near the eastern outlet of the prairie. The average hydraulic gradient of the piezometric surface near the eastern outlet of the prairie is about 23 feet per mile. Underflow and vertical leakage were computed to be about 1.8×10^7 gpd (about 20,000 acre-feet per year) and 1.6×10^7 gpd (about 20,000 acre-feet per year), respectively. Most of the underflow out of the prairie discharges into Camas Creek or Magic Reservoir east of the prairie. Little, if any, of the underflow reaches the Snake River Plain.

The main sources of recharge to the upper and lower aquifers are direct precipitation and downward percolation of stream runoff along the base of the mountains bordering the prairie on the north. The intake area is estimated to be about 75 square miles. The average annual recharge balances underflow from the valley and leakage through the clay bed and is about 40,000 acre-feet per year, or about 10 inches of water on the intake area. The average annual precipitation on the intake area is about 17 inches. It is estimated that more than half the recharge, about 25,000 acre-feet per year, or 6 inches of water on the intake area, occurs by the downward percolation of steam runoff over the part of the alluvial fans lying between the valley floor and the foot of the mountains. According to this estimate, recharge direct from precipitation is, therefore, about 4 inches. Evapotranspiration from the intake area is estimated to be in the magnitude of 11 inches, or about two-thirds of the average annual precipitation.

The estimated yearly discharge of irrigation wells on the prairie in 1957 was about 1,300 acre-feet. The water was withdrawn largely from 7 wells during an average 60-day irrigation season. About 960 acres of wheat, alfalfa, hay clover, and barley were irrigated. Total withdrawals in 1957 of ground water for irrigation, municipal, domestic, and stock use were about 2,000 acre-feet.

Present ground-water development affects water levels in the prairie to a small degree. The water levels in domestic wells within a few miles of heavily pumped irrigation wells decline several feet during the irrigation season, and the rate of flow from the wells decreases.

The specific capacities of two of the best irrigation wells in the valley-fill deposits were 18 and 22 gpm (gallons per minute) per foot upon completion of the wells. A well in which 188 feet of basalt has been penetrated has a specific capacity of about 112 gpm per foot. The large-capacity irrigation wells drilled in the valley-fill deposits have perforated pipe screens and are gravel packed. A Mills knife is used to produce vertical openings approximately three-eighths of an inch wide by 4½ inches long. The ⅜-inch slots are much too wide to control the passage of fine materials during pumping. As a result, the yields of several heavily pumped wells have decreased greatly and one well has completely failed because of sand problems. Studies indicate that a properly constructed well developed in both the upper and lower aquifers and having 70 feet of continuous slot screen probably would yield 2,250 gpm without sand problems. Existing irrigation wells with slotted-pipe screens yield on the average about 650 gpm, and there is considerable difficulty and expense in keeping the wells free from sand.

The aquifers beneath Camas Prairie are limited greatly in areal extent and the productivity of the valley-fill deposits is not great. Consequently, heavy development would result in large drawdown in wells and interference between production wells would be great. A study was made of the theoretical drawdown associated with the long-term development of 9,000 acre-feet per year from wells in the valley-fill deposits and 3,000 acre-feet per year from wells in the basalt aquifer west of Camas Creek. Computations indicate that water levels in production wells would decline to a position a few feet above the top of the upper aquifer and 50 feet below the top of the basalt aquifer at the end of a 60-day irrigation season as the result of the development of the total of 12,000 acre-feet per year. The upper aquifer would be partly dewatered in the vicinity of the wells and over-development would occur at greater rates of withdrawal. This withdrawal would be sufficient to irrigate about 7,000 acres and involves withdrawing the entire amount during a 60-day pumping season.

The postulated large withdrawals from wells on the prairie would be supplied in part by a reduction in underflow from the prairie and in part by a decrease in leakage from the upper and lower alluvial aquifers. Large-scale development would considerably reduce the artesian pressure, and wells on the prairie would cease to flow. Leakage from the deeply buried deposits into the shallow valley-fill deposits supports the shallow unconfined water body. The large drawdown of water levels accompanying heavy development would reduce the leakage and cause the water table to decline.

Camas Creek drains Camas Prairie into the Big Wood River, which is tributary to the Snake River. The average discharge of Camas Creek above a gaging station near the eastern margin of the prairie for the 11 years of record (1944–55) is 175 cfs (cubic feet per second), or 127,000 acre-feet per year. Observations of streamflow show that ground-water discharge to Camas Creek at the eastern outlet of the prairie is very small.

The waters from most wells and streams in Camas Prairie are of good chemical quality for domestic, municipal, and irrigation use.

There is a lateral decrease in grain size of the valley-fill deposits from coarse, at the foot of the mountains north of the prairie, to fine south of the center of the prairie. The deposits at the foot of the hills south of the prairie are, in general, very fine, and they will not yield large quantities of water to a well. Large-capacity irrigation wells can be successfully developed in the valley-fill deposits, near and north of the center of the prairie. The rocks of the mountains and hills enclosing the prairie act as barriers to the movement of water;

therefore large-capacity wells should not be drilled too close to the foot of mountains or hills.

The best area for development of large ground-water supplies is near the eastern margin of the prairie west of Camas Creek where basalt underlies the valley-fill deposits. Wells in basalt generally do not require screens and yield large quantities of water with moderate drawdown. The yield of wells usually increase with the depth of penetration of the well below the top of the basalt. Wells should extend at least 100 feet into saturated basalt to minimize drawdown and reduce the cost of pumping.

RECORDS OF WELLS

The information in the following well logs and well records was obtained from well owners, drillers, files of the Idaho Department of Reclamation, and the Idaho Bureau of Mines and Geology Pamphlet 15. The terminology in the well logs has been slightly modified to achieve uniformity and clarity.

TABLE 4.—*Logs of representative wells*

[Thickness and depth in feet]

Material	*Thickness*	*Depth*
1N–13E–14ca1.		
Topsoil and boulders	7	7
Granite, decomposed; and traces of clay	103	110
1N–15E–31ca1.		
Clay and gravel	160	160
Sand and clay	65	225
Hardpan	6	231
Clay	75	306
1N–16E–33db1		
Topsoil	3	3
Sand, brown, gravel, and clay	12	15
Clay, yellow, and gravel	10	25
Gravel	23	48
Gravel and traces of clay	12	60
Sandstone	50	110
Granite	64	174
1S–12E–8dc1		
Sand and clay	50	50
Granite, crevice	17	67
1S–12E–14ba1		
Dug well	15	15
Sand	10	25
Clay, sandy, blue	5	30
Clay, sandy, blue, and gravel	60	90
Sand and gravel	7	97
Clay, sandy, blue	3	100
Clay, sandy, blue and brown	123	223
Sand, coarse, and gravel	15	238
Hardpan	2	240
1S–12E–24aa1		
Sand and clay, interbedded	100	100
Clay	70	170
Sand, blue	--------	170

633992—62——4

TABLE 4.—*Logs of representative wells*—Continued

1S–12E–26cc1

Material	*Thickness*	*Depth*
Topsoil	5	5
Sand and gravel	20	25
Sand, blue, and clay	10	35
Sand and gravel	15	50
Sand and clay, blue	4	54

1S–12E–29dd1

Material	*Thickness*	*Depth*
Topsoil	3	3
Clay, sandy, yellow	33	36
Clay, sandy, blue	12	48
Sand and traces of clay	19	67
Clay, blue	1	68
Granite	1	69

1S–12E–30dc1

Material	*Thickness*	*Depth*
Topsoil	6	6
Clay, sandy, yellow	24	30
Clay, sandy, blue	50	80
Clay, sandy, blue	20	100
Granite	--	100

1S–13E–12dd1

Material	*Thickness*	*Depth*
Sand and clay, interbedded	130	130
Clay	100	230
Sand, coarse, gray	--	230

1S–13E–14da1

Material	*Thickness*	*Depth*
Sand and clay, interbedded	140	140
Clay	80	220
Sand, coarse, gray	4	224

1S–13E–15dd1

Material	*Thickness*	*Depth*
Sand and clay, interbedded	130	130
Clay	98	228
Sand, coarse	--	228

1S–13E–20ad2

Material	*Thickness*	*Depth*
Sand and clay, interbedded	120	120
Clay	74	194
Sand, blue	--	194

1S–13E–21da1

Material	*Thickness*	*Depth*
Sand and clay, interbedded	90	90
Clay	80	170
Sand, blue	--	170

1S–13E–25dc1

Material	*Thickness*	*Depth*
Sand	17	17
Clay, blue	91	108
Sand, blue	10	118
Clay	100	218
Sand, blue	--	218

1S–13E–27cc1

Material	*Thickness*	*Depth*
Sand and clay, interbedded	110	110
Clay, blue	80	190
Sand	--	190

1S–14E–5aa1

Material	*Thickness*	*Depth*
Gravel	20	20
Sand and gravel	40	60
Sand, coarse to fine	7	67

1S–14E–8dd1

Material	*Thickness*	*Depth*
Sand and clay, interbedded	140	140
Clay	180	320
Sand, fine, blue	--	320

TABLE 4.—*Logs of representative wells*—Continued

1S-14E-9aa1

Material	Thickness	Depth	Material	Thickness	Depth
Sand, yellow	160	160	Sand, blue	--	256
Clay, blue	96	256			

1S-14E-9da2

Material	Thickness	Depth	Material	Thickness	Depth
Topsoil, sand, and gravel	9	9	Sand	4	182
Clay, hardpan	3	12	Clay, blue	30	212
Sandy clay	5	17	Sand and gravel	6	218
Clay, blue	12	29	Clay, blue	12	230
Sand	6	35	Sand and gravel, cemented	6	236
Sand and traces of clay	28	63	Clay	4	240
Sand and clay, blue	18	81	Sand and gravel, cemented	3	243
Sand and clay, yellow	9	90	Clay, blue	19	262
Sand, fine, blue	13	103	Sand, gravel, and clay	6	268
Boulder	4	107	Clay, yellow	7	275
Sand, blue	17	127	Sand, blue	2	277
Clay, blue	34	161	Sand, yellow	8	285
Sand	2	163	Sand and gravel	15	300
Clay, blue	15	178			

1S-14E-9da4

Material	Thickness	Depth	Material	Thickness	Depth
Sand	140	140	Sand	--	224
Clay	84	224			

1S-14E-9db1

Material	Thickness	Depth	Material	Thickness	Depth
Topsoil	3	3	Clay	3	340
Clay, yellow, and gravel	69	72	Sand and gravel	25	365
Clay, blue, and gravel	27	99	Clay, brown	6	371
Boulder, basalt	1	100	Sand and gravel	21	392
Sand, coarse	33	133	Clay and sand	3	395
Clay, brown	5	138	Clay, brown	5	400
Clay, blue	17	155	Hardpan	3	403
Clay, brown and blue	96	251	Clay, soft, sand, and gravel	12	415
Sand, fine, and gravel	10	261	Sand	7	422
Clay, yellow	3	264	Sand and gravel	39	461
Clay, yellow, and sand	30	294	Clay, brown, and sand	6	467
Clay, yellow	6	300	Sand, gravel, and clay	30	497
Sand, yellow, gravel, and clay	30	330	Granite, decomposed	38	535
Sand, brown, and gravel	7	337			

1S-14E-10aa1

Material	Thickness	Depth	Material	Thickness	Depth
Sand, yellow	160	160	Sand, blue	--	256
Clay, blue	96	256			

1S-14E-11cc1

Material	Thickness	Depth	Material	Thickness	Depth
Topsoil	4	4	Gravel and sand	51	76
Gravel, yellow, and clay	21	25			

1S-14E-12cc1

Material	Thickness	Depth	Material	Thickness	Depth
Topsoil	12	12	Sand	8	233
Sand, blue	28	40	Clay	2	235
Sand, yellow	120	160	Sand	8	243
Clay, blue	65	225	Gravel, coarse, and sand	4	247

TABLE 4.—*Logs of representative wells*—Continued

1S–14E–13bb1

Material	*Thick-ness*	*Depth*	*Material*	*Thick-ness*	*Depth*
Clay and sand, interbedded	80	80	Clay, yellow	16	116
Clay	10	90	Sand, coarse	10	126
Sand	10	100			

1S–14E–14cb1

Material	*Thick-ness*	*Depth*	*Material*	*Thick-ness*	*Depth*
Clay and sand, interbedded	130	130	Sand, fine	10	240
Clay	100	230			

1S–14E–15ba1

Material	*Thick-ness*	*Depth*	*Material*	*Thick-ness*	*Depth*
Sand and clay, interbedded	130	130	Clay	17	226
Clay	76	206	Sand, blue	--	226
Sand	3	209			

1S–14E–15ba2

Material	*Thick-ness*	*Depth*	*Material*	*Thick-ness*	*Depth*
Sand and clay, interbedded	140	140	Clay	8	245
Clay, blue	82	222	Sand, blue	--	245
Sand, fine	15	237			

1S–14E–22db1

Material	*Thick-ness*	*Depth*	*Material*	*Thick-ness*	*Depth*
Topsoil	5	5	Sand, coarse	3	243
Sand and mud	3	8	Clay and sand, interbedded	15	258
Clay	7	15	Boulder	7	265
Sand	15	30	Clay and sand, interbedded	11	276
Clay, blue	35	65	Sand, coarse, and gravel	4	280
Sand and clay	19	84	Sand and clay	8	288
Hardpan	3	87	Hardpan	1	289
Sand	3	90	Sand, coarse, and gravel	3	292
Clay and traces of sand	15	105	Hardpan	1	293
Clay	2	107	Sand, coarse	4	297
Boulder	2	109	Sand and clay	8	305
Clay	8	117	Clay, blue, and sand	47	352
Clay, blue, and traces of sand	10	127	Clay, blue	42	394
Clay, blue	71	198	Sand and gravel	14	408
Clay, blue, traces of sand	25	223	Clay, blue	1	409
Clay, blue and brown	6	229	Gravel and sand	25	434
Clay, blue	11	240			

1S–14E–27ad1

Material	*Thick-ness*	*Depth*	*Material*	*Thick-ness*	*Depth*
Clay and sand	55	55	Clay	80	220
Sand, blue, fine	85	140	Sand, blue	20	240

1S–14E–36ab1

Material	*Thick-ness*	*Depth*	*Material*	*Thick-ness*	*Depth*
Sand, traces of clay	28	28	Gravel and sand, fine	2	92
Clay, blue, and sand	62	90	Basalt	84	176

TABLE 4.—*Logs of representative wells*—Continued

1S–15E–5db1

Material	*Thickness*	*Depth*	*Material*	*Thickness*	*Depth*
Topsoil	3	3	Gravel	4	338
Gravel	22	25	Clay, brown, and sand	52	390
Clay, blue, and sand	33	58	Clay, blue, sand, and gravel	18	408
Hardpan	2	60	Cay, brown, and gravel	13	421
Clay, blue, and sand	55	115	Sand, gravel, and traces of clay	52	473
Clay, brown	10	125	Boulder	3	476
Clay, blue	45	170	Sand and gravel	1	477
Clay, brown	10	180	Sand, coarse, and clay	13	490
Clay, blue	36	216	Clay and sand	25	515
Sand and gravel, fine	24	240	Sand and clay	35	550
Sand, coarse	37	277	Boulder	3	553
Clay, and traces of sand	57	334	Granite	25	578

1S–15E–15bc1

Topsoil	2	2	Clay, blue	62	80
Hardpan	12	14	Clay, gray	34	114
Sand and clay	4	18	Basalt, crevice	41	155

1S–15E–16db1

Topsoil	5	5	Clay, blue	10	45
Clay	10	15	Clay, blue and brown	73	118
Sand	20	35	Basalt	4	122

1S–15E–19cc1

Topsoil	10	10	Sand and gravel	5	40
Clay	5	15	Clay, blue	80	120
Sand	10	25	Basalt, loose, broken	11	131
Clay, blue	10	35	Basalt, hard, crevice	78	209

1S–15E–21ad1

Topsoil	12	12	Basalt	188	280
Sand and mud	17	29	Clay, blue	3	283
Clay, blue and brown	63	92			

1S–15E–27ba1

Topsoil	5	5	Sand, gravel, and clay	9	42
Clay, blue, and gravel	10	15	Basalt	55	97
Clay, blue	18	33			

1S–16E–3dc1

Topsoil	3	3	Clay, blue, and gravel	15	205
Hardpan	1	4	Clay, blue	4	209
Clay, sand, and gravel	101	105	Sand, coarse	8	217
Basalt	40	145	Clay and traces of sand	77	294
Clay, brown, and gravel	45	190	Sand, gravel, and clay	30	324

1S–16E–4cb1

Topsoil	3	3	Gravel	12	108
Hardpan	1	4	Gravel and brown clay	45	153
Clay, brown, sand, and gravel	86	90	Sand and gravel	35	188
Basalt, cinders on top	6	96	Sand, gravel, and clay	20	208

TABLE 4.—*Logs of representative wells*—Continued

2S-12E-9cc1

Material	Thickness	Depth	Material	Thickness	Depth
Topsoil	3	3	Clay, sandy, brown	6	241
Sand, yellow	2	5	Clay and gravel	4	245
Clay, blue	15	20	Sandstone and clay	20	265
Clay, sandy, blue	135	155	Granite(?), traces of sand	23	288
Basalt	5	160	Shale, traces of sand	38	326
Gravel, cemented	75	235			

2S-12E-16ca1

Material	Thickness	Depth	Material	Thickness	Depth
Topsoil	3	3	Gravel and clay	5	120
Hardpan	4	7	Hardpan	5	125
Gravel, cemented	8	15	Clay, gray, and gravel	35	160
Gravel and clay	7	22	Clay	12	172
Sand, black	3	25	Clay, sandy, gray	18	190
Sandy clay	30	55	Clay, sandy, brown	32	222
Sand, gravel, and clay, gray	20	75	Clay, yellow, and sand	40	262
Gravel, some clay	5	80	Granite	4	266
Gravel and clay, gray	35	115			

2S-14E-11da1

Material	Thickness	Depth	Material	Thickness	Depth
Topsoil	8	8	Granite, chalk	404	495
Gravel and clay	17	25	Chalk and clay	38	533
Clay and gravel	66	91			

2S-17E-2dc1

Material	Thickness	Depth	Material	Thickness	Depth
Topsoil	6	6	Sand, coarse to fine	11	116
Clay, boulder	4	10	Clay, brown	21	137
Clay, brown and gray	10	20	Clay, blue	23	160
Basalt	41	61	Clay, blue-black, fine rock	11	171
Clay, gray	9	70	Basalt, black	8	179
Clay, blue	9	79	Clay, green	10	189
Clay and rock	10	89	Basalt, broken, black, traces of clay	37	226
Rock, brown	8	97			
Clay and rock	8	105			

2S-17E-11db1

Material	Thickness	Depth	Material	Thickness	Depth
Clay	6	6	Rock, tan	4	41
Rhyolite, broken, brown	4	10	Rhyolite, broken	14	55
Rhyolite, solid	10	20	Clay, sandy	5	60
Rhyolite, broken	17	37	Rhyolite and clay	40	100

2S-17E-11db2

Material	Thickness	Depth	Material	Thickness	Depth
Topsoil	3	3	Rock, hard, black	13	315
Clay, brown	107	110	Rock, broken, and talc	4	319
Clay and boulders	14	124	Clay, brown	14	333
Sand, fine, and clay	12	136	Rock, broken, and clay	20	353
Clay, sandy, and boulders	9	145	Clay, red, caves	9	362
Basalt, black	140	285	Clay, brown, and rock	9	371
Clay, gray	4	289	Clay and rock	49	420
Clay and rock	6	295	Clay, tan, and sand	95	515
Clay	7	302	Sand, coarse	10	525

TABLE 5.—*Records of representative wells*

Type of well: Dr., drilled; J., jetted.
Use of water: D, domestic; I, irrigation; Ps, public supply; S, stock; U, unused.
Altitude of land surface: Determined by altimeter.

Remarks: Log, log of well is given in table 4; Temp., temperature of ground water; Reported water level, water-level data given by well owner.

Well	Owner	Altitude of land-surface datum above mean sea level (feet)	Type of well	Year drilled	Depth (feet)	Casing: Diameter (inches)	Casing: Depth (feet)	Aquifer	Water level: Above (+) or below land-surface datum (feet)	Water level: Date of measurement	Water level: Altitude above mean sea level (feet)	Use of water	Remarks
1N-13E-14ca1	B. A. Smith	5,296	Dr	1956	110	8		Granite	6.20	9/11/57	5,290	D	Log; temp. 49° F.
32db1	John Hobdey	5,123	Dr	1949	43	6	43	Sand	7.83	9/11/57	5,115	D	
33cd1	Edward Hardness	5,112	Dr	1949	96	8	96	do	20	1949	5,092	D	Reported water level.
1N-14E-16ac1	D. O. Bundy		Dug	1911	22			do	4.00	9/10/57		D	3- by 3-foot pit.
21dd1	Roland Pond	5,209	Dr	1917	200	6	100	do	30		5,179	D, S	Reported water level.
22bc1	Olga Naser	5,243	Dr	1911	105	6		do	80		5,163	D	Do.
24dc1	F. H. Wilson	5,240	Dr	1934	105	8	105	do	10.36	11/ 8/57	5,230	D, S	
29cc1	Raymond Dehmel	5,128	Dug		19	8	19	do	10.41	9/11/57	5,118	U	
32db1	Clifford Hallowehl	5,102	Dug					do	3.5	10/23/57	5,098	I	150- by 80-foot pit.
33bb1	Allien McCann	5,135	Dr	1927	72	6	72	do	15	1956	5,120	D, S	Reported water level.
33dd1	O. W. Prock	5,097	Dug	1953	13	6	13	do	7.29	9/ 4/57	5,090	D, I, Ps, S	
1N-15E-29bc1	E. G. Commons	5,236	Dr	1916	400	8		do	40		5,196	D	Reported water level.
31ca1	E. J. Pearson	5,105	Dr	1947	306	6	225	do	22	1947	5,083	D	Reported water level, log
34bc1	Fred Walton	5,122	Dr	1951	325	6	325	do	85	1951	5,037	D, S	Reported water level.
34bc2	do	5,123	Dug		12			do	5.54	9/ 6/57	5,117	U	4- by 4-foot pit.
35ca2	W. D. Simon	5,158	Dug		30			do	8.0	7/23/57	5,150	I	120- by 40-foot pit.
36dc1	Florence Gaskill	5,112	Dr	1947	60	6	60	do	15	1947	5,097	D	Reported water level.
1N-16E-32ab1	Angus Brooks	5,140	Dr	1948	55	8	55	do	10	1948	5,130	D, S	Do.
33db1	G. E. Coates		Dr	1955	174	15		do	15	1955		Abandoned.	Do.
1S-11E-25dd1	Floyd Tracy	5,102	Dr	1947	375	6		do	10	1947	5,092	D	Do.
35cc1	School Dist. 8	5,092	Dug		16			do	6.68	9/17/57	5,085	U	
36dc1	J. W. Bolt	5,086	J	1957	60	3	20	do	0	1957	5,086	D	
1S-12E-1db1	Harry Kunkel	5,104	Dr		18	6		do	7.76	10/ 4/57	5,096	D, S	
8dc1	Zane Harrison	5,169	Dr	1943	67	6	51	Granite	18.48	9/12/57	5,151	D, S	Log.
11cb1	John Humphers	5,105	Dug	1909	16			Sand	6.53	9/12/57	5,098	D	8- by 5-foot pit.
13ba1	H. E. Miller	5,090	Dr	1925	435	3	135	do	4.30	9/12/57	5,086	U	
13ba3	do	5,091	Dug	1932	18	8	18	do	6.90	9/12/57	5,084	D	
14ba1	John Humphers	5,096	Dr	1957	240	8	238	do	2.60	9/12/57	5,093	D	Log.
22bb1	James Yamamoto	5,118	Dug	1942	30	8	30	do	5.83	9/16/57	5,112	U	
22bb2	do	5,121	Dr	1950	160	4		do	8	1950	5,113	D, S	Reported water level.
24aa1	Blanc Loerven	5,112	Dr	1924	170	3	90	do	+2.3	9/12/57	5,114	U	Log; temp 62° F.

TABLE 5.—*Records of representative wells*—Continued

Well	Owner	Altitude of land-surface datum above mean sea level (feet)	Type of well	Year drilled	Depth (feet)	Casing: Diameter (inches)	Casing: Depth (feet)	Aquifer	Water level: Above (+) or below land-surface datum (feet)	Water level: Date of measurement	Water level: Altitude above mean sea level (feet)	Use of water	Remarks
1S-12E-26cc1	Jess Howard		Dr	1955	54	8	54	do	9	7/21/55		D	Reported water level, log.
28bb1	Frank Mink	5,118	Dr	1950	80	4	15		15	1950		D, S	Reported water level.
29dc1	School District 121	5,121	Dug						17.05	9/12/57	5,104	U	
29dd1	Gwinn Rice		Dr	1955	69	6	69	do	14	5/31/55		D	Reported water level, log.
30dc1	Charles Olsen	5,115	Dr	1956	100	8	100	do	12.65	10/ 3/57	5,102	D	Reported water level.
31ad1	K. B. Strom	5,099	Dr	1957	72	8	70	Granite	1.92	9/13/57	5,097	D, S	
31cb1	Floyd Tracy	5,082	Dr	1947	400			Sand	+3.0	10/ 3/57	5,085	Swimming pool.	Flow about 10 gpm; temp 85° F.
34dc1	Earl Wilson	5,051	Dr		180	3		do	+6.3	10/16/57	5,057	D	Flow about 40 gpm; temp 60° F.
35aa1	Gill and Martin	5,052	Dr			3		do	+6.5	10/16/57	5,058	D	Temp 66° F.
35bb1	Everett Trader		Dr	1941	254	6-4	254	do				D	Flow about 10 gpm; temp 58° F.
1S-13E-1aa1	W. L. Tucker	5,095	Dr	1949	105	10	105	do	15	1949	5,080	D	Reported water level.
2dd1	Fred Orr	5,076	Dug		26	6	26	do	7.07	9/ 5/57	5,069	U	
3aa1	Clifford Hallowehl	5,116	Dug		50	8	50	do	12.01	9/17/57	5,104	D	
3cc1	Fred Orr	5,110	Dr	1924	40	8		do	15	1954	5,095	D	Reported water level.
3dd1	do	5,092	Dug		10			do	6.10	9/ 5/57	5,086	U	3- by 2-foot pit.
8cc2	C. N. Ashmead	5,089	Dr	1942	150	4		do	+2.0	10/16/57	5,091	U	Flow about ¼ gpm; temp 52° F.
9dd1	K. Babington	5,096	Dr	1951	77	3		do	+0.5	9/ 5/57	5,096	D	
12dd1	Minnie Bottcher	5,067	Dr	1924	230	3-2	130	do	+9.4	10/15/57	5,076	S	Flow about ½ gpm; temp 59° F; log.
12dd2	do	5,072	Dug	1917	10			do	7.45	8/22/57	5,065	D	5- by 5-foot pit.
13da1	E. M. Thompson	5,046	Dr		250	3	150	do				D	Flow about 10 gpm.
14da1	Ernest Fields	5,040	Dr	1924	300	302	140	do	+15.3	10/16/57	5,055	D, S	Flow about 20 gpm; temp 71° F; log.
14da2	do	5,044	Dug		47	6		do	4.63	8/22/57	5,039	U	
15dd1	L. L. Barron	5,072	Dr	1924	228	3	130	do	+5.7	10/15/57	5,078	U	Flow about ¼ gmp; temp 64° F; log.
19ad1	Mannie Shaw	5,056	Dr	1946	240	4	240	do	+4.0	10/16/57	5,060	S	Flow about ¾ gpm; temp 59° F.
20ad1	C. D. Thornton	5,075	Dr	1946	220	4	220	do	+3.5	10/15/57	5,079	D, S	Flow about 1 gpm; temp 66° F; log.
20ad2	do		Dr	1924	194	3	120	do				Abandoned.	Log; temp 65° F.
21da1	Loyd Barron		Dr	1924	170	3	90	do				D, S	Flow about 2 gpm; temp 62° F; log.
22cc1	Elsie Burns	5,066	Dr					do	+4.5	10/15/57	5,071	U	

25dc1	C. W. Stewart	5,042	Dr	1924	218	6-3	108	do	+2.7	10/15/57	5,045	U	Flow about ¼ gpm; temp 59° F; log.
27cc1	Ernest Mizer	5,056	Dr	1924	190	3	110	do	+11.6	10/15/57	5,068	D	Flow about 10 gpm; temp 95° F; log.
33cc1	Loyd Barron	5,107	Dr		167	6			9.96	9/19/57	5,098	S	
35dc1	do	5,061	Dug	1924	22			Basalt	16.35	9/19/57	5,045	U	6- by 6-foot pit.
1S-14E-1bb1	Walton & Schaefer	5,092	Dr	1924		3		Sand	+0.5	9/11/57	5,093	U	Temp 54° F.
2bb1	A. A. Knowlton	5,109	Dr	1946	280	8-4		do	10	1946	5,099	D, S	Reported water level.
6aa1	A. Carmon	5,097	Dr	1955	67	6	67	do	10	7/26/55	5,087		Reported water level; log.
7dd1	Wokersien & Tucker	5,075	Dug		15	6		do	5.51	8/22/57	5,069	U	
8dd1	Minnie Bottcher	5,069	Dr	1924	320	3-2	140	do	+17.5	10/15/57	5,087	S	Flow about 3 gpm; temp 62° F; log.
9aa1	F. M. Tucker	5,079	Dr	1924	256	3	160	do	+2.0	10/15/57	5,081	D	Flow about ½ gpm; temp 52° F; log.
9aa2	do	5,078	Dug	1937	35	8	35	do	4.92	9/ 5/57	5,073	D	
9bb1	Clifford Hallowehl	5,082	Dr					do	1.98	9/ 5/57	5,080	U	
9da1	Village of Fairfield		Dr	1940	300	4		do				U	Well No. 1.
9da2	do		Dr	1941	300	4		do				Ps	Well No. 2; log; temp 60° F.
9da3	Elden Ryals	5,063	Dr	1932	164	2		do	+8.5	10/15/57	5,072	U	Temp 56° F.
9da4	Village of Fairfield		Dr	1924	224	3	140	do				Abandoned	Log.
9db1	Church of Jesus Christ of Latter Day Saints.	5,075	Dr	1954	535	15-12	495	do	+8.5	11/ 7/57	5,083	I	Flow about 50 gpm; temp 65° F; log.
10aa1	G. R. White		Dr	1924	256	3	160	do				Abandoned	Temp 54° F; log.
10ad1	do	5,078	Dr	1924	273	3	185	do	+6 2	10/15/57	5,084	U	Flow about 3 gpm temp 57° F.
10cc1	Village of Fairfield		Dr	1950	300	8		do				Ps	Well No. 3; temp 62° F.
11cc1	Harry Giesler	5,061	Dr	1955	76	8	76	do	+3.4	8/22/57	5,064	D	Log.
12cc1	do		Dr	1924	247	3	160	do					Log; temp 58° F.
13ad1	I. J. Baldwin	5,046	Dr	1928	212	2		do	+8.7	10/15/57	5,055	D,S	Flow about 2 gpm; temp 61° F.
13bb1	Howard St. Clair		Dr	1924	126	3	116	do				D	Flow about 5 gpm; temp 59° F; log.
14cb1	Ben Lasswell	5,054	Dr	1924	240	3	130	do	+10.6	10/15/57	5,065	D,S	Flow about 4 gpm; temp 61° F; log.
15ba1	D. O. Reynolds		Dr	1923	226	3	130	do					Temp 59° F; log.
15ba2	do		Dr	1923	245	3	140	do					Do.
20cd1	C. A. Andrews	5,039	Dr	1924	192	3	82	do	+1.2	10/15/57	5,040	U	Flow about ¼ gpm.
22bb1	Hannah Wyler	5,045	Dr	1924	250	3	145	do	+1.0	10/15/57	5,046	U	Flow about ¼ gpm; log.
22db1	C. W. Stewart		Dr	1953	434	22-12	434	do				I	Flow about 50 gpm; temp 71° F; log.
25bb1	Ed. Reagan	5,025	Dr	1950	205	6	185	Basalt	28.73	9/ 3/57	4,996	D	
25bb2	do	5,026	Dug		11	8		Sand	6.70	9/ 3/57	5,019	U	
27ad1	Dan Perkins		Dr	1923	240	3	140	do					Temp 62° F; log.
36ab1	Harold Lee	5,024	Dr	1955	175	6	90	Basalt	23.89	11/ 7/57	5,000	D	Log.
36ba1	School Dist. 121	5,019	Dug		21	8		Sand	9.55	9/ 3/57	5,009	U	
1S-15E-5db1	W. D. Simon	5,069	Dr	1953	578	18-12	578	do	+12	1953	5,081	I	Flow about 50 gpm; temp 64° F; log.
7dd1	Don Bouscher	5,042	Dr	1920		10-8		do	+6.90	10/15/57	5,049	D,S	Flow about 40 gpm; temp 60° F.

TABLE 5.—*Records of representative wells*—Continued

Well	Owner	Altitude of land-surface datum above mean sea level (feet)	Type of well	Year drilled	Depth (feet)	Casing: Diameter (inches)	Casing: Depth (feet)	Aquifer	Water level: Above (+) or below land-surface datum (feet)	Water level: Date of measurement	Water level: Altitude above mean sea level (feet)	Use of water	Remarks
1S-15E-9dc1	Walter Pearson	5,036	Dr	1947	360	4-3	325	do	+11.30	10/15/57	5,047	S	Flow about 3 gpm; temp 66° F.
11cb1	G. Schmidt	5,016	Dug		10			do	4.64	9/6/57	5,011	U	3- by 3-foot pit.
14db1	Ben Krahn	5,007	Dug		35	12		do	8.67	9/13/57	4,998	U	
15bc1	Newell Brooks		Dr	1954	155	10	122	Basalt	18	11/20/54		D	Reported water level; log.
16db1	George Petrie	5,015	Dr	1953	122	22-18	120	do	32.51	7/24/57	4,983	I	Log.
19bb1	Tom Spackman	5,023	Dug	1947	11			Sand	7.75	9/4/57	5,015	D	4- by 4-foot pit.
19cc1	A. R. Frostenson		Dr		209	6	131	Basalt	27			D	Reported water level; log.
21ad1	Bahr and Stokes	5,013	Dr	1953	283	16-12	101	do	17	1953	4,996	I	Log; reported water level; temp 58° F.
21cc1	Edward Krahn	5,007	Dr	1952	115	6			11.03	9/4/57	4,996	D, S	
22aa1	Ben Krahn	4,994	Dug		39	8		Sand	.97	9/13/57	4,993	U	
22ad1	do	4,982	Dr	1936	15	6	15	do	0	9/13/57	4,982	S	Temp 49° F.
27ba1	Stokes and Bahr		Dr	1954	97	6	44	Basalt				D	Temp 58° F.
30bc1	W. J. Packham & Sons	5,011	Dr	1935	330	4		Sand	19.11	9/4/57	4,992	D, S	
32dd1	James Kevan	5,006	Dug		11	8		do	6.40	9/3/57	5,000	U	
1S-16E-3dc1	J. E. Coates	5,044	Dr	1955	324	14	324	do	85.79	7/23/57	4,958	I	Log.
4cb1	W. D. Simon	5,068	Dr	1955	208	15	208	do	84.80	7/23/57	4,983	I	Do.
18ba1	L. E. Koonce	4,989	Dug		9	24		do	5.02	7/13/57	4,984	S	
2S-11E-4dd1	George Tracy	5,097	Dr		175	2		do				D	Flow about 3 gpm.
10ba1	Floyd Tracy	5,091	Dr		250	4	250	do	+5.2	10/3/57	5,096	D	
2S-12E-1da1	Leslie Ruby	5,097	Dr	1950	279	2	100	do	6.66	9/12/57	5,090	D, S	
5bb1	K. B. Strom	5,082	Dr	1937	280	4		do	+5.9	10/16/57	5,088	S	Flow about 1 gpm.
9cc1	Ralph Faulkner	5,093	Dr	1957	326	15-12	326	do				I	Flow about 5 gpm, (well not completed); log.
9cc2	do	5,092	Dr			4		do	+6.2	10/16/57	5,098	S	Flow about ½ gpm; temp 58° F.
11bd1	H. F. Petrick	5,085	Dr	1952	40	3	32	do	+4.3	10/16/57	5,089	D, S	Flow about 3 gpm; temp 56° F.
16ca1	Ralph Faulkner		Dr	1956	266	15	250	do				Abandoned	Log.
2S-13E-1da1	Loyd Barron	5,089						Basalt	39.93	9/4/57	5,049	S	
9dd1	Lela L. Wolfe	5,099	Dr	1950	116			Sand	34.84	9/18/57	5,064	D	
10ca1	I. B. Wolfe	5,059	Dug		14	40	14		4.83	9/18/57	5,054	D, S	
2S-14E-1ba1	J. E. Painter	5,011	Dr		17	8		Sand	7.09	9/3/57	5,004	D	
11da1	F. L. Clutter	5,114	Dr	1953	533	18	166	do	9.97	10/24/57	5,104	I	Log.
11da3	do	5,123	Dug		28			do	19.02	8/6/57	5,104	I	4- by 4-foot pit.
2S-15E-4bb1	Bill Simon	5,009	Dr	1935	247	6			10.72	9/3/57	4,998	D	
2S-17E-2dc1	Glen Croft	4,832	Dr	1955	226	12	226	Sand	50	1955	4,782	I	Reported water level; log.
11db1	do	4,809	Dr	1955	100	16-12	67	Rhyolite	22.89	10/21/57	4,786	I	Log; temp 51° F.
11db2	do	4,797	Dr	1955	525	16-8			38.82	9/18/57	4,758	Abandoned	Log.

REFERENCES

Babbitt, H. E. and Doland, J. J., 1955, Water supply engineering: New York, McGraw-Hill.

Bennison, E. W., 1947, Ground water, its development, uses and conservation: St. Paul, Minn., Edward E. Johnson, Inc., 509 p.

Dean, H. T., 1936, Chronic endemic dental fluorosis: Am. Med. Assoc. Jour., v. 107, p. 1269–1272.

Fenneman, N. M., 1931, Physiography of Western United States: New York, McGraw-Hill, 534 p.

Ferris, J. G., 1951, Ground water, Chap. 7, *in* Wisler, C. O. and Brater, E. F., Hydrology: New York, John Wiley and Sons, p. 198–272.

Jacob, C. E., 1946, Drawdown test to determine effective radius of artesian well: Am. Soc. Civil Engineers Proc., v. 72, no. 5, p. 629–646.

Knowles, D. B., 1955, Ground-water hydraulics: U.S. Geol. Survey open-file rept., 105 p.

Piper, A. M., 1925, Ground water for irrigation on Camas Prairie, Camas and Elmore Counties, Idaho: Idaho Bur. Mines and Geology Pamph. 15, 46 p.

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

U.S. Public Health Service, 1946, Drinking water standards: Public Health Repts., v. 61, no. 11, p. 371–384.

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

Wenzel, L. K., 1942, Methods for determining permeability of water-bearing materials: U.S. Geol. Survey Water-Supply Paper 887, 192 p.

Wilcox, L. V., 1948, The quality of water for irrigation use: U.S. Dept. Agriculture Tech. Bull. 962, 40 p.

INDEX

	Page
Abstract	1
Acknowledgments	2
Agriculture	10
Alluvial fans	9, 21
Alluvium	10
Aquifer, drawdown in	26–29
hydraulic properties	17–18
Snake River basalt	28–29, 32
test	18–19
See also Upper artesian aquifer *and* Lower artesian aquifer.	
Artesian condition, definition of	15
Bibliography	55
Challis volcanics	10
Climate	5–8
Consolidated rocks, water-bearing properties	10–11
Drainage	9
Drawdown, in aquifer	26–29, 32
in wells	11, 30–31
Evapotranspiration, definition	22
Extent of area	2
Fairfield, Idaho, public water supply	23
Geography	5–10
Ground water, chemical character	34, 36–37
discharge to streams	33–34
domestic use	23, 37
effects of development	32
irrigation use	23, 37–39
movement	16–17
occurrence	15–16
recharge	21–22, 31
temperature	36, 39–40
underflow	20, 30
Hydrogeologic boundaries, effects	29–30
Idaho batholith	10
Investigation, previous	2–4
purpose	2
Isopiestic lines, definition	16
distortion by pumping from wells	17
Lake deposits	10, 13
See also Valley-fill deposits, clay unit.	
Lava flows	8, 10, 11
Leakage, rate	21
through the clay unit of the valley-fill deposits	21, 29, 32
Location	2
Lower artesian aquifer, ground water	16
lithologic character	15
recharge to	21–22

	Page
Lower artesian aquifer—Continued	
test	18–19
wells in	24
Permeability coefficient, definition	17–18
Physiography	8–9
Piezometric surface, configuration	16, 17
definition	15
Piper, A.M., quoted	10
Population	9–10
Precipitation	5–8, 22
Roads	10
Snake River basalt, lithologic character	11
ground water	11, 16
wells	24
Specific capacity, definition	23
Storage coefficient, definition	18
Summary	41–45
Surface water, chemical character	39, 40–41
occurrence	33
suitability for irrigation use	41
Temperature of area	8
Temperature gradient	40
Transmissibility, coefficient, definition	17, 18
Upper artesian aquifer, ground water	16
lithologic character	13–15
recharge to	21–22
wells	22
Valley-fill deposits, clay unit	13, 16, 17
description	11–13
water-bearing properties	13–15
water-table conditions	15, 29
wells	24, 25–26, 27
See also Upper artesian aquifer *and* Lower artesian aquifer.	
Water quality	34–41
Water table, control of slope	16
definition	15
Water-table conditions, definition	15
Well loss, definition	18, 31
Wells, constructional features	25–26
development	22–26
distortion of isopiestic lines by pumping	17
interference and spacing	26–31
for irrigation	23
numbering system	4–5
records	45–54
in Snake River basalt	11
theoretical drawdown	30–31
See also Upper artesian aquifer *and* Lower artesian aquifer.	